State of Ohio

Department of Transportation

Construction Inspection

Manual of Procedures

Columbus, Ohio

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Construction Inspection Manual of Procedures

Ohio Department of Transportation

Division of Construction Management

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Table of Contents

Foreword

This manual provides highway construction personnel with relevant, practical information in order to perform accurate inspections and provide relevant construction procedural information for the various roadway and structures items of work. It is the responsibility and duty of all Department personnel involved in highway construction to become familiar with the content and intent of this manual.

This manual includes background information for select items of work. This information is intended to assist construction personnel with understanding and solving various field problems and issues. The examples and graphics contained in this document are intended to provide guidance for a practical approach to inspection and construction processes and procedures. This manual is not intended to be a complete, all inclusive text detailing every aspect of highway construction, but rather an operational guidebook for highway construction and inspection techniques.

In order to take complete advantage of the information in the manual, project personnel should have a comprehensive understanding of the Construction and Materials Specifications, Supplemental Specifications, Standard Drawings, and other pertinent contract documents. Unless specifically incorporated by reference into the contract documents, this manual is not contractually binding on either contracting party. The information contained in the manual does not replace, supersede or otherwise modify any specification, plan or proposal provision, or other contract document or condition except as noted.

As the on-site representatives of the Department, ODOT Inspectors and Engineers are authorized to observe all work being performed to ensure compliance with the contract. As the required inspection activity occurs, the Department also has an obligation to inform the Contractor on a regular basis regarding the quality and compliance of the work performed. Conversely, the Contractor also shares in the responsibility to provide information regarding construction problems or issues to the Department for timely resolution consistent with joint issue mitigation responsibilities.

The primary goal of this manual is to present functional highway construction information in order to provide practical guidance to personnel involved in this effort. The Department is responsible for monitoring and documenting construction activity in the project diary to ensure the intent of the contract is reflected in the final product delivered to the Department. Secondly, timely and proper inspections are critical to ensuring an acceptable level of project quality. For these reasons, this entire manual has been developed to assist in ensuring that correct, accurate and thorough inspections of the work are performed consistently statewide.

Introduction to Construction Inspection

This manual provides construction personnel with information to perform accurate inspections and documentation of the construction work items. It is the duty of ODOT Project Engineers and Inspectors to become familiar with the contents of this manual.

Included in this manual is background information for the specific items of work. This background information will help construction personnel understand various field problems and associated solutions. Examples, problems and figures are provided as guidance throughout this manual.

This manual should not be considered a complete textbook detailing all aspects of construction. In order to completely take advantage of the information in this manual, project personnel should be familiar with the Construction and Materials Specifications, Standard Drawings, and other contract documents.

Unless specifically referenced in the contract, this manual is not a part of the contract with the Contractor. The information contained in the manual does not replace, supersede or modify any specification, plan or proposal provisions of the contract.

As the representatives of the Department, ODOT Inspectors and Engineers observe the Contractors' work to ensure compliance with the specifications. As ODOT inspects the work, Inspectors and Engineers document progress and communicate with the Contractor daily about the quality and compliance of the work.

When an item of fails to perform, many times the Department suffers significant financial losses due one of the following:

- The instructions to the Contractor were in error or did not occur,
- The Department testing was performed incorrectly,
- Inspection forms or details are incomplete, or conflicting,
- No inspection occurred during the construction of the item.

All of the above reasons are arguments that could be brought up during a claim. Valid or not, these are reasons that will be debated when responsibility is discussed.

Our goal is to minimize the Department responsibility in claim situations and maximize the quality of the work performed. The Department needs to correctly monitor and document in the project diary the construction activities to ensure the contract intent is carried through during the construction.

Correct and accurate inspections are critical tools to ensure the quality of the work. Therefore, this entire manual is dedicated to documenting the correct, accurate and thorough inspections of the work.

General Documentation Requirements

Project Records

The Project Engineer or Inspector must set up a records system to adequately record the daily activities on the project. These records should include the following, as applicable:

- A folder for each reference number
- Proposals / addendum folder
- A folder for each change order
- Supplemental specifications
- TE-30 Material Inspection Reports
- TE-45 Daily Concrete Reports
- TE-31 Material Inspection Reports
- TE-24 Material Certification Reports
- Partnering file
- Pre-construction and other Meeting notes
- C-95 issues folder
- Change order items pending
- Issue folders (claims, etc) / Waste Borrow Agreements
- Correspondence from contractor
- Correspondence from others
- ODOT correspondence to contractor
- ODOT correspondence to others
- Delivered materials
- CA-EW-5 compaction tests
- Grade checks
- Contractor storm sediment and erosion control checklist
- Survey notes
- Utility folders
- Railroad folders
- Estimate folder
- CA-D-3 and CA-D-4 folders
- C-92 / Payroll / Labor compliance forms
- Schedule folder
- MOT review folder
- Value Engineering Proposals (VECP) File

General Guidelines for Documentation

Documentation consists of the written project records necessary to verify performance of the work item. Documentation is progressive and must be coordinated with the construction progress.

To meet the requirements for payment on Federal-Aid and State projects, the following two conditions must be met:

The final quantity has been determined in accordance with the specifications and the necessary weight tickets, measurements, calculations, etc., are validated properly. Procedures for meeting these conditions are contained in this handbook.

The work has been completed in substantial conformity with the plans and specifications, and this fact is documented and placed in the project files. Procedures for meeting these conditions are contained in the referenced construction procedures handbooks and manuals.

As a rule, the inspector's reports or related forms should contain information in sufficient detail to verify that construction is in substantial conformity with the plans and specifications.

Documentation shall be validated in every case with the following seven identifiers:

- Date
- Project Number
- Item Number
- Reference Number
- Subject
- Location
- Signature or Initials

As items of work are completed by the contractor, project inspectors are required to document the work as previously discussed. Accepted quantities will be turned in for payment on the Daily Diary under the area entitled "Pay Items", listing the reference number, extra work number if applicable, participation code, description of work, location, and quantity or lump sum amount. It must be emphasized that all items turned in for payment must be supported by documentation kept in the project files under the appropriate contract reference number.

Substantiation

This manual describes in detail the requirements of documenting substantial conformity with contract requirements. Substantiation includes the usage of specific forms and documentation of measurements and testing methods. Progressive project inspection and control records must be related to items being documented so that they readily substantiate and verify that documented quantities are placed in accordance with contract requirements. These records are to be placed in the project file each day.

For the purpose of documentation, project records must be identified with the seven identifiers listed above. These records must also: show location data, include computations, and be filed in the project records. Records will be on designated forms contained within this manual.

Measurement

Individual measurements will be made with sufficient accuracy and frequency to avoid unrealistic accumulations. The summary of final pay quantity is rounded off to the units shown in the proposal. Include the seven identifiers listed above with a documentation record of each pay item on a designated form and file in the project records.

Sketches

Photos, video, sketches, and drawings may be used wherever they are an aid in clarifying locations or dimensions.

Validation

The seven identifiers listed above must be included on tickets and tapes if no other documentation forms are used for the item. If separate forms are used (e.g., Asphalt tickets used along with the Bituminous Concrete Inspection Form), initials should be on the tickets, and the seven identifiers are required on the form.

The printed weight ticket from automatic or semiautomatic scale operations is acceptable documentation. Should material be delivered to the project without a verifiable weight ticket from the source, due to infrequent use or oversight, the material may be re-weighed or weight may be checked by comparison to measured volume in place. Action taken will be recorded on the ticket.

Items paid for on a unit, lump sum, length, area, volume, or miscellaneous basis, either in place or from verified plan dimensions, will be validated by the initials of the person making or verifying measurements, calculations, and observations.

Where partial loads are involved, quantities will be determined from measurements in the vehicle or calibrated tanks.

Filing

All printed project records must be maintained in the field office in a file by project number. Tickets and other bulky items may be filed separate provided they are referenced to the associated contract reference number. Upon completion of the project, the entire file will be moved to the District Office and maintained for future reference. All final quantity documentation will be delivered to the District Office in a timely manner at the discretion of the District Documentation coordinator after completion of the physical work. District project files will be maintained in a single well-organized location for the time period outlined in the ODOT record retention schedule.

List of Forms

The following forms are called out in this manual. The District may modify the forms ONLY if the modified forms contain all of the information listed on the standard forms. Forms may be found online here:

http://www.dot.state.oh.us/Divisions/ConstructionMgt/Admin/Pages/Documentation.aspx

Forms are also available in the Construction Inspection Forms Booklet.

CA-C-1	Concrete Control Test Form
TE-45	Concrete Inspectors Daily Report
CA-D-1A	Field Calculation and Measurement
CA-D-1B	Field Calculation and Measurement
CA-D-2	Field Calculation and Measurement
CA-D-3A	ODOT Inspectors Daily Report
CA-D-3B	ODOT Inspectors Daily Report
CA-D-4	ODOT P.E. / P.S. Daily Report
CA-D-5	Daily Account of Force Account Work
CA-D-6	Pavement Repair and Sawing Measurement
CA-D-7	Short Term Work Zone Review
CA-D-8	Long Term Work Zone Review - 1/2, 2/2
CA-D-10	Contractor Signature Authorization
CA-D-11	Contractor Payment Certification
CA-D-12	Contractor Final Certification
CA-EC-1	Weekly and Rain Event Checklist
CA-EC-2	Seeding Calculations
CA-EW-1	Earthwork Quantity Calculations
CA-EW-2	Proof Rolling Documentation
CA-EW-3	Log of Test Pit Investigation
CA-EW-4	Moisture Density Curve Calculation
CA-EW-5	Nuclear Gauge Compaction Form
CA-EW-6	Nuclear Gauge Compaction with Aggregate Correction

CA-EW-8	Authorization of Undercuts
	Typical Moisture Density Curves - Set C - May, 1949
	Zero Air Voids Curve
CA-EW-9	Rock Blasting Inspection Form
CA-EW-10	Rock Blasting Drilling Log
CA-EW-11	Blast Site Security Plan
CA-EW-12	Daily Earthwork Inspection Form
CA-FP-1	Warranty Asphalt Checklist
CA-FP-2	Random Selection of Asphalt Field Samples (448, 403)
CA-FP-3	Summary of Asphalt Concrete Quantities
CA-FP-4	Asphalt Concrete inspection
CA-FP-5	Asphalt Concrete Core Locations
CA-FP-6	Calculation of Liquid Asphalt Materials
CA-L-1	Report of Electrical Tests
CA-L-2	Report of Electrical Tests
CA-L-3	Report of Electrical Tests
CA-L-4	Report on Sign Lighting
CA-L-5	Report on High Voltage Direct Current Tests
CA-P-1	Pipe Construction Inspection Form - 1/2, 2/2
CA-P-2	Underdrain Construction Inspection Form 1/2, 2/2
CA-P-3	Drainage Structure Inspection Form 1/2, 2/2
CA-S-1	Inspection Record for Drilled Shafts
CA-S-2	Paint Thickness, QCP #5, #8, #10
CA-S-3	(BR-2-75) Pile Driving Log
CA-S-4	High Performance Concrete Pre-Pour Meeting - 1/3, 2/3, 3/3
CA-S-5	Micro-Silica Overlay Pre-Pour Meeting - 1/3, 2/3, 3/3
CA-S-6	Class S Concrete Pre-Pour Meeting - 1/2, 2/2
CA-S-7	QCS Inspection Documentation
CA-S-8	(BR-5) Piling Record
CA-S-11	QCS & Visual Standards Information
CA-S-12	Bridge Painting Quality Control Points, QCP #1 & #2
CA-S-13	Abrasive Blasting (QCP#3)

CA-S-14	Disposal of Hazardous / Non-Hazardous Waste for Bridge Painting, QCP#4
CA-S-15	Prime Coat Application, QCP#5
CA-S-16	Bridge Painting Grinding Fins, Tears, Slivers and Caulking, QCP #6,#9
CA-S-17	Intermediate & Finish Coat Application, QCP #8 & #10
CA-S-18	Bridge Painting Destructive Test Log, QCP #11
CA-S-19	Bridge Painting Final Review, QCP #11
CA-S-20	Erection (Demolition) Procedure Checklist
CA-T-1	DLS Report Format - Weight-Based System
CA-T-2	DLS Short Report Format - Weight-Based System
CA-T-3	DLS Report Format - Stroke Counter System
CA-T-4	DLS Short Report Format - Stroke Counter System
CA-T-5	DLS Report Format - Flow Meter-Based System
CA-T-6	DLS Short Report Format - Flow Meter-Based System
CA-T-7	DLS Report Format - Thermoplastic System
CA-T-8	DLS Short Report Format - Thermoplastic System
C-85 Letter	Sample Final Estimate Letter
C-85 Final	Report of Final Inspection
C-85 LPA	Report of LPA Final Inspection
C-85 Partial	Report of Partial Inspection
C-85 Punchlist	Report of Punch List Completion
TE-31	Sample Data

Definitions and Terms

General

Common words and terms used in this manual are defined in this section. Definitions for other words or terms that may call for clarification in this manual are found in the "Construction and Materials Specifications."

AASHTO - American Association of State Highway and Transportation Officials.

ASTM - American Society of Testing and Materials.

CAS - Construction Administration System, a part of CMS which provides support to all construction administration activities from the time at which a contract has been signed to the time at which the contract has been finalized.

Change Order - A written order issued by the Director to the Contractor, covering changes to the terms and conditions, plans or quantities, within or beyond the scope of the contract and establishing the basis of payment and time adjustments for the work affected by the changes.

Contractor - The individual, firm or corporation contracting with the Ohio Department of Transportation for the performance of prescribed work, acting directly or through a duly authorized representative and qualified under provisions of the law.

Conversion - The adaptation of one unit of measure to another unit of measure.

Density - The relation of weight to volume. The greater the weight to a given volume, the greater the density.

Department - The Ohio Department of Transportation.

Director - The Director of the Department of Transportation, the Executive head of the Department of Transportation, appointed by the Governor.

Documentation - Recording and filing evidence that the material or work is in conformance with specifications and in the amounts required.

Elevation - The height as measured from a predetermined point denoted in the plans.

Engineer - The person representing the Department who is charged with the overall responsibility at the project site for seeing that construction is in conformance with plans and specifications, and that all checks for job control and validation of pay items are documented and filed properly.

FHWA – The Federal Highway Administration, a section of the U.S. Department of Transportation.

File - The complete project file in the field office in which is placed all progress records and documentation of pay items.

Inspection - Examination by observation, measurement, or tests to determine that materials and work are in conformance with specifications.

Inspector's Daily Report - A form used by an inspector to document the activities performed by a Contractor. The Inspector Daily Report is Form CMS-1, CA-D-3A or CA-D-3B.

Laboratory (Laboratory with "L" capitalized) -The Office of Materials Management of the Department of Transportation, 1600 West Broad Street, Columbus, Ohio 43223. If reference is to the District laboratory, it is so designated.

Lane or Traffic Lane - A strip of pavement of specified width, usually 12 feet (3.6 m).

P.E./P.S. Daily Report - A form used by the Engineer or Project supervisor to document the activities performed by a Contractor. The P.E./P.S. Daily Report is Form CMS-2, CA-D-4.

Pay Item - A specifically described unit of work for which a price is provided in the contract.

Plans - The plans, profiles, typical cross sections, working drawings and supplemental drawings, approved by the Director, or exact reproductions thereof, which show the location, character, dimensions, and details of the work.

Progress Samples - Samples taken by Laboratory or project personnel not engaged in job control sampling. Samples are obtained at random from materials delivered for incorporation in the work to provide an independent spot check on the reliability of the results obtained in job control sampling and testing.

Project - The specific section of the highway together with all appurtenances and construction to be performed thereon under the contract.

Proposal - The offer of a bidder, on the prescribed form properly signed and guaranteed, to perform the work and to finish the labor and materials at the prices quoted.

Project Engineer – Also called the Engineer. The person representing the Department who is charged with the overall responsibility at the project site for seeing that construction is in conformance with plans and specifications, and that all checks for job control and validation of pay items are documented and filed properly.

Standard Drawings - The Standard Construction Drawings issued by the Bureaus of Location and Design, Bridges and Design Services.

Specifications - The directions, provisions and requirements contained in the State of Ohio, Department of Transportation Construction and Material Specifications as supplemented by the supplemental specifications and special provisions.

TAS - Testing Administration System, a part of CMS which provides support to all sampling, testing and approval or disapproval of materials used on a project, to the time at which the contract has been finalized.

Tolerance - The allowable limits of variation from a specified measurement.

Transition - The distance in which a change is made gradually from one pavement cross section to another.

Verification - The steps necessary to determine that the work or materials described are in conformance with plans and specifications.

Flexible Pavement Terms

Aggregate - Mineral material, such as sand, gravel, crushed stone, slag, or combinations hereof.

Asphalt Concrete - A mixture of aggregate and asphalt binder. Types of asphalt concrete are 301, 302, 442, 446, and 448.

Batch Plant - A plant in which dry, hot aggregate and asphalt material are proportioned in fixed or batched quantities into a pugmill (mixer) for mixing. Then the resulting asphalt concrete is either batched directly into a haul truck or stored in a storage bin for later use.

Asphalt Concrete Base - A type of asphalt concrete which is used as a base course in the construction of a pavement. Two types of asphalt concrete base are 301 and 302.

Asphalt Binder- A thermoplastic binding material obtained as a residue in the distillation of petroleum, which may contain additives to enhance performance.

Bleeding - The rising of an excess of asphalt material to the surface of an asphalt concrete mixture.

Checking - Short transverse cracks, 1 to 4 inches (25 to 100 mm) in length and 1 to 3 inches (25 to 75 mm) apart, which develop in the surface of the asphalt concrete mat during the compaction process.

Choke - Aggregate used for the purpose of filling the surface voids of a coarse aggregate mixture.

C&MS – Ohio Department of Transportation, Construction and Material Specifications

CMS – Multiple definitions as follows:

Construction Management System, a set of computer programs developed for the management of construction and testing activities on a project from the time at which a contract has been signed to the time at which the contract has been finalized; or

Cationic medium setting emulsion. See the definition for emulsion.

Coarse Aggregate - Aggregate which is retained on the No.4 (4.75 mm) sieve.

Compaction - A consolidation or compression of materials resulting in an increase in density of the materials.

Compression Rolls - The compaction load of a steel wheel roller, expressed in pounds per inch (kN/m), which is defined as the weight of the roller divided by the combined width of all the drums on the roller. The compression rolls requirements for rollers are specified in 401.13.

Course - A layer or layers of a given material or mixture placed as a part of the pavement structure.

Cross Section - In the field, elevations taken along a line at right angles to the centerline. On a drawing, a profile of the existing ground at right angles to the centerline. The drawing of an earthwork cross section also shows the shape of the finished excavation or embankment at the same point. A roadway cross section shows the thickness and width of the pavement courses.

Cross-Slope - The transverse slope of the pavement, either crown or superelevation. See section 401.19 for details on checking the cross-slope of a pavement.

Crown - The height of the center of the roadway surface above a straight line drawn between its edges. See section 401.19 for details on checking the crown of a pavement.

Cut Back Asphalt - Asphalt binder which has been rendered fluid by fluxing it with a light volatile petroleum distillate. Upon exposure to atmospheric conditions, the volatile distillate evaporates, leaving only the asphalt cement which reverts to its original semi-solid condition. Cut back asphalts are classified as rapid curing (RC), medium curing (MC), or slow curing (SC).

Degradation - A reduction in aggregate particle size due to breakage and water.

Density - The ratio of the weight of a given material to its volume.

Drum Mix Plant - A continuous production plant in which cold aggregate is proportioned and dried in the first half of a drum and then mixed with bituminous material in the second half of the drum. Then the resulting asphalt concrete is stored in a storage bin for later use.

Emulsion (Asphalt) - A suspension of extremely small droplets of asphalt in water in the presence of an emulsifying agent, which usually is a type of soap. Upon exposure to atmospheric conditions, the water evaporates, leaving only the asphalt cement which has been modified by the emulsifying agent. Emulsions are classified as rapid setting (RS or CRS), medium setting (MS or CMS), or slow setting (SS or CSS). The letter “C” in front of an emulsion type (CRS, CMS, or CSS) denotes a cationic (positively charged) emulsion. If the emulsion type does not start with the letter “C” (RS, MS, or SS), the emulsion is anionic (negatively charged) or non-ionic (neutral charge). If the emulsion type is followed by an “h” (SS-1h, CMS-2h, etc.), the emulsion was made from a harder base asphalt cement.

Fat Spots - See the definition of bleeding.

Fine Aggregate - Aggregate which passes the No.4 (4.75 mm) sieve.

Flushing - The drawing of asphalt material to the surface of an asphalt mixture, due to the action of traffic.

Gradation - The distribution of particle sizes in an aggregate or asphalt mixture.

Grade - The rate of change of the profile elevations. See section 401.19 for details on checking the grade of a pavement.

JMF - See the definition of job mix formula.

Job Control - Inspection and testing conducted to determine compliance of the materials and work with the contract requirements.

Job Mix Formula - The mix composition of an asphalt concrete approved by the Laboratory. The job mix formula (JMF) of a mix can be obtained from the "BCJMF" screen in the TAS portion of CMS. The JMF number of the mix needs to be known to use the "BCJMF" screen.

Keying - The interlocking of aggregate particles by compaction.

Laboratory - The Office of Materials Management of the Department's Central Office in Columbus, which is also known as the Central Test Lab.

Marshall Mix Design - Volumetric mix design procedure used to establish the optimum Asphalt binder content for an asphalt concrete. The procedures for designing a mix using the Marshall mix design are contained in 441.02 and the Asphalt Institute Manual Series No. 2.

Mineral Filler - limestone dust, Portland cement, or other inert mineral matter. The specifications for mineral filler are contained in 703.07.

NAPA - National Asphalt Pavement Association.

NCAT - National Center for Asphalt Technology.

Odometer - An instrument used for measuring traveled distance.

Oscillating Wheel - The vertical movement of pneumatic tire roller's wheels over irregularities in the surface on which the roller is operated, providing a kneading action.

PG (Asphalt) Binder - An asphalt binder which has been graded by the PG Binder system. An asphalt binder has to be modified with an additive to meet some of the PG Binder grades. An example of a PG Binder Grade is PG 64-28. An example of a modified PG Binder Grade is PG 70-22M (See Asphalt Binder).

Placement Rate - The placement of paving materials on the basis of a given weight and area covered. Placement rate is described in detail in section 401.21.

Plant - The plant where aggregate and asphalt material are mixed together or the plant which produces the aggregate or the asphalt material.

Pneumatic Tire Roller - A roller with 3 to 5 rubber tires mounted on two tandem axles. The wheels that the tires are mounted to oscillate, which means they are capable of moving up and down independently of each other. The pneumatic roller compacts a pavement using the combined force of weight and the kneading action of the oscillating wheels. The specifications for a pneumatic tire roller are contained in 401.13.

Prime Coat - An application of asphalt material made on the surface of a pavement layer for the purpose of binding the surface particles together. The specifications for a prime coat are contained in 408.

Profile - A line on a drawing which shows elevation of points along a selected route. A profile usually shows both ground elevations and grade-line elevations. See section 401.19 for details on checking the profile of a pavement.

RAP - The abbreviation for reclaimed asphalt pavement, which comes from reclaimed asphalt concrete pavement. The specifications for the use of RAP is contained in 401.04 and 441.03.

Raveling - The loss of aggregate from the surface of a asphalt mixture due to a lack of adequate compaction, segregation of the mixture, moisture damage, high dust content, or a lack of PG binder for binding the aggregate particles together.

Screed - A rectangular trowel on an asphalt paver used to cut off the asphalt mixture at the desired thickness, to smooth the surface and consolidate the material.

Screenings - This is No. 10 size gravel, stone, or air-cooled slag. The specifications for screenings are contained in 703.10.

Segregation - The separation of the coarse and fine particle sizes in an aggregate or asphalt mixture.

Shoving - The plastic deformation or displacement in an asphalt mixture in the direction of traffic movement.

Steel Wheel Roller - A roller which compacts an asphalt concrete with static steel drums. Types of steel wheel rollers are the three-wheel roller, tandem roller, trench roller, and vibratory roller.

Strike Off - A blade used to cut off material at the desired elevation or thickness.

Superelevation - The difference in elevation between the inside and outside edges of a roadway on a horizontal curve. See section 401.19 for details on checking the superelevation of a pavement.

Superpave - Mix design procedure, which establishes material properties of an asphalt concrete mix by using a gyratory compactor and material requirements.

Surface Texture - A term used to describe the appearance of the surface of a pavement course such as sandy, coarse, open, dense, uniform, etc.

Surface Treatment - See the definitions for chip seal, prime coat, or tack coat.

Tachometer - An instrument for measuring the speed of rotation.

Tack Coat - An application of asphalt material made on a pavement surface for the purpose of bonding the existing course to the overlying course. The specifications for a tack coat are contained in 407. Tack coats are described in Section 6.

Tandem Roller - A steel wheel roller with two drums mounted on tandem axles, which compacts a pavement using the force of the roller's weight. The specifications for a tandem roller are contained in 401.13.

Three Wheel Roller - A steel wheel roller with three drums, two drums mounted on the rear axle and a smaller drum mounted on the front tandem axle, which compacts a pavement using the force of the roller's weight. The configuration of the drums on a three wheel roller allows it to compact longitudinal joints without interfering with traffic in the adjacent lane. The specifications for a three wheel roller are contained in 401.13.

Vibratory Roller - A steel wheel roller with one (single drum) or two (double drum) drums, which compacts a pavement using the combined force of weight and the vibration of the drum or drums. The specifications for a vibratory roller are contained in 401.13.

Viscosity - Resistance to flow in a liquid. The higher the viscosity, the greater the resistance to flow.

Yield - The area of a surface covered by a given quantity of material measured in square yards (square meters).

Concrete Terms

Absorption - The soaking up of moisture (water) by aggregate.

Admixture - A substance other than cement, water or aggregate added to a batch of fresh concrete to alter one of the normal properties of concrete.

Aggregate - Mineral material, such as sand, gravel crushed stone, slag, or the combinations thereof, with which cement or bituminous material is mixed to form a mortar or concrete. "Fine Aggregate" may be considered as the material that will pass a 1/4 inch screen, and "coarse aggregate" as the material that is retained thereon.

Aggregate Base - The layer of specified, compacted material placed on the subgrade to serve as a base for pavement.

Agitation - Slow stirring or turning over of freshly mixed concrete to keep it in workable condition until placed into forms.

Air Entrained Cement -Cement into which the air entrainment admixture has been incorporated at the cement plant when the cement was ground.

Batch - The combination of amounts of cement, aggregate, water and admixture which will be mixed at one time in a mixer.

Batching Operation - Proportioning and assembling the materials which will comprise one batch.

Batching Plant - The plant either on or off the work site where the materials are assembled by batches for the mixer. Water and admixtures usually are added as the batch is introduced into the mixer.

Batch Weights -The individual weights of the cement, aggregate and water used in each batch of concrete. Aggregate is adjusted for moisture content and specific gravity.

Bleeding -Flow of water to the surface of freshly placed concrete.

Bulkhead -

A partition made of timber, concrete or steel plate, between stockpiles to prevent their intermingling.

A temporary form placed at the completion of a portion of concrete structure or pavement, or whenever production is interrupted for an extended period of time.

Cement - A mixture of clay, limestone and other selected materials heated to high temperature to form clinker. The clinker is then ground into powder. Mixed with water it forms a paste to surround and bind the aggregate into a solid and durable mass.

Charging - Filling. Charging a mixer is placing the ingredients for concrete into it.

Compacted - Made more dense. When a material is compacted, the particles are forced together more tightly so that a given weight of material takes up less space.

Concrete Control Inspector - The Inspector at the job site who is responsible for the necessary inspections and tests to assure concrete meeting specifications.

Counters -Meters on mixers which show the number of revolutions. Transit mixers may have two counters - one for mixing speeds and one for agitation speeds.

Cure - The treatment given concrete to assure sufficient water and heat necessary for chemical action so that concrete attains the strength and durability for which it was designed.

Entrained Air - Millions of microscopic voids introduced into concrete through an admixture to permit the cured concrete to undergo freezing and thawing without damage.

Entrapped Air - Large air bubbles which enter concrete through mixing or handling. Being undesirable, they can be removed by vibrating, spading or rodding.

Falsework - The bracing supporting concrete structural forms which is removed after the concrete has cured sufficiently to support its own weight.

Finishing - Shaping the surface of cement that is not shaped by forms. Also it includes filling visible voids in the concrete after the forms are removed.

Footer - The concrete pad which spreads the load of a structure over an area of supporting earthwork.

Forms, Report - Printed sheets of paper containing blank spaces for filling in desired information.

Forms, Structural - Molds of rigid material for receiving plastic concrete which will cast it to a specified shape and dimension.

Gradation - The classification of different sizes of aggregate within a given size of aggregate as determined by sieve tests.

High-Early-Strength Concrete - Concrete made with a special cement (Type III) that reaches design strength and hardness in considerably shorter time than concrete made with regular portland cement.

Honeycombing - Large voids in the concrete which are due to inadequate spading or consolidating.

Intermingling - The unintentional dilution of one size of aggregate by aggregate of a different size as a result of improper storage or careless handling.

Job Control - Steps taken to keep quality and quantity of materials and work on a project within the specifications and plans.

Mixing - Combining the ingredients of a batch of concrete into a homogenous mass through raising and dropping action of a revolving drum. Specifications cover the rate and number of revolutions which are acceptable for proper mixing.

Moisture Content - The percentage by weight of water contained in aggregate as compared to the same aggregate in a completely dry condition.

Mortar - A mixture of water, sand and cement. Mixed with coarse aggregate this mortar completely envelopes each particle of coarse aggregate to form concrete.

Paved - An area covered with a hard surface to support traffic or material storage.

Plant Bins - Bins at the hatching plant for temporary storage of aggregate and cement for use in proportioning concrete batches.

Proportioning Concrete - Determination of the amount of each ingredient used in a class of concrete with adjustments as determined by tests called for in the specifications.

Retarder - An admixture placed in concrete which slows the setting of the concrete.

Rodding - Consolidation of a concrete mix sample by the repeated insertion of the prescribed steel tamping rod.

Saturation - Condition of aggregate when it is completely soaked and will not absorb additional water.

Scaling - Peeling away of small amounts of surface concrete.

Segregation - The unintentional separation of the larger pieces of aggregate from the smaller pieces within one size of aggregate or within a mixture of sizes in fresh concrete.

Set, or set up - A stage reached by freshly placed concrete as it hardens and can no longer be worked or shaped.

Sieve Analysis - Determination of the gradation of an aggregate sample by passing through a series of screens with specified openings and weighing the separated particle sizes.

Slump - A measure of the consistency and workability of plastic concrete.

Spading - Repeatedly inserting a flat steel blade edgewise into fresh poured concrete for consolidation and to drive out entrapped air, particularly where the concrete meets the forms or imbedded objects.

Spading Blade - A small steel blade about the size of a nail file, used in making Chace air determinations.

Spading Tool - A tool resembling a garden hoe with the blade straightened out in line with the handle used for consolidating concrete.

Spalling - The breaking away of hardened parts of concrete from the main body at surface points.

Specific Gravity - The ratio of weight of any volume of a substance to the weight of an equal volume of water.

Specifications - The directions, provisions and requirements contained in the State of Ohio Department of Transportation Construction and Materials Specifications as supplemented by the supplemental specifications and special provisions.

Stabilize - To make or hold steady, and preventing fluctuations.

Stockpile - A large amount of aggregate placed in a pile for storage until ready for use.

Strike Off - Using a straight edge to scrape off excess concrete which may protrude above the mold or forms.

Subgrade - The portion of a roadbed upon which the pavement structure and shoulders are constructed.

Testing Equipment - That equipment furnished to the project for conducting field tests.

Test Weights - Ten 50-pound (22.7 kg) steel weights that must be readily available for checking weighing devices at concrete plants.

Ticket - A form record of quality, quantity, and other pertinent information which may accompany a shipment of construction materials to the project.

Validation - The signature or initials of an authorized individual on any form or ticket denoting that the information is as stated.

Verification - The steps necessary to determine that the work or materials described are in conformance with plans and specifications.

Water-Cement Ratio (W/C) - The proportion of an amount of water to the specified amount of cement used to produce concrete. Such amount of water is the sum of the calculated amount of water contained in the aggregates, plus all the water added both at the plant and at the site, less the calculated amount of water absorbed by the aggregates.

Yield - A check on the mix design made by dividing the total batch weight by the determined unit weight, weight per cubic yard (weight per cubic foot). The actual volume thus obtained is compared to the design volume.

Rigid Pavement Terms

Admixture - A substance other than cement, water or aggregate added to a batch of fresh concrete to alter one of the normal properties of concrete.

Aggregate - Mineral material, such as sand, gravel, crushed stone, slag, or the combination thereof, with which cement is mixed to form a mortar or concrete. “Fine aggregate” may be considered as the material that will pass a 4.75 mm (No. 4) screen, and “coarse aggregate” as the material that is retained thereon.

Batch - The combination of amounts of cement, aggregate, water and admixture which will be mixed at one time in a mixer.

Batching Plant - The plant either on or off the work site where the materials are assembled by batches for the mixer. Water and admixtures usually are added as the batch is introduced into the mixer.

Beam, Test - A beam of specified size molded on the job and later broken in a testing machine to determine the flexural strength of the concrete.

Bleeding - Flow of water to the surface of freshly placed concrete.

Cap - A short tube, closed at one end, placed on the oiled end of a dowel in an expansion joint to provide space for movement of the dowel in hardened concrete. A stop in the tube prevents it from being pushed all the way onto the dowel before the concrete hardens.

Cement - A mixture of clay, limestone and other selected materials heated to high temperature and ground into powder. Mixed with water it forms a paste to surround and bind the aggregate into a solid and durable mass.

Contraction Joint - A joint which controls the location of a transverse crack and permits the slab to contract and expand with changes in temperature.

Construction Joint - A joint formed in concrete pavement at the end of the day’s production or any time production is interrupted for 30 minutes or longer.

Core - A cylinder of concrete cut from pavement with a hollow drill. Cores are 4 inches (200 mm) in diameter and are used to check the thickness and strength of the concrete.

Course - The depth of concrete pavement obtained in one pour.

Crown - The height of the center of the roadway surface above a straight line drawn between its edges.

Cure - The treatment given concrete to assure sufficient water and heat necessary for chemical action so that concrete attains the strength and durability for which it was designed.

Curing Membrane - A compound sprayed over the exposed surface and edges of newly placed concrete to prevent the evaporation of water during curing.

Cylinder - A test sample of concrete molded into a cylinder 12 inches (600 mm) high and 6 inches (300 mm) in diameter, to be sent to the Laboratory for determination of strength and density.

Deformed Bar - A steel bar which has projections on its surface for increasing the bond between the concrete and the bar.

Density (Soil) - The density of soil is its weight-volume relationship, which usually is expressed in pounds of soil per cubic foot (kilograms of soil per cubic meter).

Dowel or Dowel Bar - A smooth steel bar extending across a concrete joint to transfer the applied load, prevent future misalignment of the slab and permit movement at the joint.

Dowel Assembly - A cage or basket used to hold dowels in position during placement of concrete.

Edging - Rounding the edges of concrete pavement and hand-formed joints while the concrete still is workable, using an edging tool of specified radius.

Elevation or Grade - The height as measured from a predetermined point denoted in the plans.

Expansion Joint - A joint adjacent to a bridge or intersection to absorb expansion of concrete pavement and prevent expansive pressure on the bridge or intersecting pavement.

Fine Grading - Removing approximately 1 inch (25 mm) of the primary subbase and re-rolling to bring to exact grade, upon which the concrete pavement is placed.

Finishing - Shaping the surface of concrete that is not shaped by forms. Also it includes filling visible voids in the concrete after the forms are removed.

Finishing Machine - A machine which screeds and a float for performing the final grade and smoothness of the concrete pavement to meet the requirements.

Float - A straight piece of wood or metal used to smooth the surface of plastic concrete. Small hand-held floats are called paddle floats.

Forms, Pavement - Metal plates secured together and to the subbase for shaping the sides of the pavement and controlling alignment, grade and thickness. Also, the forms serve as a track for paving equipment.

Grade (noun) - See Elevation.

Grade (verb) - To add or remove earth to obtain a desired level or slope.

Hand Finishing - Correcting manually irregularities left by the finishing machine or performing those functions which cannot be accomplished by machine, such as edging or forming of joints.

Head - The roll of plastic concrete which forms ahead of a screed plate.

Honeycombing - Large voids in the concrete which are due to inadequate spading or consolidating.

Hook Bolt - A short steel bar with hooked ends joined by a threaded connection. Use is to fasten a concrete slab to another later constructed beside it.

Inspection - Examination by observation, measurement, or tests to determine that materials and work are in conformance with specifications.

Joint Lock - The device at each end of a section of paving form for attaching the sections together.

Job Control - Steps taken to keep quality and quantity of materials and work on a project within the specifications and plans.

Joint Sealer - A compound for preventing entrance of water and solid particles into a joint. The sealer may either be preformed or liquid.

Laitance - An accumulation of fine particles on the surface of freshly placed concrete occurring when there is an upward movement of water through the concrete due to the presence of too much mixing water or excessive vibration.

Lane or Traffic Lane - A strip of pavement of specified width, usually 12 feet (3.6 meters).

Longitudinal Joint - A joint which extends lengthwise in the roadway, parallel to the centerline.

Mesh - A fabric of steel wires welded together at their intersections for placement in concrete pavement as distributed reinforcement.

Mesh Installer - A machine for imbedding wire mesh into freshly placed concrete pavement.

Mortar - A mixture of water, sand and cement. Mixed with coarse aggregate, this mortar completely envelopes each particle of coarse aggregate to form concrete. Also, mortar is used to fill honeycombing which becomes apparent upon removal of forms.

Oscillating - To swing back and forth, operating between fixed limits, such as the movement of a screed on a finishing machine.

Pin Template or Template - A device used to check the surface of the subbase.

Raveling - Slightly disturbing the surface of concrete pavement adjacent to sawing of a joint.

Random Cracks - Cracks which appear in concrete pavement due to contraction in the early stages of curing, and which follow no set pattern.

Rigid Pavement Inspector - An authorized representative of the Engineer to make detailed inspections and documentation of contract performance as pertain directly to concrete paving operations.

Sawing - Using a circular saw to cut a groove in the surface of the pavement to control the location of transverse cracks.

Scaling - Peeling away of small amounts of the concrete surface.

Screed - A long metal plate moved across the surface of freshly placed concrete with a sawing motion to consolidate the concrete and rough finish it approximately to grade.

Segregation - The unintentional separation of the larger pieces of aggregate from the smaller pieces within one size of aggregate or within a mixture of sizes of fresh concrete.

Shim - A thin piece of stone, wood or other material used to raise the object resting on it to the desired elevation. (Not permitted in adjusting forms to grade.)

Slab - A continuous portion of concrete paving bounded by joints and/or the edge of the pavement.

Slip Form Paving - Concrete paving by use of a machine carrying its own forms between which low slump concrete is compacted sufficiently to retain its shape after the machine has progressed onward.

Slump - Measured in millimeters (inches) on a vertical axis, the amount that a sample of fresh poured concrete that has filled a standard inverted cone will sink down after the cone has been removed. A measure of the consistency and workability of concrete.

Spading -Repeatedly inserting a flat steel blade edgewise into fresh poured concrete for consolidation and to drive out entrapped air, particularly where the concrete meets the forms or imbedded objects.

Spalling - The breaking away of hardened parts of concrete from the main body at surface points.

Spreader - A machine which distributes fresh concrete generally over the area between the forms.

Station Marker - A numeral impressed into the surface of newly finished concrete pavement and located at specified longitudinal intervals near the edge of the roadway for purposes of future location references.

Straightedging - Placing a 10 foot (3.0 meter) straightedge on the finished pavement surface to determine if the surface is within tolerance.

Strike Off - Using a straightedge to scrape off excess concrete which may protrude above the mold or forms.

Subbase - The layer of specified, compacted material placed on the prepared subgrade to serve as a base for pavement.

Subgrade - The portion of a roadbed upon which the pavement structure and shoulders are constructed after it is prepared.

Surge - The rise in the surface of plastic concrete following the release of compaction after the screed has passed over it.

Texturing - Slight roughening of the finished surface of concrete pavement to provide greater safety through increased traction to the tires of vehicles which will pass over it.

Thin-Bonded Patching - Repairing concrete pavement only to the depth of unsound concrete rather than the full depth of the pavement.

Tie Bar - A deformed dowel or hook-bolt placed across longitudinal joints of concrete pavement near middle depth to tie the slabs together and hold the joint closed.

Tying - Wiring together overlapped mesh that is hand-tied by use of rings similar to hog rings.

Tolerance - The permitted variation from a specified condition.

Traction Speed - The rate of forward movement parallel to the centerline by the paving equipment.

Transverse - A theoretical line running perpendicular to the longitudinal or centerline of a roadway.

Validation - The signature or initials of an authorized individual on any form or ticket denoting that the information is as stated.

Vibrator - A device for pulsating fresh concrete so that entrapped air is released, and the concrete settles uniformly about reinforcement and to the forms.

Wearing Plate - A small plate which drags over the top of the pavement forms or adjacent paving to control the height of the screed plate.

Windrow - An accumulation of material as a result of rolling up or sliding off to the side. Applies here to loose material just inside of the forms left by the subgrader in the fine grading operation.

Yield - A check on the mix design made by dividing the total batch weight by the determined weight per unit volume. The actual volume thus obtained is compared to the design volume.

Earthwork

Aggregate Correction Method - a method of compaction testing that modifies the one point proctor method. It accounts for the material retained on the ¾" sieve.

Atterberg Limits - The moisture content of a soil at certain stages of soil behavior.

Balanced Project - A project where the amount of embankment is required approximately equal to the amount of excavation.

Benching - The excavation of the existing embankment steps into an slope where new embankment is being placed on the slope. The benching connects the new embankment and the existing soil in the slope.

Blasting - The use of explosives to fracture rock or shale.

Borrow - Material obtained from approved sources that are required for the construction of the embankment.

CA-EW-12, Daily Earthwork Inspection Sheet – This form details the earthwork construction operations on the project. It details general project information, locations of the operations, construction equipment, soil types, lift thicknesses and other information.

CA-EW-5, Nuclear Gauge Compaction Form – This form details the record keeping for compaction tests. The one point proctor and test section methods A and B use this form.

CA-EW-6, Nuclear Gauge Compaction with an Aggregate Correction – This form details the record keeping for a compaction test. The aggregate correction method of compaction testing uses this form.

Canvas Shroud - A canvas curtain used to control dust during the spreading operation.

Cement - A burned and pulverized chemical that that reacts with silty and granular soils.

Centrifugal Force - The roller force or load on a base course or material that adds the weight and the vibration energies.

Checking - The cracking of a base course or stabilized subgrade due to over rolling.

Clearing - Cutting down trees and brush.

Compaction - Increasing the density of soil by mechanical means, involving the expulsion of excess air.

Compaction Equipment - Equipment used to compact materials.

Consolidation - The removal of water from a soil over time to increase its strength.

Construction Underdrains - Sacrificial underdrains placed to drain the subgrade.

Contractor Designed Chemically Stabilized Subgrade - Tests performed by the contractor to determine the optimum percentage of chemical (cement, lime, or lime kiln dust) that will stabilize the soil.

Curing - The act of ensuring that the lime or cement stabilized soil is wet for at least 5 days.

Deflections or Rutting - The vertical movement of the subgrade during proof rolling.

Density - The proportion of soil mass or weight to the volume of the soil. It is commonly expressed in pounds per cubic foot.

Depth Checks - The measuring of the thickness of the base course or embankment material.

Disking - The act of using a disk to break up a material so that it may dry.

Dozer - A machine that pushes and levels material

Drainage - Constructing the embankment to drain the water away as fast as possible.

Drainage Blanket - A system of coarse aggregate, fabric and pipe that is designed to drain large areas of the slope.

Dry Density – The density of a soil that uses only the weight of the soil. The density of the soil when the soil is completely dry.

Drying - The act of lowering the moisture content of a material by disking, plowing or other means.

Earth Moving Equipment - Equipment used to move earthen materials.

Earthwork Volumes - The calculation of a three dimensional earthwork quantities.

Electronic Grade Control - Controls on construction equipment that controls the grade.

Embankment - A structure consisting of suitable materials and constructed in lifts to a predetermined elevation and cross-section.

End Area - The cross sectional area on the plans that represents a two dimensional plane.

End Dumping - The direct loading of the base or embankment material from the truck to the subgrade or foundation.

Excavation - The removal of materials to predetermined elevations and cross-sections.

Excavator - A machine that removes material with a bucket.

Fine Grading - The act for trimming the surface to meet the specification tolerances.

Finished Surface - The top of the base or subgrade materials that has been fine graded or trimmed.

Footed Rollers - Rollers that knit the materials together. Primarily used for clayey materials.

Foundation - The location at the base of an embankment.

Gradation - The level of coarseness or fineness of a soil, referring to soil sizes.

Grader - A machine used to level surfaces.

Grading - The act of leveling the embankment surface to drain.

Granular Material Types - Granular Materials in Item 203 that have specific gradations to perform certain engineering functions.

Grubbing - Clearing by digging up roots and stumps.

Hydrated Lime - A finer form of lime.

Ingots - Heavy concrete weights in the proof roller.

Iron Slags - Air-cooled blast furnace slag (ACBF) and Granulated slag (GS).

Lift Thickness - The thickness of the material when placed on a horizontal surface.

Lime - A by-product of limestone that reacts with clayey soils.

Liquid Limit - Moisture content at which a soil passes from a plastic to a liquid state.

Maintenance - The act of constructing an embankment that minimizes construction problems. For example grading and draining to keep water off the embankment.

Moderately Soft Foundation - A foundation that is constructible with moderate changes to embankment construction techniques.

Moisture Content - The amount of water in a given soil expressed as a percent of the material's dry weight.

Moisture Density Curve - A plot of the moisture content verses the weight of a soil. This plot determines their relationship.

Natural Granular Materials - Broken or crushed rock, gravel, sand, durable siltstone, and durable sandstone placed in 8-inch (200 mm) loose lifts.

Natural Soils - All natural earth materials, organic or inorganic, resulting from natural processes such as weathering, decay, and chemical action.

Nuclear Gauge - A device that uses nuclear radiation to determine the soils' density and moisture content.

Ohio Typical Density Curves - curves that were developed in the 1930's and 40's, that represent all the types of soils in the state. They are used with the one point proctor method to pick the correct curve during compaction testing.

One Point Proctor Method - a method that determines the compaction of a soil. It requires making a proctor and using the Ohio Typical Density Curves to pick the correct curve.

Optimum Moisture - The water content at which the maximum dry density can be achieved by compacting an embankment material.

Partial Excavation Method - The act of removing only a portion of the soft material.

Pavement - The location above the subgrade that traffic runs on that is made of concrete or asphalt.

Plastic Limit - The moisture content at which the material breaks apart at an 1/8” diameter. Indicates how much clay is in the material. The moisture content at which a soil changes from a semisolid to a plastic state.

Plasticity Index - The higher the PI the more clay in the material. The numerical difference between the liquid limit and plastic limit.

Power Driven Mixer - A big roto-tiller used to mix the soil and the lime.

Prime Coat - An asphalt emulsion used to keep the lime soil moist for the cure period.

Proctor Hammer - a device that is used to compact a soil in a proctor mold. It weighs 5.5 pounds, compacts the soil 25 times for each soil lift in the proctor. The soil is placed in the proctor mold in three lifts.

Proctor Test – a procedure that uses a standard compactive effort to determine or pick a soil moisture density curve.

Proof Rolling - The use of heavy rollers to test the subgrade stability.

Quick Lime - A coarser and more concentrated form of lime.

Random Material - Mixtures of suitable materials that can be placed in 8-inch (200 mm) loose lifts.

Rectangular Foot - A footed roller with rectangular feet.

Recycled Materials - Fly ash, bottom ash, foundry sand, recycled glass, tire shreds, RPCC, or RACP

Recycled Portland Cement Concrete (RPCC) - Recycled portland cement concrete blended with natural soil or granular material.

Reclaimed Asphalt Concrete Pavement (RACP) - Recycled asphalt pavement blended with natural soil or granular material.

Rock - Sandstone, limestone, dolomite, glacial boulders, brick, and RPCC too large to be placed in an 8- inch (200 mm) loose lift.

Rock or Shale Subgrade Excavation - The 24 inches that is excavated below the pavement for drainage and uniform support.

Roller Pass - One pass over a given location.

Sand Blanket - The sand that is placed to drain the underlying soft material.

Saturated Embankment - Embankment that is full of water to the point of being unstable.

Scale – A weight measuring device used during compaction testing.

Scalping - Removal of remaining roots, sod, grass, agriculture crop, sawdust, and other vegetation so that the soil is completely exposed; however topsoil should not be removed.

Scraper Plate - A device that is used to establish a location for the nuclear gauge.

Segregation - The separation of fine and coarse material in a base course.

Self Propelled Spreading Machine - A piece of equipment that receives the base course from the truck and spreads it evenly on the subgrade.

Settlement - The compression of a soil into a more stable condition.

Severely Soft Foundation - Low lying areas with high or standing water that are not constructible with soil or standard construction techniques.

Shale - Laminated material with a finely stratified structure formed by the natural 'consolidation' of a clay or silt. The material is sometimes cemented together.

Shale Compaction Testing – Compaction testing that uses a bucket test to determine what compaction test to perform on a particular shale.

Sheepsfoot - An old footed roller that has 10% coverage per pass.

Side Drainage - Any ditches that drain the embankment away from the embankment construction.

Side Slopes - The embankment slopes that are perpendicular to the roadway. (Usually 2:1 slopes).

Slag Materials - Residual material from making iron or steels that must meet the requirements in 703.16.

Slide Repair - An area to be excavated for replacement.

Soil Classification - AASHTO classification of a soil determined from the gradation and characteristic of the different materials.

Spreading - Moving material in preparation for compaction.

Spring Drains - A system of coarse aggregate, fabric and pipe that is designed to drain small areas of the slope.

Standard Count- a procedure performed on a nuclear gauge to ensure that the readings are accurate.

Steel Slags- Open hearth (OH) slag, Basic oxygen furnace (BOF) slag, Electric arc furnace (EAF) slag or granulated slag.

Steel Wheeled Roller - Uses a drum with 100% coverage with one pass. Can be used with or without vibration. Used for granular and silty materials.

Stock Pile - A pile of material that has or will be approved by the Test Lab.

Straight Edge - A piece of lumber with a level on it to check the grade.

Subgrade – The portion of the roadbed upon which the pavement structure and shoulders are constructed.

Subgrade Compaction - The compaction of the top 12 inches of the subgrade.

Suitable Material - Natural soil, natural granular material, granular material types, slag material, brick, shale, rock, random material, or other materials that are appropriate for use in embankment construction.

Tamping Foot - A footed roller that has 40% coverage with one pass and is highly productive. Can be used for soil, rock or shale.

Test Rolling - The use of a proof roller to test the stability of the subgrade prior to undercutting or stabilizing the subgrade. Used when spot locations are detailed in the plans.

Test Section Method – A compaction method that uses the relative density between two nuclear gauge readings to determine the materials potential maximum density.

Test Section Method A – A compaction method that uses the relative density between two nuclear gauge readings to determine the materials potential maximum density. It is used when the material has a definitive moisture density curve.

Test Section Method B – A compaction method that uses the relative density between two nuclear gauge readings to determine the materials potential maximum density. It is used when the material does ‘not’ have a definitive moisture density curve. A field test section moisture density curve is developed with this method.

Test Section Method C – A compaction method that uses the relative density between two nuclear gauge readings to determine the materials potential maximum density. It is used when the material is highly variable. It uses form CA-EW-7.

Total Excavation Method - Removing all of the soft material.

Waste - Excess material removed from the project limits.

Watering - The act of adding moisture to a material for proper compaction.

Weak Plane - An area in the embankment where the soil is weak and could slide apart.

Wet Density - the density of the soil that includes the weight of water and soil. It is also expressed as the total weight of the soil.

Zero Air Void Curve - A theoretical line that is used to ensure that the nuclear gauge readings are not dramatically incorrect. It plots the moisture density curve without the voids.

Landscape

Amendments - mixed with the soil removed from the plant hole; to improve the soil texture, ph or add organic material; sphagnum peat moss, shredded pine bark, yard waste compost, and sand are all accepted amendments.

Backfill - this soil and amendment mixture is placed back into the hole after the plant has been set (see CMS661.11)

Balled and Burlapped - this is one kind of method for digging field-grown plants with a ball of earth still intact in which they are growing; can be supported by a wire basket and or burlap and laced with bailing twine; often denoted as B&B in plan notes; see appendix for correct plant/B&B sizes.

Bare Root - plants shipped by this method are done so without the soil from which they were grown; this type of plant can be seedlings, perennials, roses, fruit trees etc.; roots should be white and unbroken.

Caliper - this is measured as the width of a single stem plant; see page 6 on how to take measurement.

Competing Leaders - found at the top most branch, this condition is where the main stem (leader) has been cut or broken and has continued to grow into two main stems; one should be removed to eliminate the potential for future problems.

Conifer - cone-bearing plants; mostly evergreen but not always true

Crown - the upper part of a tree, also called the canopy.

Deciduous - term used to describe plants which lose their leaves at the end of a growing season; typically this occurs in the fall.

Fertilizer - a natural or synthetic material added to or spread on soil to increase its fertility; the three numbers indicate its percentage of ingredients; in order, these numbers are nitrogen, phosphorus and potassium,

Foliage - this is the leaf structure of a plant; can be com posted of needles or deciduous leaves.

Herbicide - a natural or synthetic product typically used to eradicate weeds; product should be applied by a licensed applicator and as directed by the manufacturer's label.

Mulch - placed onto top of the plants rootball; keeps the ground cool, retains moisture, prevents heaving and breaks down, providing nutrients to the root system (see CMS661. 13).

Multi-stem - having two or more main stems; defined as clump or shrub form.

Root Crown - this is the union between the roots and the stem; care should be taken not to bury this union with soil when planting.

Single Stem - also called the central leader or trunk; tapers gradually from root crown to top.

Shrubs - usually multi-stemmed with numerous side branches; can be evergreen or deciduous.

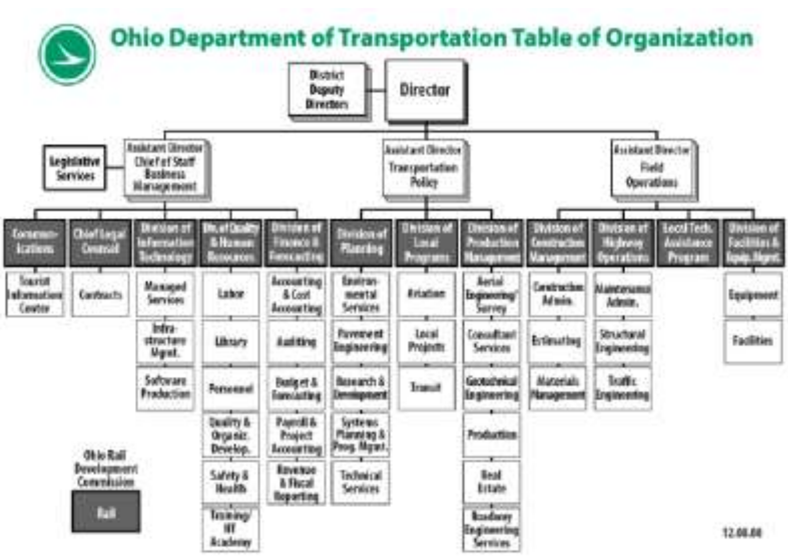
Tree Wrap - placed around a deciduous tree trunk to protect it from frost cracking, sunscald or insect damage; (see CMS661.15)

105 Control of The Work

Overview of Construction Contracts – General ODOT Organization

Central Office

District Construction needs to communicate with the Central Office on many issues, its primary contacts are within the Division of Construction and Division of Contracts. The Table of Organization for ODOT is shown below. *http://www2.dot.state.oh.us/Info/orgtable.asp*



The Central Office Division responsibilities lie in the area of policy and standard procedure development, support services and quality assurance. More specifically, its roles are:

- Work with other offices to develop specifications and policies that apply to the day to day operations at the project level.
- Acts as a liaison with other offices, the various trade organizations and FHWA on matters concerning ODOT's specifications, policies and procedures.
- Acts as a consultant to the Districts in matters concerning contract administration.
- Provides training to the Districts in contract administration.
- Reviews and reports the effectiveness of various construction methods and materials and provides advice on their use.
- Conducts Quality Assurance Reviews (QAR) to assure that ODOT's policies, procedures and specifications are being followed uniformly.
- Develops the performance measures by which the Districts are judged.
- Conducts the administrative closing of Contracts.
- Provides support to the Districts, Testing and Estimating Offices.

The responsibilities described above are of a general nature. The Division of Construction also has some specific approval functions that relate directly to the District. They are as follows:

- Answer Legal questions and depositions regarding claims.
- Answer prebid questions through the Office of Estimating.
- Testifying, and reporting extra work to the State Controlling Board.
- Create and publish the Construction and Materials Specifications, along with the quarterly publication of all other specifications.
- Tracks and reports on change orders and provides feedback to Production offices.
- Materials testing, and specification development including new product review.
- Estimating analysis of trends, bid review, and change order support.

As mentioned above, the Division of Construction has the responsibility Construction Administration, the Central Laboratory and Office of Estimating. The Office of Construction Administration has experts in the areas of concrete, asphalt, traffic, bridges, contracts, and scheduling who can provide advice to the Districts and initiate specification or policy changes.

The Division of Construction Management Policies and Standard procedures can be found online here:

http://www.dot.state.oh.us/Divisions/ConstructionMgt/Pages/ConstructionPolicies.aspx

District

All District responsibilities begin with the District Deputy Director (DDD). The DDD through the Highway Management Administrator (HMA) and the District Construction Engineer is responsible for the administration of all contracts sold for the construction, reconstruction and maintenance of the highway system within the District.

While Central Office's responsibilities are primarily general in nature, the District's responsibilities are very specific. Although the Districts have always been responsible for the administration of all contracts within the District, they now have additional authority to help in the administration of these contracts. The following is a summary of various District responsibilities required by state policies and procedures as they relate to contract administration:

- Assure that all work done on each project is performed in accordance with the project's requirements (plans, proposal, specifications, supplemental specifications, special provisions, etc.)
- Approval of all change orders that do not require approval by the Director as defined in the Interim Standard Procedure 510-010(SIP).
- Approval of all time extensions and waivers.
- Review the contractor/subcontractor certified payrolls for compliance with the contract requirements.
- Review the contractor's performance and compliance with the contracts Equal Employment Opportunity requirements.
- Approve all estimates for work completed on the projects.
- Perform the final inspection and approve the final inspection report.
- Review the project records to assure that all requirements have been met.
- Monitor Local Participating Agency (LPA) projects to assure compliance with FHWA requirements.
- Prepare and approve the Final Package on the project.
- Issue the final acceptance letter and submit the finalized project to the Auditor.

The general responsibilities and requirements assigned to each District rest in the hands of the District Construction Office and specifically the District Construction Engineer (DCE). This person, with the approval of the District Deputy Director and Highway Management Administrator, is responsible for the administration of the contracts involving the construction, reconstruction and maintenance of the District's highway system as well as local projects involving State and Federal aid on the State's system. The DCE is responsible for assigning personnel to the project for this purpose. In addition, the DCE will work to resolve issues at the lowest possible level.

As part of this reorganization, each county is now under the supervision of a County Manager. This person will be involved with all work within the county. The County Manager will ultimately be the owner of the construction end product. Therefore, they must be involved in the construction process. As part of their duties, they will provide the inspection force used in the contract administration. Their involvement will depend on their authority level which may vary from district to district.

The District is responsible for the following general issues:

- Provide a description of the work through the plans, proposal, specifications, supplemental specifications and special provisions.
- Provide a method to pay for completed work.

- Provide a project site with full access for the contractor to begin work. This includes right of way purchases and utility relocations.
- Furnish an adequate and trained inspection/engineering force at the project level.
- Secure good workmanship by the contractor. This involves the monitoring by the project staff of all operations for compliance with the documents described above.
- Arrive at decisions in a thoughtful manner with due consideration of all facts involved.
- Make decisions in a timely manner to avoid undue delay.
- Promptly pay the contractor for completed work.
- Monitor the contractor's compliance with the legal aspects of the contract such as prevailing wage and equal employment opportunity requirements.
- Review the contractor's work zone traffic control to ensure the public can pass through the work zone with the least interference.
- Respond to any complaints or questions in a timely manner.

Almost everything done at the project level affects another party. Because of this, the project personnel are constantly subject to pressures from outside sources. We should always be mindful of the needs of these parties, the effects of the project on them, their relationship to the project and their affect on the project. Many of these outside forces are shown on the facing page.

Other Agencies

Although the primary parties to any contract administered by ODOT are the contractor and ODOT, other political subdivisions may also be involved either directly or indirectly. During the administration of each project, these relationships should be recognized and addressed.

The Federal Highway Administration (FHWA) is involved in many projects administered by ODOT. Federal funds are available for many programs and are utilized by both ODOT and local political subdivisions for improvement to their roadway systems. Their involvement varies with the type of project and its location on the National Highway System. FHWA's philosophy for review of federal aid projects has evolved over the years and now is as follows:

Major projects on the National Highway System (NHS) will continue to receive the most attention from FHWA. FHWA will be involved from preliminary design to finalization. This will include periodic reviews to monitor the project's progress and participation in the final inspection.

FHWA, with the advent of ISTEA, has taken a step back in the tight oversight that had existed on all federal aid projects. On most federal aid projects, both with ODOT or local participation, FHWA has minor on site participation. It does not get involved with the project specifically but expects ODOT to administer these projects in accordance with the plans and specifications and then certify that this has been done.

FHWA will still participate in reviews of our policies, procedures and specifications. At the project level, this may involve a review of an individual process (paving, traffic control, etc.) which is being studied statewide.

Many contracts involve direct local participation. The Local Participating Agency (LPA) will provide funds for their portion of the contract and the remainder may be provided by either FHWA or ODOT or both. These projects may be administered by the Local or the Department. If the Local administers the project, the Department will monitor via the District Construction Monitor. See the Locally Administered Transportation Project Manual of Procedures for guidelines. If ODOT administers the project, the LPA will have to live with the project after we are done. Therefore, with this in mind, ODOT should:

- Invite the LPA to the pre construction meeting and all progress meetings.
- Keep the LPA informed to all changes to the contract.

The above is especially true when dealing with changes requiring large increases in the local participation.

The LPA must be involved in the final inspection.

The LPA must give their final approval and acceptance to the project.

Administration of the Construction Contacts at the Project Level

In order to implement both the letter and spirit of any contract, it is necessary to have clearly defined lines of authority and communication between ODOT and the contractor. This section will present a framework to establish these lines.

The purpose of this section is to give guidance to the project personnel on how to administer the physical work of the contract. We will briefly describe the authority levels of the project personnel and explain the different items they have to work with on the job site. We will discuss items that need submitted to different offices.

Authority / Responsibilities of the Engineer

The Engineer is in charge of all details on the assigned project. The Engineer is the direct representative of the Department and has immediate charge of engineering details of each construction project. The Engineer is responsible for the administration and satisfactory completion of the project. The Engineer has the authority to reject defective work, suspend work being improperly performed and order the replacement of defective material.

It is important to note that the Engineer’s acceptance does not constitute a waiver of the Department’s right to pursue any and all legal remedies for defective work or work performed by the Contractor in an unworkmanlike manner.

The Engineer is responsible for the following:

- Assignment of the inspection duties at the project level.
- Instruction of the inspection force in the requirements of the project and the items being constructed including:
    - Addenda, proposal and supplemental specifications, equipment, i.e. concrete testing kit.
- Review of materials to be incorporated in the work. This may involve rejection of materials.
- Timely payment for work performed by performing the following activities:
    - Input daily diaries on CMS, review estimates, verify payrolls, obtain approval of sampled materials.
- Determine the need for change orders within the scope of the contract.
- Monitors the project and discusses progress schedule with Contractor's Superintendent.
- Maintaining project records.
    - Construction daily diary, CA-D-3 or 4
    - Work performed, Contractor's equipment, materials, significant events of the day.
    - Job correspondence.
    - Letters from Contractors, Utility companies and from other public agencies, any correspondence from District or internal agencies.
    - Minutes from project progress meetings, including: who attended, items discussed, resolutions to problems.
    - Other pertinent documents.
    - Shop drawings, working drawings, erection procedures.
- Address and resolve job site problems in a timely manner
- Provide the Contractor with specific information regarding the usage of Contingency quantities, "As directed" items.
- Reports to District Construction Engineer any major change in conditions, traffic accidents, status of project.
- Determines final quantities, assures the Contractor completes the punch list items, completes project files, schedules Final Inspection.

Authority / Responsibilities of the Inspector

The Inspector is the front line ODOT representative at the project level. The Inspector has authority to inspect all work performed and materials used. Authority to reject non conforming materials, suspend operations until problem is resolved by Engineer. The Inspector can neither alter the contract nor issue orders contrary to the contract.

The Inspector is responsible for the following:

- Inspects all work performed. This inspection will be done in accordance with ODOT policies and this manual, and includes daily record keeping.

- Reports quantities of work satisfactorily completed in the units established by the contract.
- Data entry into CMS, Inspector's daily diary, CA-D-3 or 4, AP-1, drawings of work performed
- Inspects and samples the materials incorporated into the work.
- Can reject unsuitable materials and suspend operations until an issue is resolved by the Engineer or DCE.
- Inspects the material incorporated into the project.
- Familiar with manuals and specifications of items of work being inspected.
- Communicates daily issues to the Engineer.
- Communicates with Contractor to assure proper installation of work.

The Inspector cannot waive the Department’s right to pursue any and all legal remedies for defective work or work performed by the Contractor in an unworkmanlike manner.

Authority / Responsibilities of the Contractor

The Contractor's Superintendent is responsible for the work. He/she must be capable of reading and thoroughly understanding the plans and specifications and be experienced in the work. There will be only one superintendent who shall have full authority to execute instructions of the project engineer and shall be in charge of all construction operations regardless of who performs the work.

The Engineer must determine the level of the Superintendent's authority to perform the work. The Engineer should know if the Superintendent can agree to extra work, get the equipment needed to get the job done and know if they can follow through with final quantities agreed on.

Remember that the Contractor bears sole responsibility for the quality of work and compliance with the contract regardless of the Department’s level of inspection.

The Contractor must provide a Superintendent on the Project at all times, that is responsible for all aspects of the Work, irrespective of the amount of subcontract Work.

The Contractor is responsible for the following general issues:

- In order to submit a bid that adequately reflects the conditions of the contract, the contractor must research all aspects of the contract such as visiting the project site, understanding the plan notes, reviewing all plan requirements.
- The contractor must notify ODOT of the project's starting date and keep ODOT informed of the proposed schedule of operations. This allows ODOT to anticipate engineering and inspection needs and therefore, efficiently manage staff.

- The contractor must provide a list of material suppliers. ODOT then can review the proposed list and obtain required samples. It should be submitted early to avoid delays associated with sampling and testing.
- The contractor must carry out the work on the projects in a diligent manner utilizing adequate labor.
- In order to manage the project efficiently and to avoid project related problems, the contractor must be aware of all federal, state and local laws that apply. Many of the legal requirements of the contract are addressed in the proposal but the contractor must also be aware of other regulations such as safety, which is not thoroughly detailed in ODOT's specifications but is extremely important. ODOT requires the contractor to protect and indemnify ODOT from all claims and liability resulting from negligence or willful violations.
- When open to traffic, the contractor must maintain the project in order to permit the public to move safely through. This includes using clean, readable signs, and traffic control devices, and maintaining the project free of debris.
- Once notified of problems the contractor must respond quickly to correct it. This is extremely important when the situation involves public safety.

COORDINATION OF CONTRACT DOCUMENTS

Contract documents are prepared to promote agreement between the various parts of the plans and specifications that control the work. In case of disagreement between the plans and specifications, the following will govern in descending order:

- Addenda
- Special provisions / proposal
- Plans
- Calculated Dimensions
- Scaled Dimensions
- Supplemental Specifications
- Standard Specifications

The Contractor shall take no advantage of any apparent error or emission in the plans or specifications. In the event the Contractor discovers such an error or emission, the Contractor shall immediately notify the Engineer.

Proposal

The proposal details numerous bidding, EEO, regulatory, special issues and general requirements of the contract. The proposal may include details for Incentives, and the schedule requirements. It also includes a list of bid items, and the wage rates that are in effect on the project. The proposal language overrules all plan, and specification items.

Plans

The plans show details of structures, the line, grades, typical cross sections of the roadway and the location and design of structures. The contractor shall keep one set of project plans available at the project site. No changes shall be made to the plans except as approved by the engineer.

Working Drawings

The plans shall be supplemented by working drawings when required to control the work adequately. Working drawings shall be furnished by the contractor. Working drawings shall not be prepared until the applicable field and plan elevations, dimensions and geometries have been verified by the contractor. Specific items of work shall require working drawings. These requirements are stated in the specification section that is applicable to the item of work. See table below for typical examples of number of copies and where to submit the different types of working drawings.

ITEM	DRAWING	COPIES	DESTINATION
501.05	Structural steel and other metal items, prestressed concrete members, precast concrete structural elements joint sealing devices and other similar items requiring either shop or field fabrication	3	Central Office
630	Overhead sign support	2*	District
630	Roadside sign support	2*	District
632	Signal poles	2*	District
632	Traffic signal heads	2*	District
*	Certified working Drawings Section 625.06, 630.03		

Construction and Material Specifications

Sections 200 thru 600 of the Construction and Material Specifications are used to obtain the workmanship compliance required for each item. These specifications are typically arranged in the following manner:

- Description
- Materials
- Construction Requirements
- Method of measurement
- Basis of Payment

Section 700 of the Construction and Material Specifications describe the material requirements. Supplemental Specifications (SS) are standalone items that usually have their own pay items. The SS800 is a specification called out on every project that provides corrections to the Construction and Material Specifications.

105.07 Cooperation with Utilities

Utilities will be encountered on most construction projects. The proposal will include a utility note that designates the utility names and times that they will be relocated. The Plans should include the detailed locations of the utility changes. If the utility owners fail to relocate or adjust utilities as provided for in the Contract Documents and the Contractor sustains losses that could not have been avoided by the judicious handling of forces, equipment, and plant, or by reasonable revisions to the schedule of operations, then the Engineer will adjust the Contract by change orders. Change orders should properly denote the reasons codes as follows:

14, UTILITY RELOCATION DELAY.

15, IMPROPERLY LOCATED UTILITY.

16, UNKNOWN UTILITY.

17, DELAY CAUSED FOR REASONS OTHER THAN UTILITIES.

105.13 Haul Roads

Prior to hauling equipment or materials, the Contractor will provide written notification to the Engineer of the specific roads or streets on the haul route. The following procedure should be followed:

- The contractor requests, through ODOT, that certain local roadways be used for hauling material and equipment to and from the project.
- ODOT reviews the request and contacts the LPA.
- If there is no objection by ODOT or the LPA the roadway is designated as a haul road.
- The roadway's condition is reviewed prior to hauling.
- If, during the course of the project, the roadway becomes dangerous, ODOT will have the contractor repair it.
- Once the project is completed, the condition is again reviewed.
- The roadway will be restored to its original condition either through the contract or by other means.

105.16 Borrow and Waste Areas

The purpose of this section is to establish uniform practices for administering borrow and waste areas. It is the Department’s policy to approve requests to locate borrow and waste areas, providing that:

- The location would not adversely affect the highway.

- The material is disposed of legally.
- The disposal minimizes the Department's future liability.
- All environmental laws are observed.
- The offsite locations are serving the public and land owners best interest.
- The areas are restored according to the contract.
- This section covers all borrow or waste areas on or off the right-of–way.

Material from outside the right-of-way used in embankment construction is considered to be borrow even though it is not paid for as borrow. Therefore, this section applies to all borrow and waste areas, including areas from which material is furnished and paid for under "203 Embankment," as well as areas from which material is furnished and paid for under "203 Borrow."

Requests from the Contractor to locate borrow and waste areas shall be directed to the Engineer, who shall either approve or disapprove the request. Action on each request shall be based on the information contained in the plan submitted by the Contractor, approvals from other ODOT Offices, certifications from environmental consultants, and other supplemental information available to the Engineer.

See section 107.10 for criteria for evaluating borrow and waste environmental and other significant issues.

General Approval

Specific considerations, which are made a part of the general conditions for approval, include, but are not limited to, the following:

1. All of the general information listed in A through G of 105.16 are addressed in the Contractor's submittal.
2. For borrow and waste areas which will not become ponds when the work is completed:
    a. The area shall be graded to assure positive drainage.
    b. Restoration of all borrow and waste areas shall include cleanup, shaping replacement of topsoil, and establishment of vegetative cover by seeding, and mulching according to 659.
3. For pits which will become ponds when the work is completed:
    a. In general, ponds are not considered objectionable, and often are considered highly desirable by property owners and persons engaged in conservation of natural resources and wildlife. The creation of additional ponds from borrow pits can provide enhanced environmental benefits, providing that they are constructed properly to avoid shallow stagnant water and are left in a condition to present a aesthetically pleasing appearance. If the pond is on the right of way then approval should be sought from the County Manager and District Production since the District may not want to take the long-term responsibility for the pond.
4. Borrow Pit Final Grading:

a. The tops of the pit slope shall be at least 25 feet (8m) from the highway right-of-way. This distance may be increased if there are slope stability or erosion problems. Twenty-five feet (8m) has worked well in the past.
b. Borrow pit slopes adjacent to the highway shall not be steeper than 3 to 1, and all other borrow pit slopes shall not be steeper than 2 to 1.
c. The borrow pit must be left in a condition satisfactory to the Engineer to blend with adjacent topography when the work is completed.

Stability and Settlement Concerns

Slope stability problems resulting from borrow and waste area construction is the sole responsibility of the Contractor. The Department is keenly interested in the Contractor's filling and cutting operations. The Department must assess the potential for settlement and future slides. The proper design and construction of the borrow and waste areas are provided in 105.16 and references in the Location and Design Manual.

Most of the 'Stability and Settlement' issues can be evaluated by using the following general guidance:

1. If the material is placed according to C&MS, use a maximum slope of 2:1. Use a 3:1 slope if the embankment is higher than 30 feet (9 m).
2. Only end dump in nonstructural locations. Use a 4:1 slope if the material is end dumped. These areas may need to be re-graded at some future time. Large settlements should be anticipated if the material is end dumped in lifts greater than 3 feet (1 m).
3. Areas with soft foundations should be closely evaluated when the fill height is greater than 20 feet (6.1 m).
4. If the off site location exceeds the above criteria, or when constructing a non-structural fill, then the property owner should be explicitly told in the agreement with the Contractor. The borrow or waste agreement must explicitly state that the property owners know that these location may settle and potentially slide. If this is not explicitly stated then the public may be misled in believing that the final fill will be stable. The Department has a stake in making sure that the property owner is not misled.
5. For proposed locations in the right-of way that exceeds the above criteria or looks suspicious, contact the District Geotechnical Engineer or the Office of Geotechnical Engineering.

105.17 Construction and Demolition Debris

The EPA regulates materials that come from structure removal, pipe removal, clearing or grubbing, and tree and brush removal operations. The EPA encourages the reuse of construction materials.

The OAC 3745-37, OAC-3745-400 and ORC Chapter 3714 regulate the use and disposal of this material. The law is governed by the OEPA or the Local Boards of Health whichever has jurisdiction. The law governs the debris from construction sites that are not covered under solid or hazardous waste or other regulations. Use the following links:

http://codes.ohio.gov/orc/3714

http://codes.ohio.gov/oac/3745-27-01

By the EPA definition, "Construction and demolition and debris" (debris) is the material resulting from the alteration, construction, destruction, rehabilitation, or repair of any manmade physical structure. Those materials are those structural and functional materials comprising the structure and surrounding site improvements (e.g. fences, sidewalks). The definition identifies structures that are included and materials that comprise the structure, which are considered debris. Any materials that are removed prior to demolition or are not part of the structure and surrounding site will not be considered debris.

The contract documents may require TCLP (Toxicity Characteristic Leaching Procedure) testing of the debris prior to transport and disposal.

Debris does not include materials identified or listed as solid wastes, infectious wastes, or hazardous waste.

The rule identifies other process materials (e.g. mining operations, non-toxic fly ash, etc.) that are not debris.

The legal removal and disposal of all of the following materials are the responsibility of the Contractor. The specifications have been radically changes to address these issues. The project should monitor the Contractor's work to minimize the Department's future liability.

Clean Hard Fill

Clean hard fill material (such as asphalt millings), or portland cement concrete material (or mixtures of these materials with soil, aggregate etc.) coming from pavement or structural removal operations. Clean hard fill may be used as:

- Fill, recycled, or taken to an approved Construction and Demolition Debris Site.
- Fill on or off the project provided the material is acceptable under Item 203. If the material is being used as fill off the site, the OEPA or local board of health in the area of the filling operations needs written notification seven days prior to the filling operation. See the definition of "on site".

- These materials cannot be indiscriminately piled up and left. These materials must be placed in fill areas not in disposal piles.
- May be taken to a recycling operation for recycling and storage. Storage must be less than 2 years.

Construction Debris

Construction Debris such as wood, plaster, etc. in whole or mixed with clean hard fill.

These materials are:

- Usually associated with building debris.
- Do not meet the 203 embankment specifications and cannot be used in fill operations.
- Must be taken to an approved construction demolition debris site or licensed solid waste disposal facility.

Landscape Wastes

This law also regulates the disposal of landscape waste that result from roadway clearing and grubbing operations. Landscape wastes include brush, trees, stumps, tree trimmings, branches, weeds, leaves, grass, shrubbery, yard trimmings, crop residue, and other plant matter, excluding soil and garbage.

These wastes may be re-used by:

- Constructing a wildlife habitat according to published guidelines from the Ohio Division of Wildlife, U.S. Fish and Wildlife Services, or Natural Resources Conservation Services. This is subject to local board of health or local OEPA approval;
- Chipping waste into mulch and using or donating it for use on or off the site;
- Selling or donating the waste for non-burial beneficial purposes;
- Using the waste for any beneficial use or re-use approved by the local OEPA offices or the local board of health; or
- Using the waste as fill material 'on site' from which the waste was generated. Item 203 Embankment does not allow these wastes in embankments or structural areas. On-site placement is permitted in non-structural areas. See 105.16 Borrow and Waste, "Stability and Settlement Concerns" in this manual. *(OEPA guidance for 'on site' means any location on the right of way. This can be outside the construction limits or even on other state owned properties. If large amounts of these wastes are to be generated then the designer may provide specific right-of way locations to dispose of these wastes. See 105.16 Borrow and Waste Areas section "Approval of Wasting on the Right of Way" in this manual.)*

All landscape wastes associated with ODOT projects are required to be disposed of at an appropriate landfill.

These wastes may be disposed of by:

- Open burning with permission from OEPA. See 105.16 Borrow and Waste, “Open Burning Permits” in this manual;
- Composting at an OEPA registered composting facility; or
- Sending material less than 4 inches (10.6 cm) in size to a sanitary landfill and material greater than 4 inches (10.6 cm) in size to construction and demolition debris landfill. Leaves cannot be taken to a construction and demolition debris landfill.

Portland Cement Concrete Waste

In recent years, we have increased the amount of Portland Cement Concrete Waste that is wasted on and off the right of way.

Large accumulation of Portland Cement Concrete Waste can cause high pH runoff in the range of 11 to 12. Runoff with a pH of 12.5 is considered a hazardous waste. Uncontrolled disposal of Portland Cement Concrete Waste can cause significant environmental degradation in the ground water and surrounding water bodies.

The potential for environmental problems are a function of the availability of water, geometry of the flow net, permeability of the material and the distance to a water body or ground water.

To minimize these potential future environmental problems, we have changed the specifications. In 105.17, we require the following (see Figure 105.17.A):

- Mixing of the inner core of the Portland Cement Concrete Waste with at least 30 % soil.
- Covering the mixed Portland Cement Concrete Waste with 3 feet (1 m) of soil on the top and 8 feet (2.4 m) on the sides.
- Placing and compacting the Portland Cement Concrete Waste according to 203.06.D.

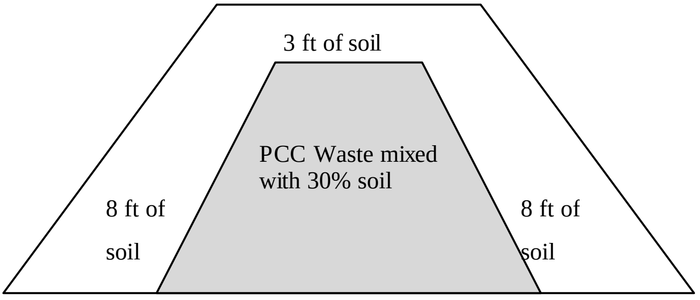


Figure 105.17.A Typical Drawing of the Wasting of Portland Cement Concrete Waste

106 CONTROL OF MATERIALS

Control of materials is a necessary and important part of every construction project. The intent is to assure that only quality (specification) materials are incorporated into the work. The Contractor must order materials sufficiently in advance of related work to allow enough time for sampling and testing. The Contractor must identify the project and the specification item number on all material orders which are defined in the construction and material specifications. The specification gives you the item which in turn references the appropriate material specification (700 series) used in conjunction with the material sampling and testing program manual gives you the proper procedure for material acceptance. Additional information may be found on the material code screen, (MATL) on CMS/TAS.

The following examples identify the different methods of accepting materials on the project and methods of testing acceptance.

- Physical sample from the project which would require no additional information.
  - Cable, Curing Compound
- Electronic TE-24, material comes from pretested stock.
  - Concrete pipe, Guardrail, Fence bolts
- Pre-qualified or pre approved list for pre qualified materials:
  - Concrete sealers, Epoxy, Silane, Functional alternates RPMS and adhesives
- Material from brand name sources:
  - Loop detector sealant,
  - Trowelable mortar,
  - Caulk for OZEU,
  - Loop detector slot sealant SS 1048,
  - Cable splicing kit
- Materials from Manufacturers certified test data:
  - Section 712.09, Filter fabric Type D.
- Material accepted on letter of certified test data:
  - Water line AWWA cert., Proposal 516 517 Proposal Note, 518
- Physical sample and certified test data:
  - Reinforcing Steel.
- Visual inspection:
  - Dumped Rock, Mulch
- Acceptance of proprietary items:
  - Impact attenuator G.R.E.A.T.
- Catalog cuts and shop drawings:
  - Electrical, Traffic control items

MATERIAL DOCUMENTATION PROCESS

The District Highway Management Administrator will determine the extent of application of responsibilities for material compliance under the policy for Material Documentation Process, 515-001(P) based on project staffing level/and or expertise. It may be applied on either a wholesale or project by project basis.

Under this policy the Engineer may approve certain materials as listed below and may modify the project bill of materials. Materials that maybe approved include:

- Any materials that are on approved or pre qualified lists.
- Materials for which there are approved catalog cuts.
- Proprietary materials.
- Temporary applications.
- Materials that require visual inspection only.
- Materials under the control of the Office of Structural Engineering.
- Any materials accepted as "small quantities" per Section 106.031.

The District Testing Engineer/Test Lab will perform the following functions:

- Sample, test, review and authorize samples for which the Engineer does not have the authority to approve.
- Provide staff advice to Engineer concerning material requirements.
- Perform independent reviews of material certifications by Engineer, using current guidelines for documentation of final quantities.
- Perform quality assurance reviews on active construction projects to insure compliance with material approval requirements.

The material certification for the projects will be approved by the District Highway Management Administrator.

PROCEDURES

The CMS will be used to document material requirements.

- Materials approved by Engineer
  - Project personnel will complete appropriate documentation (TE 30, etc.) create sample ID's and assign materials to the proper reference numbers.
  - The Engineer must review and authorize/approve all samples.
- Materials approved by District Testing Engineer or the Office of Materials Management
  - Project Personnel will complete appropriate documentation (TE31 physical sample), create sample ID's and assign material to appropriate reference numbers.

  - The Engineer must review all documentation for completeness, sign forms, and forward paperwork or physical samples to the District Lab.
  - The District Testing Engineer or the Office Materials Management, as appropriate, will review the documentation or conduct testing of samples and authorize materials.
- Certification of Project Materials:
  - As final quantities are determined, the Engineer, using the C&MS, will insure that the contract and material requirements are met.
  - After all final quantities and material issues are resolved, the Engineer will complete and sign the Material Certification Letter and forward it along with the final quantities list to the District Documentation Review Team.
  - The District Testing Engineer in conjunction with the Documentation Team will perform a review of the material requirements using the same guidelines as required for final quantities.
  - A final certification letter will be prepared and signed by the District Highway Administrator. This letter will be directed to the Division Administrator of the Federal Highway Administrator for Non Certification Acceptance Projects (CAP) or to the project file for all other projects.

Quality Assurance Reviews

Personnel from the District Test Lab will conduct quality assurance reviews during the actual construction phase of projects. These reviews will assure that Project Engineers are following the policies and procedures for material approvals, and identify material deficiencies while corrective action is still possible. The Division of Engineering Policy will establish guidelines for performance of the quality assurance reviews.

Unapproved Material

In the event that unapproved materials are incorporated into the work, these materials must be monitored to determine if they will function properly in the judgment of the Engineer. If so then the Engineer must follow the process to modify the contract to allow these materials to remain in place. See Standard Procedure 510-009(SP).

Delivered Material

All materials must be approved prior to invoice payments and all material must be inspected at the stock piled location. All materials being used are subject to inspection or tests at any time during preparation or use. Any material which has been tested and accepted at the source of supply may be subjected to a check test after delivery or a minimum visual inspection.

Sources Of Additional Information And Guidelines For The Control And Conduct Of The Work:

- Standard Operating Procedures
  - Standard Operating Procedures (SOP'S) are technically focused unit specific procedures affecting the management and operation of specific divisions and offices of the Department, with references to technical manuals and other procedural documentation used by the various operating units.
- Supplemental Specifications
  - These are detailed specifications which supplement or supersede the specification sections in the C&MS. (Appendix H)
- Manual of Procedures and Other Technical Bulletins
  - Manual of Procedures (MOP) are to provide construction personnel with information necessary to control the work to be performed in accordance with the requirements of the contract, the measurement of quantities for payment and the documentation of compliance and measurements.
- Standard Drawings
  - The Department furnishes Standard Drawings which provide specific details on various aspects of construction on ODOT Projects.

General Materials Inspection, Sampling And Testing (106.01)

General

Control of Material 106 provides that all materials are to be inspected, tested, and in compliance with the specifications prior to incorporation in the work. Minimum requirements for sampling materials are given in CMS Section 700, Material Details. Samples of materials taken to meet these requirements are called job control samples. Job control samples also include samples taken as judged necessary to determine continued compliance of materials previously approved. These samples always represent a definite quantity of material.

Advance notice by the Contractor of the intended source of supply for specified materials is required to permit sampling and testing of the materials. Evidence of the approval of the materials by the Laboratory is required.

The purpose of material sampling and testing and construction inspection is to determine that only approved materials are used and that the materials are processed and placed in accordance with all contract provisions. Systematic record keeping is necessary to furnish documented evidence that this has been accomplished. The minimum requirements for the necessary records are stated under the individual items of work covered in this section of the manual.

The administration of the unit price contract also requires the determination of pay quantities. The contract states the method of measurement for each item of work and it is very important that each pay quantity determination be adequately documented.

Standards and Definitions

The term flexible pavement, used throughout this manual, includes pavement or surfacing material construction composed of asphalt material and aggregate mixtures or various combinations of layers of these mixtures on layers of aggregate base or subbase. Although designs may vary in the combination of these materials, the flexible pavement functions in a definite manner under traffic loads. It is the intent of the design that deflection of the pavement in reaction to wheel loads will not stress the materials to the point of fracture within a reasonable life expectancy of the pavement.

Except for chip seals and other surface treatments, the strength of all flexible pavement layers, including subgrade, is dependent upon the density of the material and the gradation of the particle sizes. In addition, the strength of the subgrade and granular base material is dependent on moisture content, and the strength of asphalt mixtures is partially dependent on the quantity and viscosity of the asphalt material. While the strength of granular base materials is less affected by moisture content than soil subgrade material, adequate drainage of this material is necessary to prevent saturation of soil subgrade material and loss of subgrade strength.

All flexible pavement courses, except microsurfacing, etc, are placed loose by means of spreading and leveling equipment and then compacted with compaction equipment. The typical sections or other plan details specify the width and thickness of the individual courses. For granular subbase and base courses, the thickness shown in the plans is the actual compacted thickness to which the course is to be constructed. Normally, the thickness specified for all other courses is to be used to calculate a weight of material to be placed per unit of area.

Aggregate

Aggregate may be hauled to the paving site from approved stockpiles located at the source, on the project, or at some intermediate storage point. In any case, it is necessary to maintain sufficient surveillance to assure that loading is from approved stock and that identity of the stockpile is not altered by addition of material or other cause. It also is necessary to inspect the aggregate for uniformity as it is being loaded or placed. When such observations are made, they should be recorded for the project record.

Aggregate Stockpiling

Two fundamental requirements are included in 703.01 for aggregate stockpiles: separate identity and freedom from contamination. In addition to these considerations, knowledge of the method used in constructing the stockpile is necessary to have an understanding of the characteristics of the material as it is drawn from the pile for use.

The characteristic of an aggregate most affected by the method of stockpiling is its gradation. The larger size aggregate particles have a tendency to separate from the smaller size particles in parts of the stockpile; this is called segregation. A reduction in aggregate particle size also can occur due to breakage or wear; this is called degradation.

Segregation is more likely to occur in an aggregate having a relatively large particle size range from coarse to fine. The amount of segregation of aggregate particle sizes usually depends on the degree of freedom the aggregate has to flow from one place to another during stockpiling or handling. Usually, segregation is minimized when the stockpiles are formed by placing the aggregate in successive small mounds or layers. Small pockets of segregated aggregate are not objectionable in the stockpile, when re-mixing occurs in the loading and spreading operations, resulting in a uniform appearance. When these pockets are sufficiently large that non-uniform areas can be observed in the material placed on the grade, however, the results are unsatisfactory and corrective measures assuring uniform material in place are required.

Degradation of an aggregate may occur during stockpiling due to the action of hauling and spreading equipment operating on the stockpile. Aggregate particles may be broken into smaller sizes by heavy compressive forces exerted by such equipment: also, excess fine particles may be produced by interparticle abrasion caused by repeated application of these forces. Normally, however, degradation is severe only in the case of very brittle or very soft aggregate particles.

Liquid Asphalt Materials

The Laboratory maintains a certification program throughout the year with all participating liquid asphalt material producers. Reference should be made to Supplement 1032, regarding forms used for identification of loads from approved stock. Loads arriving without proper identification are not to be used until specification compliance can be determined.

Since liquid asphalt materials may become contaminated and errors in shipment may occur, it is necessary to observe the delivered materials. Where there is a question concerning the quality of the material, the Contractor should be notified and a check sample should be taken.

Asphalt Concrete

The quality control of an asphalt concrete mix is performed by the Contractor in accordance with 401.02, 441, and/or 442.

107 Legal Relations and Responsibility to Public

107.01 Laws to be Observed

Prevailing Wage and EEO/DBE

This section is a guide to the proper contract administration of projects that require Disadvantaged Business Enterprise (DBE) participation and are subject to Davis-Bacon prevailing wage requirements.

The Prevailing Wage Laws were enacted as part of general reform efforts to improve working conditions at the end of the 19th and the beginning of the 20th centuries. The prevailing wage law requires state and local governments to pay the equivalent of union wages on most public construction projects. In addition, most public construction projects contracted by the federal government or the District of Columbia are covered by the federal prevailing wage laws, the Davis-Bacon Act.

To research laws for Project with Federal-aid - Title 29 Code of Federal Regulations, Subtitle A, Parts 1, 3 and 5.

Projects without Federal-Aid: Ohio Revised Code (ORC), Chapter 4115.

Prevailing Wage Laws are meant to ensure that wages commonly paid to construction workers in a particular region will determine the minimum wage paid to the same type of workers employed on publicly funded construction projects.

Prevailing Wage Requirements

As outlined in ODOT Policy No. 26-002 (P), both State and Federal law requires the payment of prevailing wages to all contract employees performing duties of a laborer or mechanical on a project site.

Prevailing Wage means:

- The base hourly rate of pay
- The rate contribution irrevocably made by a contractor or subcontractor to a trustee or to a third person pursuant to fund, plan, or program.
- Medical or hospital care or insurance
- Pensions on retirement or death or insurance
- Compensation for injuries or illness resulting from occupational activities if it is in addition to that coverage required by Chapters 4121 and 4123 of Revised Code.
- Supplemental unemployment benefits that are in addition to those required by Charter 4141 of the Revised Code.

- Life insurance
- Disability and sickness insurance
- Accident insurance
- Vacation and holiday pay
- Defraying of costs for apprenticeship or other similar training programs which are beneficial only to the laborers and mechanics affected.
- Other bona fide fringe benefits

The public authority must appoint a wage coordinator whose duties include:

- Establishing a monitoring process
- Maintain payroll reports and affidavit
- Receive affidavits from primes and subs
- Report delinquencies in filing payrolls and affidavits
- Dates of payments to employees
- Obtains from all prime and subcontractors copies of weekly certified payrolls

Prevailing Wage Exceptions

The list of work types exempt from the payment of prevailing wages includes:

- Mowing
- Herbicidal Spraying
- Center Line Survey
- Sign Inventory
- Tree Trimming and Tree Removal
- (With no other construction to follow)

Trucking

All employee drivers working on the *site of work* must be paid prevailing wages.

The "**site of work**" is defined as follows:

It is the physical place where the building or work called for in the contract will remain; and any other site where a significant portion of the building or work is constructed, provided that such site is established specifically for the performance of the contract or project.

Job headquarters, tool yards, batch plants, borrow pits, etc. are part of the site of the work, provided they are dedicated exclusively, or nearly so, to performance of the contract or project, and provided they are adjacent or virtually adjacent (within a 1 mile radius) to the site of the work.

Not included in the site of the work are permanent home offices, branch plant establishments, fabrication plants, tool yard, etc. of a contractor or subcontractor who location and continuance in operation are determined wholly without regard to a particular federal or federally assisted contract or project.

In addition, fabrication plants, batch plants, borrow pits, job headquarters, tool yards, etc. of a commercial or material supplier, which are established by a supplier of materials for the project prior to the opening of bids and not on the site of work. Such permanent, previously established facilities are not part of the site of the work, even where the operations for a period of time may be dedicated exclusively, or nearly so, to the performance of a contract.

Project Bulletin Boards

The boards must be displayed at a central location and must display current project prevailing wage rates and all current state or federally required postings. Company EEO policy and officers' names must also be displayed.

For mobile operations (i.e. guardrail or asphalt), the bulletin board information may be kept in the foreman's truck provided all employees are apprised of the location and have easy access to the material.

EEO/DBE Requirements

Disadvantaged Business Enterprise (DBE) goals are set on federally funded projects in excess of $1 million. For state funded projects, the EDGE program is used – Encouraging Diversity, Growth and Equity. They are set for projects in excess of $500,000.

On those projects for which a DBE goal has been established, ODOT personnel act as the eyes and ears on projects to ensure that those DBE subcontractors are performing a commercially useful function (CUF).

In order to perform a commercially useful function, the DBE must carry out its contract responsibilities by actually performing, managing and supervising the work on a project.

Here are some items to consider in determining if a subcontractor is performing a commercially useful function.

Management

The DBE must schedule all work operations.

The DBE must receive quotes and order equipment and materials.

The DBE must prepare and submit certified payrolls.

The DBE must hire and fire employees.

The DBE must make all operational and managerial decisions.

The DBE must supervise daily operations either personally or with a full time, skilled superintendent under the DBE's direct supervision.

Management Red Flags Include:

- DBE employees are supervised by another contractor.
- The DBE provides little or no supervision of work.
- The DBE's superintendent is not a regular employee.
- Supervision is done by the prime contractor or another firm.
- The DBE's owner is unaware of the project's status or the performance of the business.

Equipment

The DBE firm may lease equipment if consistent with industry practices and competitive rates.

A lease agreement is required and should be for a long term.

A DBE firm may lease equipment from another contractor, but not from the prime contractor or a subsidiary.

A DBE is not permitted to lease and use equipment with the payment subtracted from the prime's payment to the DBE.

The DBE is to have full control of the operation of equipment.

An operator may be provided if the equipment is specialized.

Equipment Red Flags Include:

- The equipment used by the DBE belongs to the prime or another contractor with no formal lease agreement.
- Equipment signs and markings cover another owner's identity, usually through the use of magnetic signs.
- A DBE trucking business uses trucks owned by the prime.

Workforce

DBE firms must keep a regular workforce.

DBE firms cannot share employees with non-DBE contractors, especially a prime contractor or subsidiary.

The DBE firm is responsible for all payroll and labor compliance requirements for all employees within control of the company.

Workforce Red Flags Include:

- Watch for movement of employees between contractors.
- Watch for instances of employees paid by the DBE and the prime.

Materials

The DBE must negotiate the cost, arrange delivery, take ownership and pay for the materials and supplies for a project.

The DBE must prepare the estimate, the quantity of material, and be responsible for the quality of the materials.

Materials Red Flags Include:

- Materials are ordered by or paid for by the prime.
- Two-party checks from the prime to the DBE subcontractor and supplier or manufacturer.
- Materials or supplies necessary for the DBE's performances are delivered to, billed to or paid for by another business.

Performance

The DBE must be responsible for the performance, management and supervision of a distinct element of the work, in accordance with normal industry practice.

Performance Red Flags Include:

- The work is being done by the DBE firm and another contractor.
- The work to be done is beyond the DBE's known experience or capability.
- Some portion of the work is done by the prime or another firm.
- The DBE firm is working without a subcontract agreement.
- The DBE prime contractor subcontracts more than customary or standard industry practice.
- The agreement between the prime and the DBE artificially inflates the DBE participation.
- The DBE works for only one prime contractor or a large portion or a large portion of the firm's contracts are with one contractor.
- The volume of work is beyond the capacity of the DBE firm.

If a DBE subcontractor is suspected of engaging in any of the aforementioned practices, the ODOT project personnel should contact the district Equal Employment Opportunity coordinator an alert them of the suspected infractions.

Oversight of the DBE program is necessary in ODOT's effort to reduce fraud and ensure that the DBE program benefits the truly disadvantaged businesses.

107.10 Protection and Restoration of Property

All properties to be utilized by the Contractor outside the project right-of-way must be cleared for all environmental resource impacts prior to the beginning of work. The project right-of-way consists of the right-of-way the project is being constructed upon. Environmental Resource features pertinent to the construction activity should be shown on the contract drawings. The contractor is responsible for evaluating all impacts on environmental resources outside the project right-of-way.

Environmental resources include but may not be limited to:

1. Cultural Resources
    a. Buildings, structures, objects, and sites eligible for or listed on the National Register of Historic Places
    b. Historic or prehistoric human remains, cemeteries, and/or burial sites (pursuant with ORC 2909.05 and 2927.11
2. Ecological Resources
    a. Wetlands
    b. Streams
    c. Wooded areas with trees to be removed in excess of 8 inches diameter at breast height
3. Public Lands
    a. Lands meeting the criteria of 49 U.S.C. 303, 23 CFR 771.I35: 4(f).
    b. Lands meeting the criteria of 16 U.S.C. 4601-4, 36 CFR59.1: 6(f).
4. FEMA Mapped 100 year Floodplains
5. Hazardous Waste Areas

All areas proposed to be utilized by the Contractor outside the project construction limits shall be reviewed by environmental contractor(s) that are prequalified by the Department for each environmental resource. Have the consultant(s) certify that the proposed site to be utilized for the contractor will not impact:

- Cultural Resources
- Ecological Resources
- Public Lands
- FEMA Mapped 100 year Floodplains
- Hazardous Waste Areas

Provide all documentation and the consultant certification to the Department's Office of Environmental Services.

107.11 Contractor's Use of the Project Right of Way or Other Department Property

General

This section compiles the requirements for sections: 104.03 Rights in and Use of Materials Found on the Work, 105.16 Waste and Borrow Areas and 105.17 Construction and Demolition Debris.

Under 104.03 "Rights in and Use of Materials Found on the Work," the Contractor has the right to all materials found in the contract work. However, the Contractor does not have the right to materials outside the plan work. For example, the Contractor does not have the right to rock found outside the cross section work. On the other hand, if the Contactor finds rock within the cross section, they can use the rock for other items of work.

In order for the Contractor to have the "fee free" right to the material, the Designer needs to detail borrow and/or waste areas in the plans prior to bid. If the locations are not shown and the Contractor receives approval to borrow and/or waste on ODOT property then a charge of $ 0.50 per cubic yard will be assessed. When borrow and/or waste areas are shown on the plans there is not a charge for the material.

This requirement was put into the specifications to even the bidding process for all Contractors.

All of the environmental requirements in 105.16 Waste and Borrow Areas and 105.17 Construction and Demolition Debris apply to on site locations. The exceptions to these requirements are detailed in 105.16 "Waste and Borrow Areas" of this manual.

Approval for Borrowing and/or Wasting on the Right of Way

All borrow and waste location requests on the right-of-way need the District Office of Production approval. The guidance document for the approval can be found at the following link:

http://www.dot.state.oh.us/roadwayengineering/L&D Vol I/Waste_Borrow_4-30-02.pdf

The District Office of Production will look at the following during the approval process:

- Safety Grading and Clear Zone.
- Sight Distances.
- Future Expansion.
- Environmental Regulations (404, 401,NPDES etc.), (See Environmental Approval in 105.16 "Waste and Borrow Areas" of this manual.)
- Public Commitment.
- Effects on Utilities.

- Stability (See Stability and Settlement) in 105.16 "Waste and Borrow Areas" of this manual.

As this process evolves, there may be changes to this criterion.

Portable Plants within the Project Limits (107.11.B &107.11.C)

The use of ODOT property for portable plants is restricted under this section of the specifications. Production may detail potential locations on the plans. If the locations are detailed on the plans then the location is fee free. If the location was not shown in the plans and the site is approved by the district for use then the Department will consider this change a Value Engineering Change Proposal.

There are four issues detailed in C&MS 107.11.C. The noise ordinances and EPA permits need approved the District Environmental Coordinator. The traffic plan needs approved by District Production.

Equipment Storage and Staging (107.11.D)

The "fee free" use of Project Right-of-Way for staging, equipment storage, and/or office site is granted in this section.

The only restrictions are that these locations do not interfere with the work and are not otherwise restricted in the contract documents.

Documentation for Waste and Borrow Sites. (105.16, 105.17 and 107.11)

It is the intent of this section to recommend minimum documentation and critical inspection requirements for the above sections. All of the following documentation requirements need recorded in the project daily reports. References to the appropriate laws, specifications, and proposals and plan notes or details for all the inspector reports are required. Specifications or other requirements waived by the Project Engineer shall be noted on the daily diaries.

Regulated waste work may be inspected and documented by the District Environmental Coordinator (DEC), District Hazardous Waste Coordinator (DHWC) or Regulated Waste Project Engineer (RWPE). When the inspection is required by these individuals it will be denoted below.

In addition, clearances or reviews need to be performed by other offices or individuals in the Department will be denoted. These are as follows, District Office of Production (DOP), Office of Geotechnical Engineering (OGE).

1. Contractors operational plan approval.
2. Stability and Settlement (OGE).
3. NPDES Permit and Erosion Control (DOP).

4. 404 and 401 Permit or Evaluation (DEC).
5. Flood Plain Clearance (DEC).
6. Cultural Resource Clearance (DEC).
7. Open Burning Permit (DEC).
8. Any Disposal Requiring Manifesting (DEC, DHWC or RWPE).
9. Construction and Demolition Debris
    a. Determination if Clean hard fill or Construction Debris.
    b. Quantities and locations of material leaving and filling on the site.
    c. Seven day notice to the local board of health or OEPA.
    d. Record quantities going to the C & D landfills.
        i. Manifest properly (DEC, DHWC or RWPE)
10. Landscape Wastes.
    a. Record quantities and locations of materials leaving and buried on site.
    b. Record what happened to the rest of the material.
    c. Recycled.
    d. Reused.
        i. Manifest Properly. (DEC, DHWC or RWPE)
11. Open Burning.
    a. Obtain a copy of the permit.
    b. Is the smoke causing a hazard?
    c. Is the burning at the correct time?
    d. Is an Air Curtain used?
    e. Are there any fire hazards?
12. Proper Disposal of Concrete waste.
    a. Three foot cover on top.
    b. Eight foot cover on the sides.
    c. Core mixed with 30 percent soil.
    d. Is the fill stable?
13. Contractor Use of the Right of Way.
    a. Approval (DOP)
    b. All clearances. See 3 thru 7 above.
    c. Fifty cents a cubic yard or free.
    d. Portable Plant Approval (DOP)
14. Cross section the site if required for payment.
    a. Wasting
    b. Borrowing
15. Owners permission statement.
    a. Material not the Departments.
    b. ODOT not a part of the agreement.
    c. ODOT held Harmless.
16. Restoration.

108 PROSECUTION AND PROGRESS

The purpose of this section is to discuss tools available to the Department for use in tracking the Contractor's progress and timely completion of the project.

Following the signing of a contract for a construction project, the District will contact the contractor and schedule a preconstruction meeting. On or about that time, a Project Engineer/Supervisor will be chosen by the Department for that project.

Once the Project Engineer/Supervisor is chosen, it is the responsibility of that individual or team to review all of the project documents and terms of the contract prior to the preconstruction meeting. Special attention must be paid to the following items:

- Plan Notes
- Completion Date
- Interim completion dates
- Special uses of "As Per Plan" reference items
- Proposal notes, and supplemental specifications
- Phasing requirements
- Special provisions
- Addenda

A check of the status of utility relocation (must be performed immediately as to avoid delays to the start of the project)

PRECONSTRUCTION MEETING

The purpose of the preconstruction meeting is to review the various items of work as set forth in the detailed construction plans, bid proposal, specifications and the contractor's work schedule. Those items to be discussed are the necessary utility adjustments, availability of right of way, maintenance of traffic and the Department's responsibility for the inter related activities so that all concerned might have a better understanding of the problems involved and thus be able to coordinate the project.

The rationale of employing a thorough Pre-Construction meeting is pervasive as regards claim avoidance in that it seeks to uncover problems at a time when there is the greatest flexibility available for their solution and with the least disruption to the project. It is designed to create, for all parties, an overview of the conduct of the work and flush out any misconceptions or erroneous assumptions.

Understandings reached at meetings of this nature have resulted in improved relations and coordination of the inter related activities by all concerned.

The pre con meeting really is the place to establish communication, voice and discuss intentions, discuss concerns and layout the road map and rules for the conduct of the project.

A preliminary study of the project shall be made in advance of the meeting in order that the pertinent problems involved are known.

The District Construction Engineer shall invite the following parties to the preconstruction meeting:

- Contractor
- State Personnel, including the Project Engineer/Supervisor and staff, utilities coordinator, EEO Coordinator, design engineer, traffic engineer, test engineer, public information office, county manager and all parties involved with the preparation of the plans.
- Utility companies with facilities located within the right of way, including all railroads and local park boards.
- Maintaining Agency
- Regional Transit Authority
- Parties funding project including FHWA/County/Local

At the preconstruction meeting, the project engineer must obtain a list of contacts for all parties involved with the project. This list will be useful in the future for timely resolution of problems which surface during the project construction. These contacts should also be invited to attend the progress meetings held on site once the project begins.

Items which the contractor needs for the preconstruction meetings are as follows and are listed in C&MS 108.02:

- Progress Schedule
- List of Material Sources
- List of Subcontractors
- List of Haul Roads
- Executed Contractor Signature Authorization form (CA-D-10)

An Agenda should be used at every pre-construction conference. The checklist below represents the more common items that should be included in the agenda.

Administrative requirements covered:

- Announce the appointment of the PE/PS and explain their authority.
- Material approval, inspection, and payment processes.
- Change order process including who has authority to approve and grant permission to proceed.
- Contractor evaluation process and C-95 form.
- Proposal, special provisions, and general plan notes.

Legal requirements covered:

- Prevailing wage requirements and procedures.

- Project bulletin board responsibilities and give the Contractor necessary posters to be posted.
- Contractor EEO responsibilities: nondiscriminatory hiring requirements, hiring goals for the area, and procedures under the voluntary on-the-job training program.
- Contractor responsibilities under l07.l2 for protection and restoration of property.
- Environmental permit requirements and Contractor responsibilities for sediment and erosion control.

Review of planned project work:

- Special environmental commitments.
- Right-of-way issues.
- Utility relocations.
- Railroad coordination, including any agreements between the Contractor and a railroad.
- Any pending change orders or contemplated extra work.

Information from the contractor:

- State the proposed date for the start of project work.
- Announce the name of the Project Superintendent.
- Present a progress schedule or CPM.
- State all known subcontractors, suppliers, and material sources.
- State, in general, work procedures, type of equipment to be used, and the number of working shifts to be used.
- State the haul roads (C&MS Section l05.l3l)l3 and waste and borrow areas (C&MS Section l05.l5l)l6 to be used.
- Submit documentation itemizing the payroll taxes that the project will incur under l09.04(a) 05(C)(2) if extra work is added to the project.
- Submit documentation stating the method of paying fringe benefits to workers required by prevailing wage law.
- Requests for clarification of any questionable aspects of the contract or project site conditions.

Documentation of the preconstruction:

- A list of conference attendees and their affiliation.
- Written minutes or a tape recording of the conference.
- Record the date of the precon on the CMS 'KETRK' screen.

Informal partnering session:

- Establishment of an RFI process, specifically to whom an RFI must be addressed, acceptable format (letter, e-mail), and standard response time.
- Review the Dispute Resolution Process as specified in proposal note 109.
- If the time frames given in Proposal Note 025 are not realistic for the project the DCE and Contractor shall agree upon new time frame to resolve issues at each step.

- Empower the district staff to quickly resolve issues in steps l or 2 of the Dispute Resolution Process.
- Review the chains of commands of the Department and Contractor.
- Obtain understanding and agreement that ignoring an issue or making no decision is not acceptable.
- Individuals are not expected to make a decision with which they are uncomfortable, but should escalate upward in the dispute resolution process.
- The informal partnering session should agree to Finalize-As-You-Go.
- The agreements made will be documented and placed in the project file with a copy to the Contractor.

PROGRESS SCHEDULE

The Contractor must submit a progress schedule, pursuant to C&MS 108.02. This schedule must show the contractor's plan to carry out the work, the dates which the contractor and subcontractor will start the critical work, including the procurement of materials and equipment, ordering special manufactured articles, working drawings and the planned dates of critical project milestones.

A bar chart schedule is the default schedule required for all projects. More complex project may require the contractor to use the Critical Path Method (CPM) progress schedule, as specified by proposal note 107.

The progress schedule must be reviewed and accepted by the District Construction Engineer. The Project Engineer will review the schedule and forward his comments to the District Construction Engineer. The following items are to be used in determining an acceptable schedule:

- All major items of work must be included in the schedule.
- Completion of the entire project must follow contract requirements.
- Duration of activities must be reasonable.
- Sequence of operations must be logical.
- Schedule must be arranged per plan phases if required.
- Schedule must include special provisions in the contract, including completion dates.
- Special material requirements of the plans must be included.

The progress schedule is the responsibility of the contractor. If the schedule does not make sense or is illogical, the District must ask for clarification. A revision of the details in question is required prior to acceptance.

Reviewing and Accepting the Contractor's Schedule

- Is the project identified?
- Does the schedule graphically depict the work?
- Is there sufficient detail to truly describe the work?
- Are the sequences and activity durations reasonable?
- Are critical deliveries shown?
- Is there consideration for winter months?
- Are special ODOT requirements from plan notes or special provisions accounted for?
- Does the schedule fit within the duration allowed by contract?
- Are there clear relationships shown between activities?

The progress schedule is the main tool with which the owner can monitor the progress of the contract and determine at an instant the status of work. It is therefore very important that the Project Engineer accurately review the schedule before acceptance. Monitoring the progress schedule is very important in determining "fault" or responsibility for project delays. C&MS 108.06, allows the director to grant requests for an extension of time if the work was delayed. Guidelines for the review and acceptance of the bar chart schedule specified in C&MS 108.02.B. Guidelines for the review and acceptance of Critical Path Method Progress Schedules are specified in proposal note 107.

TOOLS FOR MONITORING PROGRESS

Schedule Updates

There are several tools for monitoring the status of a project. The main tool as stated above is the monitoring of the progress schedule. The progress schedule must be reviewed at regular intervals with the contractor at the project level by the Engineer and at the following times:

- The start of the project to detect if the contractor began as scheduled.
- Every two weeks on larger more complex projects, monthly on smaller less complex projects.
- Following the completion of a major item of work.
- Following the completion of a phase or sub phase of work.
- Before, during and after any type of delay to determine whether or not the delay was owner caused, contractor caused or concurrent.

Results of this review must be included in the daily diary. The diary entry must list the reasons the contractor cannot proceed with certain portions of the work. Accuracy and details in the daily diary concerning delays will protect the Department against the successful prosecution of many claims.

Progress Meetings

Effective progress meetings are very productive tools for enhancing communication, discussing issues, solving problems and thus furthering progress on the project. The Engineer must invite the appropriate personnel to attend the progress meetings. The status of the project must be discussed with the contractor. This time would be ideal to determine if the schedule must be updated. Suggested items for discussion are include:

- To assess needs and progress of project
- To change scope as needed
- To deal with current and upcoming issues
- To make decisions and problem-solve
- To communicate needed information to team members
- To assess how well we are working together and adhering to the charter

Before the progress meetings, the Engineer should prepare an agenda. An agenda should cover the following topics in a similar format:

PROJECT XXX(0X)

COUNTY-ROUTE-SECTION

PROGRESS MEETING

MONTH DAY, YEAR

Attendees: See sign-in sheet.

Agenda Topic:	**Action Items:**
Corrections to last Progress Meeting Minutes:	Description: Person Responsible: Deadline:
Outstanding Issues:	Description: Person Responsible: Deadline:
Safety:	Description: Person Responsible: Deadline:
Work in Progress: Prime In progress Look ahead (time period) Subs In progress Look ahead (time period)	Description: Person Responsible: Deadline:
Progress Schedule Current Schedule Update Critical Path Activities Current Completion Date Next Schedule Update	Description: Person Responsible: Deadline:
Critical Delays (work on critical path):	Description:

Agenda Topic:	**Action Items:**
Any delays since the last meeting? Current Excusable Non-Excusable Concurrent? Potential Excusable Non-Excusable Concurrent?	Person Responsible: Deadline:
Non-Critical Delays (work NOT on critical path): Any delays since the last meeting? Current Potential	Description: Person Responsible: Deadline:
Time Extensions Requests by Contractor Compensable Granted Pending Non-Compensable Granted Pending Non-Compensable	Description: Person Responsible: Deadline:
R/W and Utilities:	Description: Person Responsible: Deadline:
Environmental: Regulated Materials Stock Piles Handling	Description: Person Responsible: Deadline:

Agenda Topic:	**Action Items:**
MSDS/PPE Regulated Wastes Location Handling Documentation Regulatory Permits 404/401 NPDES FEMA BUSTR	
Change Order Status:	Description: Person Responsible: Deadline:
Maintenance of Traffic: Upcoming Closures Other	Description: Person Responsible: Deadline:
Public Relations: Complaints Other	Description: Person Responsible: Deadline:
Testing/Materials:	Description: Person Responsible: Deadline:
Submittals: Under Review To Be Submitted	Description: Person Responsible: Deadline:
Value Engineering Change Proposals (VECPs):	Description: Person Responsible: Deadline:
Request For Information (RFIs):	Description:

Agenda Topic:	**Action Items:**
Outstanding RFIs Upcoming RFIs Other	Person Responsible: Deadline:
Completed Items & Agreement on Final Quantities:	Description: Person Responsible: Deadline:
Dispute Resolution: Disputes Current Potential Claims Current Potential	Description: Person Responsible: Deadline:
Estimates:	Description: Person Responsible: Deadline:
EEO/Wages:	Description: Person Responsible: Deadline:
Partnering:	Description: Person Responsible: Deadline:
C95 Issues:	Description: Person Responsible: Deadline:
Contractor Issues:	Description: Person Responsible: Deadline:
ODOT Issues:	Description:

Agenda Topic:	**Action Items:**
	Person Responsible: Deadline:
Open Discussion:	Description: Person Responsible: Deadline:
Next Meeting: Date Location	Description: Person Responsible: Deadline:

DETERMINATION OF A TIME EXTENSION

The Department may grant a time extension for excusable delays. The contractor must make a written request giving details which will justify the granting of the request for this extra time. Methods to analyze requests for time extensions are explained in detail in C&MS 108.06 and Standard Procedure Policy 510-012(SP), Time Extensions and Waiver of Liquidated Damages.

It is more important than ever that the contractor submit the request for a time extension in the following time frame:

- Requests for an extension of time due to weather or seasonal conditions shall be submitted in writing to the engineer at the end of each month.
- Requests for extensions other than for weather and seasonal conditions shall be submitted in writing to the engineer within 30 days following the termination of the delay and prior to the expiration of the extended contract date.

Extensions of time are processed as change orders by the District.

BEHIND SCHEDULE

In the event that a request for an extension of time is not justified by the District and/or the contractor falls behind schedule due to their own fault or responsibility, the contractor may need to submit a recovery schedule.

When the progress differs appreciably from the original schedule (more than fourteen calendar days), a revised schedule must be requested by the Department. A letter from the District Construction Engineer to the contractor must be written to request a revised schedule and reasons for the delays. Once a new schedule is submitted and the reasons for delay are given by the contractor, the Engineer must review the daily diary to determine the accuracy of these delays. If delays are due to poor or inexperienced workmen, Section 108.05 allows for removal of unskilled workmen from the project. If the delays claimed are caused by the contractor, the revised schedule must show finishing by the original completion date and the method for recovery must be included.

The methods of monitoring a progress schedule are as follows:

- Percentage of completion by dollars paid to the contractor
- Examination of actual start and finish dates of line items

Judgment must be used when reviewing the progress schedule. It may be possible that the dollars paid to the contractor do not truly reflect the progress on the project. These issues must be discussed with the contractor. A good time to do this is usually during the progress meetings when all parties involved with the project are present.

WAIVER OF LIQUIDATED DAMAGES

If the contractor fails to complete the work by the contract completion date (original or revised), he must request permission of the Engineer to remain in control of the work. The contractor must make this request in writing and may be required to provide a written plan for completion of the work. This requirement is described in Section 108.07 of the C&MS which includes a table of liquidated damages.

Certain plan notes may require interim dates for phase completion and include special liquidated damages. Different methods of bidding may include special liquidated damages.

Since the advent of the Construction Management System (CMS), the computer now deducts liquidated damages automatically from the estimates until dates for completion are entered into the "KETRK" screen or the time extension/waiver is processed and entered into the system.

TERMINATION

The two types of project termination are as follows:

Termination for Convenience

Termination by convenience is explained in Section 108.09 of the C&MS and allows the Department to terminate a contract at anytime. Several projects involving huge plan errors have been terminated. This is done to give the Department time to revise the plans and to allow the project to be bid competitively, rather than perform all work on change orders on the existing project.

Termination by Default

Termination by default is explained in Section 108.08 of the C&MS. The Director has the right to terminate the project for the following reasons:

- Contractor abandons, fails or refuses to complete work.
- Improperly performing the work.
- Has not commenced work in a reasonable time or does not make reasonable progress.
- Contractor goes out of business or files bankruptcy.

Termination by default or cause is not an immediate event. This type of default requires a series of events to occur over a period of time, all of which must be documented by the Department. Progressive documentation must occur and extensive records must be kept to avoid any legal action against the Department.

109 METHOD OF MEASUREMENT AND PAYMENT

This section is presented to provide information and guidelines for the proper method of measurement of completed items of work and the proper payment to the contractor. This section is divided into the following parts:

- General Information
- Documentation
- Daily Diary
- Estimates
- Project Approval of Estimates
- District Office Approval of Estimates
- Method of Measurement
- Basis of Payment

GENERAL

In the administration of construction projects, it is the policy of the Department to provide the Contractor with prompt payment for all completed and accepted work. After an item of work is completed, but before payment is made, a determination must be made based on the quantities of the various items of work performed. This will be the basis for final settlement between the Contractor and the Department. It is the responsibility of the Engineer to assure this determination of quantities is performed. The Project Inspector is likewise responsible for making the detailed inspections necessary to measure, document, and turn in for payment the determined quantities.

As promptly as everyone expects their paycheck, the contractor is entitled to prompt and accurate payment for all completed and accepted items of work. As outlined in the Ohio Revised Code Sections 126.30 and 5525.19 and the Policy 27-016(P), "Payment for Contract Work" the Department has the obligation to pay for completed items of work promptly. This payment must be made to the contractor within thirty (30) days of the first estimate date after the completion of the work, except for additional quantifies found during the finalization process. Failure to meet the progressive payment time will result in interest being paid to the contractor from monies deducted from the District's budget. To assure prompt payment, the measurement of quantities and the recording for payment must be performed on a daily basis as the items of work are completed.

Project personnel are responsible for preparing documentation to support payment for work performed by the contractor by measurement of completed and accepted quantities of work. This documentation serves two important purposes:

It provides validation that the quantity for payment has been determined in accordance with contract requirements (contract proposal, plans, specifications) with the necessary measurements, calculations, weight, etc. This is further detailed under the next section entitled "Method of Measurement".

It also verifies that the work was done in close conformity (as defined in Section 101.03 of the C&MS) to the plans and specifications.

Details on project documentation can be found throughout in this manual.

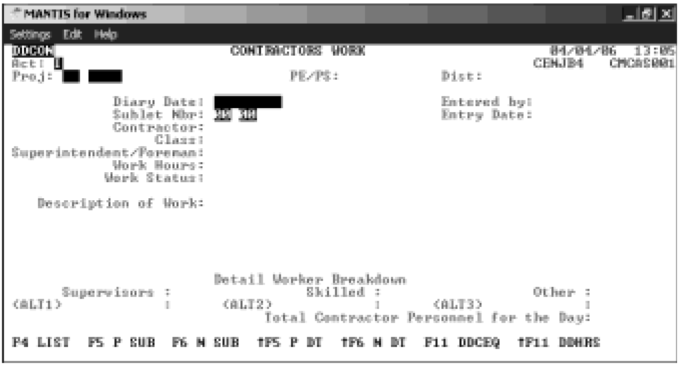
This Manual is not intended to alter or replace the specifications, its purpose is to supplement the specifications and provide assistance to the project personnel in the interpretation of the specifications. As such, this manual is not part of the contract by which the contractor bids the project. This manual does provide the recommended minimum documentation requirements and guidelines with respect to measurement of quantities and basis of payment.

DAILY DIARY

The daily accumulation of the information entered on the project is found in CA-D-3 and/or CA-D-4. These forms will become, when entered into the Construction Management System (CMS), the Construction Daily Diary. This Construction Daily Diary in the Construction Management System consists of five (5) individual screens altogether.

- Contractor Work (DDCON)
- Contractor Equipment Usage (DDCEQ)
- State Employees Hours Worked (DDHRS)
- Weather and Pay (DDWAP)
- Daily Remarks and Engineer Approval (DDRMK)

Contractor Work - DDCON



All information contained on the CA-D-3 / CA-D-4 forms are transferred by the project personnel to one of these screens. For purposes of payment of completed items of work, pay items listed on the CA-D-3 / CA-D-4 forms are entered on the "Weather and Pay" (DDWAP) screen.

Once all information is entered on the various screens of the Construction Daily Diary and the diary is completed, the Engineer, or alternate who has update authority, reviews the diary and if found acceptable, approves the diary. This approval is performed by changing the "N" on the "Project Engineer/Supervisor Approval" line on the "Daily Remarks and Engineer Approval" (DDRMK) screen to a "Y”.

Once approval of the Daily Diary takes place, the CMS system automatically transfers any quantities turned in for payment on the DDWAP Screen to the "Paybook" Screens (PBOOK). This CMS screen lists details about individual reference number quantities completed for payment. Any amount shown on this screen as being completed, but not previously paid will now be picked up for payment when the next estimate is generated.

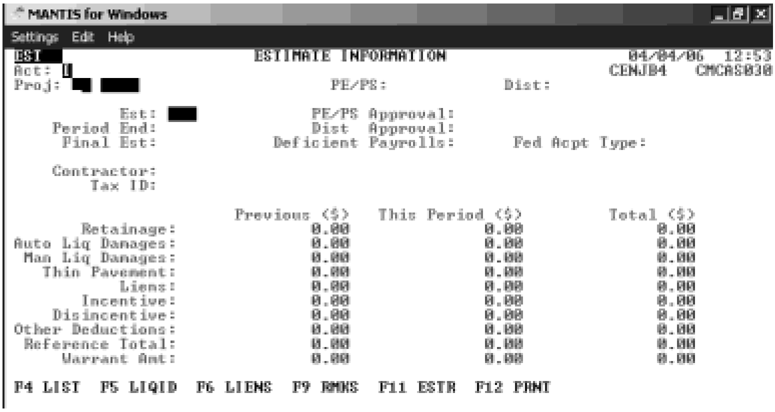
ESTIMATES

It is the District Construction Engineer's responsibility to establish the first estimate date for a project. This first estimate date, in general, should be (2) weeks after the first day of work or as otherwise agreed to by the contractor at the preconstruction meeting. Once the first estimate date is established, a second estimate will automatically be generated fifteen (15) days later. Estimates will continue to be automatically generated on the same two (2) dates per month as long as the project is under construction and the automatic generation of estimates remains actuated in the system.

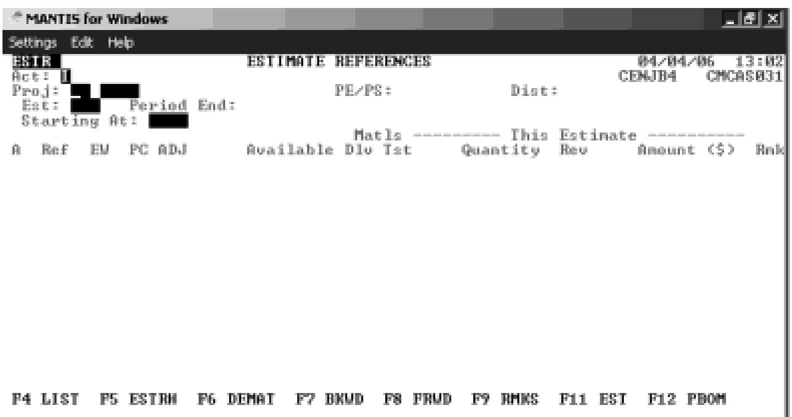
Below are examples of the two (2) screens created automatically by the CMS from information contained on the various " Paybook" reference screens for a project.

- Estimate Information (EST) screen. It displays overview information and adjustments for generated estimates. This screen allows both the project personnel and the District Construction Personnel to delete or approve the estimate.
- Estimate References (ESTR) Screen. It displays the list of references having quantities for payment. This screen allows all individuals with update authority the ability to review individual reference quantities, adjust/delete quantities when necessary, and/or add other reference quantities that may have previously been omitted. Any quantity added to the ESTR Screen requires comments to be added on screen and will automatically be posted back to the "PBOOK" Screen.

Estimate Screen - EST



Estimate Screen – ESTR



PROJECT APPROVAL OF ESTIMATES

The Engineer is responsible for the electronic approval of their project's estimate on each estimate day. Before this approval takes place at the project level, the Engineer must be assured that:

- The pay quantities and delivered material quantities entered into CMS are correct.
- That any liquidated damages due to failure to meet an interim completion date are entered into CMS.

- That any pay item deficient in material approval and not eligible for override be deleted from the estimate.
- Obtain from the Contractor an executed Contractor Progress Payment Certification CA-D-11 form.

With respect to delivered materials, payment is allowed in accordance with Section 109.07 of the C&MS and ORC Section 5525.19. Payment is limited to approved, durable items that have a significant value in comparison to the total price of the contract and shall not be in excess of what is required to do the contract work. The unit costs allowed are the invoiced material costs and any reasonable delivery charges less any contractor's discounts. The allowed unit cost shall not exceed the applicable contract unit price. Delivered material invoices shall be kept in the project file. Costs for stockpile materials may be established by documents other than invoices.

Payment for approved materials outside the vicinity of the project may be made if it is determined that it is not practicable to deliver the material to the project site. This should apply to only bulky material that represents approximately $5000 or more for related items of work. For small projects, payment for materials less than $5000 may be made at the discretion of the District Construction Engineer. These materials are intended to include but not be limited to, guardrail, fence, aggregates, structural steel, precast concrete, light/strain poles, etc. Materials that have established shelf life or are temperature susceptible shall be protected in accordance with the manufacturer's recommendations. Small warehouse items shall not be included. Certain additional requirements also must be met before payment of delivered material off the project takes place.

- The storage site of the material must be approved and documented in writing. This can be performed by the project personnel or other ODOT individuals (in cases where it is more practical for other Districts or Central Office Plant Inspectors to perform the inspection and provide the documentation).
- The material must meet the same level of approval at the storage site as that required of material at the project.
- The existence of the stored material must be verified and documented provided that it is designated or reserved for the particular project. This can also be performed by personnel from another District or Central Office when warranted by the location of the material.
- Payment for off site storage of material must also be supported by invoices kept on file in the project records.

Liquidated damages due to the failure of the contractor to meet the project completion date are automatically accounted for by CMS. The Engineer must however, enter into CMS any liquidated damages as a result of failure to meet an interim completion date such as a road closure limitation required by the plan notes. This is performed by entering the dates subject to liquidated damage and the amount per day into the "Liquidated Damages" (LIQID) Screen in CMS. Both automatic and manual Liquidated Damages are then automatically posted to the "EST" Screen for inclusion into the estimate total. CMS automatically checks to see if enough materials have been reported, approved, and entered into CMS to cover the amount paid at the time the estimate was generated. If a deficiency occurs, the estimate is "flagged" by means of a "Y" indicator under the Matl/Tst column on the "ESTR" Screen for the affected reference number. It is the responsibility of the Project Engineer/Supervisor to delete the affected quantity from the estimate if it is determined that the material lacks approval. If the Engineer establishes that the material in question is approved and the "flag" is caused by the approval not being processed in time for the estimate, then the "unjustified flag" can be overridden. Overriding of "unjustified flags" is performed at the District Approval Level by the District Construction Engineer or back up person. The Engineer should provide on screen remarks to the DCE or backup person to indicate why the flag is not warranted so that the "unjustified flag" can be overridden.

Once the Engineer has determined all the above has been accomplished, electronic approval of the estimate at the project level can take place. This is accomplished by changing the "N" indicator by "PE/PS Approval" on the EST Screen to a "Y" indicator. The estimate is now ready for the District Level Approval.

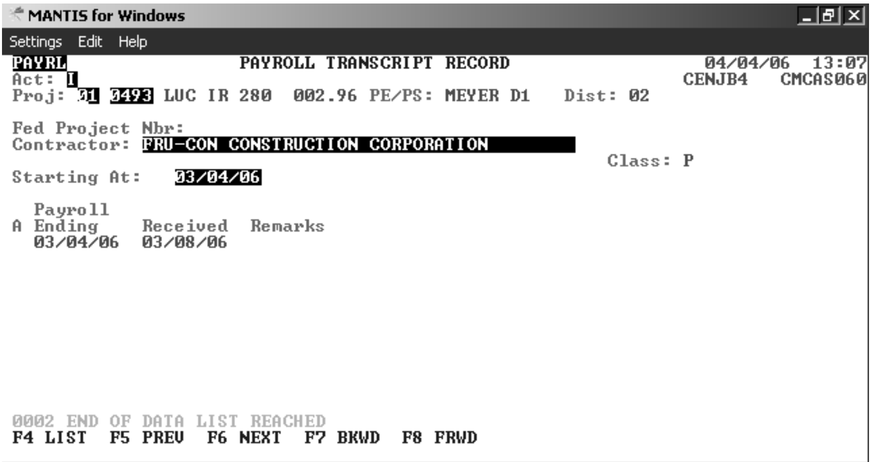
DISTRICT OFFICE APPROVAL OF ESTIMATES

District Level Approval is the responsibility of the DCE or back up person. Before this level of approval takes place, all "unjustified flags" must be overridden. This includes the previously discussed "flags" related to deficient material approvals. This also includes "flags" associated with deficient payrolls.

CMS automatically checks to see if payrolls submitted by the prime and any subcontractors for a project are up to date. Payrolls are entered for both prime and subcontractors into CMS on the "Payroll" (PAYRL) screen. This is done after the payrolls are reviewed and approved for prevailing wage compliance by either the Engineer, District Wage Rate Coordinator, or other assigned by the DCE. Once an estimate is generated, CMS automatically checks to see that payrolls have been entered into the system to cover the prime contractor and any subcontractor that would have worked on the project between the time span of the previous two (2) estimate dates. If a deficiency exists, the estimate will be "flagged" by a "Y" indicator beside "Deficient Payrolls" on the "EST" screen. If this occurs, the estimate is held at the District until the deficiency is resolved. The DCE or backup person can override the "flag" once it is determined that all required payrolls have been submitted, reviewed, and found acceptable. This is accomplished by changing the "Y" indicator to an "N".

Once all "unjustified flags" have been overridden, the DCE or back up person can now approve the estimate. This is accomplished by changing the "N" indicator by "District Approval" on the "EST" Screen to a "Y" indicator. The estimate is now automatically forwarded to the Office of Accounting in Central Office for further processing and payment to the prime contractor.

Payroll - PAYRL



METHOD OF MEASUREMENT

In determining the proper method of measurement for a particular item of work encountered on a project, several sources of information exist. Section 109.01 of the C&MS provides general information for the determination of various units of measurement. These include items measured by weight, those measured by cubic meter (cubic yard) and those measured by the liter (gallon). In addition, specific information can be found for every listed pay item, with few exceptions. Every item number in the C&MS contains a unique section entitled "Method of Measurement" which provides this specific information. For example:

> ***603.14 Method of Measurement***. *The Department will measure conduit by the number of feet (meters), measured from center-to-center of appurtenant small structures or between open ends inclusive of lengths of pipe bends and branches. The Department will not deduct for catch basins, inlets, or manholes that are 6 feet (2 m) or less across, measured in the direction of flow. Where the location of an appurtenance or an open end is changed with the approval of the Engineer to accommodate full conduit sections, the Department will measure the length placed. Conduits placed on slopes steeper than 3:1 or with beveled or skewed ends will be measured along the invert.*
>
> *When the pay item calls for concrete encasement, payment for furnishing and placing the concrete encasement, and for any additional excavation required shall be included in the unit bid price for the pertinent conduit. When the pay item calls for a new conduit to be field paved, payment for the field paving, including all work and materials necessary for the item, shall be included in the unit bid price for the pertinent conduit.*

The Department will measure field paving of existing pipe by the number of feet (meters).

The few exceptions includes: items 402,403,404,412,446, and 448. These are all asphalt concrete items with the "Method of Measurement" for all these items described under Section 401.21. Likewise Section 641.12 provides the "Method of Measurement" for all the pavement stripping items, 642,643,644, and 645. No specific section exists for the Items 441, 499, 501, 502, 505, 506, 508, 510, and 623. These are all general specifications, items involving lump sum payment, or items not paid separately, but included in other items for payment.

For items of work not covered in the C&MS, other sources can be utilized to determine the proper "Method of Measurement". Supplemental Specifications are individual documents which describe the construction and material specifications for items whose requirements are changing from year to year, are still in the development or experimental stage, or are used only occasionally. These can be identified by their 800 series number. Just like the C&MS, these Supplemental Specifications contain a unique section entitled "Method of Measurement" which provides the specific information for measurement purposes.

Items listed as "Special", having no item number, also have specific information with respect to proper measurement. This is likewise included in a section entitled "Method of Measurement" and is incorporated in either the plan notes or listed in the specific proposal for the project.

Another possible source of information with respect to "Method of Measurement" are items listed "as per plan". Reference items with an "as per plan" designation have been modified in some way from what would normally be required by the Specifications, Proposal, Standard Drawings, etc. This modification will be found in a plan note within the contract plans. The project personnel must investigate these "as per plan" modifications to determine what has been changed with the item.

For those projects designed in metric units, specific information with respect to measurement can be found. Section 109.02 of the C&MS provides information with respect to "Metrification" along with a list of conversion factor for converting English to metric.

BASIS OF PAYMENT

As per Section 109.03 " Scope of Payment' in the C&MS, payment to the contractor for an item of work performed by the contract shall be full payment for furnishing all materials and performing all work under the contract in a complete and acceptable manner. The "Basis of Payment" for any item of work details that the unit bid price is full compensation for certain work and/or materials essential to that item. As such, this work and/or material will not also be measured or paid for under any other pay item which may appear elsewhere in the plans or Specifications. Like "Method of Measurement", with few exceptions, every item number in the C&MS contains a unique section entitled "Basis of Payment" which provides specific information as to what is covered by the pay item. The following example is provided:

> ***604.09 Basis of Payment.*** *The Department will pay for accepted quantities at the contract prices as follows:*

Item	*Unit*	*Description*
604	*Each*	*Manholes*
604	*Each*	*Inlets*
604	*Each*	*Catch Basins*

The few exceptions include Items 441, 499, and 501. These are all general specifications dealing with asphalt concrete, concrete and structures.

Likewise, for items of work not covered in the C&MS, the same type sources exist. As with "Method of Measurement", item numbers in the 800 series are covered under Supplemental Specification.

Items listed as "Special" also have a unique section entitled "Basis of Payment". These are found either in plan notes or the proposal.

Likewise "as per plan" modifications need to also be investigated by the project personnel. These modifications could change the "Basis of Payment" of the particular item of work.

CHANGES AND EXTRA WORK

The purpose of this section is show how modifications are made to ODOT construction contracts by change order. We will discuss reasons for change orders, pricing, preparation and processing and record keeping.

ODOT contracts are unit price contracts using estimated quantities of work. Simply by the nature of this type of contract, change orders will occur if for no other reason than to adjust estimated quantities to the quantities of work actually performed. Change orders amend the contract by adding or deleting work, making reimbursement for additional costs incurred, making material substitutions, changing specifications, etc.

The Director is empowered by Section 5525.14 of the Ohio Revised Code to amend contracts for highway improvements by change order. This authority has the following statutory limitations:

- Any original bid item can be increased to the lesser of 5% of the total original contract amount or $100,000.00.
- A new item of work can be added to a contract to a value of the lesser of 5% of the original contract value or $100,000.00.

Additions beyond these limitations must be approved by the State Controlling Board. However, the director can exceed these limits if there are circumstances that warrant the declaration of an emergency. These circumstances could include a threat to public safety, idled equipment costs, delay costs, etc.

Guidelines for preparation of change orders are given in:

- C&MS Section 104.02, 109.03, 109.04
- ODOT Policy 27-010 (P), and Standard Procedure 510-010(SP)

REASONS FOR CHANGE

The necessity for a change orders to an ODOT construction contract may arise for many reasons. The most common causes for change orders are discussed below.

Changes in Quantities of Work

The quantities of work actually performed differ from the quantities originally estimated and established in the contract for the following reasons:

- Final measurements/calculations
- Quantity changes to meet field conditions
- Plan errors

Differing Site Conditions

Existing field conditions differ from the plan to the extent that performance of additional or non bid work is required for the following reasons:

- Differing subsurface conditions
- Presence of any conditions not shown in the plan

Changes in the Scope of Work

Changes to the project that are so far reaching that they can be considered outside the original intent of the work can be caused by:

- Significant changes in the quantities of work
- Significant alteration of the work due to:
    - sequence of construction
    - method of construction
    - materials

Changes for the convenience of the owner

Changes in the work ordered by the owner to meet the needs of the owner. The following changes are typically not required for the proper construction of the project:

- Addition of new work or deletion of work

- Acceleration
- Change in Materials
- Suspension of Work

Actions by others

Restriction, regulation or delay imposed on the contractor beyond the terms of the contract by an entity who is not a party to the contract can be caused by:

- Utility Companies
- Railroads
- Regulatory agencies
- Local governments

GENERATING AND PROCESSING A CHANGE ORDER

The actual process for generating and processing a change order will vary from district to district depending on the level to which authority or responsibility has been delegated within the district. The process usually begins with the recognition of a need for a change order at the project level. This need is usually communicated to the District Construction Office which will either grant or obtain concurrence or authorization. A decision is then made as to the type of change order that is needed, a District Change Order or an Extra Work Change Order, and the change order is entered into CMS via the "CO" screen by the Project Engineer or the District Construction Office. CMS then generates both an electronic and a paper change order. The paper change order is signed by the District Construction Engineer and/or the District Deputy Director and submitted to the contractor for signature. Once the contractor signs and returns the change order the required approvals are then entered into CMS via the "CO" screen and the change order is electronically approved and is ready for payment.

CHANGE ORDER TYPES

ODOT construction contracts are modified using two types of change orders, a District Change Order and an Extra Work Change Order. Guidelines for use, authorization limits and requirements and approval authority for each type are given in ODOT policy 27-010(P), and standard procedure 510-010(SP).

COMMON CHANGE ORDER ELEMENTS

Practically every change order will contain the following elements:

Face

- Project Identification: Project Number, County, Route, Section, Federal Number, Federal Acceptance Type.
- Change Order Identification: Change Order Number, Type of change order.
- Work Item information: Reference Number, Participation Code, Item Code, Item Description, Units of Measure.
- Cost Information: Unit Price/Lump Sum Amount, Reference Total, Addition/Non performance, Change Order Total Addition /Non performance.

Body

- Reference Number Identification: Reference Number, Extra Work Number Participation Code.
- Reason Code: Mandatory field in CMS "EXPL" screen for each reference. CMS contains a list of 22 reason codes to choose from.
- Explanation of Necessity.

Signatures

- For request and approval by the Department.
- For agreement by the contractor.
- For agreement by the Local (when applicable).

Preliminary Approvals and Attachments (when applicable)

- Emergency Declaration, Preliminary Approval, or Final Measurement request as approved by the Director.
- Support Documentation: Additional information describing need for the change order.
- Cost Documentation: Cost analyses, Comparative pricing information, etc.
- Forms and detailed instructions are available on the Division of Construction Management webpage.

CHANGE ORDER PRICING

Once the need to perform extra work on a project has been identified a basis of payment for this work must be established. Pricing for extra work is usually established using one of the following methods.

Agreed Unit Price

This method of pricing is used when the extra work can be broken down into measurable units. The number of units necessary to perform the work is estimated and a unit price is determined and agreed upon as described below. Final payment is based upon the final measurement of the number of units of work actually performed:

- Unit prices already established in contract.
- Comparative pricing. Contract unit prices for similar work on other projects (CMS database).
- Use force account type analysis (Appendix V).

Force Account (Section 109.05 of the CM&S)

A force account method is used when the work cannot be broken into measurable units or when a unit price cannot be agreed upon. This method reimburses the contractor the actual costs of labor, equipment and materials incurred in the performance of the work including allowable overhead and markup. This method requires a significant amount of record keeping and is described in Section 109.05 of the CM&S.

This method usually requires the preparation of two change orders both of which use the same format. The first change order is known as an "Estimated Cost Force Account" and is established so that money can be encumbered and payments can be made to the contractor as the work is performed. The second change order is known as an "Actual Cost Force Account" and represents the final accounting of the cost of the performance of the work and is used to reconcile the "Estimated Cost Force Account" change order.

Agreed Lump Sum

This method of pricing is a negotiated amount and can be used when the extra work can be identified as something that is usually paid as a "lump sum". The "Agreed Lump Sum" can also be used as an alternate to the force account method:

- Prepare lump sum using force accounts style analysis
- Maintain force account record of the work for a period of time and use to develop lump sum
- 3rd party billing
- Lump Sum Adjustment

ADDITIONAL CONTRACT TIME FOR EXTRA WORK

The performance of extra work or additional quantities of work may warrant an extension of contract time. Extensions of contract time may involve additional direct project overhead costs.

Record Keeping

Record keeping is an integral part of contract administration and is especially important when considering change orders. Adequate records must be maintained to document the need for changes and to establish pricing for extra work.

QUANTITY MEASUREMENTS

Measurements of the quantities of work in the units prescribed by the plan actually performed by the contractor must be recorded by the project personnel. Change orders must be prepared to make adjustments for any differences between contract quantities and the quantifies actually performed.

Issues of efficiency or other similar factors may arise that may impact unit costs when the quantities actually performed differ significantly from those shown in the plan. For these occasions the quantity records must be thorough enough to determine actual production rates and other such items.

FORCE ACCOUNT WORK AND EXTRA WORK USING FORCE ACCOUNT STYLE ANALYSIS

The records required for force account pricing of extra work must accurately depict all labor, equipment and materials used by the contractor to perform the work. The items that are necessary to record are as shown below:

- Description of Work
- Contractor's work force
    - Employee Name
    - Classification
    - Hours worked regular and overtime
- Contractor equipment
    - Type
    - Model
    - Age
    - Capacity
    - Hours Worked
    - Hours Idle
- Materials
    - Description
    - Quantity
    - Invoices

PROJECT CLOSEOUT

The purpose of this section is to explain the process by which ODOT construction contracts are closed out. We will discuss final inspections, the completion of contract requirements, the determination of the final contract value and the issuance of the final payment and release.

Following the completion of the physical work of a project a process to "closeout" the contract begins. This process ultimately leads to the final payment and release of the contractor from further responsibility for the project. This process includes gaining acceptance of the project from all participating agencies, determining the final value of the contract, the completion of all remaining contract requirements and the issuance of a final change order. It is the Department's goal that this process be completed within six months of the completion of the physical work for at least 90 percent of our projects.

FINAL INSPECTION

When work on a project has been completed to the satisfaction of the Project Engineer/ Project Supervisor, a final inspection is conducted. The final inspection is typically conducted by a team that is headed by the District Deputy Director's Appointee for Final Inspection. This Team shall include representatives of all local participating agencies and FHWA, when applicable, ODOT maintenance personnel, the Engineer and the contractor. The Team will determine the need for any corrective or additional work and prepare a "punch list" for the project. In the case of any disagreements among the Team, the District Deputy Director's Appointee is empowered with final authority. The "punch list" is provided to the contractor in writing along with a specified time frame or a specified date for completion of the prescribed work. Final inspection must follow the ODOT policy 27-007(P), and standard procedure 510-007(SP) and generally must include the following items:

- Resolution of Punch List: It is the responsibility of the Engineer to perform any follow up necessary to assure that the contractor completes the punch list work in a timely manner.
- Obtain acceptance of project by all local agencies: Upon completion of all physical work, including punch list work, the District Construction Office must obtain a letter of acceptance of the project from all local participating agencies.
- Issuance of Report on Final Inspection: Following the completion of punch list work, if any, the District Deputy Director's Appointee for Final Inspection issues the Report on Final Inspection, form C-85. This report represents an informal acceptance of the project.

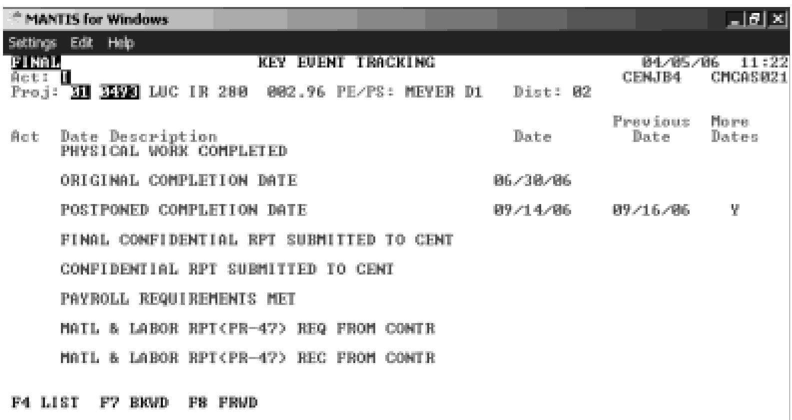
COMPLETION OF CONTRACT REQUIREMENTS

Once the physical work is completed for a project there are a number of administrative contract requirements that must be completed before final payment can be issued. These requirements may differ from contract to contract and typically include the processing of various documents or the Contractor supplying certain information:

- Payroll requirements completed
- Affidavit of Compliance Final Wage Affidavit (State Projects Only)
- Profilometer Report
- Concrete Core Report

The dates on which each of these contract requirements has been satisfied are entered and recorded in CMS on the "FINAL" screen.

FINAL screen



DETERMINATION OF FINAL CONTRACT VALUE

A key element of the project closeout process is the determination of the final dollar value of the construction project. This is accomplished by determining the final number of units to be paid for each item of the contract and by processing all necessary change orders including a final change order.

In order to ensure timely closeout, it is strongly recommended that some of the activities that will be discussed be performed as work is completed on the project.

Prepare and audit final contract quantities

The Engineer is responsible for determining and preparing support documentation for the final quantity (final number of units) to be paid for every item of work contained in the construction contract. Ideally this is accomplished progressively as the items are completed during the course of construction of the project. Once the physical work has been completed for the project, the Engineer submits all project records to the District Office for an audit. This audit is performed by the District Level Reviewer for the purpose of verifying the final quantities and assuring that adequate documentation exists to support payment of those quantities. It is currently the Department's policy to audit a minimum of 25% of all projects awarded each calendar year. The District can audit additional projects at its discretion. Again, it is preferred for larger projects that the audit be performed progressively as items of work are completed and documented. Upon completion of the audit, or periodically during the audit for larger projects, a list of "approves' final quantifies is prepared and is forwarded to the contractor for concurrence. Once agreement with final quantifies has been obtained a change order is prepared to make any necessary adjustments between the final and original contract quantities. Any necessary pay estimates resulting from these change orders are initiated by the District Construction Office.

Material Certification

As discussed in earlier sections, all materials incorporated into construction projects must be approved for use. Once the work is completed for the project an audit must be performed to ensure that sufficient quantities of material have been approved for each reported final quantity. As the final quantity audit is being performed and final quantities are approved, the quantities are reported to the District Engineer of Tests for the material audit. The District Engineer of Tests and staff review the project testing and acceptance records to ensure that sufficient materials are approved for the final quantity for every contract item. Material deficiencies are reported to the Engineer who is responsible for resolution of the deficiency. Once all material deficiencies are resolved, the District Engineer of Test generates the Letter of Certification of Materials for the project. This letter is signed by the District Engineer of Tests and the District Highway Management Administrator and included in the final estimate package.

The project closeout process is modified as follows for projects constructed under the material acceptance process described in Policy 515-001(P).

Under this policy the Engineer prepares a material certification for the project and submits it along with the final contract quantities to the District for an audit. The final quantity documentation is audited by the District Level Review Team as described earlier. The District Engineer of Tests now only audits the Engineer’s material certification using project audit guidelines similar to those used by the District Level Review Team. Deficiencies identified by the District Engineer of Test's audit are reported to the Engineer who is responsible for their timely resolution.

The Highway Management Administrator approves the material certification and it is included in the final estimate package.

Issuance of Final Change Order

A final change order is required for every construction project. Change orders for all quantity adjustments, extra work, additional costs, price adjustment or contract amendments must be processed prior to the issuance of the final change order. Approval of the final change order signifies that all necessary changes have been made to adjust the contract from the original bid condition to the final "as built" condition.

FINAL PAYMENT AND RELEASE

Following the approval of the final change order, the final estimate is prepared and processed and the contractor is released from any further responsibility for the project in accordance with C&MS Section 109.12.

Preparation of Final Estimate Package

A final estimate package is prepared for the project and includes the following items:

- Final estimate (reconciles payment to final quantities)
- Letter of Certification of Materials
- Certification of Payroll Affidavit (100% State projects only)
- Letter of Acceptance from Participating Agency
- Affidavit as to Non Specified Materials (when applicable)
- Receiving ticket for Salvaged Materials (when applicable)
- Signed Contractor Certification Form CA-D-12

The final report is certified by the District Construction Engineer and the District Deputy Director. The final estimate is approved by the District Deputy Director.

Issue final payment and release contractor from further responsibility

Once submitted the final estimate package is audited and approved for payment. Following this approval the District Construction Office generates a letter to the contractor advising of the final value of the contract and of their release. This letter also serves as the Department's formal acceptance of the project.

CLAIMS

General

ODOT, by the nature, volume and complexity of the work which it does, is subject to claims by Contractors who perform the work. The underlying "rules of the game" between ODOT and a Contractor exist in the Contract (the Proposal), the Specifications and the Plans. These are the stated terms. There are certain terms which are not stated in the contract documents. These are known as implied terms. For instance there is an implied warranty that the plans and specifications are free from defects and, unless stated otherwise, that there will be safe and continuous access to all areas within the project's boundaries. Claims arise from both stated and implied terms.

Claim or Dispute?

The words “dispute” and “claim” are often used interchangeably but the words, as used in ODOT contract language, do have different meanings. A “dispute” is a disagreement and/or a difference of opinion between ODOT personnel and the Contractor. A “dispute” matures into a “claim” when an issue in dispute cannot be resolved at the Project or District level. A “dispute” officially becomes a “claim” when the Contractor files a Notice of Intent to File a Claim or a Notice of Intent to Appeal to the Dispute Review Board. At this time the Contractor will be asked to “certify” the claim. The Contractor must certify under oath, by signing in front of a notary, that the claim is made in good faith, that it is accurate and complete and that it represents the actual costs incurred both in time and money.

On Federal Oversight projects, once the dispute becomes a claim, ODOT is responsible for providing all subsequent documentation involving that claim to the Federal Highway Administration. The Department’s Claims Coordinator is responsible for these submittals.

Who can file a claim?

The only entity that can assert a claim against the Department is the legal contractor of record. If the project is being performed by a joint venture then only the joint venture can assert a claim. Likewise, a subcontractor cannot assert a claim directly against the Department but can make a claim against the Contractor who in turn can assert a claim against the Department for damages incurred by the subcontractor. Do not discuss a dispute resolution with a subcontractor without having the Contractor’s responsible representative present.

Elements of a claim

Every claim has two distinct elements:

- **Entitlement** is the theory under which the Contractor asserts the claim. Examples of this would be: differing site conditions, conflict between plans and specifications, delays, etc.
- **Damages** are the monetary and/or time impacts incurred by the Contractor which are a direct result of the claim event.

Duty to provide notice (104.02 G)

Most construction contracts, including ODOT's, include a requirement for the contractor to provide prompt notice of circumstances that may require a revision to the Contract Documents. This notice of the existence of a potential change to the contract is required before the Contractor begins any changed or extra work. Failure to give prompt notice could defeat an otherwise properly documented claim.

The purpose of requiring early notice is so the owner has the option of proceeding with the work, redesigning the work, and/or otherwise reducing the effect of a claimed event. Early notice also allows the owner the opportunity to begin keeping careful and specific records of the contractor's activities, manpower, equipment and materials which are related to the claim.

Types of claims

Certain types of disputes by their nature are those which are most likely to result in a claim. The most common claims deal with:

- Interpretation of Contract Documents (102.05, 102.07, 104.01, 105.01, 105.04)
- Differing site conditions (102.05, 102.07, 104.02.B)
- Extra work (104.02.F, 109.05)
- Repair of defective work/material (105.01, 105.03, 105.10, 105.11, 106.07, 107.15)
- Suspension of work/Failure to continue work (104.02.C, 104.02.G.3, 108.05, 108.08)
- Acceleration (109.06)
- Significant changes in the character of the work (104.02.D, 104.02.E)
- Interference by/Cooperation with third party (105.07, 105.08, 107, 108.04)
- Inspection (over/under) (105.01, 105.03, 105.09, 105.10, 105.11, 106.03, 106.07, 109.12)
- Inefficiencies (109.07)
- Quantity variations (102.04, 109.01, 109.04)
- Delays (108.06, 109.05.D)

Delays (108.06)

Delays may be associated with some of the claims listed above, and may require careful analysis to determine who is responsible for the delay. It is important to keep the following principles in mind when evaluating a Delay Claim:

The contractor must demonstrate that the delay was critical. It must be shown that the delay in question affected the overall project schedule and was a controlling operation with respect to project completion.

Excusable Delays (108.06.B) Are those delays which are unforeseeable and beyond the control of the contractor. Excusable Delays may be either compensable or non-compensable.

Excusable/Compensable (108.06.D) These are delays caused by the owner.

Examples include: lack of site access, late shop drawing approval, redesign etc.

Excusable/Non Compensable (108.06.B) These are delays caused by third parties outside the contractors' control. Examples include: area wide labor disputes, floods, transportation industry delays, fire, vandalism etc.

Non Excusable (108.06.E) Non Excusable delays are always non-compensable. These delays are caused by the contractor or under his control. Examples are: subcontractor delay, late mobilization, production takes longer than scheduled, equipment breakdowns etc.

Very often delays can occur from various sources at the same time. These are called Concurrent Delays (108.06.F). An ODOT caused compensable delay occurring at the same time as an excusable delay which is non-compensable should result in a time extension but no recovery of costs. An ODOT caused delay occurring at the same time as a contractor caused delay should result in a time extension but no recovery of costs. Both cases relieve the contractor from liquidated damages for the time in question.

The contractor is entitled to plan and pursue the work in order to finish ahead of the contract completion date (108.02.B.2). If ODOT delays the contractor, the contractor may be entitled to impact costs.

Duty to mitigate (108.06.A)

The Contractor and the Department must make a reasonable effort to mitigate damages resulting from a claim event, whether caused by the Department, Contractor, third party or intervening event. Mitigation might include: re-sequencing work activities, acceleration, continuing work through a planned shutdown period, etc. The contractor may be entitled to recover the costs of mitigation. Prior to implementing a change of any kind the Contractor and the Department must have agreed on the method of compensation and time responsibilities in writing.

Proof of claim

Proof of entitlement and proof that additional costs were incurred rests solely with the contractor. The Contractor has the burden of proving BOTH entitlement and damages. If the Contractor cannot prove entitlement, the claim must be denied. Likewise, if the Contractor proves entitlement but cannot prove that it incurred any cost and/or time impacts, the claims must be denied.

Claim cost approaches

Contractors utilize various approaches to present the damages associated with a claim. Below are the most common:

- Total Cost. In this method the contractor submits the Total Cost to perform the work. This method presupposes that there are no contractor inefficiencies or unanticipated contractor costs. ODOT rarely accepts this approach.
- Modified Total Cost. In this method the contractor submits his Total Cost to perform the work and then deducts an agreed upon contractor inefficiency. A little better than the Total Cost method but still not ODOT friendly.
- Force Account (Time and Materials) (109.05 C). Based on actual records and actual contractor costs. Cumbersome to assemble and check but has a certain essential fairness built in. Mark ups and determination of costs defined in the specifications.
- Measure Mile. Force Account records are kept for a specified length of time and the cost is calculated. This production rate and cost is then assumed constant throughout the rest of the work. Applicable only when a large quantity of similar extra work is to be done for an extended period of time.
- Agreed Unit Price/Agreed Lump Sum (109.04 B). Uses Unit Prices agreed upon by the Contractor and ODOT. Good for ODOT since ODOT has large amounts of data concerning unit prices. The Office of Estimating is available to provide expertise on work items not available in database.

Analyzing a claim

The following step by step process should be used to analyze a claim.

- Did the Contractor give the required Early Written Notice (104.02.G)?

ENTITLEMENT:

- What is the Contractor’s theory of entitlement?
- What do the Contract Documents say?
- Determine the actual sequence of events giving rise to the claim.
- Identify each specific claim issue.
- What is the position of both sides on each issue?
- If delay related:
- Did the claim circumstance delay work on the critical path (108.06.A)?
- Is it an excusable or non-excusable delay (108.06.B through 108.06E)?
- Is it a compensable or non-compensable delay (108.06.B through 108.06.E)?
- Were any of the delays concurrent (108.06.F)?

DAMAGES:

- Has the Contractor proven the damages directly relate to issue being claimed?
- Do ODOT records agree with the Contractor's submitted documentation?
- Does the Contractor's cost submittal meet the guidelines for extra work (109.05)?
- Are the damages reasonably in line with industry standard costs for the same work? If not, is there a reason why?
- Did the Contractor mitigate the monetary and time damages?

Importance of project documentation

It is impossible to overemphasize the need for consistent, complete and accurate project documentation. Contemporaneous records, documents written at the time of the event, normally carry more weight in claims decision-making than records written up at the time the claim is submitted for analysis. Project documentation must be clear and legible, written in real time, be a regular practice and be sufficiently detailed to describe the writer's thoughts. Examples of project documentation that are routinely used to support a claim position include: pre-bid, pre-construction and progress meeting minutes; daily diaries; force account records; idle equipment records; correspondence, including e-mails; RFI's; transmittals/submittals; project schedule and changes; phone conversations; and photos and videos.

CLAIM MANAGEMENT

The Department as a general policy takes a proactive approach which seeks to avoid disputes. In the event claims do arise, an orderly procedure is in place to assist with managing the claims.

Each project includes a dispute resolution process designated by proposal note. The Dispute Resolution and Administrative Claims Process (PN109) is the default process and is included on all projects except those that use the Dispute Review Board Process (PN108). The Dispute Review Board (DRB) Process is used on select projects that are typically over $20 million and/or of a highly technical nature. The applicable process must be followed by the Contractor in order to seek additional compensation or contract time.

Claim avoidance

Claim avoidance, at its most basic level, is accomplished by removing or lessening the factors which contribute to claims. Discussed below are some of the methods used by the Department:

- Prequalification & Post Project Assessment of Contractors:

  - Qualified, capable contractors with the resources to undertake a project can lessen the factors which lead to claims (i.e. qualified superintendents, capacity to maintain schedule, quality work). Some contractors are also very astute at recognizing claim opportunities. So, qualifications alone are not a guarantee of claim avoidance.
- Constructability Review: The Department has instituted Constructability Reviews which occur at the District level. The review team is generally designated by the DCE. The review team will:
  - Review General Notes and Special Provisions.
  - Review Plans
  - Personnel should walk the project paying particular attention to:
    - Right of way encroachment or obstructions
    - Utilities
    - Drainage
    - Pavement or bridge condition (i.e. heaving, cracking, deterioration)
    - Sediment and erosion problems and other geological features
    - Stream & Stream diversions
    - Railings & Signs
    - Joint conditions
    - Impact on signals
    - Quantities
  - LISTEN to Operations personnel. They know existing problems.
  - LOOK for the obvious discrepancies in location, missing information, obstructions, conditions or quantities.
- Change Order Review: At the time a change order is written its creator is required to choose a reason code for each reference item included on that change order. If the chosen reason code is (Plan) “Error or Omission” the change order is targeted for review by the Department’s Change Order Review Team. This Team reviews these change orders for recurring problems, recommends steps for correction and provides this information to the District Production Offices. This Team also identifies changes caused by plan errors or omissions on which ODOT may pursue compensation for the cost of the required change from the designer of the plan.
- Claims Tracking: Disputes and claims are tracked by ODOT to identify the causes of disputes and claims and when applicable clarify and/or correct the contract documents to avoid future disputes and claims.

Dispute Resolution and Administrative Claims Process (PN 109)

The Dispute Resolution and Administrative Claims Process is a step by step sequence of events which occur following the Contractor's Early Notice submittal described in C&MS 104.02.G. This Notice is required when the Contractor discovers a circumstance that may require a revision to the Contract Documents or may result in a dispute.

Proposal Note 109 (PN 109) sets forth the details of each of the three steps of the Dispute Resolution and Administrative Claims Process. These three steps include: On-Site Determination, District Dispute Resolution Committee and Director's Claims Board. PN 109 sets forth specific submittal timeframes at each step which must be met by both the Contractor and ODOT personnel to move a dispute toward resolution. These timeframes are included in PN 109 as recognition that: first, the Contractor deserves timely responses; and, second, that it is easier to resolve a dispute when the events are clear in everyone's mind rather than allowing an issue to remain until the finalization stages of a project.

Dispute Review Board Process (PN 108)

Proposal Note 108 (PN 108) provides that a Dispute Review Board (DRB) be established prior to the beginning of construction of a project and exists through the life of that project. A DRB is comprised of three members, each with a minimum of 10 years experience in construction, contract administration and dispute resolution techniques. One member is chosen by the Contractor, one member is chosen by ODOT and the Chair of the Board is chosen by the other two members.

The DRB conducts quarterly meetings and is provided with monthly progress meeting minutes, project schedule updates and any other information it requests to keep up-to-date on the progress of the project. The DRB may also conduct special hearings at the third step in the Dispute Review Board Process and provide recommendations to the Director of ODOT as to the disposition of that claim.

Proposal Note 108 (PN 1089) sets forth the details of each of the three steps of the Dispute Review Board Process. These three steps include: On-Site Determination, District Dispute Resolution Committee and the Dispute Review Board. PN 108 sets forth specific submittal timeframes at each step which must be met by both the Contractor and ODOT personnel to move a dispute toward resolution.

The DRB may also be asked, by mutual agreement of both parties, to render an Advisory Opinion. An Advisory Opinion may be used to provide the parties with a preliminary assessment of the merits of each party's position in a dispute based upon the information presented. The process is meant to be expedient, shall be primarily oral and will not prejudice a future formal DRB hearing of the dispute.

The expectations and responsibilities of the Contractor, ODOT and the DRB, as well as the agreed upon compensation of the DRB members is included in the Dispute Review Board Three Party Agreement. This contract is signed by ODOT, the Contractor and all three DRB members prior to the first DRB quarterly meeting.

Payment

- A Special Item, Lump Sum, Dispute Review Board will be furnished in the Proposal to pay for the services of the DRB members.
- Monthly, the Chair shall submit to the Contractor the billable time and travel expenses for each Board member.
- The Contractor will pay the DRB members' invoices. The Contractor will then submit the paid invoices to the ODOT Project Engineer for reimbursement payment under the above referenced pay item.
- Under the Special Item described above, the Contractor will be reimbursed 100% of the costs associated with the quarterly meetings plus 50% of the costs associated with the development and issuance of Step 3 proceedings or advisory opinions.
- The ODOT Project Engineer will review each paid invoices. All billable time is to be at the hourly rates agreed to in the Third Party Agreement and travel expenses are to be in accordance with Ohio Office of Budget and Management's Travel Policy. Any adjustments necessary should be made on the subsequent invoice.

Documentation Requirements – PN 109 Dispute Review Board Process

1. Check monthly DRB member invoiced hours for accuracy and reasonableness
2. Invoiced hourly rates cannot exceed hourly rates set up in Three Party Agreement
3. Invoiced travel expenses cannot exceed maximums established in Ohio Office of Budget and Management's Travel Policy.
4. Verify all totals are mathematically correct.
5. Verify items paid at 100% ODOT and 50/50% ODOT/Contractor split are correct
6. Document monthly Contractor reimbursement total on CA-D-1B

200 Earthwork

201 Clearing and Grubbing

General

The purpose of this section is to establish uniform practices for clearing, grubbing, scalping, and removing trees and stumps within the areas designated in the plans.

The following terms are defined for clarity:

- "Clearing" is cutting down all of the trees and brush.
- "Grubbing" is clearing by digging up roots and stumps.
- "Scalping" is removing the remaining roots, sod, grass, agriculture crop, sawdust, and other vegetation so that the soil is completely exposed. This does not include removing topsoil.

Varying interpretations as to the extent of removal are possible where these removals are set up on a lump sum basis. It is necessary to exercise judgment in the administration of this item to accomplish the desired results.

Specification Changes

There only specification change from the 2005 to 2008 specification book consisted of adding additional restrictions on the movement of regulated material into and out of Ohio. These changes were the result of the Emerald Ash Borer infestation.

Disposal of Materials

All material disposals in the 200-series of C&MS refer to sections 105.16 and 105.17. The following statement is in 201.01 and is repeated throughout the 200's:

> *"Use all suitable excavation material in the work. Alternatively, legally use, burn, or dispose of all material according to 105.16 and 105.17."*

The use, reuse, and/or disposal of these materials may be regulated. (See section "105.16 Borrow and Waste" of this manual).

Policy

It is Department policy to remove only those trees that must be removed for the construction and maintenance of the highway and for the safety of the traveling public. In certain circumstances, it is desirable to leave healthy trees in place.

Plan Notes

There are three plan notes that may be used by the Department to determine the extent of the clearing and grubbing work on the project. These notes are described below and in the Location & Design Manual, Volume 3, Appendix B. In every case, the plan will denote the limits of the clearing and grubbing.

Plan Note G109A

When Plan Note G109A is used, no trees will be specifically called out for removal. Everything is removed within the areas denoted in the plan. In this case, the Contractor has the maximum risk if his field count is not accurate. This note is often used on small projects.

Plan Note G109B

When Plan Note G109B is used, trees and stumps are marked for removal on the plan. This note is used where the designer can reasonably count all of the trees within the work limits. This count should be accurate at the time of the count.

The count is not necessarily correct at the time of construction. The Contractors are responsible to visit the site prior to the bid. This allows the Contractor to take tree growth into account. Typical increase in growth is generally about 25 percent. This depends on the time between the count and construction.

The Contractor should bring large discrepancies between the plan count and the actual conditions to the Department’s attention prior to the bid.

Plan Note G109C

When Plan Note G109C is used, everything in the plan limits is removed except for the trees denoted as “Do Not Disturb”.

The plan denotes some trees and stumps, where feasible. In other locations, the plan denotes heavy wooded areas. An estimated count is given in the heavy wooded section. This estimate is based on representative counts in the heavy wooded areas.

There are inherent inaccuracies in this count. The Contractor will be able to make an informed decision in his bid by the knowledge of how the count is made. By denoting the type and accuracy of the tree counting, it minimizes the claims and change orders from this item of work.

Markings for trees to remain in place should be temporary and not result in an undesirable appearance beyond the life of the contract.

Trees Located within the Plan Limits Allowed to Remain

Trees that are located within the plan clearing and grubbing limits technically must be removed. There are circumstances, however, where the Engineer may consider leaving trees in place or making other changes to the contract.

It may be desirable to leave some trees because they are aesthetically pleasing and can provide structural value to an embankment or slope. Leaving flowering trees and shrubs such as dogwood, redbud, hawthorn, and other attractive growth should be given serious consideration. Special consideration should be given to rest areas or other specific nature locations.

The Project Engineer will contact the District Environmental Coordinator for recommendations on the attractiveness of trees to remain in place.

Where trees are allowed to remain in place, the area surrounding the trees should be cleared of undesirable undergrowth to provide an attractive appearance and to simplify maintenance.

Trees located within the plan work limits but outside the clear zone may not require removal. It is required to remove trees within the clear zone or a minimum distance of about 30 to 40 feet (9 to 12 meters) from the edge of the travel lanes. The actual clear zone distance depends on the roadway type. The Project Engineer needs to contact the District Office of Production to give approval recommendations on the clear zone.

It is not necessary to remove trees beyond areas required for construction if the grading section is in a cut with a 3:1 back slope, or is in fill with a depth requiring a guardrail.

All trees considered for remaining in place must be in good condition. A tree should be removed if it is dead, fallen, or unhealthy.

It may be necessary to remove some trees for fence or noise wall construction. This type of removal must be within the right-of-way limits and should not be greater than 10 feet (3 meters) in width in dense growth. Where trees are scattered, the removal should be confined to trees that are in line with the fence or noise wall.

The appearance of a mechanical cutting swath should be avoided when trees are left. This can be accomplished by having a curved or irregular tree line defining the area rather than a straight-line effect.

Scalping (201.04)

It is essential that the project enforce scalping work when it is required.

Scalping is not required under an embankment where the embankment height is greater than 9 feet (3 m) to the subgrade elevation and when the existing slope is 8:1 or flatter. Both conditions must be true for the location not to be scalped. See Figure 201.04.1 for an illustration.

This requirement is in the specifications to ensure good friction between the existing foundation and the new embankment. This construction technique minimizes future potential sliding.

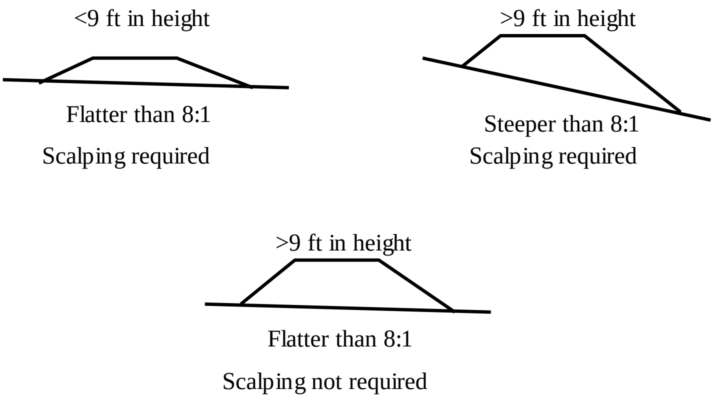


Figure 201.04.1 - Scalping Requirements

Documentation Requirements - 201 Clearing and Grubbing

1. Proper Disposal (see 105.16 and 105.17).
2. Mark Right-of-Way or cutting limits.
3. Check the field conditions for accuracy.
4. Count Trees or Stumps, if these are set up for individual payment.
5. Check material removals according to 201.03.
6. Check the required scalping locations.
    a. Use 201.04 for embankment foundations.
    b. Use 203.05 for benching areas.
7. Measure and pay according to 201.05 and 201.06.
8. Document on form CA-D-3A or CA-D-3B.

202 Removal of Structures and Obstructions

Description (202.01)

This work consists of removing all buildings, fences, guardrails, structures, old pavements, conduits, storage tanks, septic tanks, privy vaults, and other obstructions not designated or permitted to remain, and disposing the removed items in accordance with the requirement of 105.16 and 105.17. This work also consists of backfilling the resulting trenches, holes, and pits, and salvaging designated materials according to 202.02.

General Construction Requirements (202.02)

Raze, remove, and dispose of all buildings and foundations, structures, fences, guardrails, old pavements, abandoned pipe lines, storage tanks, septic tanks, privy vaults, and other obstructions within the Right-of-Way, except for utilities and those items where other provisions have been made for removal. Remove and store, at the specified locations within the Project limits, or reuse all designated salvageable materials.

The Department will take ownership of all salvageable items specified for storage. Reuse all salvageable items specified for reuse on the project. When the Proposal does not indicate for storage or for reuse, take ownership of the material.

Use all suitable material in the work. Alternatively, legally use, recycle or dispose of all removal items according to *105.16* and *105.17*.

Do not remove any item in use by traffic until after making arrangements to accommodate traffic.

When backfilling is required, and when the removal item is under the proposed pavement or paved shoulder, backfill the resulting cavities, voids, or trenches with Item *603* Structural Backfill Type 1 or 2. When backfilling is required, and when the removal item is outside the proposed pavement or paved shoulder limits or when rollers greater than 8 tons (7.25 metric tons) are used, the Contractor may use Item *203* embankment material. Place and compact the embankment or Item *603* Structural Backfill according to Item *203*.

For areas backfilled outside the plan construction limits, provide a final grade that presents a neat, well-drained appearance that conforms to the final topography and prevents water from draining onto adjacent properties.

Excavate the caved material in trenches and cavities resulting from the removal operation, and backfill the trench and voids according to the above specification, except when the trench lies within the limits of subsequent excavation.

Check appendix for more details and for requirements of other material encountered in the project site.

Bridges Removed (202.03)

The plans will include a note regarding the bridge removal, the note will usually include, the phasing of the demolition procedure, the requirement of the demolition plan, the specification of the equipment to be used, the necessary protection for water ways and traffic.

Before the demolition starts, the contractor should obtain an approval of the demolition plan, and notify the owners off all existing utility conduits using the structure. The contractor should disconnect all utilities according to local requirements.

Remove the substructures of existing structures, including piling, down to the proposed stream bottom. For those parts outside the stream, and for bridges that do not span over streams, remove substructures to a minimum of 1 foot (0.3 m) below proposed ground surface.

Where the plans call for the removal of portions of the structure, remove those portions with sufficient care. Avoid damage to the remaining portion of the structure. In case of damage to the existing structure, repair or replace the damaged portions of the structure at no expense to the Department.

Backfill the cavity created by the removal item according to 503.09, except when the cavity lies within the limits of subsequent excavation or other work.

Asbestos on Bridges

The plans will include a note regarding asbestos on bridges, contact the District Environmental Coordinator (DEC) to check changes in the current law regarding Asbestos removal. For a typical plan note, see the section, “Typical Regulated Waste Plan Notes”, Asbestos Abatement. This note is similar but not the same as 202 Asbestos Pipe Removal specification requirements in Item 202.

The contractor should adhere to plans note and specification while conducting the removal.

If the existing conduit attached to the structure is not specifically denoted in the Contract Documents as Item *202* Asbestos Pipe Removed, perform the work according to *109.05*.

Pipe Removed (202.04)

Remove and store, or dispose of pipe, head walls, or culvert as specified in the Proposal for payment. Seal openings left in walls of manholes or catch basins that are to remain in place. Encountered inactive and to be abandoned pipes, should be plugged or sealed before proceeding with backfilling operations. Perform plugging by using approved precast stoppers. Perform sealing by using masonry bulkheads.

If the removed pipe is designated for storage, the contractor should remove a sufficient section of the pipe to allow the Engineer to determine the quality of the pipe and the possibility of its removal without damage to pipe specified for reuse or storage. If the Engineer determines the pipe is salvageable, the contractor should carefully remove the remainder of the pipe and avoid breaking or damaging the pipe. Transport and store the removed pipe, as necessary before relaying. The contractor should replace sections of pipe lost or damaged by negligence or by use of improper methods at no additional cost to the Department. Clean all pipe before reusing. Remove salvageable pipe under Item *202* Pipe Removed for Reuse or Storage. If the Engineer determines the pipe is unusable, remove unusable pipe under Item *202* Pipe Removed.

Perform work according to *202.03* when removing conduits from or around a stream.

Asbestos Pipes

If removing an existing concrete water line pipe that was constructed before 1980, it may be an asbestos pipe. Test the pipe by using a Department prequalified environmental consultant to determine if it is an asbestos pipe. If it is determined that the pipe is asbestos, then a certified asbestos Contractor must perform the removal. Dispose of all asbestos pipes at a solid waste facility that is licensed by the Local Health Department and permitted by the OEPA. Contact the District Environmental Coordinator (DEC) to check changes in the current law regarding Asbestos removal.

If the existing conduit attached to the structure is not specifically denoted in the Contract Documents as Item *202* Asbestos Pipe Removed, perform the work according to *109.05*.

Asbestos is not a hazardous waste or a solid waste; it is a special waste. This pipe is regulated and must be removed and disposed of properly. .

When evaluating the potential for asbestos in the pipe, the project should look at the "Markings" on the pipe. Concrete underdrain, waterline, and sanitary sewer pipe with the following “Markings” are known to contain asbestos:

- ASTM C-663
- AASHTO M-217
- AWWA-C-400-64-T
- ASTM-C-296-65-T

Individual utility companies and Local Planning Associations (LPA's) may have used asbestos pipe under their own specifications.

Asbestos Cement Perforated Underdrain Pipe was allowed in 706.15 in the 1970's. In addition, Asbestos Bonded Bituminous Corrugated Steel Pipe and Pipe Arches were allowed in the 1980's in 707.09.

Testing for Asbestos

Test the pipe for asbestos if there is any doubt about the pipe's composition or identity.

Asbestos inspectors in Ohio are required to have a certificate of training from an EPA accredited company for Asbestos Building Inspector and Asbestos Management Planner. The certificates are sent to the Ohio Department of Health (ODH) to obtain the required Asbestos Hazard Evaluation license. Both the EPA accredited certificate and the ODH license are required to perform inspections.

Asbestos Contractor Qualifications

There are a multitude of rules, laws, and regulations that govern asbestos operations. One of the best web sites is:

http://www.ehso.com/Asbestos/asbestreg.php

In addition, more information can be found under the Ohio Revised Code 3745-20 or the Ohio Administrative code OAC-3701-34 at the following web site:

http://onlinedocs.andersonpublishing.com/oac/

http://onlinedocs.andersonpublishing.com/revisedcode/

Asbestos removal Contractors must obtain the Asbestos Hazard Abatement Specialist license or Asbestos Worker License from Ohio Department of Health (ODH). Each asbestos removal company also needs to have an Abatement Contractor license through ODH as well.

The training requirements are under CFR 1926.1101(9) (i-viii) requirements for the truck drivers to haul the asbestos. The only training required for the truckers to haul the asbestos is two hour OSHA Awareness training.

Asbestos Pipe Removal

It is highly recommended that the Project hire a third party 'Certified Asbestos Inspector' to provide oversight during the removal.

Concrete pipe is non-friable asbestos. The pipe becomes friable if it is chipped, crumbles, or crushed during the removal. Therefore, the same requirements are required for friable and non-friable asbestos pipe. Cutting and crushing the asbestos pipe is strictly forbidden. Follow the instructions of the asbestos inspector or contractor.

The project may need to notify the local air quality authority and follow strict OSHA demolition and removal requirements.

The material must be taken to a solid waste facility that is licensed by the Local Health Department. See the boiler plate note listed under 202.04 at the following link:

http://www.dot.state.oh.us/construction/OCA/Specs/SSandPN2002/default.htm

Manifesting for disposal is required. The Regulated Waste Project Engineer or the District Environmental Coordinator is required to sign the Manifest for the Department. See Appendix 202 Regulated Waste Requirements, “Manifesting” for more information.

Pavement, Walks, Curbs, Steps, Gutters, or Traffic Dividers Removed (202.05)

The plans will designate the items for removal using a balloon with (R for Removal) attached to a line pointing out the removal item. As designated, remove and dispose of the existing Item. If removing only a portion of an existing item saw cut a neat joint at the removal limit.

Pavement Removal limit will be detailed in the plans. If Item *202* Wearing Course Removed is specified in the Contract, remove all asphalt from the surface to the top of the concrete or brick. If *202* Base Removed is specified in the Contract, remove the specific layer as shown on the plans. If Item 202 Pavement removed in the plan, remove all asphalt, concrete, or brick from the surface to the bottom.

Buildings Demolished (202.06)

Whether the building is located partially or totally on temporary or permanent Right-of-Way perform the demolition the same.

The contractor should disconnect all utilities according to local requirements, and notify the owners of water, electric, or gas meters when the meters are ready for removal.

The contractor should not disturb buildings until the Engineer provides a Notice of Possession and Approval to Proceed. The demolition should be performed under the Engineer’s direction in order to accommodate utility rearrangements and clearance of structures.

The Contractor may use buildings for storage, or other purposes. The Engineer should secure a documented agreement, to allow such use during the period of the Contract, and save the Department harmless from any claims whatsoever by reason of such use.

Raze the building (including all items) to a minimum of 1 foot (0.3 m) below the grade of the surrounding area.

Break up and remove all floor slabs under which a pit, well, cistern, or tank exists. Completely remove all tanks and clear basements of all materials, so only masonry walls and concrete basement floors remain. Break up basement floors to be left in place, and seal remaining drains with masonry or with precast clay or concrete stoppers.

If the building contains any hazardous materials that require remedy before the start of the demolition, perform the necessary work under other items in the Contract or according to *109.05*.

The Engineer should approve the demolition work and the contractor should immediately backfill the cavity created.

(Asbestos in Buildings)

All structures torn down by the Department are required to have an Asbestos Inspection. Ensure that the Office of Real Estate performed these asbestos inspections. An Ohio EPA form 'Notification of Demolition and Renovation' must be filled out by the Department or the contractor Ten days prior to the Demolition.

This form details the type and quantity of asbestos removed and small amount of asbestos left in the building. Generally, the Asbestos Abatement Contractor performs all of the asbestos removal. In rare cases, the asbestos abatement is performed under the highway contract.

The instructions and more details can be found at the following link: *http://www.epa.state.oh.us/dapc/atu/atu.html#Asbestos*

Normally, friable asbestos cannot be left in the building during demolition. In rare cases, the asbestos abatement Contractor may leave a small amount of asbestos in the structure. Of course, large amounts of asbestos cannot be crushed or rendered friable. If the amount of asbestos is small and the 'Notification of Demolition and Renovation' allows the building to be demolished, then this material can be hauled away to a Construction and Demolition Land Fill if allowed by the local Board of Health.

If asbestos is left in the building, the building cannot be burned. Even if the Notification of Demolition and Renovation allows the building to be burnt.

The Notice will specifically mark on the form that the building can be burnt. In addition, an Open Burning Permit would be required if the structure is burned.

Burning or disposing of the building is allowed in 105.16 and 105.17. The Contract will specifically state whether burning is restricted due to the asbestos left in the building. This restriction will be based on the 'asbestos' remaining in the building, and not on the Ohio Administrative Code (OAC) 3745 in 105.17.

Contact the Office of Real Estate, Regulated Waste Project Engineer or District Environmental Coordinator for a clear recommendation on the disposal.

Septic Tanks and Privy Vaults Removed (202.07)

Prior the start of the demolition work, empty all septic tanks and privy vaults. Dispose of the removed contents in a manner that conforms to the requirements of the State and Local Boards of Health or other authorities having jurisdiction..

Completely remove and dispose of septic tanks and privy vaults located above the subgrade or finished ground surface. For septic tanks and privy vaults located below the subgrade or finished ground surface, remove tops and walls to a minimum depth of 3 feet (1 m) below subgrade or 1 foot (0.3 m) below finished ground surface. Break up floors and seal remaining drains with masonry or with precast clay or concrete stoppers.

Underground Storage Tanks (202.08)

The Department evaluates all project sites during the planning process to determine if Underground Storage Tanks (USTs) are present on the project. Typically the plans identify the tank location and requirements for removing or avoiding the UST in the work. USTs that were not identified in the planning process will be handled in the same manner as described below.

If an unidentified UST is encountered, take precautions to prevent a release of the tank contents to the environment. The Project Engineer should notify the Regulated Waste Project Engineer, District Environmental Coordinator or District Construction Engineer. In the event of a tank release or safety related issue, contact the local fire authority immediately.

Prior initiation of the underground storage tank removal, empty the tanks and dispose of the contents in conformance with all applicable regulations (OEPA and/or BUSTR).

Obtain the required permit prior the start of the UST removal. Provide a State Certified BUSTR inspector employed by BUSTR, Delegated Authority (local fire department), or independent Certified Underground Storage Tank Inspector (CUSTI) contractor, to perform the BUSTR required inspections. Remove and dispose of the tank and its contents according to the Bureau of Underground Storage Tank Regulations of the Division of Fire Marshal (BUSTR), Ohio EPA, and all applicable Federal, State, and local regulations. Provide a Certified Tank Installer to supervise the removal. For tanks containing hazardous substances other than petroleum, use and comply with the Ohio *EPA* regulations in addition to State Fire Marshal regulations.

Testing is required for any excavated material and related water prior to disposal. Perform the work under other items in the Contract or according to *109.05*. In addition to the required disposal sampling, conduct the closure testing in accordance with all applicable BUSTR regulations and prepare the BUSTR Closure Report.

BUSTR Requirements

The state fire marshal and OEPA generally follow BUSTR regulations. The State Fire Marshal's Office, Bureau of Underground Storage Tank Regulations (BUSTR), controls the vast majority of the installations, uses, and removals of underground storage tanks in Ohio.

See the BUSTR Web site for more information. Valuable information can be found by looking up 'download' documents. Additional information can be found by looking at the fact sheets at the following web location:

https://www.com.state.oh.us/odoc/sfm/bustr/Downloads.htm

Project personnel must review the fact sheets and this section of the manual to become familiar with the UST removals.

The types of tanks regulated by BUSTR are detailed on the Fact sheet entitled "What Type of Tanks does BUSTR Regulate".

Specification and BUSTR Requirements

1. A 'Certified Installer' is required for any removal of an UST regulated by BUSTR. The Certified Installers are required to have photo identification. The project engineer should check for this identification. There is a list of the Certified Tank Installers on the BUSTR web site.
2. A 'Certified Inspector' is required to inspect the work. This inspector may be a State Certified BUSTR inspector employed by BUSTR, Delegated Authority (local fire department), or independent Certified Underground Storage Tank Inspector (CUSTI) contractor. The Contractor must supply this person as part of the bid work. There is a list of these inspectors on the BUSTR web site.
3. A tank removal permit must be applied for 30 days prior to the work. The Project Engineer should obtain a copy for the project records. The delegated authority (local fire department) or BUSTR may issue the permit. See the Fact Sheet entitled "The BUSTR Permit Process." A copy of a permit application is on the BUSTR web site.
4. Even though the permit may be issued by the local fire department, BUSTR must receive a copy of the permit application 30 days prior to the removal.
5. Tank registration may be required if the tank is not registered. See the Fact Sheet entitled "Underground Storage Tank Registration". In many cases the Department is the owner, the District Environmental Coordinator will handle tank registrations. The registration form is on the BUSTR web site.
    a. For unidentified tanks, the owners are typically unknown. Make certain that the registration and tank removal permit forms accurately identify the owner as "UKNOWN". **Never identify ODOT as the owner**.
    b. If a tank was last used prior to 11/8/84, then ownership is the last person who used the tank which may not be known. In this case, make certain that the registration and tank removal permit forms accurately identify the owner as "UKNOWN". **Never identify ODOT as the owner.**
6. The actual removal is summarized in the BUSTR Fact Sheet entitled "Closure Guidelines". The Certified Inspector must sign the permit and the project should keep a copy for a permanent record.

7. The BUSTR Closure Report is required after the UST removal has been completed. The Contractor is required to submit the completed report to the Project Engineer within 30 days of the tank removal. The Regulated Waste Project Engineer should sign and submit the Closure Report to BUSTR within 45 days of the tank removal. The Regulated Waste Project Engineer may elect to have this closure report reviewed by an environmental consultant.
8. The District is required to retain the Closure Report record in perpetuity. The report should be given to the Regulated Waste Project Engineer and/or District Environmental Coordinator. The Regulated Waste Project Engineer must ensure that these records are given to the District Environmental Coordinator for final record keeping.
9. Depending on the result of the closure assessment, further investigation, risk assessment, and remedial action may be necessary. The District will determine if an Environmental Consultant will be needed to perform the assessment work. A task order contract may be used to perform this work.
10. The specification requirements in 202.08 do not cover risk assessment, remedial action, environmental cleanup, or the cleanup of the contamination plume beyond a "few feet" outside the UST footprint. If the assessment work is not described in the Plan Note this work should be considered extra work.

Other Governing Agencies

The following personnel must be contacted when the UST is removed and 25 gallons or more of petroleum is released, or if the product reaches a body of water or travels off the project site. Project Personnel should use the following web site during a release:

http://www.epa.state.oh.us/derr/ersis/er/er.html

1. Immediate Notification:
    a. Regulated Waste Project Engineer
    b. District Environmental Coordinator
    c. Local Fire Department
    d. The OEPA Emergency Response Unit at 800-282-9378
2. BUSTR Corrective Action Hotline at 800-686-2878 within 24 hours
3. Contact all of the following if a Hazardous chemical in excess of its reportable quantity is released:
    a. Regulated Waste Project Engineer
    b. District Environmental Coordinator
    c. Local Fire Department
    d. The Ohio EPA at 800-282-9378

Reportable chemical quantities may be between 1 and 500 pounds depending on the chemical. The web site refers to Code of Regulation (CFR) that gives the reportable quantities limits. In addition, it gives explicit instructions about what action should be taken by the project personnel.

The Contractor and the Regulated Waste Project Engineer should know the reportable quantities prior to the UST removal.

The District will determine if an environmental consultant will be retained to assist the District in regulatory compliance.

Guardrail and Fence Removed (202.09)

When guardrail or fence is designated for reuse or storage by the Department, Carefully dismantle and store existing guardrail including anchor assemblies, terminal assemblies, attached posts, signs, delineators and fence. Otherwise, dispose all removed material according to *202.02*. Wood posts are not considered salvageable.

If guardrail is next to a lane maintaining traffic, do not remove the guardrail until the replacement material is on the site and ready for installation. Do not leave hazards unprotected adjacent to a lane maintaining traffic, except for the actual time required to remove the existing guardrail and install the proposed guardrail in a continuous operation. The Engineer should suspend work for failure to comply with this requirement.

When fence is designated for replacement, do not remove the existing fence until the replacement material is on site. Begin the new installation within 7 workdays of beginning the removal process.

Raised Pavement Markers Removed (202.10)

Remove raised pavement markers in concurrence with the maintenance of traffic phases so that their existence or removal will not conflict with the temporary pavement markings or the snow and ice removal.

Remove all standing water and fill with asphalt concrete, by the end of the next workday, depressions caused by removing the castings. Compact the asphalt concrete flush with the pavement.

Manhole, Catch Basin, and Inlet Removed (202.11)

Remove existing drainage structures of the types designated for removal and take ownership of castings unless otherwise noted on the plans.

Manhole, Catch Basin, and Inlet Abandoned (202.12)

Remove existing drainage structures of the types designated to be abandoned to a minimum of 1 foot (0.3 m) below the finished subgrade or ground surface.

Do not damage pipes that are to remain.

Connect existing pipes with new pipe through the structures. Seal the existing inlet and outlet pipes with precast vitrified or concrete stoppers or with masonry of a type and thickness to fill the inlet or outlet pipe. Carefully hand tamp backfill under and around the pipe according to *202.02*.Method of Measurement/Basis of Payment (202.13) & (202.14)

The following are in addition to the requirements of 202.13 and 202.14:

- Items encountered that are obstructing the constructing of the roadway as intended, are necessary to be removed, in order to remove the items specifically denoted in the Contract, or are at the same location where proposed items of work such as drainage structures are to be constructed, should be removed and paid for under other items in the Contract or according to *109.05*.
- Reconstruct and pay for items of work not detailed in the plans, such as pavement and curbs necessary to be removed in order to remove Contract removal items, in accordance with the specifications of other similar items in the Contract or according to 109.05.
- Repair or replace the damaged portions of the roadway due to the contractor negligence at no expense to the Department.

Appendix 202 Regulated Waste Requirements

Importance

The Department has experienced contract administration problems during the disposal of regulated wastes, underground storage tanks and asbestos pipe and administrating borrow and waste areas. The main causes of these problems are: the lack of understanding of the regulations, new regulations that govern construction debris, and the infrequency that some of these items are included in the contract. The improper disposal or management of regulated materials can create substantial construction delay problems and a potential future liability to the Department.

The Department has approximately 300 projects in design, construction or completed requiring the disposal of regulated wastes; such as hazardous wastes, solid waste, special waste or petroleum-contaminated soil.

Regulated waste for the purposes of this manual will be defined as a hazardous waste, solid waste, construction and demolition debris, petroleum contaminated soil or any other regulated material denoted for removal under the contract. For further explanation about hazardous waste classifications, types and characteristics see the Hazardous Waste Management Program Manual or other Hazardous Waste Training Manuals.

This section is to be used in conjunction with the Hazardous Waste Management Program Manual (HWMPM) and the handouts and manuals received in the 24 or 40 hour Hazardous Waste Operations and Emergency Response (HAZWOPER) training or the 8 hour HAZWOPER refresher courses.

Additional references also can be found by reviewing the 8 Hour Construction Safety or Construction HAZWOPER manual.

This section does not expand on the technical environmental details explained in these other manuals. This manual should be used as a reference to other manuals when technical details are needed beyond the scope of this manual.

This section replaces the "The Handbook for the Removal of Regulated Waste" dated 04/00.

Responsibility

Project Engineer and Regulated Waste Project Engineer (RWPE)

The person in charge of the work on the construction projects is called the Project Engineer. A Supervisor or an Inspector may run the project on a daily basis depending on the District level of staffing for the project. The project engineer will randomly check in on the project and make any engineering decisions.

The Regulated Waste Project Engineer (RWPE) is in charge of all removal operations of regulated waste on the projects. The RWPE signs all manifests from the projects and ensures that all environmental documents from the project are transferred to the DEC for permanent storage. Each District will have at least two Engineers working at this function.

In some Districts, the District Environmental Coordinator (DEC) or District Hazardous Waste Coordinator (DHWC) may substitute for the RWPE if the RWPE is not available.

Administering the Contract

The RWPE has the responsibility to effectively administer all aspects of regulated waste on the construction project. They must familiarize themselves with the specifications, the contract, and Appendix 202 to perform their duties. The RWPE makes interpretations of the regulated waste contract documents and this manual to the project engineer, supervisors, or project inspectors. In addition, the RWPE insures that trained inspectors are inspecting the work.

The RWPE's main contacts for environmental advice are the District Environmental Coordinators (DEC's). The DEC's coordinate environmental decision making with the District Hazardous Waste Coordinator, District Safety Representatives, Emergency Coordinators, and the Environmental Site Assessment Section in the Central Office of Environmental Services.

The following is a link to their names and numbers:

http://www.dot.state.oh.us/oes/

The list is at the bottom of the web page.

Reporting of Significant Changes

The Project Engineer is responsible for reporting any significant deviations in the contract documents to the District Construction Engineer and/or the County Manager. The Project Engineer has the authority to order the Contractor's personnel and the environmental consultant to perform "as directed work" in all situations within the contract limits. This authority is tempered with a great deal of responsibility for their actions. If the Project Engineer orders work contrary to the recommendations of the RWPE, environmental specialist, or the environmental contractor, then the Project Engineer may become personally liable for their actions. The Project Engineer must be sure that their instructions are not contrary to any laws or regulations that govern the work before making any final decision.

Health and Safety Responsibilities

The RWPE, who has 24 hours Of HAZWOPER training, is responsible for the health and safety of the Department inspection forces.

Additional health and safety responsibilities are listed below:

1. Ensures that inspections are being performed on the project with adequate personnel, equipment, and resources to complete the inspections safely.
2. Ensures that telephone communications between the Department inspectors and emergency response personnel is maintained.
3. Ensures that all inspectors are adequately trained and qualified to work at the site.
4. Reviews the SSHSP, and ensures that the SSHSP is adapted by the Department to include ODOT inspection forces. For this review, the environmental consultant can be hired by third party billing through the Contractor or by the District Task Order Contract.
5. Reviews the Contractor's Site Specific Health and Safety Plan (SSHSP). Do not accept the SSHSP for liability reasons.
6. Provides oversight of the Contractor's operations as it pertains to the Contractor's SSHSP.
7. Reviews the SSHSP with the inspectors.
8. Serves as the primary contact to review ODOT health and safety matters that may arise on the project.
9. Informs the inspectors of revised or new safety protocols for the field operations.
10. Informs the inspectors of revisions to the SSHSP.
11. Reviews accident reports and the results of the inspections.

Project Inspector

The Project Inspector is responsible for the detailed inspection of the work and to follow the directions given by the RWPE, Project Engineer, and the SSHSP.

Contractor's Responsibilities

The Contractor is responsible for prosecuting the work according to the plans and specifications. The 2008 CMS section 107.01, explicitly states that the Contractor shall comply with the construction safety rules and regulations. Employers are always responsible for the safety of their employees.

District Environmental Coordinator (DEC)

The DEC is responsible for giving technical advice to the RWPE, reviewing or hiring an environmental consultant to review the Health and Safety Plan for ODOT workers, and coordinating matters of safety and hazardous waste with the District Hazardous Waste Coordinator and District Safety Representative.

Construction Geotechnical Engineer (CGE) and Advisory Construction Engineers (ACE)

The CGE and ACEs in the Office of Construction Administration are responsible for giving technical contract administration advice to district construction personnel, updating this manual, and performing Quality Assurance Reviews and Training.

Training

General

Where the disposal of regulated wastes is necessary during construction, the District Construction staff must have knowledge beyond the plan note requirements in order to make appropriate and legally correct decisions when facing actual field mandated changes to the contract.

An understanding of the requirements of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), the Resource Conservation and Recovery Act (RCRA), and Occupational Safety and Health Administration (OSHA) requirements is essential during the construction phase.

Training is available through the Office of Environmental Services in Central Office, Environmental Site Assessment Section (614-466-7942); Bureau of Workman Compensation, Division of Safety and Hygiene (800-644-6292); or through a variety of private training sources. The private training may be charged against the project on third party billing through the Contractor.

The following is a link to the Bureau of Workman Compensation, Division of Safety and Hygiene for some 'free' training courses:

http://www.ohiobwc.com/employer/programs/safety/SandHCourses.asp

Nothing in this manual requires ODOT project personnel to enter a hazardous waste site without the consent of the employee. All regulated waste removal work is performed by the Contractor, and no ODOT personnel should actively participate in this work.

The majority of the regulated waste removal operations on highway construction projects consist of the removal of solid waste or petroleum-contaminated soil. The minimum training requirements listed below should be observed for all regulated waste or underground storage tank removal projects.

Project Engineers

All Project Engineers are required to have the 8-hour 'Construction Safety Awareness Class and 8 hour Construction HAZWOPER Awareness Class'. This training will be given every three years. This training will be enough to recognize hazards or conditions that require further investigation by other more specialized personnel.

Regulated Waste Project Engineer (RWPE)

The District will designate at least two Project Engineers with 24-hour Construction HAZWOPER training. These RWPE's will deal with all regulated waste issues that arise on the projects. An 8-hour annual refresher course is required.

Project Inspector

All Project Inspectors are required to have the 8-hour Construction Safety and 8-hour HAZWOPER Awareness Training. Students completing this training will be able to recognize hazards or conditions that require specialized training.

Some consideration should be given to having a project inspector for inspecting underground storage tanks removals. Certified Underground Storage Tank Inspector training can be obtained from BUSTR. See 202 'Removal of Structures and Obstructions' in this manual.

Specialized Inspection

Additional environmental consultant inspectors may be hired through the Districts or Central Office Environmental Site Assessment Task Order Contract to provide specialized inspection. The RWPE should contact the District Environmental Coordinator to obtain these services. The procedure is further explained in the section, 'Obtaining Technical Advice or Inspection' of this manual.

Medical Monitoring

Medical monitoring is required for employees working on hazardous waste projects who are:

1. Exposed to contaminants above the permissible exposure limits (PEL) for more than 30 days per year.
2. Wear a respirator for 30 days or more per year.
3. Injured or become ill due to exposure to hazardous substances.

OSHA 29 CFR 1910.120 covers this requirement. The SSHSP, the District Safety Coordinator and the District Environmental Coordinator should be consulted to determine the need for medical monitoring of an employee. Medical monitoring is rarely needed due to the type of contaminates, solid wastes, or petroleum contaminated soil normally encountered on highway construction projects.

Changes to the Training Requirements

The SSHSP may alter the above requirements because of the particular contaminants on the project. Review Site Specific Health and Safety Plan Requirements and the project SSHSP.

Training and Medical Records

All training and medical records shall be kept according to sections 1105 and 1106 in the Hazardous Waste Program Manual (HWMPM).

Construction Safety Training

Confined Space, Trenching, Excavation Safety, and other construction related issues are covered by the 8-hour Construction Safety Awareness class. The 8-hour Construction Safety Awareness Training will be offered to all construction personnel every 3 years.

Additional training can be taken 'free' through the Bureau of Workman Compensation at 800-644-6292. Any personnel wanting extended training should take the following courses:

- Trenching and Excavation, Course SAF112
- Confined Space Assessment and Work, Course IHY214

These courses are offered all around the state at various times. Construction personnel can sign up for the courses at the following web site:

http://www.ohiobwc.com/employer/programs/safety/SandHCourses.asp

Site Specific Health and Safety Plan Requirements

The Contractor is required by OSHA and the contract documents to have a Site Specific Health and Safety Plan (SSHSP) when working within the exclusion or contamination zones of a construction project. Depending on the material contents of an underground storage tank, these exclusion zones may include the areas around the removal of underground storage tanks.

The Contractor is responsible for the health and safety of their personnel. The Contractor is required to have the SSHSP available at the project site for inspection. In no case will the Department accept or approve a Contractor's SSHSP.

Under CMS 105.10, the Contractor must provide access to Department personnel to perform work inspections. The Contractor cannot restrict the inspection of the work when the inspection forces meet the minimum training requirements of the SSHSP.

The RWPE is responsible the health and safety of the inspection personnel. See "Health and Safety Responsibilities" in the Responsibility section of this manual. The RWPE may forward the Contractor's SSHSP to the District Environmental Coordinator (DEC) for review. The DEC will note how the SSHSP affects the qualifications of the inspection forces. The RWPE, in consultation with the DEC, will determine whether department forces or consultant forces should inspect the work. If consultant inspectors are used, the consultant will be responsible for the health and safety of its employees.

Minimum Contents of the SSHSP

The SSHSP will contain the following information:

1. Safety and Health Risk or Hazard Analysis
2. Employee Training Assignments
3. Personal Protective Equipments Requirements
4. Medical Surveillance Requirements
5. Frequency and Types of Air Monitoring
6. Site Control Measures
7. Decontamination Procedures
8. An Emergency Response Plan
9. Confine Space Entry Procedures (if necessary)
10. Spill Containment Program

Further information about the SSHSP is detailed in the 24-hour training for the Regulated Waste Project Engineer.

Obeying the SSHSP Requirements

All construction personnel, including ODOT project personnel, will work under and obey the requirements of the SSHSP during the inspections. The project personnel should thoroughly review the SSHSP to become familiar with all the aspects of this document.

All ODOT personnel entering the contamination zone must wear the personal protective equipment (PPE) listed in the SSHSP. The training and equipment may be obtained by contacting the District Environmental Coordinator or Safety Coordinator. If the required equipment and training are not available to ODOT personnel, then this training may be paid for under third party billing through the Contractor.

Absence of a SSHSP

In the absence of a project SSHSP, the RWPE should contact the District Environmental Coordinator to determine the need for a SSHSP. There will be instances where an SSHSP is not required. Some solid waste or petroleum contaminated soil operations will generally not require a SSHSP.

Regulated Waste Designated for Removal in the Contract

General

Most hazardous waste sites are identified through environmental site assessment during the preliminary development process. These sites are avoided where possible. When these sites cannot be avoided, plans or notes will be placed in the contract to instruct the project personnel how to safely remove, cap, or remediate the contaminated material. Some typical plan notes are shown in the section “Typical Regulated Waste Plan Notes” of this manual.

Projects involving the removal of regulated material may quickly become complicated from an administrative perspective. The District Planning and Production staffs should coordinate the plan notes and specialized requirements for each project with the District Construction staff to ensure that the construction inspection staff, including the Project Engineer, understands why the special notes are in the plans and what special administrative requirements are necessary. Time should be allotted to develop contracts for outside environmental inspectors if necessary and to determine if specific training is needed for ODOT inspectors.

Construction projects with complicated remediation work requiring a major amount of specific equipment, project staff, or time may be separated from the highway construction project to avoid overly complicating the project. Proper management and disposal or remediation of regulated waste and UST’s are essential to prevent future liability for the Department.

The Contractor is responsible for the proper removal of regulated waste. The project personnel are responsible to control the Contractor’s work according to the contract documents and all applicable laws and regulations.

Reference Material for Regulation Requirements

The Hazardous Waste Program Manual is an excellent reference to help the project personnel to familiarize themselves with the regulation requirements and the waste types, characteristics, and generation requirements. Also, consult the 24-hour Construction HAZWOPER training manual when dealing with these regulated wastes.

Plan Notes

The plan notes and/or environmental site assessment reports are available to the project construction personnel to help familiarize them with the type of contamination that will be encountered on the project. These reports should be available through the DEC, production, or the Office of Environmental Services in central office.

The specialized plan notes may require department or consultant environmental inspectors to field screen samples, and analyze soils excavated from areas of environmental concern. Contractors may be required to stockpile, containerize, or dispose of contaminated soils. The plan notes should allow the project to efficiently manage the disposal of the regulated wastes and/or UST's encountered on the project.

The plan notes will outline who is responsible for what operation on the project. The RWPE should review the plan notes before the Contractor starts work. The following is a general outline of responsibilities.

Pre-Excavation Checks

The regulated wastes are usually located on the plans. Work can begin in these areas once the Project Engineer is satisfied that all of the following are complete:

1. The SSHSP is present on the project.
2. The Department has appropriate environmental inspectors.
3. The Contractor has the appropriate work force to proceed with the work.
4. The Contractor has set up the appropriate zoning as noted in the SSHSP.

The zoning includes but is not be limited to all of the following: Contamination Zone, Decontamination Zone, and the Safe Zone. These areas must be secured at all times, and are usually separated by a construction fence.

Excavation

Contamination areas are sometimes marked in zones designated as hazardous, solid, or other waste classifications. This gives the Project Engineer an insight into the general classification of the material in the contamination zones. This classification is generally not used for final disposal. The environmental inspector may field screen the regulated material prior to the stockpiling, but all materials are stockpiled and tested prior to the final disposal of the material.

In some cases, and with the permission of the regulatory agency and the District Environmental Coordinator (or as allowed by the plan notes), the material may be excavated and directly placed in trucks for disposal at the landfill. This may require additional testing of the excavation area. Substantial savings can be obtained when changing to this method on the project.

The plans generally call for the removal of enough material to build the highway. Unless otherwise called for in the plans, the Department does not clean up all the regulated material in the right of way. Contact the District Environmental Coordinator for cleanup instructions, unless a regulatory authority is overseeing this portion of the project.

Temporary Storage

The contract documents give general details about the temporary storage methods. The RWPE should review the Contractor's proposed storage method and determine if the proposed method meets the intent of the plans. The project should review the storage locations daily to ensure the work is progressing satisfactorily while the work is in progress. A sample inspection form is in the Hazardous Waste Management Program Manual (HWMPM) in appendix k. All storage areas must be inspected weekly as per section 507 in the HWMPM when the work is not in progress.

Material Sampling

The contract or plan may require that the state's environmental consultant or Contractor's environmental specialist test the regulated waste after it is stockpiled. The testing amount and location will be detailed in the plan or determined by the environmental consultant.

ODOT employees should not be testing or sampling suspect hazardous waste material; this should be done by an environmental consultant. The Contractor is responsible for any other testing required by the landfill for disposal purposes. The Contractor is required to give all the testing results to the project.

The testing results shall be kept according to section 1104 in the HWMPM.

Evaluation

Once the material is tested and the results are known, the material may be classified into a regulatory category such as hazardous waste, solid wastes, petroleum contaminated waste, special, or non-regulated wastes. The material may be shipped to the appropriate landfill or onto other areas of the project if allowed. Petroleum contaminated soil is allowed under 203.02.K to be used as fill.

Manifesting

The manifest documents must be filled out and completed prior to the disposal of any hazardous waste material. Manifest documents are prepared by the Contractor and signed by the RWPE on behalf of the Department.

The RWPE receives one copy of the manifest; the remaining copies go out with the trucker.

The Destinies of the various copies of the Manifest are as follows:

1. Landfill: Original signed copy
2. Project: 1st copy signed by Landfill
3. Contractor: 2nd copy signed by Landfill
4. Trucking Company: 3rd copy signed by Landfill
5. Project: 4th copy kept by the Regulated Waste Project Engineer (RWPE) after they sign the manifest; it does not go with the load. The RWPE matches it with the Landfill signed 1st copy that is returned to the Project. The RWPE verifies that the two copies match.

The manifest form has these terms for the various parties:

Party	Form Term
Landfill	DESTINATION
ODOT Project	GENERATOR
Contractor	OPERATOR
Trucking Company	TRANSPORTER

There are four (4) carbon copies, so the RWPE needs to sign the forms with a lot of pressure.

One copy of the manifest comes back to the project when the regulated material is disposed at the regulating facility. The RWPE must ensure that all copies and material quantities are accounted for in a timely manner. See section 603 in the Hazardous Waste Management Program Manual for information about the action to be taken when a manifest does not come back to the project.

Examples of Manifests and a full description are shown in the Hazardous Waste Management Program Manual (HWMPM) in section 602. Most of the regulated material removed from construction projects will be either petroleum contaminated soils or a solid waste. Manifesting is required but there will not be an RCRA generator number on a solid waste manifest. An example of one is on Figure 202.APP.1.

BFI NON-HAZARDOUS SPECIAL WASTE & ASBESTOS MANIFEST

If waste is asbestos waste, complete Sections I, II, III and IV
If waste is NOT asbestos waste, complete only Sections I, II and III

No. 395666

Section I — GENERATOR (Generator completes all of Section I)

a. Generator Name: Ohio Dept. of Trans. — b. Generating Location: Same
c. Address: Greenbelt Parkway, Toledo,OH 43608 — d. Address:
e. Phone No.: (419)243-5267 — f. Phone No.:
If owner of the generating facility differs from the generator, provide:
g. Owner's Name: — h. Owner's Phone No.:
i. BFI WASTE CODE: 0 H 6 4 8 | 9 9 0 3 1 5 | 2 4 2 0 7 8 — Containers
j. Description of Waste: Contaminated Soil & Const. Debris — k. Quantity, Unit: T, No: 01, TYPE: T

TYPE: DM - METAL DRUM; DP - PLASTIC DRUM; B - BAG; BA - 6 MIL. PLASTIC BAG or WRAP; T - TRUCK; O - OTHER

UNITS: P - POUNDS; Y - YARDS; M[3] - CUBIC METERS; Y[3] - CUBIC YARDS; O - OTHER

GENERATOR'S CERTIFICATION: I hereby certify that the above named material is not a hazardous waste as defined by 40 CFR Part 261 or any applicable state law, has been properly described, classified and packaged, and is in proper condition for transportation according to applicable regulations; **AND, if the waste is a treatment residue of a previously restricted hazardous waste** subject to the Land Disposal Restrictions, I certify and warrant that the waste has been treated in accordance with the requirements of 40 CFR Part 268 and is no longer a hazardous waste as defined by 40 CFR Part 261.

ODOT — Generator Authorized Agent Name; Signature; Shipment Date

Section II — TRANSPORTER (Generator complete a-d; Transporter I complete e-g; Transporter II complete h-n)

TRANSPORTER I
a. Name: Sylvester Material
b. Address: 7901 Sylvania Ave, Sylvania, OH 43560
c. Driver Name/Title: (Print/Type)
d. Phone No.: 885-4658 — e. Truck No.:
f. Vehicle License No./State:
Acknowledgement of Receipt of Materials
g. Driver Signature — Shipment Date

TRANSPORTER II
h. Name:
i. Address:
j. Driver Name/Title: (Print/Type)
k. Phone No.: — l. Truck No.:
m. Vehicle License No./State:
Acknowledgement of Receipt of Materials
n. Driver Signature — Shipment Date

Section III — DESTINATION (Generator completes a-d, destination site completes e-f)

a. Site Name: Vienna Junction Landfill — c. Phone No.: (313)848-3528
b. Physical Address: 6233 Hagman Road, Erie, MI 48133 — d. Mailing Address:
e. Discrepancy Indication Space:
I hereby certify that the above named material has been accepted and to the best of my knowledge the foregoing is true and accurate.
f. Jackie Cartner — Name of Authorized Agent; Signature; Receipt Date

Section IV — ASBESTOS (Generator complete a-d, f, g. Shipper* completes e.)

a. Shippers's* Name: — b. Shippers's* Phone No.:
c. Shippers's* Address:
d. Shippers's Special Handling Instructions and additional information:
CERTIFICATION: I hereby declare that the contents of this consignment are fully and accurately described above by proper shipping name and are classified, packaged, marked, and labeled/placarded, and are in all respects in proper condition for transport according to applicable international and national governmental regulations.
e. Shippers's* Name & Title: Print/Type — Shipper's Signature — Date
f. Name and Address of Responsible Agency:
g. ☐ Friable; ☐ Non-friable; ☐ Both ____ % friable ____ % nonfriable

* Shipper refers to the company which owns, leases, operates, controls, or supervises the facility being demolished or renovated, or the demolition or renovation operation, or both.

REORDER ONLY THROUGH BFI / STANDARD REGISTER CONTRACT — DESTINATION RETAIN

Figure 202.APP.1 – Non-Hazardous Manifest

For more information regarding manifesting see sections 603 and appendix I of the HWMPM.

Pre-Transportation Requirements and Placarding

The Hazardous Waste Management Program Manual (HWMPM) is an excellent resource to determine the pre-transportation and placarding requirements. Sections 504, 605 and appendix P of the HWMPM provide a pre-transportation requirements and checklists. The Contractor is required to provide all of the material and manpower to provide for the proper identification, transportation, and disposal of the regulated waste. The RWPE must ensure that the packaging, labeling, and placarding are done according to the regulations.

Records of the Disposal

All documentation of the regulated waste operations should be recorded on CMS 1 or 2 and in the daily diaries. All records should be kept with the project files. The Regulated Waste Project Engineer needs to ensure that the records are kept in the District for future reference. The records need kept by the District Environmental Coordinator in the District.

If the regulated waste is classified as a hazardous waste, then all of the records keeping requirements listed in section 1101 in the HWMPM apply.

Weekly Project Inspections

When the project is conducting hazardous waste removal operations, then the RWPE will perform the weekly inspection requirements in 1107 in the HWMPM.

Regulated Wastes Found During Construction

General

Special procedures must be followed when the Contractor encounters potential regulated materials that were not anticipated by the plans. Section 203.04 of the 2002 CMS (page 102) describes the process for notifying Contractors and Department personnel of these special procedures.

Limit Access to the Suspect Area

Suspected regulated material must be left in place until identified by a qualified specialist. This may require the temporary discontinuance of work in the area of the suspect materials. The area in question should be secured to prevent access. This can be accomplished by cordoning off the area with rope or construction fence and posting a guard. On large projects, work may continue at locations sufficiently removed from the site in question.

Notification

The Project Engineer must be notified immediately, and should contact the RWPE. The Department will evaluate the level of risk to workers and to the public, and notify all responsible parties and regulatory agencies as required. The District will determine a course of action based on consultation with the appropriate environmental regulatory agencies and ODOT staff with specialized expertise in the hazardous waste field in the Office of Construction or the Office of Environmental Services. If it is determined that the area in question is or may be contaminated with environmentally regulated substances, the District will initiate the evaluation and remediation of the problem area as described below.

In the event of a life-threatening situation to human health outside the project, contact the Local Fire Department and the Local Police. Report the incident to the District Construction Engineer and the Highway Manager to determine if local involvement is required. When local involvement is required, notify the County Emergency Manager Director listed in the current version of the Incident Management System Responders Listing.

Releases

If a Hazardous chemical in excess of its reportable quantity is released to a water body or leaves the project site, all of the following must be notified:

1. RWPE or DEC
2. Local Fire Department
3. The Ohio EPA at 800-282-9378

Reportable chemicals may be between 1 and 500 pounds depending on the chemical. The following web site refers to the Code of Regulation (CFR) that gives the reportable quantities limits. In addition, it gives explicit instructions about what action should be taken by the project personnel.

http://www.epa.state.oh.us/derr/ersis/er/er.html

At some point, the project should hire an environmental consultant to help with the required paperwork and technical advice.

Obtaining Technical Advice or Inspection

"It is imperative that "Action" be taken to mitigate the problem in a timely manner."

If required, the District may seek the services of a qualified consultant specializing in regulated waste assessment and remediation, or third party billing through the Contractor, through the district or central Office task order contract.

The District or Central Office Environmental Site Assessment Task Order Contract can be used to provide specific environmental expertise for the consultation, evaluation and testing in these situations. The District's Planning and/or Environmental staff can aid in developing a request for a proposal for these services when the Task Order Contract is used. This can be provided at no cost to the project.

The specific consultation, testing, or inspectors hired through the Task Order Contract or other contracts should specify the type of environmental expertise needed. For example, a project involving underground storage tanks or petroleum contaminated soils requires knowledge of BUSTR rules and regulations, operation of organic vapor analyzers, and the ability to interpret laboratory data. A good minimum qualification for these projects would be a Certified Installer or Inspector under BUSTR's rules. Projects involving hazardous solid wastes or other types of wastes require the appropriate type of expertise.

Development of the Remediation or Disposal Plan

The chosen environmental consultant must submit a sampling plan for the Department and OEPA (if applicable) for approval. Upon approval, the environmental consultant will perform the required sampling, testing, mitigation, and possible disposal.

If it is determined that no contamination exists, or that the problem has been resolved on the site, the Contractor will be directed to return to work.

If required, the environmental consultant or contractor will develop a removal or remediation plan jointly in consultation with ODOT, OEPA, or BUSTR as applicable.

Implementing the Plan

Once the contaminant is known and a plan to eliminate or mitigate the regulated material is determined, the Department may seek competitive bids from a qualified regulated waste disposal firm contractor to remove or mitigate the waste.

If the project cannot tolerate the time it would take to obtain competitive bids, the Department may request a waiver of competitive bidding from the Controlling Board and award it to an approved qualified environmental firm via third party billing through the Contractor.

Where treatment or disposal of the regulated material must be conducted concurrently with construction, it may be made a part of the construction contract.

Disposal and Remediation

A remediation contract will be initiated once all the approvals are obtained. The environmental consultant, contractor, or sub contractor will perform work according to this manual and the approved remediation plan.

The Department will keep complete records of all activities performed in the treatment, removal, transport, and disposal according to all applicable laws, rules, and regulations. These records are the same as detailed in the "Regulated Waste Designated for Removal in the Contract" section of this manual.

All of the disposal requirements of a regulated waste outlined in the Regulated Waste Designated for Removal in the Contract section still apply. A plan note similar to the ones in the Typical Regulated Waste Plan Notes section of this manual , an excavation plan, and a SSHSP should be developed before the work begins.

Other Wastes and Environmental Considerations

General

It is important to be aware of other common construction materials that can cause environmental problems during or after construction. The most common materials are construction and demolition debris, landscape waste (buried or burned on site), and asbestos pipe. These materials were detailed in sections 105.16, 105.17 201 and 202. Other materials such as slag, scrap tires, railroad ties, and recycled materials are detailed in this section.

Slag Use on the Projects

Air-Cooled Blast Furnace Slag

Air-cooled blast furnace slag (slag made from making iron) has been known to produce a green, yellow, white, or black runoff (which can also smell like rotten eggs). The color is usually pH driven, and usually goes away in about six months but not always. The runoff may exceed the allowable pH limits under the Clean Water Act.

To minimize these problems all air-cooled blast furnace slag used for Items 203, 304, 306, 307, 503, 603, and SS-855 must pass the Sulfur Leachate Test detailed in Supplemental Specification 907 under the 1997 CMS and Supplement 1027 under the 2002 CMS.

The problems first showed up in Cleveland around 1992. The Ohio EPA wanted the slag industry to regulate themselves and change the ACBF slag chemistry by adding chemicals.

This did not work well, and in 1998 the Ohio EPA requested that the Department specify the bucket test. The bucket test was pre-2002 SS-907, and was successfully used in Chicago. The bucket test can detect if the sulfur content in the slag is too high. The bucket test was implemented by SS-907 in 1998.

Last year, the Ohio EPA found several more projects with environmental problems. One of the projects was ODOT's. This Department project used RPCC (Recycled Portland Cement Pavement) and ACBF Slag. The RPCC was used in the undercut and the ACBF SLAG was used in the 304 material. The Department was cited for violating the Clean Water Act. This problem has cost approximately $120,000 to date, and has led the Department to hire an Environmental Consultant to remediate the problem.

The environmental problems on non-ODOT projects were clearly caused by the ACBF slag. On one of the projects, it cost millions of dollars to remove the ACBF slag because of the environmental problems. Another project is costing thousands of dollars a month to containerize and remove the runoff.

By reviewing the Ohio Administrative Code and environmental reports and performing lab tests, ODOT has developed the following solution in the 2002 version of SS-907 and S-1027:

1. We have lengthened the time of the bucket test.
2. We have incorporated some of the Ohio Administrative Code Water Quality requirements.
3. We are testing for pH, conductivity and total dissolved solids.

These tests will minimize ODOT’s environmental liability. It is important that the Project personnel recognize these requirements and only use materials that meet these specifications.

Steel Slag

Steel slag can expand and produce tufa, which can block underdrains. All steel slag for Items 203, 304, 306, 307, 410, 411, 617 503, or 603 are restricted under Supplemental Specification 905 or in 703.14 and 703.15 in the 2002 CMS.

There are three types of slag detailed in these specifications, Open Hearth, Basic Oxygen Electric Arc slag. All slags are by products of making steel or iron. Open Hearth Slag (OH Slag) was produced pre-1970. Basic Oxygen Furnace slag (BOF slag) and Electric Arc (EA) are produced from a newer and faster process for making steel. The problems are worse for basic oxygen slag than for open hearth because the OH process is slower; the slower process burns more chemicals out of the OH slag. Very little Electric Arc slag was used for ODOT work but it has more detrimental effects than any of the steel slags.

Background on Open Hearth and Basic Oxygen Slag Restrictions

In the mid-1970's, the Department had severe expansion problems associated with bedding, backfill, and base material placed using OH and BOF steel slag. This problem caused the Department to spend hundreds of thousands of dollars due to premature failures.

As result of several years of research, the Department required a 6-month aging of all OH and BOF slags to solve the problem. It also eliminated the use of OH or BOF slags in confined areas such as pipe bedding and backfill, underdrains, and around structures.

In the late 1970's and early 1980's, OH and BOF slags were found clogging up underdrains systems. The use of OH and BOF slags was eliminated in Items 310 and 304.

In early 1990’s, the Department allowed the use of some OH slags if the field performance proved that the OH slag did not block underdrains.

In the 1997 specification book, the Department allowed OH slag in Items 203, 307, 306, 304, 410, 411, 603 and 617. BOF slag was allowed for Items 203, 410,411 and 617. The following is some of the reasoning behind the 1997 and 2002 specification changes.

1. We consulted with Industry, Illinois, Indiana, Pennsylvania, and the Ohio Turnpike on this matter. ODOT reviewed past research and consulted with John Hurd, Stu Schwotzer and Phil Hall, who performed the majority of the research done in the past.
2. The words "from sources on file at the Laboratory" have been misinterpreted in Items 304, 410, 411, and 617. The intent of this note was to verify tufa performance before the sources are used. This has been clarified.
3. The expansion potential of OH and BOF slags are related to the concentrations of CaO and MgO. CaO leaches out during the aging process, while MgO may not. A test method is recommended to help determine the expansion risk. The recommended expansion test has a 20-year field performance related history.
4. The risk is too great to allow BOF slag in base material. Therefore clear identification of OH slag is critical to base performance. A procedure to verify the material source as OH slag is detailed.
5. Water and confining pressures cause additional expansion potential in OH and BOF slag. Therefore, all OH and BOF slag was eliminated in areas where the material is confined.

Summary

The problems found in the mid-1970's were primarily from projects built in the mid- 1960's. Tufa was not found blocking underdrains for about 10 years. Problems associated with ODOT projects built today may not arise for ten years or more.

The easy way out is to eliminate OH and BOF slag from use in all Department items of work. Certainly, the Department has documented enough bad performance related problems associated with OH and BOF slag to justify this elimination.

Most states do not allow steel slag for any base or confined areas period. Instead, we have implemented a method and procedure that allows the use of OH and BOF slag in certain applications to minimize the potential for premature failures.

The restrictions on the use of OH and BOF slag are intended to ensure we do not revisit those past expansion and tufa problems. Using materials that comply with the specifications minimizes environmental and engineering concerns.

Tufa Removal

Lime precipitant from slags used in the bases of older projects can create deposits that form on the side slopes. The deposited material will have a high pH, and may have to be taken to a solid waste landfill, if permitted. The material may be a hazardous waste if the pH is above 12.5.

When the project personnel notice these materials within the project limits, the deposits should be tested and removed as follows:

1. This material should be tested under the task order contract.
2. The contractor should perform the removal by force account.

Some projects may have special plan notes for the removal operations. The following plan note will be used to remove the tufa. If a large amount of tufa is on the project there may be other removal notes.

Environmental Work General Tufa Note (11/28/01)

A field review has determined that there are tufa deposits located between stations ______and stations _______ at the underdrain outlets. If these materials are encountered, manage this material according to the following.

Obtain all necessary testing for disposal, permits and approvals, and transportation of the material to a licensed (by the local health department) and permitted (by the state environmental protection agency) solid waste disposal facility.

Provide areas to stockpile the material. Stockpile the materials in a leakproof and covered container.

Ensure that all transport vehicles used for the movement of regulated material meets all applicable Local, State, and Federal requirements. Maintain records (such as manifests, landfill tickets, daily logs, etc.) to document the source, movement, and destination of each truckload of contaminated material. Submit one copy of each of these records to the Engineer.

Furnish all the labor, equipment, and materials necessary to excavate, store, test, transport, and dispose of the tufa material, including any required permits, approvals, or fees, within the aforementioned limits.

The Department will pay for this work according to 109.05 (2008 CMS).

Scrap Tires

Scrap Tires found on the project are transported under OAC 3745-27-56. The tires must be disposed of at a registered and permitted scrap tire facility as per OAC 3745-27-61 thru 65.

Use the following link to the OAC:

http://onlinedocs.andersonpublishing.com/oac/

Under these requirements, the transportation company and the disposal facility are regulated by the OEPA. Shipping papers are required to ship the tires to and from the facility. The District Environmental Coordinator or 24-hour trained Regulated Waste Project Engineer will sign the shipping papers for the Department. The records must be kept for three years.

Railroad Ties

The Ohio EPA encourages the use of railroad ties as landscape materials or other uses. When they must be disposed, they are disposed of in a construction and demolition debris site or a solid waste facility.

To date, creosote in railroad ties does not pose an environmental threat.

Recycled Materials

Supplemental Specification 871 allows the use of fly ash, bottom ash, foundry sand, glass, and tires in fills.

Supplemental Specification 871 can be found at the following web site:

http://www.dot.state.oh.us/construction/OCA/Specs/SSandPN 2002/default.htm

Recycled materials are defined in the 2002 CMS on page 100 in 203.02.N Recycled materials may be fly ash, bottom ash, foundry sand, glass or tires.

Under certain circumstances, petroleum contaminated soil in 203.02.K may also be used in fills. The environmental requirements are in 203.03.I on page 101 and 102.

The recycled materials are allowed in the interior sections of the fills. The approval on existing contracts will be on a case by case basis or if SS-871 is in the contract. Recycled materials are not allowed under the terms of the contract unless SS-871 is included.

The following Designer Note should be reviewed prior to considering using Supplemental Specification 871, Embankment Using Recycled Material:

> *The specification was written to allow the Districts to use recycled materials in embankment construction. It was written to safely use these recycled products without jeopardizing the embankment or pavement integrity or long-term performance. The Department does not require the use of recycled materials because this specification does not eliminate all risk or liability to the Department. It only minimizes these risks. The utilization of SS-871 is at the District's discretion. Districts are advised to consider all the benefits and potential problems prior to allowing these materials.*

Benefits

Recycled materials can be cheaper and provide engineering improvements to the embankment construction. For example, fly ash and tires can provide lighter weight materials.

By using these materials, the Department will save landfill space in the state. The Department may minimize the potential future legislation that would require the use of these materials. (Note: A few years ago, the state legislators required ODOT to allow petroleum-contaminated soil for embankment material, now under 203.02.K)

Potential Problems

Once these materials are placed on ODOT property, then the recycled materials will become the responsibility of the Department. ODOT will assume any future liability and costs for removal and proper disposal of material according to future EPA regulations. If this embankment is repaired in the future, the material may have to be disposed of in a landfill if required by Ohio EPA regulations.

A small percentage of tire fills have spontaneously caught fire. Fly ash is a silt and may be susceptible to frost heave and capillary action. Both problems are minimized by the engineering controls in the specification.

The District may pick and choose which recycled material to use or allow all of the recycled materials.

The District may allow different materials at certain locations along the project.

No change in the cross sections is needed to include SS-871 in the plans. This specification delineates the areas in which recycled materials are allowed.

The following plan note can be used to incorporate SS 871 in the contract.

> ***Embankment Construction Using Recycled Materials***
>
> *On this project, Supplemental Specification 871 Embankment Construction Using Recycled Materials applies. ____________________________ (Put in the materials wanted or needed) may be substituted for Item 203 Embankment in the contract. The Department will measure and pay for all work detailed in SS-871 according to the Unit Bid Price for Item 203 Embankment.*

Typical Regulated Waste Plan Notes

Typical Plan Note for: Non Regulated Materials, Petroleum Contaminated Soil and Underground Storage Tanks

> **ENVIRONMENTAL WORK**
>
> **1. Introduction**
>
> Soil adjacent the New Hamlet Cleaners property (SE corner of SR 132 and SR 125) was tested and contained petroleum substances. These substances are present within the excavation limits for proposed underdrains, proposed 36" storm sewer, other utilities and/or roadway

construction from Station 1+50 Lt. along SR 132 Station 370+70 Right along SR 125 (see Sheet 22/57). This material must be handled by the Contractor according the following notes. In addition, the Contractor shall remove four (4) underground storage tanks located within the proposed right-of-way limits in accordance with Item 202 of ODOT's Construction and Material Specification (CMS).

1.2 Site Specific Health and Safety Plan (SSHSP)

The Contractor shall certify in writing to the Engineer within two weeks after contract execution that the Contractor has prepared a SSHSP in accordance with OSHA 29 CFR Part 1910.120 for operations involving hazardous substances within the aforementioned limits. The Contractor shall make the SSHSP available at the project site. Copies of the environmental studies are available for examination in the Office of Contracts and the ODOT District 12, Office of Planning. This information may be used by the Contractor to develop the SSHSP.

1.3 Material Sampling

The Contractor shall provide the Engineer with five (5) days notice prior to beginning any excavation within the aforementioned limits to permit arranging for the necessary testing services. All material excavated by the Contractor between these limits during construction shall be subject to testing by an Inspector provided by the Engineer. The Inspector shall field-screen the excavated material for petroleum contamination using an organic vapor analyzer (OVA). At the discretion of the Inspector, the excavated material, which exhibits petroleum contamination, shall be stockpiled and segregated while samples of the material are analyzed by an independent analytical laboratory. Field-screening results and visual observation will be the basis for segregating excavated material. Soil samples shall to be tested for BTEX (Benzene, Toluene, Ethyl benzene, & Xylene) by Method 8020 and TPH by Method 8015. If the BTEX and/or TPH levels exceed levels set forth by the Ohio EPA Petroleum Contaminated Soil Policy, the material shall be treated as petroleum-contaminated soil. All field-screening instruments and initial sampling and analysis of soils will be provided by the Engineer at no cost to the Contractor.

1.4 Temporary Storage of Contaminated Soils

All excavated material, which is determined to be potentially contaminated with petroleum substances, shall be stockpiled in an area provided by the Contractor and approved by the Engineer. The Contractor shall stockpile the material in a leak proof, covered container provided by the Contractor. The material shall remain on-site until analytical results are received by the Engineer.

As an alternate, the Engineer may permit temporary storage of suspected contaminated soils on an impermeable membrane. The membrane should be surrounded by bales of straw to prevent the suspect soils from coming in contact with the original soils. An impermeable membrane shall be placed over the stockpile to prevent contact with precipitation and/or surface run-off.

1.5 Material Evaluation

The Inspector shall use the analytical results to determine the regulatory classification of the excavated materials. The excavated material may be classified in one or all of the following three categories:

1.5.1 ITEM SPECIAL - Work Involving Non-regulated Materials

The Inspector will determine if the excavated material is non-regulated. The work involved in this Item Special includes developing and complying with a SSHSP; handling, storage, and disposal/use of non-regulated materials. This material may then be used as backfill for other project purposes, if it meets the appropriate ODOT specifications.

1.5.2 ITEM SPECIAL - Work Involving Petroleum-Contaminated Soil

The Inspector will determine if the excavated material is petroleum-contaminated soil (PCS) based on the analytical test results. The Engineer will provide the Contractor with these test results. The Contractor shall be responsible for obtaining all necessary permits and approvals and to transport the material to a licensed (by the local health dept.) and permitted (by the Ohio Environmental Protection Agency) solid waste facility or a Petroleum Contaminated Soil Remediation Facility (PCSRF) for proper disposal or remediation. Prior to disposal, the Contractor shall contact the proposed facility to determine the additional testing required for disposal or remediation at that facility. The prices for these tests are to be included in the above pay item. The work involved in this pay item includes developing and complying with a SSHSP; handling, storage, testing (for disposal or remediation); and disposal or remediation of PCS. When directed by the proposed facility, the Contractor shall have an independent laboratory collect samples and test the excavated or stored materials for PCS disposal or remediation approval.

1.5.3 Work Involving Hazardous Waste

In the event the analytical test results for disposal purposes show the excavated material is a hazardous waste, disposal of this material shall to be paid for in accordance with section 109.04 of ODOT's CMS.

1.6 Backfill of Excavated Areas

All excavated areas shall be backfilled with suitable material in accordance with the project plans, applicable ODOT specifications, and/or as directed by the Engineer. All surplus or unsuitable excavated material that can be used in embankments shall be disposed of in accordance with Item 203.05 of ODOT's CMS.

1.7 General Notes

All transport vehicles used for the movement of regulated soils and/or water shall meet applicable Local, State, and Federal requirements. The Contractor shall maintain records (such as daily logs, landfill tickets, manifests, etc.) that document the source, movement, and destination of each truckload of contaminated soil. One copy of each of these records shall be submitted to the Engineer.

1.8 Basis of Payment

The Contractor shall furnish all the labor, equipment, and materials necessary to properly develop and comply with a SSHSP, excavate, store, test (for disposal), transport, and dispose of contaminated materials, removal of underground storage tanks, including any required approvals or fees within the limits identified above. Payment for this work shall be made at the contract prices bid per ton and per regulated underground storage tank. Work involving hazardous waste shall be paid for in accordance with section 109.04 of ODOT's CMS.

The following estimated quantities have been included in the General Summary for the work noted above:

Item Special - Work Involving Non-regulated Materials, 160 Ton

Item Special - Work Involving Petroleum-Contaminated Soil, 160 Ton

Item 202 - Regulated Underground Storage Tank Removed , 4 each

Typical Plan Note for: Solid Waste, Water, and Regulated Water

ENVIRONMENTAL WORK (CUY - Aerospace Parkway, PID 16802)

1.1 Introduction

Environmental studies have shown that regulated material (foundry sand, etc.) is present within the following excavation limits:

All excavations within the aforementioned limits shall be paid for under the original plan bid items. The Contractor shall manage this material according to the following notes. The estimated quantity has been included in the General Summary for this work.

1.2 Site Specific Health and Safety Plan (SSHSP)

The Contractor shall determine if a SSHSP is required in accordance with 29 CFR Part 1910.120. Environmental studies information is available for examination at ODOT District 12, Planning Dept., 5500 Transportation Blvd., Garfield Heights, OH 44125.

1.3 Material Handling

All material excavated by the Contractor between these limits may be stockpiled in an area provided by the Contractor and approved by the Engineer. The Contractor shall stockpile the material in a leak proof, covered container provided by the Contractor.

The Engineer may permit temporary storage of the regulated soils on an impermeable membrane. The membrane shall be surrounded by bales of straw to prevent the suspected soils from coming in contact with the original soils. An impermeable membrane shall be placed over the stockpile to prevent contact with precipitation and/or surface run-off.

As an alternative, the Engineer may permit the Contractor to direct load the excavated regulated soils (located within the aforementioned limits) into trucks for subsequent disposal.

1.4 Material Sampling and Disposal

The Contractor shall provide the Engineer with five (5) days notice prior to any excavations within the aforementioned limits to permit arranging for the necessary testing services. All material excavated by the Contractor between these limits shall be subject to testing by an Inspector provided by the Engineer. The Inspector will conduct sampling and testing every 100 cubic meters of material excavated. Samples will be tested by the following USEPA test methods:

The Contractor shall properly transport and dispose of the excavated material that is considered surplus or unsuitable material in a licensed (by the local health department) and permitted (by the Ohio Environmental Protection Agency) solid waste facility. If required by the solid waste facility, the Contractor shall be responsible for conducting any additional sampling and analysis of the excavated material.

In the event the analytical test results for disposal indicate the excavated materials is a hazardous and/or TSCA waste, disposal shall be paid for in accordance with section 109.04 of ODOT's CMS.

1.5 Backfill of Excavated Areas

All excavated areas shall be backfilled with suitable material in accordance with the project plans or as directed by the Engineer.

1.6 Potential Dewatering Of Excavated Areas

If excavations within the aforementioned limits require dewatering for construction purposes, the Contractor shall dewater and subsequently dispose of waters by methods approved by the Engineer. All water containerized by the Contractor between these limits shall be subject to testing by an Inspector provided by the Engineer. Samples will be tested by the following USEPA test methods:

1. The Contractor shall obtain all the necessary permits and/or authorizations needed to store, transport and dispose of the

water in accordance with applicable local, state or federal regulations.

2. The Engineer will classify the water removed from the excavation into one of the two following categories.

1.6.1 ITEM SPECIAL - Work Involving Water

The Engineer will determine if the water is non-regulated. The method for disposing of the non-regulated water shall be approved by the Engineer. Work involved with this Item Special includes the handling, storage, and disposal of the non-regulated water.

1.6.2 ITEM SPECIAL - Work Involving Regulated Water

The Engineer will determine if the water is regulated. The Contractor shall be responsible for disposal of the regulated water. The method for disposing of the regulated water shall be approved by the Engineer. The work involved in this Item Special includes the handling, storage, testing, and disposal of regulated water.

1.7 General Notes

All transport vehicles used for the movement of regulated soils shall meet applicable Local, State, and Federal requirements. The Contractor shall maintain records (such as manifests, landfill tickets, daily logs, etc.) to document the source, movement, and destination of each truckload of contaminated soil. One copy of each of these records shall be submitted to the Engineer.

1.8 Basis of Payment

The Contractor shall furnish all the labor, equipment, and materials necessary to properly handle, store, test, transport, and dispose of regulated materials, including any required permits, approvals, or fees within the limits identified above. Payment for this work shall be made at the contract price bid per metric ton and/or cubic meter. The basis for conversion from cubic meter to metric ton is 2 metric ton/cubic meter. The following estimated quantities have been included in the General Summary for the work noted above:

690M65010 Item Special - Work Involving Solid Waste, Mton

690M65020 Item Special - Work Involving Water, Cubic Meter

690M65024 Item Special - Work Involving Regulated Water, Cubic Meter

Typical Plan Note for: Ground Water Monitoring, Regulated Underground Storage Tanks and Scrap Tires

Environmental Work (HAM - 127 - 5.47, PID 9135)

Abandonment of Ground Water of Monitoring Wells

A total of three monitoring wells are present on the vacant lot located at 4135 Virginia Avenue (corner of Chase and Virginia). These wells shall be abandoned in accordance with the Ohio Department of Natural Resources' (ODNR) Technical Guidelines For Sealing Unused Wells (Appendix 4, Sealing Monitoring Wells and Boreholes). Payment for this work shall be as per Item Special - Ground Water Monitoring Well Abandonment.

Removal of Underground Storage Tanks

The Contractor shall remove two (2) petroleum underground storage tanks in accordance with ODOT Construction and Material Specifications (CMS) Item 202. These tanks are located at 4135 Virginia Avenue (corner of Chase and Virginia).

Removal and Disposal of Scrap Tires

Scrap tires are located throughout the project area. The Contractor shall be responsible for removing, transporting, and disposing of these scrap tires as per this plan note.

The Contractor shall ensure that the tires are removed and transported in a manner that satisfies all the appropriate OEPA regulations. Specifically, the transportation of tires is governed by OAC 3745-27-56. The disposal of tires shall be at a registered and permitted scrap tire facility as per OAC 3745-27-61 thru 65. Payment for this work shall be as per Item 202 - Removal Miscellaneous: Scrap Tires.

Basis of Payment

The Contractor shall furnish all the labor, equipment, and materials necessary to perform the aforementioned work. The following estimated quantities have been included in the General Summary for the work noted above:

Item Special - Ground Water Monitoring Well Abandonment, 3 each

Item 202 - Regulated Underground Storage Tank Removed, 2 each

Item 202 - Removal Miscellaneous: Scrap Tires, Lump Sum

Typical Plan Note for: Asbestos Abatement

Environmental Work (MIA - 48 - 8.534, PID 12860)

Asbestos Abatement

An asbestos survey of the bridge structure scheduled for demolition was completed 6/99 by a certified asbestos hazard evaluation specialist (CAHES). Approximately 440' of conduit, which contains asbestos materials, was identified on the bridge structure. A copy of the Ohio Environmental Protection Agency Notification of Demolition and

Renovation Form with sections I-VII, XVII, XVIII completed is available at the District 7 ODOT office (Planning Department). The form must be submitted to OEPA-SWDO, DAPC (401 E. Fifth Street, Dayton, OH 45402) at least 10 days prior to demolition/renovation activities.

The Contractor shall take whatever precautions are possible to ensure that the asbestos containing material (ACM) does not become friable. To assure that the nonfriable asbestos material does not become friable or in the event that the nonfriable material becomes friable, the Contractor shall provide an individual trained in the provisions of NESHAP that will be on-site during the demolition and/or removal of the ACM conduit. All ACMs shall be properly containerized, transported, and disposed of in accordance with the state and federal regulations.

Basis of Payment

The Contractor shall furnish all the labor (including a CAHES), equipment, and materials necessary to complete, submit, and comply with the OEPA notification for and to remove, transport and dispose of asbestos containing materials in a licensed (by the local health department) and permitted (by the OEPA) solid waste facility. Payment for this work shall be made at the contract prices bid Lump Sum. The following quantity has been included in the General Summary for the work noted above:

690M98400 Item Special - Misc.: Asbestos Abatement, Lump Sum

Typical Plan Note for: Removal and Disposal of Scrap Tires

Removal and Disposal of Scrap Tires (GRE - 42 - 14.25, PID 13134)

Scrap tires are located at approximately STA 23+660 to STA 23+720. The Contractor shall be responsible for removing, transporting, and disposing of these scrap tires as per this plan note.

The Contractor shall ensure that the tires are removed and transported in a manner that satisfies all the appropriate OEPA regulations. Specifically, the transportation of tires is governed by OAC 3745-27-56. The disposal of tires shall be at a registered and permitted scrap tire facility as per OAC 3745-27-61 thru 65.

Basis of Payment

The Contractor shall furnish all the labor, equipment and materials necessary to remove, transport and dispose of scrap ties in a registered and permitted scrap tire facility. Payment for this work shall be made at the contract price bid Lump Sum. The following estimated quantity has been included in the General Summary for the work noted above:

Item 202 - Removal Miscellaneous: Scrap Tires, Lump Sum

Typical Plan Note for: Solid Waste and Regulated Water

ENVIRONMENTAL WORK (TRU - Belmont Avenue, PID 11910) 3/8/00

1.1 Introduction

The Ohio Department of Health has issued a Contact Advisory for the sediments of the Mahoning River for polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), Mirex (a pesticide) and phthalate esters. Environmental studies conducted on sediments in the project area have shown that low levels of PAHs and metals are present within the stream bed. The Contractor shall manage all material required to be excavated from the river bed according to the following notes. Estimated quantities have been included in the General Summary for this work.

1.2 Site Specific Health and Safety Plan (SSHSP)

The Contractor shall certify in writing to the Engineer within two weeks after contract execution and prior to any excavation that would disturb the sediment in the river bottom that the Contractor has prepared a SSHSP in accordance with 29 CFR Part 1910.120 for operations involving hazardous substances within the aforementioned limits. The Contractor shall make the SSHSP available at the project site. Copies of the environmental studies are available for examination in the Office of Contract Sales (Room 118) and the District 4 ODOT office (Planning Dept.). This information may be used by the Contractor to develop the SSHSP.

1.3 Material Handling and Disposal

The Engineer may permit temporary storage of the excavated material in a lined and covered roll-off box. As an alternative, the Engineer may permit the Contractor to direct load the excavated material into trucks.

The Contractor shall properly transport and dispose of the excavated material in a licensed (by the local health department) and permitted (by the Ohio Environmental Protection Agency) solid waste facility. If required by the solid waste facility, the Contractor shall be responsible for conducting sampling and analysis of the excavated material.

1.4 Potential Dewatering Of Excavated Areas

If the excavations in the aforementioned sediments require dewatering for construction purposes, the Contractor shall dewater, containerize, test, and subsequently dispose of waters by methods approved by the Engineer. The Contractor shall obtain all the necessary permits and/or authorizations needed to store, test, transport and dispose of the water in accordance with applicable local, state, or federal regulations.

1.5 General Notes

All transport vehicles used for the movement of regulated sediments or water shall meet applicable Local, State, and Federal requirements. The Contractor shall maintain records (such as manifests, landfill tickets, daily logs, etc.) to document the source, movement, and destination of each truckload of contaminated sediments and/or water. One copy of each of these records shall be submitted to the Engineer.

1.6 Basis of Payment

The Contractor shall furnish all the labor, equipment, and materials necessary to properly develop and comply with a SSHSP, and handle, store, test, transport, and dispose of regulated materials, including any required permits, approvals, or fees within the limits identified above. Payment for this work shall be made at the contract price bid per metric ton and cubic meters.

The following estimated quantity has been included in the General Summary for the work noted above:

Item Special - Work Involving Solid Waste, 50 MTON
690M65010

Item Special - Work Involving Regulated Water, 5 CU M

690M65024

Documentation Requirements - 202 Removal of Structures and Obstructions, and Regulated Waste Requirements

Regulated waste work may be inspected and documented by the District Environmental Coordinator, District Hazardous Waste Coordinator, or Regulated Waste Project Engineer. When the inspection is required by these individuals it will be denoted below.

In addition, clearances or reviews need to be performed by other offices or individuals in the Department will be noted. These are as follows, District Office of Production, Office of Geotechnical Engineering.

Obtain a copy of the waste agreement from approved landfill or the property owner whose land was used for the waste area.

1. Structure Removed (lump sum)
    a. Statement on inspector’s diary as to amount removed
    b. State where material is disposed (waste agreement will be necessary)
2. Pipe Removal

   a. Cavity backfilled or in proposed excavation
   b. Measure length and pipe diameter for pay
   c. If pipe was abandoned how was it plugged?
   d. State how abandoned pipe was disposed
3. Pavement, Wearing Course, Sidewalk
   a. Measure length and width for pay
   b. Station and offset
   c. State how removed and how material was disposed
4. Curb Removal
   a. Measure length for pay
   b. State how removed and how material was disposed
5. Guardrail Removal
   a. Measure length for pay. Holes backfilled or in proposed excavation
6. Catch Basin, Manholes, Inlets removed or abandoned
   a. Inspector's statement that work was performed
   b. State what happened to existing conduits (abandoned and how plugged or hooked thru)
   c. Backfill of cavity (if necessary) and material disposal
7. Buildings removed
   a. Must have notice of possession and approval to proceed
   b. Remove all tanks, foundations, basements, concrete slabs, and/or cisterns as outlined in 202.06. Document how and where the material is disposed.
8. Underground Storage Tanks
   a. Remove in accordance with the " Bureau of Underground Storage Tank Regulations of the Division of Fire Marshal", Ohio EPA, and applicable Federal, State and Local regulations
9. Septic tank and privy vaults
   a. Empty tank and dispose material
   b. Remove as outlined in 202.07
10. Raised Pavement Markers
   a. Document location and quantity removed for disposal by Contractor
   b. Fill voids before the end of the next working day

Appendix 202 Regulated Waste Requirements. (DEC, DHWC or RWPE)

Responsibility

1. Report all significant changes. (Project)
2. Health and safety requirements. (DEC, DHWC, or RWPE)

Training.

1. Check Training for the project engineers, project inspectors, consultant inspectors.

2. Check the medical monitoring needs.
3. Check the training changes based on the health and safety plan.
4. Keep training and medical records according to sections 1105 and 1106 in the HWMPM.
    a. Regulated Waste Project Engineer gives these records to the District Environmental Coordinator for storage.
5. Check all personnel for construction safety training.

Site Specific Health and Safety Plan

1. Obtain a copy of the health and safety plan.
2. Review of the health and safety plan.
3. Obtain a new health and safety plan, if required.

Regulated Waste Designated for Removal in the Contract

1. Review the contract requirements in the plan, proposal, or specifications.
2. Perform the pre-excavation checks.
3. Record the excavation operations and quantities.
4. Record the type of temporary storage.
5. Record the material sampling evaluation.
    a. Hazardous Waste?
    b. Solid Waste?
    c. Special Waste?
    d. Non-Regulated?
6. Proper manifesting.
7. Record the pre-transportation requirements and placarding.
8. Keep disposal records.
    a. Regulated Project Engineer ensures these records are given to the District Environmental Coordinator for storage.
9. Keep running lists of the weekly inspections.

Regulated Wastes Found during Construction.

1. Who and when was notified ?
2. Who was hired to evaluate the wastes?
3. What Tests were taken?
4. What are the results?
5. Perform the Work as in the previous section, “Regulated Waste Designated for Removal in the Contract”.

Other Wastes and Environmental Considerations

1. Slag (Project)
    a. Check environmental requirements in the specifications.
    b. Check the runoff from the materials after placement.
    c. Check the underdrain outlets for Tufa.
    d. Record the Tufa removal operations.
    e. Same as hazardous or solid wastes. (DEC, DHWC, or RWPE)

2. Scrap Tires (Project)
    a. Document the removal.
    b. Requirements the same as solid waste. (DEC, DHWC, or RWPE)
    c. DEC keeps the record for storage (forever) (DEC, DHWC, or RWPE)
3. Rail Road Ties
    a. Same as construction and demolition debris.
    b. Recycling is encouraged.
4. Recycled Materials (Project)
    a. Ensure of Stability (OGE)
    b. Check the Environmental Consultants Certification. (DEC, DHWC, or RWPE)
    c. Check the placement procedures in SS-871.

203 Roadway Excavation and Embankment

Introduction

After many years of solving soil and rock problems throughout the state, the author of this section can assure the reader of 'One Constant'.

"Soil and Rock Conditions Vary, Vary and will Vary Again."

The author could repeat this statement a hundred times throughout this manual and it would be a hundred times too few.

Earthwork consists of roadway excavations (cuts) and roadway embankments (fills) for highways and associated items of work. Earthwork includes all types of materials excavated and placed in embankment, including soil, granular material, rock, shale, and random material. Associated items of work considered to be in the broad range of earthwork that includes: preparation of foundations for embankment, disposal of excavated material, borrow, preparation of the subgrade, proof rolling, rock blasting, base construction, and berm aggregate construction.

If pavement is to remain smooth and stable during years of service under traffic, the earthwork on which it is built must be stable and must furnish uniform support. Where roughness, settlements and other distress develop in pavement during service under traffic, the cause often is a deficiency in the stability of earthwork, which supports the pavement.

Uniformity of earthwork is necessary and important to obtain high stability and long-term performance at all locations throughout the length and width of the project. Consider, for example, a highway project where 95 percent of the earthwork was performed according to the specifications. But 5 percent was non-specification and low-stability material, which appeared in many small areas throughout the project. Pavement roughness and distress developed in these areas during service under traffic loading. Such a project probably would be evaluated by the traveling public as a "rough job" or a "poorly constructed" project. No notice or credit would be given to the 95 percent of the work, which was constructed properly. The entire project might be discredited and be considered poor because a relatively small proportion of the project was constructed with poor earthwork construction procedures or practices.

The foregoing assumed example is intended to illustrate the need for consistent compliance with earthwork specifications in all areas, both large and small, throughout the length of the project, and throughout the time from the beginning to the end of earthwork construction.

Importance of Proper Embankment Construction

The embankments that ODOT constructs are structures. The success of these structures is directly proportional to the project's emphasis on correct embankment techniques.

The importance of proper construction practices during construction cannot be overemphasized. The results of improper construction practices may or may not show up during construction. But, these improper practices will eventually become evident at some point during the life of the embankment structure.

The construction requirements in the specifications are written to maximize the embankment structure's life. When the specifications are not followed, the life expectancy will decrease and the future maintenance cost will increase.

The embankment structure is shown in Figure 203.A. The structure consists of three main components:

1. Foundation
2. Embankment
3. Pavement

A geotechnical engineer ensures that the embankment will be stable as designed. The pavement is constructed on top of the embankment.

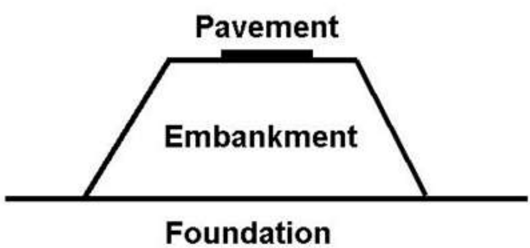


Figure 203.A – Embankment Structure

The embankment that is shown in the plans structurally bridges the foundation and supports the pavement. The embankment is built by compacting layers of materials in horizontal lifts, as shown in Figure 203.B. These lifts consist of soil, granular material, rock, shale, asphalt, concrete, or recycled materials. The embankment's resistance to movement relies on the proper construction of these lifts. These lifts work together as a unit to resist the loads.

Figure 203.B – Embankment Layers

A condition such as the one in Figure 203.C can occur if an embankment is not properly constructed. When this condition occurs the Factor of Safety is less than 1.0 and the embankment fails.

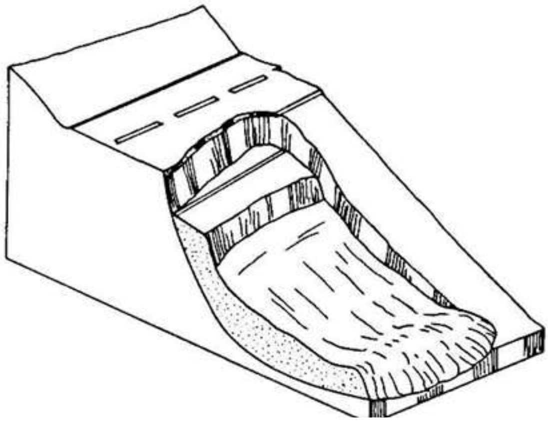


Figure 203.C – Embankment Failure

A factor of safety is the ratio of the Resisting Forces divided by the Driving Forces, as shown in the following equation.

$$\text{Factor of Safety} = \frac{\text{Resisting Forces}}{\text{Driving Forces}}$$

Minimum factors of safety for embankment structures are low, on the order of 1.2 to 1.5. Figure 203.D illustrates the resisting and driving forces. The weight of the fill works to move the foundation and the embankment counter clockwise to the right. The internal strength of the embankment layers and the foundation work together to support the pavement. Failure may occur in a circular fashion as shown, in a semi-circle, in a block mode or wedge. The basic principles are the same in all three modes of failure.

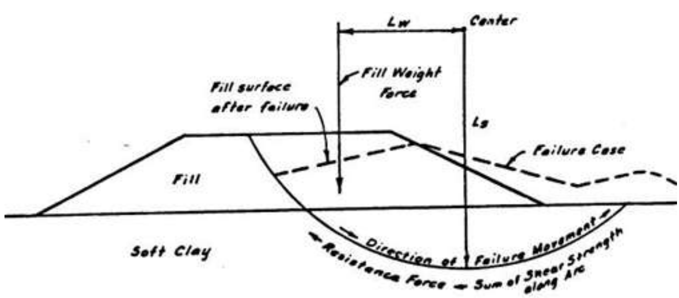


Figure 203.D – Resisting and Driving Forces for Embankment Failure

Importance of Proper Excavation

Proper excavation techniques in cut sections are just as important as embankment construction; the only difference is that in the failure mode the rock or soil falls onto the roadway instead of the roadway failing.

This is illustrated in Figures 203.E-1 and 203.E-2. If a soil cut is cut too steep then the soil can flow on to the roadway as illustrated in 203.E-1. This figure shows a deep-seated wedge failure. This failure can occur in an embankment condition also.

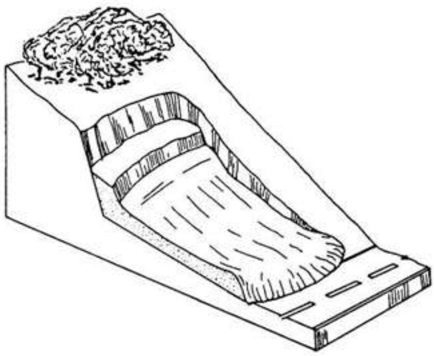


Figure 203.E-1 – Cut Slope Failure (deep seated wedge)

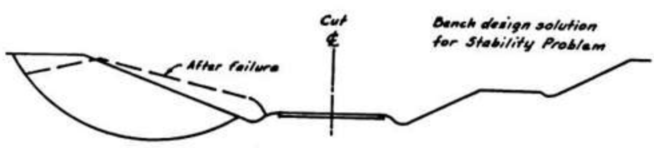


Figure 203.E-2 – Cut Slope Failure (rotational failed condition)

Figure 203.E-2 details a rotational failed condition on the left. The right side shows a design that is properly benching so that it reduces the driving forces. If a rock cut is cut too steep, the rock can fall on the roadway.

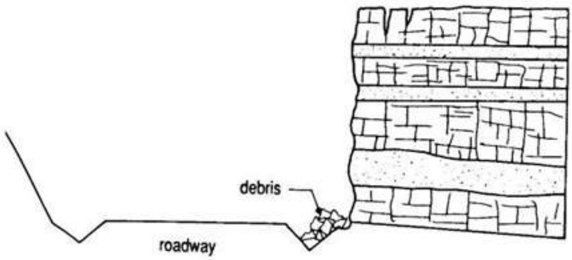


Figure 203.F – Falling Debris from Vertical or Nearly Vertical Faces near Roadway

The above rock and soil conditions can be avoided during the design or construction of a project. Ensure that the plan intent is followed in these cut locations on the project. Rock and shale excavations will be detailed under Section 208 Rock Blasting.

Materials (203.02)

The biggest changes in the 2002 version of the specification were the definitions and material requirements of the type of material allowed under the specifications.

In order to properly detail the requirements, it was necessary to divide up natural and recycled material requirements. Too many times in the past Contractors would try to obtain approval for materials that were not intended under the specifications.

A natural material is a material that was created by nature; a material that is mined or excavated and graded is a natural material. A material that is chemically altered by a manufacturing process such as concrete, fly ash, foundry sand, or slag is a recycled material.

Materials are defined in 203.02. As the materials are defined in 203.02, all of the allowed materials are detailed in 203.02.R as "Suitable Materials." Specific, more detailed material requirements are located in 703.16.

In the following sections, the materials will be detailed in the specific 203.02 sections for clarity.

If there is any doubt on the condition, status, acceptability, or approval of the materials throughout the following sections, then the project should contact one of the following: the District Engineer of Tests, the District Geotechnical Engineer, the Aggregate Section of the Office of Materials Management, or the Office of Geotechnical Engineering.

Natural Soil (203.02.I)

The definition for natural materials in 203.02.I is as follows: "All natural earth materials, organic or inorganic, resulting from natural processes such as weathering, decay, and chemical action."

Allowable materials are materials such as clay, silt, sand or gravel. These are allowed as suitable materials and are further defined in 703.16.A.

Department Group Classifications A-4-a, A-4-b, A-6-a, A-6-b, and A-7-6 are allowed. All of these materials are fine graded and have more than 35 percent of the particles passing the No. 200 sieve. More detail can be found by examining Figure 203.G. These classifications are further defined on the right side of the chart under Silt-Clay Materials.

Materials must have a maximum laboratory dry weight of at least 90 pounds per cubic foot (1450 kg/m^3). Materials that are less than this weight usually have too much organic matter or clay materials.

Soils that have a liquid limit in excess of 65 or identified as Department Group Classifications A-5, or A-7-5 are not allowed. The A-5 material is highly elastic by virtue of its high liquid limit. The A-7-5 material is highly elastic and subject to volume change.

Natural Granular Materials (203.02.H)

These materials are defined in 203.03.H as follows: "Natural granular materials includes broken or crushed rock, gravel, sand, durable siltstone, and durable sandstone that can be placed in an 8-inch (200 mm) loose lift."

These materials are allowed in 203.02.R, Suitable Materials. The material requirements are further detailed in 703.16.B and 703.16.C.

Under 703.16.B, Department Group Classifications A-1-a, A-1-b, A-3, A-3-a, A-2-4, A-2-6, or A-2-7 are allowed. All of these materials generally are mixtures of coarse and fine graded materials. These materials have less than 35 percent of the particles passing the No. 200 sieve. More detail can be found by examining Figure 203.G. These classifications are further defined on the left side of the chart under Granular Materials.

Granular material classified as A-2-5 is not allowed because of its low weight, high optimum moisture, high LL, low PI, and its propensity to slough.

Section 703.16.C allows durable sandstone and durable siltstone. If these materials meet the slake durability requirements in ASTM D 4644, then the material is considered equivalent in strength and durability to other natural granular materials.

Section 703.16.C allows slags and recycled Portland cement concrete to be used as granular material types.

Contact the Office of Geotechnical Engineering to arrange for the appropriate materials testing if sandstone or siltstone is used for this application.

General Classification	Granular Materials								Silt-Clay Materials						
	35 percent or less of total sample passing No. 200 (75 µm)								More than 35 percent of total sample passing No. 200 (75 µm)						
Group Classification	A-1		A-3 [1]		A-2				A-4		A-5	A-6		A-7	
	A-1-a	A-1-b	A-3	A-3a	A-2-4	A-2-5	A-2-6	A-2-7	A-4a	A-4b		A-6a	A-6b	A-7-5	A-7-6
Sieve analysis, percent passing:						*				**	*			*	
No. 10 (2 mm)	50 max														
No. 40 (425 µm)	30 max	50 max	51 min	[2]					[3]	[4]					
No. 200 (75 µm)	15 max	25 max	10 max	35 max	35 max	35 max	35 max	35 max	36 min	50 min	36 min	36 min		36 min	
Characteristics of fraction passing No. 40															
Liquid limit	—	—	Non-	—	40 max	41 min	40 max	41 min	40 max		41 min	40 max		41 min	
Plasticity index	6 max	6 max	Plastic	6 max	10 max	10 max	11 min	11 min	10 max		10 max	11 – 15	16 min	≤LL-30	>LL-30
Group Index	0						4 max		8 max		12 max	10 max	16 max	20 max	
Usual types of significant constituent materials	Stone fragments, gravel and sand		Fine sand	Sand	Silty or clayey gravel and sand				Silty soils			Clayey soils			
General rating as subgrade	Excellent to good								Good to fair						

Notes

With the test data available, the classification of a soil is found by proceeding from left to right on the chart. The first classification that the test data fits is the correct classification.

* A-2-5 is not allowed under 703.16.B. A-5 and A-7-5 is not allowed under 703.16.A. See "Natural Soil and Natural Granular Soils" (203.02.H) in this manual

** A-4b is not allowed in the top 3 feet (1.0 m) of the embankment under 203.03.A

[1] The placing of A-3 before A-2 is necessary in the "left to right" process, and does not indicate superiority of A-3 over A-2.

[2] A-3a must contain a minimum 50 percent combined coarse and find sand sizes (passing No. 10 but retained on No. 200, between 2 mm and 75 µm).

[3] A-4a must contain less than 50 percent silt size material (between 75 µm and 5 µm).

[4] A-4b must contain 50 percent or more silt size material (between 75 µm and 5 µm).

Figure 203.G - Department Soils Classification Chart

Identifying Soil and Granular Materials in the Field

It is sometimes necessary to make field decisions based on very little (if any) laboratory soils information. Or, it may be necessary to verify the accuracy of plan soil borings in the field. In these two cases and on other occasions, it is important to have a basic understanding of how to identify types of soils and granular materials in the field. The following is some, but certainly not all, of the methods that can be used to identify these materials in the field.

Granular Soils

Granular soils are easily identified by their particle size in the field. A sample may be taken inside and spread on a table to dry. A rough estimate of the material retained or passing each sieve may be obtained by examining the material when dry: the finer materials such as clays and silts cannot be separated and can only be distinguished between one another by a settling technique. This can be accomplished by using a hydrometer or by performing a crude settling test. This technique is beyond the scope of this manual.

Fine Grained Soils (Clays and Silts)

It is more important, yet harder, to distinguish between a clay and silt material in the field. Clays and silts should be treated and used differently in the field because of their difference in engineering and compaction properties. See the properties of soils in the next section.

A clay material can be easily rolled into a thread at moisture contents at, near, or above the plastic limit of the material. Clays can often be rolled into 1/8 inch (3 mm) diameter threads (about half the diameter of a pencil). See the plastic limit test later in this manual for further information. The thread may be easier and may be rolled into smaller sizes as the clay content increases. You cannot roll a pure silt material into a 1/4 inch (6 mm) thread no matter what the soil content.

Clay forms hard pieces that cannot be broken by hand pressure when it is dry. Place an irregular piece of dry soil between the index finger and the thumb, and try to break the material. If the material is difficult or impossible to break, it is probably clay. A silt or sandy material will generally break easily with this amount of hand pressure.

Clay fines are generally greasy, soapy, and sticky. When wet, clay dries slowly, while silt dries faster than clay.

When performing these hand techniques, observe the soil residue found on your hands for further information. If the soil on your hands is difficult to remove and the hands need to be rubbed briskly together to remove the soil, the material is probably a clay. A silt material is generally easily removed from the hands when rubbed together.

A silt material will react to vibration or shaking. Place a small amount of pliable soil in your hand. Hold the material in one hand and drop that hand on the other hand or a hard surface. Water will form on the surface of a silt material. You can also put the soil in a bowl and tap it on a table to get the same result. Clay will not react to this test.

The above crude identification techniques should not replace classification by the laboratory but should be used as a supplement.

If there is any concern, send a sample to the District Engineer of Tests for further classification as soon as possible.

Engineering Properties of Soil and Granular Materials

The following are general statements regarding the engineering properties of soil and granular materials. Consider these properties when solving field problems.

Properties of Granular Soils

1. Good foundation and embankment material.
2. Not frost susceptible, if free draining.
3. May erode on embankment side slopes.
4. Identified by the particle size.
5. Easily compacted when well graded.

Properties of Fine Grained Soils

1. Often have low strengths.
2. Plastic and compressible.
3. Lose part of their shear strength when wet or if disturbed.
4. Practically impervious.
5. Slopes are prone to slides.

Properties of Silts

1. High capillary action and frost susceptible.
2. No cohesion and non-plastic when pure silt.
3. Highly erodible.
4. Difficult to compact.
5. Release water readily when vibrated.
6. Acts like an extremely fine sand during compaction.

Properties of Clay as They Relate to Silt

1. Better load-carrying qualities.
2. Less permeable than silt.
3. Easier to compact than silt. (Any soil is easier to compact than silt.)
4. More volume change potential.
5. Plastic or putty-like property.
6. Clays are weaker when compacted wet of optimum.

Moisture Effects on Soils

Granular soils are less affected by the moisture content than clays and silts, have larger voids, and are free draining. Granular materials have relatively larger particles as compared to silts and clays.

Water content has a large effect on the physical properties of fine-grained soils. The Atterberg Limits are used to describe the effect of varying water contents on the consistency of fine-grained soils. See Figure 203.H.

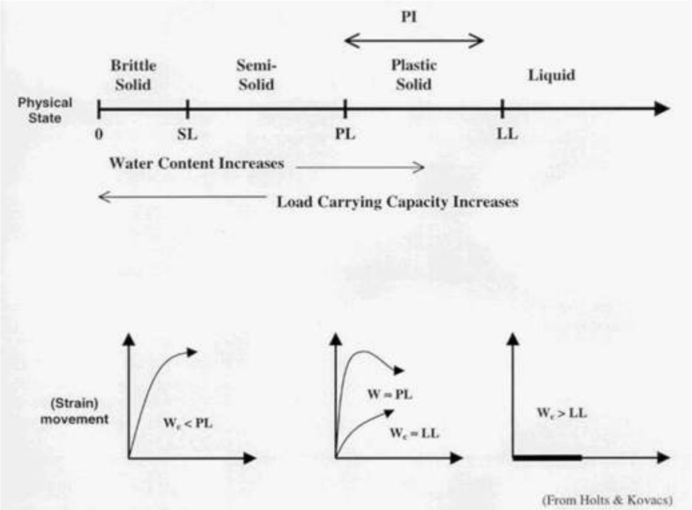


Figure 203.H – Atterberg Limits

The plasticity index (PI) is used to classify soils. The plasticity index is calculated by subtracting the plastic limit (PL) from the liquid limit (LL) (e.g. PI = LL – PL). Liquid limits as well as plastic limits are the water content at the condition of the test.

Liquid Limit

1. State between the plastic solid and liquid state.
2. At liquid limit of 100 the soil contains equal weights of soil and water. (example Wc = Ww/Ws = 50/50)
3. At liquid limit of 50, the soil is 2/3 soil and 1/3 water. (example Wc = 33/66)
4. High liquid limit indicates soils of high clay content and low load carrying capacity.

Plastic Limit

1. State between semi-solid and the plastic solid.
2. The soil condition, when it contains just enough moisture to be rolled into an 1/8 inch diameter thread without breaking, just starts to break up.
3. Governed by the clay content.

4. The greater the clay content, the higher the plasticity (PI = LL – PL) and cohesiveness.
5. Load carrying capacity increases rapidly as the moisture content decreases below the plastic limit.

The following is a brief description of the characteristics of soils in the physical states.

Liquid Soil State Characteristics

1. Highly saturated state.
2. Flows under its own weight.
3. Very little or no friction between the particles.

Plastic State Characteristic

1. Soil can be remolded into various shapes.
2. Like modeling clay.

Semi-Solid Soil State Characteristics

1. No longer pliable.
2. Sample will crumble when rolled.

Brittle Solid Soil Characteristics

1. Soil ceases to change volume due to the loss of water.
2. No real engineering application.

Detailed Soil Property Explanation

Each term used in geotechnical engineering has specific meaning and application. Each soil test has specific meaning and application and indicates certain soil properties. Care in using correct terminology will prevent confusion and misunderstanding.

Soil

Soils have properties that influence their behavior and value. The properties of soil will vary with its gradation (composition), its moisture content, its vertical position in relation to the surface of the ground, and its geographical location. The more common properties encountered and used in highway work are defined and discussed in Section 203.

Most soils originally were solid rock; time and climate have broken the rock into progressively smaller particles. This can be shown in the laboratory by taking two or three pieces of gravel or stone and pulverizing them. First, sand-size particles can be made, then silt-size particles, and finally clay-size particles. However, chemical changes also take place as nature reduces rock into finer particles. Therefore, clay produced by nature over a period of many years will vary from clay-size material produced in a short time in a laboratory.

Particle Size

By naming and defining the size of the soil particles, all soil tests are placed on a common ground for comparison. The amount of soil retained or passing each sieve is one of the major tools used in judging, analyzing, and classifying a soil.

The quantities of each are determined by a laboratory analysis that separates the soil into groups of particle sizes. The standard methods of test prescribed by AASHTO T-88 and ASTM D-422 have been used widely in highway engineering and are used by the Department.

The distribution of particle sizes larger than 0.074 mm retained on the No. 200 (75 µm) sieve is determined by sieving, while the distribution of particle sizes smaller than 75 µm is determined by a sedimentation process, using a hydrometer to determine the necessary data.

Definitions of sizes used by the Department are the same as established by AASHTO T-88, with the exception of the definition of clay, and are as follows:

Component		**Size**
Boulders		Larger than 12 inches (300 mm)
Cobbles		3 to 12 inches (75 to 300 mm)
Gravel	Coarse	¾ to 3 inches (19 to 75 mm)
	Fine	#10 sieve to ¾ inch (2 to 19 mm)
Sand	Coarse	#40 sieve to #10 sieve (0.42 to 2.0 mm)
	Fine	#200 sieve to #40 sieve (0.074 to 0.42 mm)
Silt		0.005 to 0.074 mm
Clay		Smaller than 0.005 mm

Texture

The amount of each soil type (i.e., boulders, cobbles, silt, and clay) contained in a soil mixture determines its texture or feel. Classification of soils by texture must not be confused with classification of soils for engineering purposes. Sometimes they are similar but at other times they may be different. The amount of each soil type in the soil is determined by laboratory tests. These test results are then compared with the texture definitions in use to determine the texture name.

Soil texture is classified after its sieve size is determined. It is possible to make approximations of texture by the feel of moist soil when rubbed and ribboned between the thumb and index finger.

The texture of soil is given to tell as much as possible about a soil in a few words. Using a texture classification, approximations and estimates can be made of many soil properties, such as bearing value, water-holding capacity, probability to frost heave, permeability, etc.

Soil Components (Major and Secondary)

It is the practice of the Department to describe soil components and texture of a soil as follows:

Major Components

Major components are described as gravel, sandy gravel, gravelly sand, sand, silty sand, clayey sand, sandy silt, silt, clayey silt, silty clay or clay. More than 35 percent of the total sample is required in order to classify a major component. Where two words are used to describe the major component, the second word describes the greater quantity.

Examples: Sand predominates in "silty sand" while silt predominates in "sandy silt".

Secondary Components

Descriptions of secondary components are preceded by the term listed below, according to the percent of total sample indicated:

Term	Percent of Total Sample
Trace	0 to 10
Little	10 to 20
Some	20 to 35
And	35 to 50

Examples of material texture descriptions based on component test results are as follows:

Material Components	Texture Description
Sand 30%, silt 55%, clay 15%	"sandy silt with little clay"
Sand 8%, silt 55%, clay 37%	"silt and clay with trace sand"
Gravel 20%, sand 68%, silt 12%	"gravelly sand with little silt"
Gravel 2%, sand 12%, silt 42%, clay 38%	"silt and clay with little sand, trace gravel"

Internal Friction

Internal friction is defined as the resistance to sliding within the soil mass. Gravel and sand impart high internal friction and the internal friction of a soil increases with sand and gravel content. For sand, the internal friction is dependent upon the gradation, density, and shape of the soil particle, and is relatively independent of the moisture content. Clay has a low internal friction, which varies with the moisture content. A powder-dry, pulverized clay has a much higher internal friction than the same soil saturated with moisture, since each soil particle can slide on adjoining soil particles much more easily after it is lubricated with water.

Various laboratory tests have been devised to measure internal friction. It is defined as the angle whose tangent is the ratio between the resistance offered to sliding along any plane in the soil and the component of the applied force acting normal (perpendicular) to the plane. Values are given in degrees. Internal friction values range from 0 degrees for clay just below the liquid limit to as high as 34 degrees or more for a dry sand. Very stiff clay may have a value of 12 degrees.

The governing test should be based on the most unfavorable moisture conditions that will prevail when the soil is in service. This "angle of internal friction" is not the same as the natural angle of repose or degree of slope on the soil in fills.

Cohesion

Cohesion is defined as the mutual attraction of particles due to molecular forces and the presence of water. The cohesive force in a soil varies with its moisture content. Cohesion is very high in clay but of little or no significance in silt and sand. Powder-dry, pulverized clay has low cohesion. However, as the moisture content is increased, the cohesion increases until the plastic limit is reached. Then the addition of more moisture reduces the cohesion. By partially over-drying wet clay, most free water is removed and the remaining moisture will hold the clay particles together so firmly and give the soil such high cohesion that a hammer may be required to break the particles apart. These conditions are illustrated, respectively, by the dry dirt road in summer that dusts easily but carries large loads; the muddy, slippery road of spring and fall; and the hard-baked surface of a road immediately after summer rains.

Various laboratory tests have been devised to measure cohesion. Results are usually given in pounds per square foot (psf) or kilopascals (kPa) and may vary from 0 psf in dry sand and wet silt to 2,000 psf (96 kPa) in very stiff clays. Very soft clays may have a value of 200 psf (10 kPa). The governing test should be based on the most unfavorable moisture condition that will prevail during service.

Internal Friction and Cohesion

The stability and hence the structural properties of soil are determined largely by the combined effects of internal friction and cohesion. In most soils these combine to make up the shearing resistance. The combined effects are influenced by other basic factors such as capillary properties, elasticity, and compressibility.

All these factors plus the site on which the soil is located determine the moisture content that will prevail in the soil in service. They also govern the load-carrying capacity of a soil, which is the primary concern. The clay-gravel road made up largely of gravel and sand, with a small amount of silt to fill voids and a small amount of clay to give cohesion, illustrates a soil of high bearing value produced by high internal friction due to sand and gravel and high cohesion due to clay. Clay illustrates a soil of low bearing value, because when clay is wet, internal friction is negligible since no coarse grains are present, and cohesion is low since it has been destroyed by moisture. The same clay, air-dry, will have high bearing value due to high cohesion brought about by the removal of moisture.

Capillarity

Capillarity is defined as the action by which a liquid (water) rises in a channel above the horizontal plane of the supply of free water. The number and size of the channels in a soil determine its capillarity. This soil property is measured as the distance moisture will rise above the water table by this action, and will range from 0 in some sand and gravel to as high as 30 feet (9 meters) or more in some clay soils. However, it often requires a long period of time for water to rise the maximum possible distance in clay soils because the channels are very small and frequently interrupted, and the frictional resistance to water is great in the tiny pores.

Moisture in silt soils may be raised by capillarity only 4 feet (1 meter) or so. Since the capillary pores are larger than for clay, a larger quantity of water is raised in a few days rather than over a long period. Silts are considered to have "high capillarity" by geotechnical engineers because of this rapid rise of water. The capillary rise in gravels and coarse sands varies from zero to a maximum of a few inches (centimeters).

Complete saturation of the soil seldom occurs at the upper limits of rise of capillary moisture. Capillarity of a soil and the elevation of the water table under the pavement determine whether the subgrade will become saturated in this manner. Whether or not the subgrade becomes saturated from capillary action (or from condensation, seepage, etc.) determines the bearing value of the soil to a considerable extent. Subgrade saturation by capillarity also determines whether frost heave and similar occurrences in subgrade will create a problem requiring treatment for satisfactory performance in service.

Compressibility and Elasticity

Compressibility and elasticity are the properties of a soil that cause it to compress under load or compaction effort, and to rebound or remain compressed after compaction. Most soils are compressible. Silty soils of the A-5 group are the most elastic of Ohio soils, and make poor subgrades for pavements. Fortunately, A-5 soils are limited in occurrence in Ohio. The A-7 soils in Ohio are moderately elastic, but do not present special problems in embankment or subgrade. A-4 soils are elastic under some moisture conditions, and sometimes present problems of stability during construction, but provide adequate support for pavements where good design and construction practices have been followed.

When a soil elasticity measurement is required, it is determined by special tests that simulate moisture changes and loading conditions anticipated in the field.

Elasticity and Deformation of Soils

When heavy rubber-tire construction equipment moves over an embankment layer foundation of wet fine-grained soil, some movement of the embankment surface occurs. One type of movement, called elastic movement, is described as follows: When the tire moves onto an area, the surface is deformed, and when the tire moves off the area, the surface rebounds, or springs back, with little or no permanent rutting of the surface. Cracking of the surface may or may not occur following this type of movement.

However, cracking occurs in cases of "pronounced" elasticity. In the case of pronounced elasticity or deformation, there is displacement of some surface soil to each side of the tire, with resulting deformation, rupture, cracking, and rutting.

The magnitude of the elastic movement or deformation may depend on one or more of a number of factors, including the following:

1. Weight of equipment.
2. Size of tires
3. Tire pressure

4. Soil moisture
5. Type of soil
6. Depth of soil layer
7. Stability of material underlying the soil layer being observed

Some embankment elasticity and deformation is expected under construction equipment loading. Moderate movement of less than a ½ inch (13 mm) can occur with heavy equipment weighting around 35 tons on embankments of satisfactory stability. This moderate movement is not considered detrimental. Greater movement is likely on adequately stable embankments under very heavy equipment weighting greater than 35 tons. Except for specialized situations, such as soft foundation soil at shallow embankment depth under the layer being observed, the greater movement due to these very heavy loads is not detrimental. In general, elastic or deformation movement under heavy or very heavy loads should be permitted if the moisture of the embankment is at least 2 percent below optimum.

Moisture control specifications are not intended to limit or restrict the use of very heavy construction equipment on embankment construction. The intent of the specifications is to limit the moisture to obtain a stable embankment.

The amount of elasticity and permissible deformation under any given load varies with job circumstances. For example, for the first layer over a soft original ground embankment foundation, considerable movement under loaded construction equipment is inevitable due to the soft foundation material. The resistance to deformation is more critical in the top portion of embankment, near the subgrade, than in lower portions of the embankment. If the lower embankment layers are low-stability material, such as wet silt, elasticity and deformation of the lower embankment layer must be closely monitored. This would not be necessary if successive embankment layers were of high stability material such as rock, shale, granular material, or dry soil.

Equipment which can be used successfully to test for embankment stability includes: rubber-tired roller, grader, loaded scraper, or loaded truck. Remember, more movement is to be expected under very heavy equipment than under heavy equipment ordinarily used in highway work. When rubber-tire construction equipment such as scrapers, graders or rollers, are being used over the entire general area during normal embankment construction operations, and observation shows no area of questionable stability, it is not necessary to have a piece of testing equipment systematically cover the entire area for the specific purpose of observing stability.

However, when the Engineer or Inspector questions or desires to check further the stability of an area during embankment construction, they are authorized to require the Contractor to move suitable equipment over the area to check for pronounced elasticity or deformation.

The determination of pronounced elasticity or deformation under the action of loaded rubber-tire construction equipment is based on the description given in the second paragraph of this section.

The administration of this requirement should be tempered with sound judgment backed by construction experience.

Shrinkage

Shrinkage refers to the apparent decrease in volume of a soil during its removal from the cut or borrow and its placement in the embankment. A greater density in the fill than in the cut or borrow area is the cause of the shrinkage. Shrinkage is not accounted for nor contemplated in the design of the project.

The amount of shrinkage resulting from increased density in the embankment material may be estimated by using a volume or dry density basis.

Either of the following equations can be used to calculate the Shrinkage Factor (SF).

$$SF = \frac{\text{Excavated Material Volume}}{\text{Compacted Material Volume}} \qquad SF = \frac{\text{Average Dry Density of Borrow}}{\text{Average Dry Density in Fill}}$$

Example of the use of a shrinkage factor:

$$\text{Payment adjustment} = \frac{\text{Borrow or Cut}}{\text{SF}}$$

The adjustment due to shrinkage is only used where the material is measured in a borrow pit and the embankment is placed outside of the plan allowed tolerances. Due to specification and design changes the use of borrow as a pay item should be minimized in the future.

Settlement and Scalping Losses

Losses due to scalping are usually insignificant as a percentage of the overall embankment construction quantities. Scalping losses of around six inches from the original cross-sections can be expected during construction. This is not compensated by the Department. If there is significant losses beyond this then it can be accounted for by taking cross-sections and compensation should be made.

Settlement of the embankment foundation can be an area where the contractor can lose material that is not measured directly. It can be accounted for in the earthwork quantity calculations.

Losses due to settlement of the embankment foundation, where the foundation is compressible, can be calculated by using settlement platforms. A settlement platform or several can be placed on the foundation. The platform is measured throughout the life of the embankment construction. A settlement verses time curve can be used to determine the amount of additional payment that is due. See Figure 203.I.

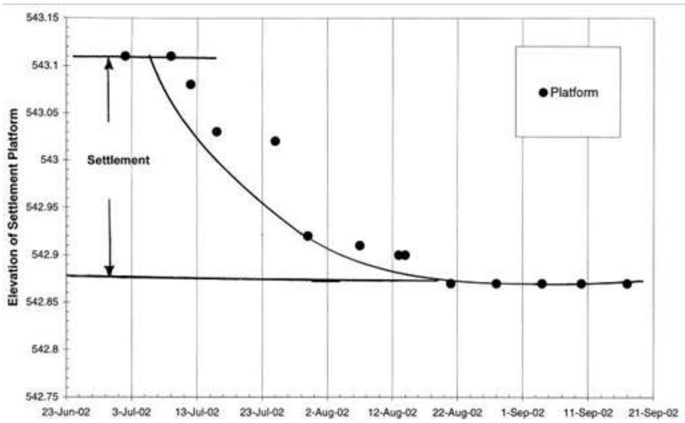


Figure 203.I – Settlement Curve

The amount of settlement that occurred over the life of the embankment construction is a function of this Total Settlement Curve. To make the additional embankment payment, multiply the settled amount by the length and width of the settled area. This length and width should be calculated at the half height of the embankment in the affected area. Some judgment is required as to the length of influence of individual or multiple settlement platforms.

In this example, the total settlement is as follows:

$$543.11 - 542.88 = 0.23 \textit{ feet}$$

Permeability

Permeability is a property of soil that allows it to transmit water. It is defined as the rate at which water is transmitted by soils. It depends on the size and number of soil pores and the difference in height of water at the point where it enters the soil and the point where it emerges. It is determined by tests on a representative soil sample and expressed as the coefficient of permeability, and it equals the velocity of water-flow in centimeters per second (cm/sec) under a hydraulic gradient of 1. A hydraulic gradient of 1 exists when the pressure head (or height of water) on the specimen in centimeters divided by the depth of the specimen in centimeters equals 1.

The permeability of a soil varies with such factors as void ratio, particle size and distribution, structure, and degree of saturation. Obviously, the permeability of a particular soil will vary with the degree of compaction since this influences the size of the soil pores. A particular soil loosely packed will be more permeable then the same soil tightly packed. Nature produces these differences, in connection with shrinkage forces that may be present, by surface freezing in winter (loosening a soil) and by repeated wetting and drying in the summer (consolidating the soil).

The coefficient of permeability, k, is used to determine the quantity of water that will seep through a given time and distance under a known head of water. It is calculated using the following equation.

$$k = \frac{QL}{HAt}$$

The equation can be rearranged to find the quantity of seepage, Q, as shown below.

$$Q = \frac{kHAt}{L}$$

where:

Q	=	quantity of water, in cubic centimeters (cm^3)
k	=	coefficient of permeability, in centimeters per second (cm/sec)
H	=	hydrostatic head, in centimeters
L	=	thickness of soil, in centimeters, through which flow of water is determined under hydrostatic head H;
A	=	cross-sectional area of material, in square centimeters (cm^2);
t	=	time, in seconds (sec).

Tile can drain very porous soils, such as sands that have a k of 1.0 to 10^{-3} (0.001) cm/sec. Silty and clayey sand soils have a k of about 10^{-3} (0.001) to 10^{-7} (0.0000001) cm/sec. Highly cohesive clays have a k of less than 10^{-8} (0.00000001) cm/sec. It is difficult, if not impossible, to reduce the water content of soils by tile drains when the permeability coefficient is less than about 10^{-3} (0.001). For earth dams, the U.S. Bureau of Reclamation classifies soil with k values about 10^{-4} (0.0001) as pervious and soil with k below 10^{-6} (0.000001) as impervious.

Soil Group classifications A-6a, A6b and A-7-6 are generally considered impervious.

Plastic Limit

The plastic limit (PL) of soils is the moisture content at which a soil changes from a semisolid to a plastic state. This condition is said to prevail when the soil contains just enough moisture that it can be rolled into 1/8 inch (3.18 mm) diameter threads without breaking. The test, ASTM D-424 or AASHTO T-90, is conducted by trial and error, starting with a soil sufficiently moist to roll into threads 1/8 inch (3.18 mm) in diameter. The moisture content of the soil is reduced by alternating manipulation and rolling until the thread crumbles.

Clay content controls the plastic limit. Some silt and sand soils cannot be rolled into 1/8 inch (3.18 mm) threads at any moisture content; these have no plastic limit and are termed non-plastic. The test is of no value judging the relative load-carrying capacity of non-plastic soils.

A very important change in load-carrying capacity of soils occurs at the plastic limit. Load-carrying capacity increases very rapidly as the moisture content is decreased below the plastic limit. On the other hand, load carrying capacity decreases very rapidly as the moisture content is increased above the plastic limit.

Liquid Limit

The liquid limit (LL) is the moisture content at which a soil passes from a plastic to a liquid state. The test, ASTM D-423 or AASHTO T-89, is performed by determining, for various moisture contents, the number of blows of the standard cup needed to bring the bottom of the groove into contact for a distance of more than 0.5-inch (12.7 mm). These data points are then plotted and the moisture content at which the plotted line (called flow curve) crosses the 25-blow line is the liquid limit.

Sandy soils have low liquid limits of the order of 20. In these soils the test is of little or no significance in judging load-carrying capacity.

Silts and clays have significant liquid limits that may run as high as 80 or 100. Most clays in Ohio have liquid limits between 40 and 60.

High liquid limits indicate soils of high clay content and low load-carrying capacity.

Liquid limit can be used to illustrate the interpretation of moisture content as a percentage of the oven-dry weight of the soil. See an example in the previous section on liquid limit.

Plasticity Index

The plasticity index (PI) is defined as the numerical difference between liquid limit and plastic limit. Calculation details are included in ASTM D-424 and AASHTO T-90. The plasticity index gives the range in moisture contents at which a soil is in a plastic condition. A small plasticity index, such as 5, shows that a small change in moisture content will change the soil from a semisolid to a liquid condition. Such a soil is very sensitive to moisture unless the combined silt and clay content is less than 20 percent. A large plasticity index, such as 20, shows that considerable water can be added to the soil before it changes from a semisolid to a liquid.

When the liquid or plastic limit cannot be determined or when the plastic limit is equal to or higher than the liquid limit, the plasticity index is considered non-plastic (N.P.).

The moisture conditions at the plastic limit and liquid limit, and the plasticity index, often are called the “Atterberg Limits” (named after Albert Atterberg, the Swedish agricultural scientist who developed the concept).

Detailed Description of the Soil Classification Groups

The following is a brief description of the materials in each classification group detailed in Figure 203.G.

Group A-1

The typical material of this group is a well-graded mixture of stone fragments of gravel, coarse sand, fine sand, and a non-plastic or feebly plastic soil binder. However, this group may also include the same material without the soil binder.

Subgroup A-1a

This material consists of predominantly stone fragments or gravel, either with or without a well-graded soil binder.

Subgroup A-1b

This material consists of predominantly coarse sand either with or without a well-graded soil binder.

Group A-3

The typical material of this group is fine beach sand without silty or clay fines or with a very small amount of non-plastic silt. The group also includes stream-deposited mixtures of poorly-graded fine sand and limited amounts of coarse sand and gravel. These soils are sometimes difficult to compact similar to the A-4 group. The fineness of the material and the silt fines make stabilization difficult. See the group A-4 for further explanation.

Subgroup A-3a

This material consists of mixtures of coarse and fine sand with limited amounts of silt of low plasticity.

Group A-2

This material consists of a wide variety of “granular” materials which are borderline between Groups A-1 and A-3 and the silt-clay materials of Groups A-4, A-5, A-6 and A-7. It includes all materials containing 35 percent or less passing the No. 200 (75 µm) sieve which cannot be classified as A-1, A-3 or A-3a, due to fines content or plasticity (or both) in excess of the limitations for those groups.

Subgroups A-2-4 and A-2-5

This material consists of various granular materials containing 35 percent or less passing the No. 200 (75 µm) sieve and with a negative No. 40 (425 µm) portion having the characteristics of the A-4 and A-5 groups.

This material consists of materials such as gravel and coarse sand with silt contents of plasticity indexes in excess of the limitations of Group A-1, and fine sand with non-plastic silt content in excess of the limitations of Group A-3. A-2-5 soils are unsuitable embankment material under 703.l6.B because of its low weight, high optimum moisture, high LL, low PI, and its propensity to sloughing in service.

Subgroups A-2-6 and A-2-7

This material consists of materials similar to those described under Subgroups A-2-4 and A-2-5 except that the fine portion contains plastic clay having the characteristics of the A-6 or A-7 group. The approximate combined effects of plasticity indexes in excess of 10 and percentages passing the No. 200 (75 µm) sieve in excess of 15 are reflected by group index values of 0 to 4.

Group A-4

The typical material of this group is a non-plastic or moderately plastic silty soil usually having 75 percent or more passing No. 200 (75 µm) sieve. This group also includes mixtures of fine silty soil and up to 64 percent of sand and gravel retained on No. 200 (75 µm) sieve. The group index values range from 1 to 8, with increasing percentages of coarse material being reflected by decreasing group index values. The A-4 group soils are usually very difficult to compact or stabilize. Minimizing the water content to obtain the required density and stability usually works. It is not unusual, nor is it a change in condition, to have difficulty in stabilizing or compacting these soils. This condition should have been expected for this type of material.

Subgroup A-4a &A-4b

Subgroup A-4a contains less than 50 percent silt sizes. Subgroup A-4b contains more than 50 percent silt sizes. A-4b is only allowed 3.0 feet (1.0 m) below subgrade elevation because of frost heave potential. Both are susceptible to erosion.

Group A-5

The typical material of this group is similar to that described under Group A-4, except that it may be highly elastic as indicated by the high liquid limit. The group index values range from 1 to 12, with increasing values indicating the combined effect of increasing liquid limits and decreasing percentages of coarse material. This soil is unsuitable under 703.16.A for use as embankment material because of its elasticity.

Group A-6

The typical material of this group is a plastic clay soil usually having 75 percent or more passing the No. 200 (75 µm) sieve. The group includes also mixtures of fine clayey soil and up to 64 percent of sand and gravel retained on the No. 200 (75 µm) sieve. Materials of this group usually have high volume changes between wet and dry states. The group index values range from 1 to 16, with increasing values indicating the combined effect of increasing plasticity indexes and decreasing percentages of coarse material.

Subgroup A-6a & A-6b

Subgroup A-6a contains material with plasticity index of 15 or less. Subgroup A-6b contains material with a minimum plasticity index of 16.

Group A-7

The typical material of this group is similar to that described under Group A-6, except that it has the high liquid limit characteristics of the A-5 group and may be elastic as well as subject to high volume change. The range of group index values is 1 to 20, with increasing values indicating the combined effect of increasing liquid limits and plasticity indexes and decreasing percentages of coarse material.

Subgroup A-7-5

Includes those materials with moderate plasticity indexes in relation to liquid limit and which may be highly elastic as well as subject to considerable volume change. This soil is unsuitable under 703.16.A because of its elasticity.

Subgroup A-7-6

Includes those materials with high plasticity indexes in relation to liquid limit and which are subject to extremely high volume change.

Slag Materials (203.02.Q)

Slags are by-products from manufacturing steel or iron. Under 203.02.Q, air-cooled blast furnace slag (ACBF), granulated slag (GS), open hearth (OH) slag, basic oxygen furnace (BOF) slag, and electric arc furnace (EAF) slag that meet the requirements in 703.16 are allowed under Item 203.

Air Cooled Blast Furnace Slag

Air Cooled Blast furnace slag is a by-product from making iron. It is a very hard and durable aggregate containing visible holes. ACBF slag may have maximum dry weight of about 80 lbs/ft^3 (1280 kg/m^3), and is lighter than most soils.

ACBF slag can produce a green, yellow, white, or black runoff; the color is usually pH driven. This runoff can also smell like rotten eggs, and usually goes away in about six months (but not always). The runoff may exceed the allowable limits under the Clean Water Act.

The potential for the runoff to exceed the Clean Water Act is based on the following factors:

1. The contaminate concentration of the ACBF slag.
2. The permeability of the ACBF slag.
3. The geometry of the in-place system. ACBF slag next to an underdrain has a higher potential than ACBF slag located in a fill surrounded by clay.
4. The amount of water flowing through the system.

5. Time of contact with the slag. Stagnant water around slag increases the potential for problems.

To minimize this problem in embankment construction, ACBF slag must pass the sulfur leachate test described in Supplemental Specification 1027. The manufacturers are required to certify that their material meets this requirement. Contact the District Testing Engineer or the Aggregate Section of the Office of Materials Management to verify that the material may be used.

Further details about the potential problems can be found in Other Wastes and Environmental Considerations in Section 202 “Regulated Waste Requirements” of this manual.

Granulated Slag

Granulated Slag (GS) is a by-product of making iron or steel. GS is a slag that has been quenched with water during the cooling process instead of air-cooling. Most of the granulated slags are iron slags. If steel slags are quenched with water they may cause explosions. Steel slag has about 20 to 25 percent iron in the slag while iron slag has less than one percent. It is a very light and brittle material, almost like powder in the pre-compaction condition. After compaction, it is very hard, durable, and almost impermeable. This material sets up like concrete in service. The maximum dry weight can range from 50 to 90 lbs/ft^3.

Steel Slags

Steel slags are by-products of making steel. There are three kinds of steel slag defined in 203.02.Q: OH slag, BOF slag, and EAF slag. OH Slag is the slag that was produced mainly pre-1970. But some OH slag was made in the 1970’s. BOF and EAF slags are newer and faster processes for making steel. However, some BOF plants were in operation in the late 1950’s.

The problems associated with steel slags are worse for EAF and BOF slags than for OH slag. The process for making OH slag is slower than the other two materials. This slower process allows more of the harmful chemicals to be burnt out of the OH slag. Consequently, OH slag is a better product for embankment applications.

Some steel slags can expand, clog up underdrains, or have a high pH runoff. The specifications were written to minimize these problems. Similar to ACBF slag, the following factors were considered when writing the specification requirements:

1. The contaminate concentration (mainly MgO and CaO) of the steel slag.
2. The permeability of the steel slag.
3. The geometry of the in place system.
4. The amount of water flowing through the system.
5. Time of contact with the slag. Stagnant water around slag increases the potential for problems.
6. The load or weight on the material.

Further details can be found in Other Wastes and Environmental Considerations in Section 202 “Regulated Waste Requirements” of this manual. OH, BOF, and EAF slags may be used in embankment construction if the materials comply with Section 703.16.

Section 703.16 requires that OH, EAF, and BOF slag to be completely blended with natural soil or natural granular material. For OH slag, the blend must be at least 30 percent natural soil or natural granular materials. For BOF or EAF slags, the blend must be at least 50 percent natural soil or natural granular material.

The OH, EAF, and BOF slag must also comply with Section 703.15, which states that the aging, stockpiling, deleterious substances, and crushing requirements of 703.14 apply.

OH, EAF, and BOF slag and blends are further restricted in 203.03.E and 203.03.F. These materials must be at least 1.0 foot (0.3 m) below the underdrains to minimize underdrain clogging. These materials cannot be used underwater because of the potential pH problems.

All of the above restrictions minimize the factors that can lead to expansion, clogged underdrains, or high pH runoff problems.

Granular Embankment Material Types (703.16.C)

These materials replace the old granular embankment requirements under the 1997 specification book. The old requirements were too loose and just about any material could pass as granular material, even though it may not fit the engineering or designed need in the plans.

In 703.16.C, the following kinds of material are allowed: limestone (crushed carbonate stone or CCS), gravel, ACBF Slag, durable sandstone, durable siltstone, GS, or blended natural soil or granular materials with OH, BOF, EAF, or RPCC.

Durability requirements for sandstone and siltstone were previously covered in this manual under “Natural Granular Materials 203.02.H”. The slag requirements were also previously covered in “Slag Materials 203.02.Q” of this manual. RPCC will be covered later in this manual and must be blended similar to the slags. GS was covered earlier and is not required to have a specific gradation.

Six different gradations or types are available for use in construction. Below is a general description of these materials:

1. Type A Granular Material has less than 25 percent passing the No. 200 (75 µm) sieve.
    a. Used as a general granular material with less fines.
    b. Probably going to get sand most of the time. Sand is less expensive and widely available.
    c. Gradation is too open for bridging soft areas in the subgrade.
    d. Can be used to cover soft embankment foundations in thick lifts, such as in swamp treatment construction or with wick drains.
2. Type B Granular Material has the gradation of Items 304, 411, or 617, except 0 to 20 percent can pass the No. 200 (75 µm) sieve.

   a. Well-graded and stable material.
   b. Can be used to bridge soft subgrades or foundations.
   c. Must be drained to be effective.
   d. Unstable in the presence of free water.
3. Type C Granular Material has a top size of 3 inches (76 mm).
   a. It is well graded.
   b. Stable material and resistant to water influences.
   c. Can bridge soft areas better than Type B.
   d. Underdrains are difficult to construct through this material.
4. Type D Granular Material has a top size of 8 inches (200 mm).
   a. It is well graded.
   b. Stable material and resistant to water influences.
   c. Can bridge soft areas better than Type B or Type C.
   d. Underdrains cannot be constructed through this material.
   e. Consider placing geotextile fabric or 304 to prevent piping. (See Figures 203.J and 203.K)
5. Type E Granular Materials are very free draining and open materials.
   a. Coarse aggregates from No. l through 67 are used.
   b. Used to bridge areas that cannot be drained.
   c. Surround with geotextile (712.09, Type D) or Type B or C Granular Material to prevent piping. (See Figures 203.J and 203.K)
6. Type F Granular Material has general requirements only:
   a. Well graded material.
   b. Top size from 8 to 3 inches (76 mm) with a bottom size of No. 200 (75 µm) sieve.
   c. Evenly graded material between the top and bottom sizes.
   d. Compactable, stable, and serves the intended use.
   e. Almost never specified.
   f. Can mainly be used to accept materials that do not meet the specific Type A thru E requirements.

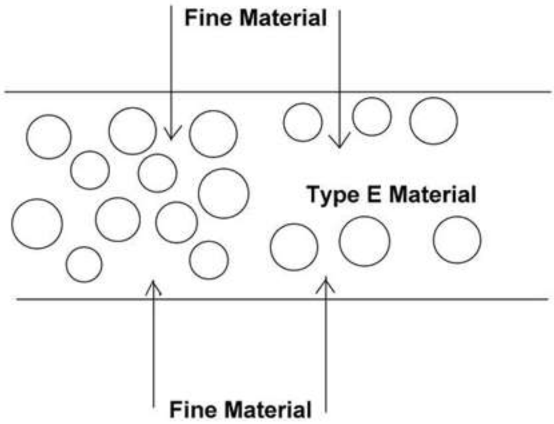


Figure 203.J – Fine Material Migration

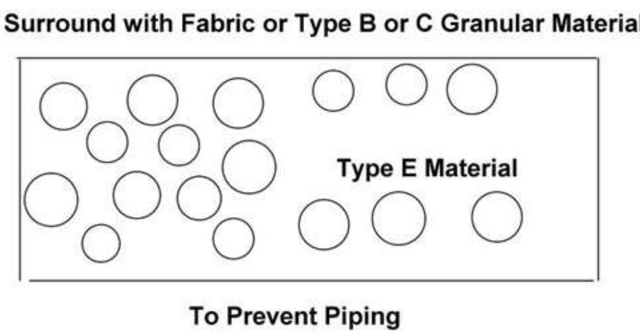


Figure 203.K – Preventing Piping

Rock (203. 02.O)

The following rock description is in the specifications: “Sandstone, limestone, dolomite, glacial boulders, brick, and RPCC too large to be placed in an 8-inch (200 mm) loose lift.” The construction of rock fills are different than the construction of soil or shale fills; therefore, it is important to clearly identify them in the field.

Rock Identification

It is important to understand the differences in these materials and to have a basic understanding or their origins.

Almost all rock in the state of Ohio is sedimentary rock. Sedimentary rock is formed by cementation, precipitation from solutions, or by consolidation.

Sandstone is a deposition of sand from rivers, wind, or oceans. This material was cemented together under earth pressure or consolidation. Coarse sandstone can be readily identified by the sand grains in the field. Fine-grained sandstone can be confused with siltstone or limestone.

Limestone is calcite formed from ocean deposits of sea organisms (seashells) that were cemented chemically and or by pressure. Chert is similar to limestone but it consists of silica minerals rather than calcite. Dolomite is limestone with magnesium and calcium carbonate.

Limestone or Dolomite can be readily identified by using a solution of diluted hydrochloric acid. When hydrochloric acid is dropped on the limestone or dolomite the acid will fizz or bubble. The amount of fizzing depends on how much calcium is in the rock. A pure dolomite may not fizz unless the fines of the rock are tested.

Rock boulders are materials brought from Canada during the glaciers and can consist of just about any stone. The amount of earth pressure or chemical crystallization greatly influences the hardness of the stone.

Almost all rock will have a ringing sound with a rock hammer. However, some punky or loosely cemented rock will not ring.

Shale (203.02.P)

By the specification shale is defined as “Laminated material with a finely stratified structure formed by the natural consolidation of soil. For the purpose of this specification, the following bed types are also considered as shale: mudstone, claystone, siltstone, and clay bedrock.”

The way we evaluate shale in the field has changed from earlier versions of the specification. In the past, shale was identified and compacted “as directed by the Engineer”. The new approach gives the Engineer a systematic approach to evaluate the shale to ensure long-term durability of the shale fill. It enables the Engineer to identify these materials and to distinguish between durable, nondurable, soft, and hard shale.

Shale Identification (703.16.D)

Shale is a sedimentary material that consists of silt or clay particles. Shale was formed when earth pressure squeezed water out of silt and clay mud. In short, shale is consolidated mud. In addition, some shale may be crystallized or cemented together into a stone like form.

The following procedure is detailed in 703.16.D. Shale is evaluated for durability and hardness as follows:

Obtain a typical 6-inch (150 mm) diameter piece of shale.

1. If it cannot be obtained because the material is too weak, weathered, or deteriorated, then the shale is soft shale.
2. Place the shale in a bucket of water. Examine the deterioration or slaking after 48 hours.
3. If the material has not deteriorated, then try to break the shale down by hand pressure. If 75 percent or less of the material is retained on the ¾-inch sieve, then the shale is soft shale. Otherwise, use a roller to perform a field test for hardness.
4. Field test for hardness as follows:
   a. Use a roller with a minimum compression of 500 pounds per linear inch (57 kN/mm) of roller drum width.
      i. Roller centrifugal force divided by the roller width.
      ii. The Contractor must provide verification of the force.
   b. Make six complete passes. Visually determine the amount of shale that breaks down.
      i. If the percentage of shale that breaks down is more than 40 then material is soft shale
      ii. If the percentage of shale that breaks down is 40 or less then material is a hard shale

Different materials will always be mixed together in a fill situation. However, this hardness or durability test will give the project a good indication of how the material should break down during compaction. It also provides a ready means to determine the test method to use for compaction acceptance. The following is a summary.

1. If less than 25 percent is retained on the ¾-inch (19 mm) sieve, then test and break down like soil.
2. If 25 to 75 percent is retained on the ¾-inch (19 mm) sieve, then break down to granular material size and compaction test the same as granular material.
3. When greater than 75 percent is retained on the ¾-inch (19 mm) sieve, use field test for hardness.
   a. If more than 40 percent breaks down under roller, then break down and test like granular material.
   b. If less than 40 percent breaks down under roller, then it is a hard durable shale. Treat it like rock and use roller passes per C&MS 203.06.

Further descriptions are detailed in Supplement 1015 “Compaction Testing of Unbound Materials” in this manual.

The following table, based on color alone, can be used for the expected general condition of shale:

Color	Expected Shale Condition
Red	always soft non-durable
Green	1/3 Soft non-durable 1/3 Hard non-durable 1/3 Hard durable
Grey	1/3 Soft non-durable 2/3 Hard non-durable

Black	1/2 Soft non-durable 1/2 Hard non-durable

Of course, this should never be used as acceptance criteria. These numbers will change depending the project location and geologic formation.

Random Materials (203.03.L)

By definition, random materials are: "Mixtures of suitable materials that can be placed in 8-inch (200 mm) loose lifts."

Other Allowed Materials under 703.16 and 203.02

Asphalt Concrete (203.02.A & 703.16)

Recycled asphalt concrete is allowed if the material is less than 4 inches and is blended with at least 30 percent natural soil or natural granular material. The mixing and maximum size requirements are used to minimize the effects of water on the asphalt consistency. Place a piece of asphalt in a bucket of water and see what happens.

In addition, this material is restricted in 203.03.A & B.

Portland Cement Concrete (203.02.M & 703.16)

Recycled Portland Cement Concrete is allowed if the material is blended with at least 30 percent natural soil or natural granular material. Additional mixing requirements are in 203.06.D when used as random material. This material is further restricted in 203.03.B, E &F. This material can clog underdrains and produce a lime rich high pH runoff similar to steel slags as discussed earlier.

Petroleum Contaminated Soil (203.02.K & 203.03.J)

The use of Petroleum Contaminated Soil (PCS) is regulated by law. The legal contamination level of this material is listed in 203.03.J.

This material is usually found around underground storage tanks. The level of contamination is so low that you may not be able to see or smell the petroleum in the soil.

Section 203.03.J requires that an environmental consultant review the proposed use and test the material. Submit the report to the Chemical Section in the Office of Materials Management for approval.

Coal (703.16)

Coal is a very lightweight material and is not very durable. It is allowed in natural embankment materials when it comprises less than 10 percent of the blend. It is impossible to keep this material out of the fill on large earthwork construction projects.

Recycled Materials (203.02.N, 203.02.R & SS-871)

The specifications define recycled materials as fly ash, bottom ash, foundry sand, recycled glass, tire shreds, or other materials or manufacturing by-products not specifically named as suitable materials in 203.02.R.

The construction and acceptance details are in Supplemental Specification 871. These materials may have levels of contamination that must be controlled and are regulated by law. Like all other materials ODOT uses, these materials are restricted and have certain engineering properties that must be accounted for in the specifications.

A general discussion of the specification is in Section 202, "Regulated Waste Requirements" of this manual. All supplemental specifications can be found on the Division of Construction Management's webpage on the Department's website.

The specification requires environmental and geotechnical approval. Submit the environmental report to the Chemical Section in the Office of Materials Management for approval. The geotechnical report and materials acceptance is approved by the Office of Geotechnical Engineering.

Figure 203.L is a typical application of recycled materials. These materials are used in the inner core of the embankment structure. This controls the chemicals leachate and minimizes the detrimental engineering properties.

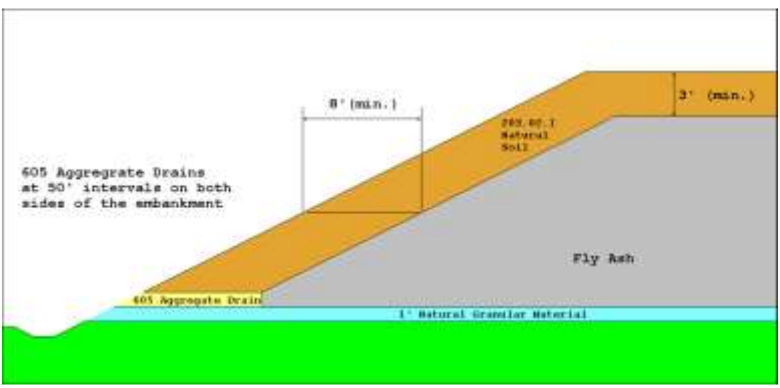


Figure 203.L – Typical Cross-Section for Recycled Materials

Figure 203.M details what can go wrong if one uses a recycled material in the wrong fashion. Read the article and be careful. Further discussion about the recycled material is beyond the scope of this manual.

Rubber roadbeds burning

Associated Press

■ Using recycled tires wasn't a good idea. The underground combustion is generating toxins such as benzene, a known carcinogen.

ILWACO, Wash. — What at first seemed like a brilliant way of getting rid of mountains of old tires has now given new meaning to the old saying about what paves the road to hell.

Two highways repaired with chunks of rubber are smoking and oozing a toxic, oily goo that is threatening nearby marshes on the Columbia River.

Digging the mess out will cost more than $1 million.

The state used the rubber from a million recycled tires in place of rock or gravel to provide 7,000 cubic feet of fill when it rebuilt a 150-foot stretch of state Route 100 here in October.

The road runs atop an embankment above Baker Bay, a pretty inlet at the mouth of the Columbia River, tucked into the little curlicue at the state's southwest tip.

The first sign of trouble came in December when asphalt pavement laid over the fill began to crack, split and give off wisps of noxious smoke, with temperatures up to 160 degrees.

Some of that buried rubber had started burning, apparently through natural processes, similar to what heats up a compost pile. And as the rubber heats up, it releases a goo that oozes to the surface and flows onto the mud flats below, dangerously close to a saltwater marsh and freshwater wetlands.

It smells like creosote, with a burned-plastic undertone.

And the underground combustion is generating toxins such as benzene, a known carcinogen, said Coast Guard Lt. Rob Myles.

Workers at the site must wear protective masks.

In southeastern Washington, a 350-foot stretch of a Garfield County road has been emitting smoke — and even flames — since January at the site of another repair job late last year that used chipped tires.

Both roads have been closed. The removal of the tires may begin as early as this week.

"They're going to go in and take the part that's burning out," said Dana Humphrey at the University of Maine.

Above-ground tire fires are not uncommon — a huge tire dump fire in Philadelphia earlier this month damaged an elevated highway that ran over the site.

But this rubber is underground, with not enough air to allow complete combustion.

See TIRES on Page 4

Figure 203.M - Tire Fire

Tires

Concluded from Page One

"There's never been a tire fire under a road. There's no history of methods to use," said Joe Zellibor, a former science adviser to the Scrap-Tire Management Council in the Rubber Manufacturers Association. His expertise is being tapped by state officials.

Route 100 leads to Fort Canby State Park, where the expedition led by Meriwether Lewis and William Clark reached the Pacific in 1805.

The cleanup is complicated because eagles are nesting nearby and by the spring migration of ocean-bound salmon fingerlings, said biologist Thom Hooper of the state Department of Fish and Wildlife. And salmon spawning will begin in about a month.

While there are concerns about the effect on the wildlife of all of the heavy equipment and people to be used in the cleanup, there's a sense of urgency because the rubber in each tire contains hydrocarbon compounds equivalent to about a gallon of oil.

"We're here because there is potential for a million-gallon oil spill," said Myles of the Coast Guard's San Francisco-based oil-spill strike team.

Humphrey, an civil-engineering professor, is completing a report on the proble[illegible]r the Federal Highway Administration, which has encouraged use of recycled-tire materials.

Lessons learned here will help with future projects, Humphrey said. About 250 million used tires are discarded each year in the United States, and "we can use up a heck of a lot of tires even on small projects," he said.

His report surveyed 70 known projects using tire-chip fill.

On Friday, state officials estimated the cost of tire removal and cleanup at $1 million to $3 million.

At Ilwaco, the recycled rubber is piled to a maximum depth of 27 feet on a 4-foot gravel bed, topped with 3 to 5 feet of soil. In Garfield County, where the repair involved a gully, the tire layer is about 45 feet deep.

It's not known exactly what is happening to the 4- to 6-inch chunks of rubber buried beneath the two roadways.

Figure 203.M – Tire Fire (continued)

Restrictions (203.03)

Section 203.03 lists materials restricted by the specifications. These restrictions ensure that the embankment structural integrity is sound in the short and long term. Keep in mind that what seems to be a good product in the field may have serious long-term consequences once in place. Many of these restrictions were detailed in the previous sections in this manual.

Many embankment materials are allowed in several locations throughout the embankment structure. These allowable material types are further restricted in the top 2 to 3 feet of the embankment to ensure long-term structural integrity of the pavement.

Some of the general reasons for these restrictions are:

1. Water accumulates under the pavement and deteriorates the material.
2. Frost causes some materials to heave and break down to smaller pieces.
3. The load or stress at this location is higher.

General Construction (203.04)

This section details general information about earthwork construction. No explanation is needed for most of this section except for the following subsections.

Drainage and Maintenance of the Work (203.04.A)

It is vital to the embankment for the Contractor to maintain a well-drained construction operation. Contractor's can provide proper drainage without an enormous effort.

Here is some relevant text from the specifications.

> *"Maintain a well drained embankment and excavation operation. ... Construct the embankment with sufficient cross-slope to drain in case of rain."*

Maintained cross slopes ensure that the rain runs off the embankment construction area instead of filtering into the embankment. It is difficult to remove water once it is in the embankment. Further embankment construction is compromised once the existing embankment is saturated.

Using a saturated embankment as a haul road can destroy the embankment structure and density. The following sentences are from the specification.

> *"If precipitation saturates the embankment construction, stay off the embankment construction until the embankment dries or stabilizes. Expedite the construction by removing the saturated embankment or dry the embankment by scarifying, plowing, disking, and re-compacting the embankment."*

The specifications continue to give the project significant leverage to use with the following passage.

> *"Throughout the embankment construction operation and at the end of each day's operation, shape to drain, compact, and re-compact the work area to a uniform cross-section. Eliminate all ruts and low spots that could hold water.*
>
> *If using embankment construction or cut areas to haul on, continuously move the hauling equipment around on the area to take advantage of the compactive effort. Continually re-grade and compact the haul roads and maintain the construction according to 105.12 and 105.14."*

Contractors will use a multitude of excuses to avoid maintaining a well-drained embankment area. Some of them are legitimate and some are not. The project will have to use common sense in evaluating them.

Staged Construction (203.04.G)

Plans will often have fill restrictions that mandate the monitoring of the fill height. The plans may call for limiting the fill construction to 3 to 5 feet a week, and may require waiting periods of 30 to 90 days.

In any case, these restrictions usually mean that the embankment will be constructed on a soft foundation. By limiting the load, it allows the foundation to consolidate slowly and allows the pore pressure to dissipate so that the embankment does not fail.

In many cases, it is required that the project monitor the fill height, pore water pressure, and settlement versus time. Figure 203.N shows such a plot.

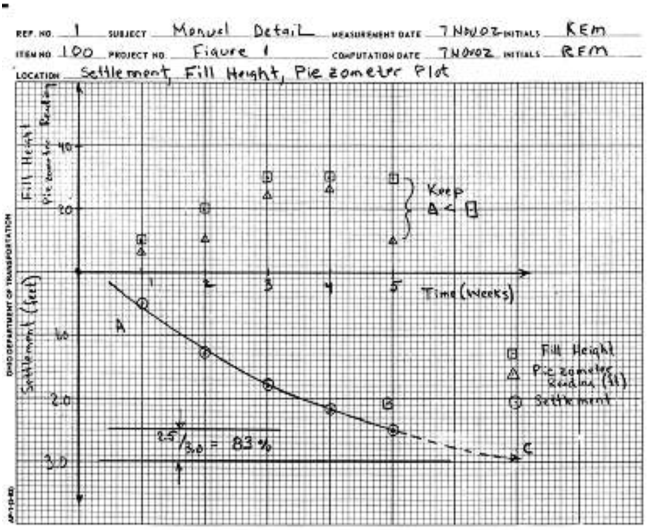


Figure 203.N – Settlement Plot

On the horizontal axis is a plot of time, usually plotted in weeks. There are three simultaneous plots on the vertical scale.

Settlement is plotted on the lower half of the drawing. The majority of plans will call for a certain percentage of consolidation or a number of days. The number of days can be waived if a certain percentage of consolidation is achieved.

A best-fit line is drawn between points A and B once the settlement is plotted. This line is then extrapolated to point C, which is the anticipated flattening point of the curve.

As an example, ODOT is asked to estimate the consolidation in week 5. The total settlement that has occurred to the 5th week is 2.5 feet. By extrapolation, the settlement is predicted to stop at 3.0 feet. Therefore the consolidation is 2.5/3.0 = 83 percent. If the required consolidation is 95 percent then more readings are required.

The designer should always give the consolidation percentage to construction personnel.

Pore water pressure and fill height may be monitored in some cases. In Figure 203.N, the fill height is 25 feet and was completed in week 3. If the pore pressure is in excess of the fill height, then stability is probably going to be a problem.

The project engineer should obtain the maximum pore water pressure from design prior to the beginning of the project. Notice in Figure 203.N that the pore pressure dissipated from week 4 to week 5.

Embankment Construction Methods (203.05)

Foundation of Embankments

If you recall from Section 201.04, scalping is not required if the fill height is greater than 9 feet (3 m) and the existing slope is 8:1 or flatter. Both conditions must apply for the areas to be left un-scalped. Figure 203.O shows the conditions when scalping is required and when it is not.

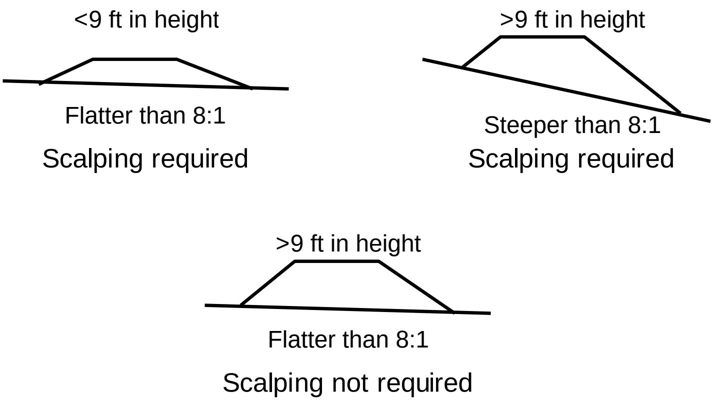


Figure 203.O – Scalping Requirements

There is a minimum compaction requirement for all foundations that require scalping. The compaction requirement is 95 percent of standard proctor or 95 percent of the test section maximum value. This minimum value is easily achieved. An alternate method may need considered if density cannot be achieved.

Soft Foundations

Foundation conditions are occasionally encountered that require treatment to obtain stability either within or beyond what is proposed in the contract documents. These soft foundation conditions do not take into account the long term settlement potential. The following details are to allow the project to correctly construct the embankment in order to ensure a stable embankment. There are two general conditions detailed below:

1. Moderately Soft Foundation.
    a. Low lying poorly drained areas with high moistures.
    b. Soil unstable due to extreme high moistures.
    c. Equipment rutting less than 12 inches (0.3 m).
    d. Elastic or pronounced elastic movement.
    e. All of the above are constructible with moderate changes.
2. Severely Soft Foundation
    a. Peat deposits.
    b. Swampy areas that contain organic soil with high moisture.
    c. Underwater conditions.
    d. Buried Equipment.
    e. Un-constructible with soil replacement.

The nature and degree of the foundation instability will vary considerably.

Moderately Soft Foundation

The first step in determining the proper treatment for a soft foundation and ensuring embankment stability is to determine and consider the following:

1. Planned embankment height above the foundation.
2. Allowed construction time frame.
3. Nature of the foundation material.
    a. Water content.
    b. Location of free water.
    c. Location of possible outlets for drainage.
    d. Extent in depth and area of unstable material.
4. Type of embankment material.

The following types of corrective measures have been successfully used for many years. Measures required to correct unstable foundations often are apparent when the cause and extent of the instability are known. The following sections consider three different moderately soft conditions that can occur during construction:

Embankment Heights Greater than 12 feet (4 m)

The higher the fill height above the foundation, the better chance the project has in bridging over soft foundation locations with very little additional expense.

Section 203.05 allows the Engineer to increase the lift thickness to bridge soft foundation locations. The specifications refer to areas that do not support the weight of the trucks or hauling equipment (areas with less than 12 inches (305 mm) of rutting or a moderately soft foundation). For areas with more than 12 feet (4 m) of fill, this method should be the first alternative utilized.

Section 203.05 allows the following technique when placing material over the soft foundation:

1. Dump successive loads of material in a uniform lift.
2. Do not exceed the lift thickness required to support the equipment placing the material.
3. Manipulate, blade, distribute, level, and doze the material until the area is stabilized.
4. Once the bridging has been accomplished, construct the remaining lifts according to 203.06.

This is standard practice in soft foundation locations. Density controls during this initial construction are not required. If the soft foundation is just wet and does not have standing water, then soil dryer than optimum may be used.

If the foundation has standing water, consider placing construction underdrains or ditches to drain the soft areas (if the area can be drained). If the areas cannot be drained then use rock, granular material, or hard durable shale in 1 to 3 foot lifts (0.3 to 1 m).

Observe the embankment stability once the bridging material is in place, and make adjustments as required. Reevaluate the conditions when the embankment is 6 feet (2 m) below grade.

Embankment Heights Less than 12 feet (4 m) but more than 6 feet

Investigate the source of the problem. Evaluating foundation conditions is similar to evaluating the condition of a subgrade. Before determining the solution, first evaluate the foundation conditions by digging test pits, evaluating the soil borings and observing the rut depth.

Use the section "The Investigation" under Item 204 of this manual, Figure 204.G Subgrade Test Pit Investigation and Figure 204.H Subgrade Treatment Chart to help evaluate the foundation.

Determine the average N, average U, and rut depth values using the above sections. Evaluating soft subgrade and soft foundations is similar with a slight variation. If the soft material is less than 2 feet (0.6 m) in depth, remove it and replace with soil.

If the average U > 0.5 tons/ft^2, average N > 5, and the rut depth is less than 6 inches (150 mm), then use an initial lift of soil that is about 1 to 3 feet (0.3 to 1 m) thick. The soil should be less than optimum moisture.

Do not use soil to bridge areas with standing water or in conditions where some embankment has already been placed as in the previous section.

If the soil conditions are worse than these values or the rut depth is more than 6 inches (150 mm), then use an initial lift thickness of 1 to 3 feet (0.3 to 1 m) of rock, granular material, or hard durable shale.

Drain the soft foundation by using construction underdrains or ditches, if the slope allows the area to be drained. Continue to evaluate the conditions when constructing the remaining fill, and adjust when required according to the next section.

Embankment Heights Less than 6 feet (2 m)

If the source of the problem has not been previously evaluated, then investigate the source of the problem as detailed in the previous section.

Determine the average N, average U, and rut depth values. Again, evaluating soft subgrade and soft foundations are similar with slight variations.

To determine the correct fix, use the Subgrade Treatment Chart in Figure 204.H and find the correct undercut depth or stabilization depth.

Subtract the fill height from the recommended undercut depth to determine the required undercut depth in the foundation. See Figure 203.P

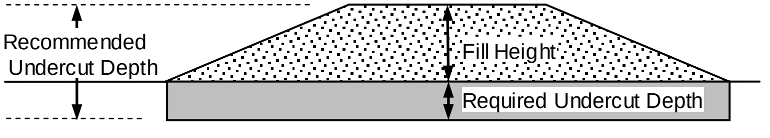


Figure 203.P – Fill Undercut Depth

Example

Given:

New Construction Project
2 feet (0.6 m) of fill
U=0.5 tons/ft^2, N=5 and Ruts > 6 inches (150 mm)
From Figure 204.H Subgrade Treatment Chart,
recommended undercut depth = 3 feet (1 m)

Solution:

Required undercut is 1 foot and place 3 feet (1.0 m) of Granular Material for the fill. As an alternative, consider stabilizing the foundation with cement or lime and then placing 2 feet (0.6 m) of stabilized soil.

Severely Soft Foundations

Severely soft foundations are conditions that cannot be constructed without using rock or granular material. These conditions usually are in standing water or even underwater. Construction equipment either gets buried in the areas or cannot operate in these locations. Peat deposits or swampy areas that contain organic soil with high moisture are the norm in these locations.

Unless these areas are called out in the plans, it is best to contact the District Geotechnical Engineer or the Office of Geotechnical Engineering to evaluate the depth and extent of the required undercut.

This section examines two different methods to remove and replace this soft material.

1. Total Excavation Method
2. Partial Excavation and Displacement Method

There will be plan notes associated with these methods. The following is a brief description of the methods of construction of these two.

Total Excavation Method

Below is a cross-sectional view of the total excavation method. This method, as the name implies, is used to where all of the soft material can be removed down to a firm foundation.

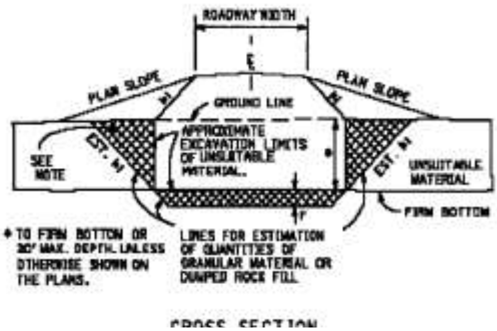


Figure 203.Q – Cross-Section View of a Total Excavation

The excavation and backfilling progresses across the soft foundation for depths up to 20 feet (6 m) deep or the reach of the track hoe. Below is a plan view of the same operation. The filling progresses at the same time as the excavation.

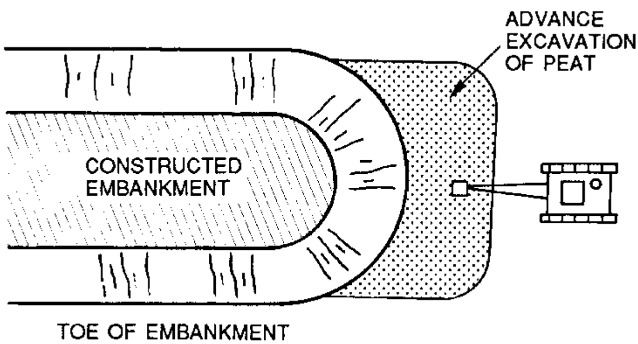


Figure 203.R – Plan View of the Filling and Excavation

Many times the excavation is performed on the same side, the embankment side, as the filling but this takes some coordination by the Contractor. Below is the longitudinal view of the same operation. The filling operation normally keeps the fill at least a foot (0.3 m) above the soft material of water level.

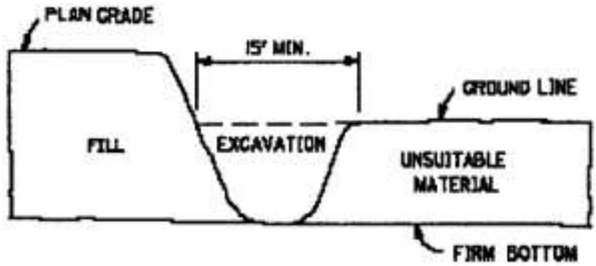


Figure 203.S – Longitudinal View of the Total Excavation

Partial Excavation and Displacement Method

At times it is economical to only remove portions of the soft foundation. The cross-section view is shown below.

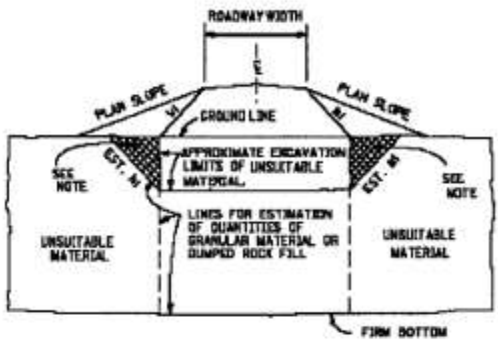


Figure 203.T – Partial Depth Removal

Below is a longitudinal view of the partial depth operation. A surcharge of material is required to displace the soft material forward as much as possible. The work needs to progress across the soft foundation such that soft material does not get entrapped in the replacement material. This is true for either full or partial depth replacement.

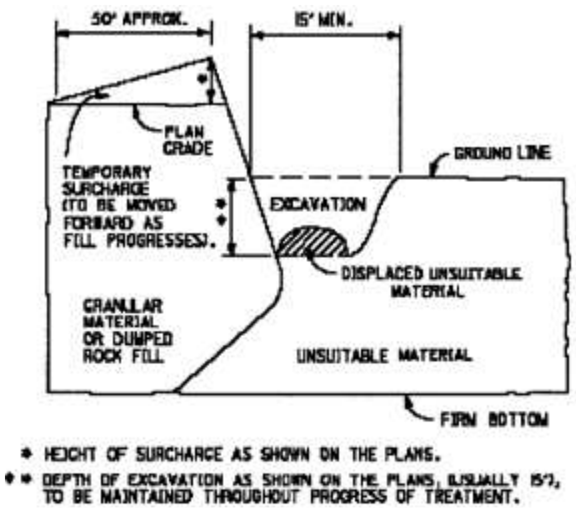


Figure 203.U – Longitudinal View of Partial Depth

In these operations, the plan will denote which method of excavation it to be used for the work. In the past, the volume of the work was very difficult to quantify. A new plan note has been developed to simplify this measurement. The designer will choose the type of replacement material to be used to replace the soft foundation material. Use a table similar to the one below to convert the weight of the replacement material to volume.

Table 203.A – Conversion Factors for Replacement Materials

Granular Materials		Dumped Rock Fill	
Type	Tons/Cubic Yard	Type	Tons/Cubic Yard
A	1.6	A	1.9
B	1.9	B	1.9
C	1.8	C	1.8
D	1.8	D	1.7
E	1.6		

The replacement material may be granular material or dumped rock fill. Prior to the material being dumped into the soft foundation, weight tickets are taken to finalize the replacement quantities estimated in the plans.

After the quantities for the replacement materials in tons are known, then this quantity is converted to cubic yards using the above table. This cubic yardage is used to determine the quantity of excavation to be paid. This simplifies the measurement of the material that normally cannot be measured directly in the field.

Materials

The material used for this operation may be granular material or rock fill types. Usually Granular Material Type C or D is used for these conditions. Dumped Rock is usually specified for depths greater than 10 feet (3.3 m). The project should check the potential for piping. See Figures 203.J and 203.K.

Disposal of Material

The unsuitable excavated material may be temporarily left in place or used for flattening adjacent slopes outside the plan lines. This material must be either shaped into the final slope or disposed of 2 weeks prior to paving the project.

Consolidation Method

There is another method to bridge a soft foundation. It is the consolidation method. It was mentioned in Section 203.04.G. It is beyond the scope of this manual but a typical cross-section is presented below.

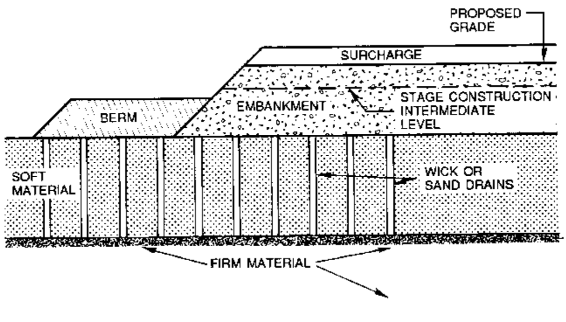


Figure 203.V – Consolidation Method

A layer of sand is placed to bridge over the soft foundation usually around 3 feet thick. Wick drains are then placed through the foundation soils. These wick drains allow the pore pressure to dissipate faster as the fill is constructed.

Benching

Beginning with the 2002 C&MS, the language was more explicit than in the previous versions of C&MS. This new language was put in C&MS to ensure that benching is properly performed in the field. Figure 203.W details where benching is required. Benching is required for all embankments placed on or against a slope steeper than 8:1. Of course, the existing slope has to be scalped first. This applies on all embankment areas whether the existing embankment cross slope is in the transverse or the longitudinal direction.

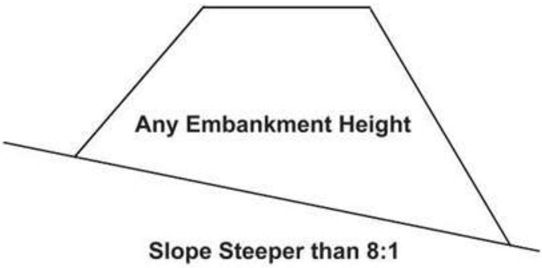


Figure 203.W – Benching Required

Figure 203.X details the bench into the existing embankment. For side hill fills, the existing embankment is physically notched out and connected to the new embankment. Benching requires horizontal cuts in the existing slope.

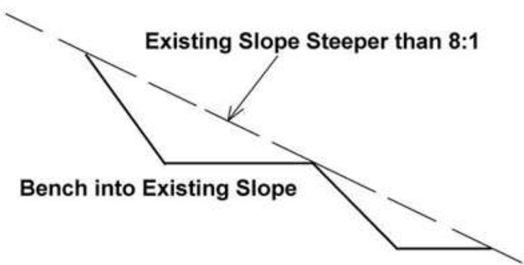


Figure 203.X – Benching

The bench needs to be wide enough to blend the new embankment with the existing embankment. In Figure 203.Y, the total width between point A and B must be the width of the dozer blade and the compaction equipment.

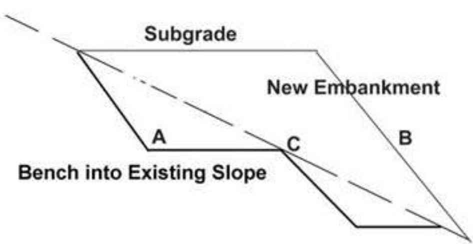


Figure 203.Y – Benching in New Embankment

If the plan calls for a new embankment, or the distance between C and B is less than a blade width or about 8 feet, then the existing embankment must be benched in the difference or a of distance A and C.

In Figure 203.Z, the horizontal distance between points D and E is about 4 feet (1.3 m). Therefore, the existing embankment must be benched into for about 4 more feet (1.3 m) to complete the bench.

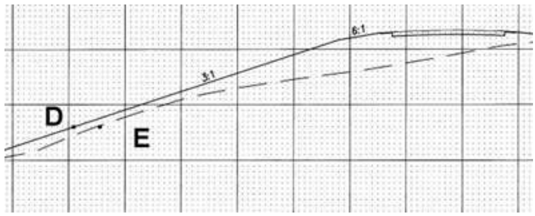


Figure 203.Z – Sliver Fills

Bench into the slope as the embankment is placed, and compact into layers. Begin each bench at the intersection of the existing slope and the vertical cut of the previous bench. The re-compaction of the cut materials is required.

Benching is nothing more than a side hill foundation. Benching knits two embankments together to ensure that a failure plane does not occur. Figure 203.AA details typical benching seen on some plans.

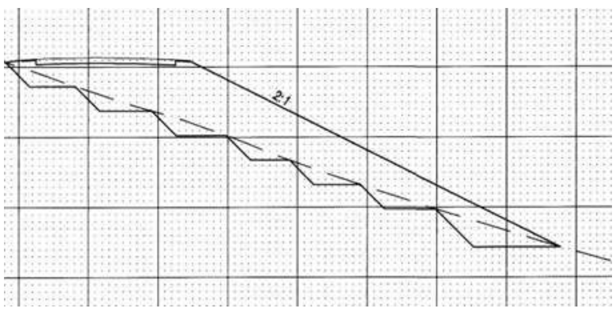


Figure 203.AA – Typical Benching

In this case, the designer anticipated that there was a stability problem or weak soils in the existing embankment (or both). This is called special benching.

Side hill embankments present unique problems in that they may be stable when originally constructed yet become unstable later. The result is usually a landslide.

If the bench is not benched into the existing embankment far enough then a weak plane can develop as shown in Figure 203.BB. A failure may occur along this weak plane and the bench material will move laterally. The project should evaluate the existing soil conditions and determine if more benching is required than shown on the plans or required by the specifications.

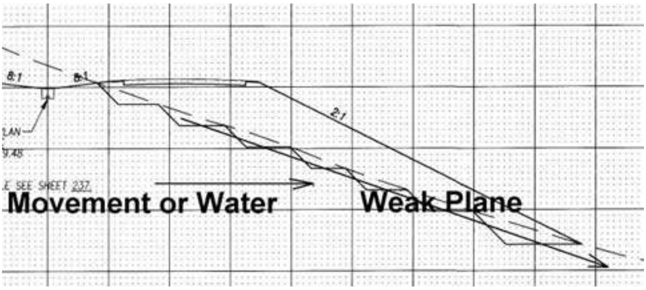


Figure 203.BB – Benching Problems

Bench Drainage

In many cases, the main cause of an embankment benching failure is water related. Seeping water into the embankment from the side hill or foundation can cause considerable instability in the existing and the new embankment. Water is an elusive quantity to capture during the design phase because of many factors. Notice in Figure 203.BB how water can move into the bench material and weaken the bench material.

Special attention must be given to side hill embankments. Consult the plans and soil profile to see where special benching, if any, is required; to see whether or not spring drains are provided, and to see if any potential spring or wet zones are mentioned. The areas should be inspected in detail for possible springs. In dry seasons, green or lush vegetation are often indicative of a semi-dormant spring that may become active during prolonged periods of precipitation. If spring zones are encountered and no spring drains are provided in the plans, then drains should be added to the work.

If there is any indication of water, then drainage should be added if it is not detailed in the contract. The following pages detail some typical solutions to use in the field.

Spring drains are detailed on the plans by plan note D109 and on the second sheet of Standard Drawing DM 1.1. Plan note D109 can be found in Location & Design Manual – Volume 2, *Drainage Design*. Links to the Location & Design Manuals and the standard drawings can be found on the Design Reference Resource Center on the Department's website.

The standard drawing is partially shown in Figure 203.CC. The standard drawing does not call for it but it is recommended to use non-perforated pipe outside the #57 stone and perforated inside the #57 stone. Wrap or coil the pipe inside the #57 stone for maximum efficiency. Completely wrap the #57 stone with Type A geotextile fabric. In many cases #8 stone can be substituted for the #57 stone without sacrificing much drainage capacity and it also reduces the risk of piping. The application of a spring drain is for local wet spots.

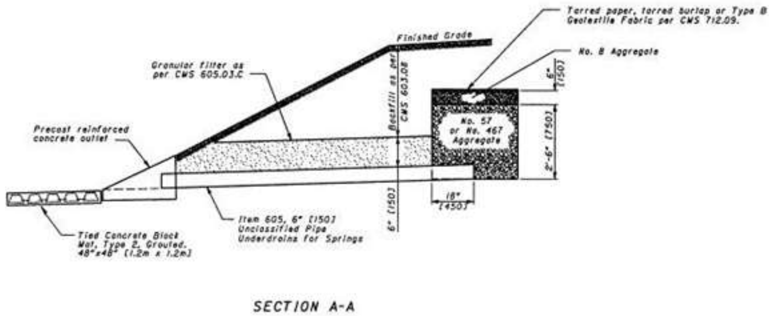


Figure 203.CC – Spring Drains

Severe Bench Drainage Problems

Drainage always should be added when the benching embankment is placed next to a rock or shale cut. In this case, add drainage along the entire length and width of the shale/rock benching interface. Experience has shown that water always leaches from this interface. In addition, if a large quantity of water is coming into the bench or water is leaching from several locations and elevations then drainage should be added across the entire bench face. In both examples above a different approach needs to be taken because of the severity of the water issue. There are two potential solutions to the severe drainage problems.

Adding Drainage when Benching from the Top Down

If the slide repair benching plan has 1 to 1 back slopes and consists of minimum 10 foot wide and high benches and the slope can be excavated from the top of the cut all the way to the bottom then the following drainage should be considered.

The use of geotextile fabric and #8 stone as detailed in Figure 203.DD to take the water flow is one solution to solve the drainage issue. The geotextile is used to stop the migration of fines into the #8 stone. Notice that the geotextile fabric is used on both sides of the #8 stone to prevent migration from either side.

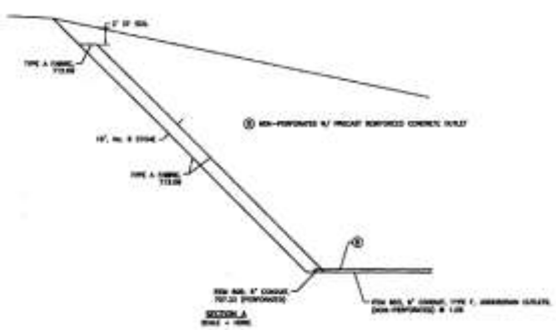


Figure 203.DD – Severe Water Problems in a Bench

The geotextile fabric that is generally used is 712.09 Type A geotextile. The drainage aggregate can be number #8, #9 or #89 size. The drainage pipe going into the page is a 6-inch Item 605, 707.33 perforated pipe. The lateral drain is a 6-inch Item 603 Conduit Type F non-perforated. This lateral drain backfill should be surrounded by at least 12 inches (300 mm) of sand. This will provide a secondary outlet if the pipe gets clogged.

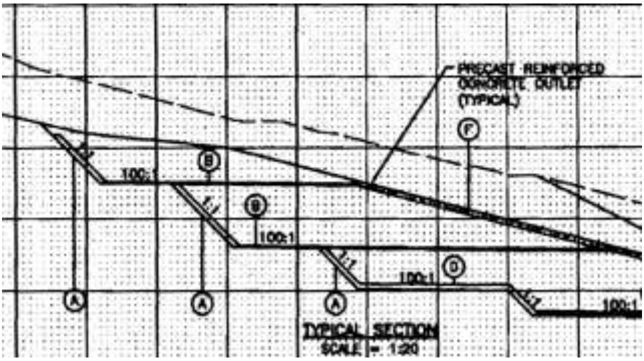


Figure 203.EE – Multiple Bench Layout

These benches can be interconnected and outlet as detailed in Figure 203.EE. Section A is the #8 stone and the geotextile fabric. Section B is the non-perforated pipe with an outlet to Section F. Notice that the bench and the pipe are outletted using a one percent grade or 100:1 slope. This ensures that the water can effectively be removed from the system without leaching into the soil mass.

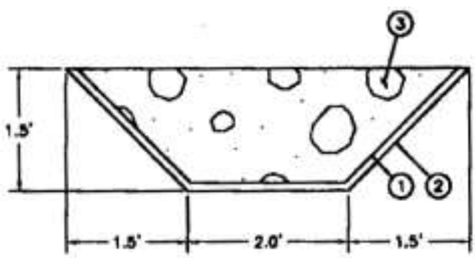


Figure 203.FF – Detail for outlet F

Figure 203.FF details the outlet configuration. The balloon number 2 is a 20 mil plastic to prevent the water from entering the soil along the slope. Balloon number one above details 712.09 Type D geotextile fabric that serves to protect the plastic from getting torn during the rock installation. The balloon 3 details the Rock Channel Protection. In this case the rock type was Type C. This rock type should be used in most cases.

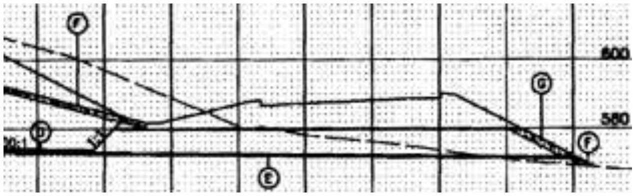


Figure 203.GG – Lower Bench Outletting

Figure 203.GG details the lower benching. In the above slide repair, the lower embankment was existing and did not require reconstruction. But the lower benches needed to be drained. The bench and pipe drainage into the page of the cross-section was sloped at a one percent grade. The slope of the outlet E from left to right is sloped at a one percent grade. The outlet pipe excavation was about 20 feet deep. This is a high risk operation during construction. This construction can be done without trench boxes or laying back the slope if necessary. The trench is excavated in maximum 50-foot lengths. The pipe is jointed together above ground and dropped into the hole. Grade is kept by conventional methods or by GPS. In this case, sand is dumped in the trench up to an elevation 580. The sand should be hoe rammed in place in thick lifts. Compaction requirements are secondary in this case to the ability to keep the trench from collapsing. Keep the open trench as small as possible and no personnel are to enter the trench during these operations.

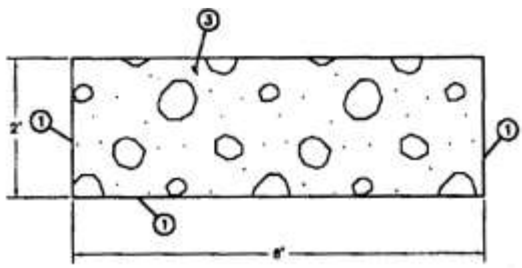


Figure 203.HH – Detail for Slope Protection G

After the outlet is constructed, the outer slope will be sand for about 6 feet wide. Detail G in Figure 203.HH, details the erosion protection required. A 712.09 Type D geotextile is placed under Type C Rock Channel Protection. The width of the material should be the width of the sand.

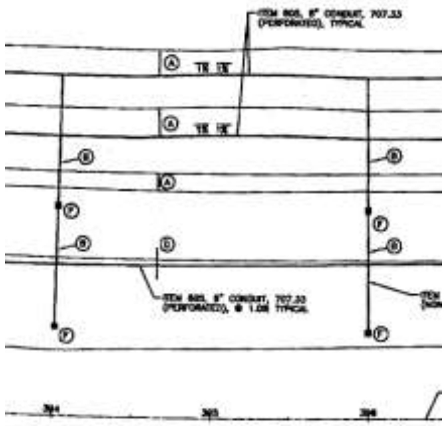


Figure 203.II – Top View of the Drainage

Figure 203.II details the plan view of the drainage pattern in the slide repair. You will notice that the outlets are spaced at 200 feet intervals and that the benches are sloped at a one percent grade toward them. Notice that the high point on the bench is 100 feet from the outlets and goes in both directions toward the outlets.

When the benching cannot be performed from the top down or the benches are small another method of adding drainage to the benching plan needs to be considered. Figure 203.JJ, shows adding a 20 foot drainage trench to drain an upper unstable slope(to the left) and to prevent the embankment from becoming saturated. The drainage into the page is sloped at a one percent grade.

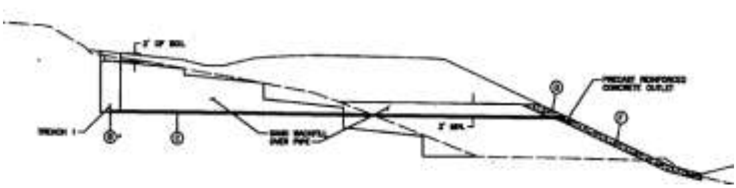


Figure 203.JJ – Using Trenching and Sand

Since this trench is around 20 feet deep it is a high risk operation during construction. This construction can be done without trench boxes or laying back the slope if necessary. The trench is excavated in maximum 50 feet lengths. By keeping the trench length to a small interval it minimizes the potential for collapse or upper slope damage. The pipe is jointed together above ground and dropped into the hole. Grade is kept by conventional methods or by GPS. Sand is dumped in the trench up to about 3 feet below ground level. The sand should be hoe rammed in place in thick lifts. Compaction requirements are secondary in this case to the ability to keep the trench from collapsing.

In Figure 203.KK below, the above trenching technique is expanded to drain the entire counter berm. The drainage at the toe is provided by the rock fill while the three trench drains to the left drain at third point intervals along the existing new fill interface. The center two sand drains are placed at the interface of the existing ground and the new embankment. The construction of the middle two sand drains is slightly different than the other sand drain but only slightly. The embankment is constructed to the top elevation of the sand trench. Then the sand trench, pipe and outlets are constructed as previously described.

The sand that is generally used for these operations is asphalt, concrete or masonry sand. There is a possibility that the soil will pipe into the sand or the soil will clog the sand. The possibility of this happening is considered a small risk and is beyond the scope of this manual.

In Figure 203.JJ, the pipe in section B is perforated and wrapped with geotextile fabric to prevent the sand from piping in the pipe.

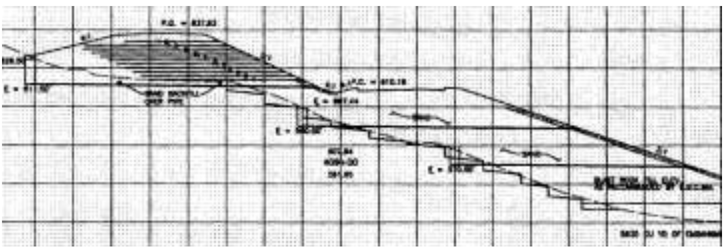


Figure 203.KK – Multiple Benching with Sand

Figure 203.LL details the plan view of the drainage system. It is basically the same as detailed previously. The outlets are spaced at every 200 feet and everything drains at a one percent slope.

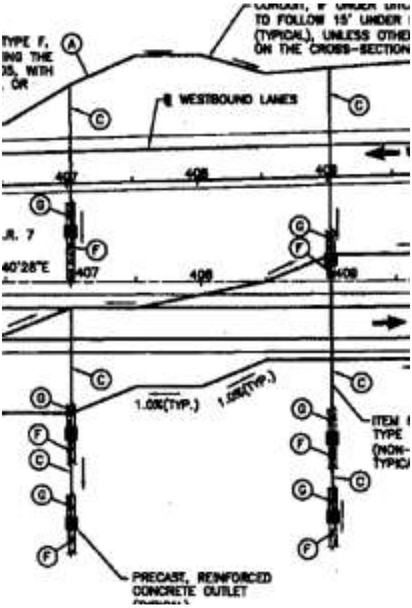


Figure 203.LL – Plan View of Drainage

Spreading and Compacting (203.06)

This section covers a general description of spreading and compacting materials. A more detailed explanation can be found in Section 1015 "Compaction Testing of Unbound Materials".

The procedures outlined in this section will make or break the quality of the earthwork construction. Control over the lift thickness and compaction of the materials is vital to the success of the project.

Certain materials require compaction at thinner lifts than others to obtain their maximum strength. Other materials can be compacted in thicker lifts without sacrificing quality. Some materials require the addition of water to help in the compaction effort or to help break down the material, while other materials require mixing to get the desired results.

All embankment materials, except for rock in 203.06.C. and RPCC in 203.06.D, are spread in horizontal loose lifts not exceeding 8 inches (200 mm). All embankment material lifts, except for rock and hard, durable shale, are compacted to a specified density and moisture requirements in 203.07.

The material is spread using dump trucks, scrapers, and dozers. In general, a sheepsfoot or tamping foot roller is used to compact rock, shale, clay, and silt material. Granular materials are generally compacted using a smooth drum vibratory roller.

To record the embankment construction operations an inspection sheet was created to help document the work. The CA-EW-12 Daily Earthwork Inspection Sheet is required to be filled out for all filling operations according to Supplement 1015. There are several sections to check off on the form that denote project information, location of the work, type of equipment used and embankment operation information. With this form, it should make it easier for the earthwork inspector to determine what the minimum inspection requirements are during the earthwork operations.

The four methods used for compaction acceptance are proctor testing, test section method, aggregate correction method, and roller pass method.

Soil and Granular Embankment (203.06.A)

Use a maximum lift thickness of 8 inches (200 mm) for soil and granular embankment. Soil compaction acceptance is based on the proctor testing, test section method, or aggregate correction method. Granular material compaction acceptance is based on the test section method.

These methods are covered in the “Compaction Testing of Unbound Materials” Section 1015 of this manual.

Shale (203.06.B)

Shale is consolidated mud. Shale may seem hard but in many instances it can be broken down to soil size with very little effort. See 203.02.P and 703.16.D in this manual for a full description of the material.

Some hard, durable shale can be excavated or blasted in very large sizes. Contractors control the size of the material by the way they blast the material. During the typical rock blasting operation, the bench height/burden (L/B) ratio is greater than one, the production hole spacing (S) is 10 to 15 feet (3.3 to 5 m), and the production hole diameter (D) is 6 inches (150 mm). These dimensions are typical in order to maximize production. In addition, it generally leaves large chunks of rock or shale. These large pieces are fine for rock fills but are not conducive to shale fills.

To produce smaller shale or rock fragmentation, the blaster can increase the L/B to about 3, decrease S to 6 to 8 feet, and reduce the D to about 4 inches (100 mm). These dimensions are changed in a trial and error method. The most efficient method depends on the shale and rock formations.

If the Contractor does not control the material size during the excavation or blasting, then the amount of spreading, manipulation, compacting and watering will be extensive to get the material in 8-inch (200 mm) lifts.

All shale material is placed and compacted in 8-inch (200 mm) lifts. If the material is placed and compacted in thicker lifts then a situation such as in Figure 203.MM can happen. Loose and non-durable shale intermixed within the lift can deteriorate later when water runs though the system.

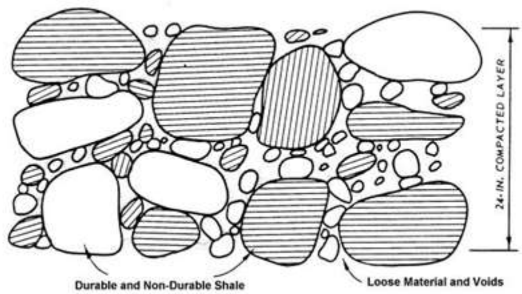


Figure 203.MM – Thick Lift of Shale

In many cases, when thick lifts are used, the compaction in the top 8 inches (200 mm) may pass. If the top 8 inches (200 mm) is removed, the lower material is made of loose and large chunks of soft shale.

Figure 203.NN details what happens when shale is not properly placed and broken down. The embankment load on the shale along with the water going through the embankment causes the soft shale to break down.

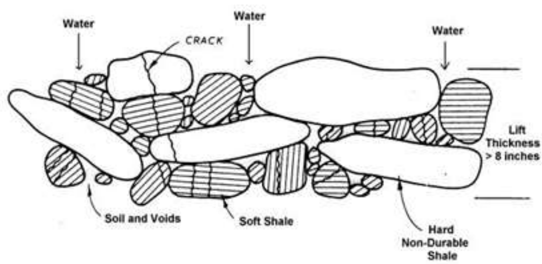


Figure 203.NN – Inadequate Shale Compaction and Breakdown

In order to ensure long-term durability, the project needs to determine how much to break the shale down in the field. The amount of breakage during construction is directly related to the durability and hardness of the shale. The hardness and durability are correlated to the bucket test and roller pass methods in the specifications.

The specifications require that the shale be tested for compaction and broken down according to the bucket test and the subsequent roller pass evaluation.

A summary of this evaluation follows:

1. Perform initial test for hardness in 703.16.D (Bucket Test).
2. Consult the following:
    a. If less than 25% retained on ¾-inch sieve then shale should be broken down to soil size.
    b. If 25% to 75% retained on ¾-inch sieve then, an even percentage of soil, small-, and coarse-sized shale is obtained (maximum contact with all particles). Shale should have a

granular texture when properly broken down in the field (see Figure 203.OO).
   c. If more than 75% retained on ¾-inch sieve then field test for hardness (703.16.D).
3. Use six passes with rollers specified in 703.16 to field test for hardness.
4. Consult the following:
   a. If greater than 40% breaks down then break material into a granular texture as detailed in Figure 203.OO.
   b. If 40% or less breaks down then use the procedure in Section 203.06.B in C&MS (Hard Durable Shale): 10 passes with a 15-ton roller, and fill the voids.

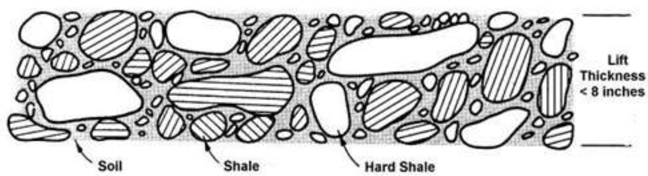


Figure 203.OO – Granular Texture Shale

The above procedure is a systematic approach to evaluating potential shale breakage in the field. In practice, field results will vary because of variability of shale and the mixing of different types of shale and rock. Some judgment is required by the project during construction.

The most important factors in the long-term quality of shale fills are:
1. Water shale until the material is at least 2 percent above optimum moisture throughout the lift.
2. Manipulate or mix by dozing until a maximum 8-inch (200 mm) loose lift is achieved. Remove large chunks of shale or rock that exceed this lift thickness.
3. Compact each lift to a maximum density, except for hard durable shale. Use 10 passes with a 15 ton roller in 203.06.B for hard durable shale.
4. Typically about 5 to 10 passes are sufficient for shale compaction.

Rock (203.06.C)

Maximum loose lifts are as follows:
1. Six inches larger than the largest rock piece with a maximum lift thickness of 3 feet (1 m). Some examples follow for clarification.
   a. The maximum rock size in a 3 foot lift is 2.5 feet.
   b. If the largest rock size in a lift is 1 foot then the maximum lift thickness is 1.5 feet.
2. Near Bridges, within a length of 6 times the height of the fill at the abutment. Use less than 18-inch (0.5 m) lifts.
   Example: Fill height is 20 feet (6 m), so within 120 feet of abutment.
   (20 × 6 = 120 feet)

The rock fill construction is outlined below:

1. Distribute full width of the lift.
2. Evenly distribute the larger rocks.
3. Reduce the voids.
4. Place the smaller rock in the upper portion of the lift.
5. Compact with 8 passes of a 10 ton (9 metric ton) roller.

When using other embankment materials with rock, use rock as:

1. Base of the embankment. It provides better support.
2. On the outer portions of the embankment. It provides better drainage.
3. Place the larger rocks on the outside side slopes. It provides better drainage.

Use other embankment material as follows:

1. On the inner portion of the fill.
2. Keep the top higher than the rock.
3. Construct wide enough for compaction.
4. When rock is on top of other embankment material, construct at a side slope grade of 4 percent prior to placing the rock. This provides better drainage.

When the rock fill contains more than 15 percent shale, then compact like a shale fill.

Random Material (203.06.D)

Random materials are a wide variety of materials which do not fit any other groupings. They may be rock mixed with soil, brick, asphalt mixed with soil, or Portland cement concrete mixed with soil.

Soil mixed with any other random material must be at least 2 percent below optimum. This will help fill the voids and create a stable embankment.

Recycled asphalt or concrete are mixed with at least 30 percent natural materials.

Random material mixtures are placed in 8-inch lifts, except for RPCC:

1. Maximum size of the RPCC is less than 3 × 3 feet (1 m).
2. The mix is dozed and mixed to fill the voids.
3. Lift thickness is less than 12 inches (300 mm).
4. Use 18-inch lifts (0.5 m) when the lift is more than 50 percent RPCC.
5. Compact the natural material to a test section maximum.

Compaction and Moisture Requirements (203.07)

Except for granular material types D and E, rock and hard, durable shale, the moisture and density controls in this section apply. The Department will perform all compaction tests according to Supplement 1015. This supplement is detailed in Section 1015 “Compaction Testing of Unbound Materials” of this manual.

Moisture Controls (203.07.A)

Water is added or subtracted to a condition to obtain the density and stability. Dry or add moisture throughout the lift. Expedite and manipulate the material by using plows or discs. For soils with pronounced elasticity or deformation, reduce the moisture content to ensure stability.

In a fill situation without a soft foundation, heavy equipment may deflect the soil but no permanent rutting or cracking should be evident afterwards.

Some soils require moisture contents 5 percent below optimum to ensure stability. Materials such as A-4a, A-4b, and A6a's are notorious for this problem. These materials are difficult to compact during marginal weather conditions and just after a rainy day.

The elasticity may be caused by foundation conditions. See Materials 203.02, "Elasticity and Deformation of Soils" in this manual.

Do not mix shale in the lifts to reduce the moisture content. The shale will bring the moisture down then break down later causing settlement or a landslide.

Compaction Requirements (203.07.B)

Table 203.07-1 details the "Embankment Compaction Requirements". The percentage is based on the maximum dry weight of the soil. This table is used for materials tested using proctor testing or aggregate correction testing methods.

Table 203.07-1 – Embankment Compaction Requirements

Max. Dry Weight (lb/ft^3)	Minimum Percent Compaction
90 to 104.9	102
105 to 119.9	100
120 and more	98

Test sections are required for granular materials and other materials. If test section results are used then the following apply:

1. Use at least 98 percent of the maximum value obtained in the test section for acceptance in the production area.
2. Use the same number of passes used in the test section for the production areas. Reduce the number of passes if detrimental to the compaction.
3. Construct a new test section when the material or supporting foundation changes.
4. Reduce the moisture content if the material becomes unstable.

More detail is in Supplement 1015 "Compaction Testing of Unbound Materials" in this manual.

Method of Measurement (203.09)

This section of the manual is intended to give a brief outline of some of the methods to determine earthwork quantities. Methods described in this section are acceptable for making this check. Many of these methods are outdated because of GPS systems but they are still presented.

Specification Requirements

The specifications require that the average-end-area method be used to determine volumes of earthwork for payment.

End Area Determinations

There are many acceptable methods for determining end areas for earthwork computations. Any method that gives accurate determinations may be used. Some of the most common methods for determining cross-section end areas are as follows:

Planimeter

In this method, an instrument with a wheel and a graduated dial is run around the perimeter of a cross-sectional end area. The area is found by multiplying the reading on the dial by a constant factor or by setting a factor on the planimeter and by reading the area directly from the planimeter dial.

Counting Squares

In this method, the number of unit squares in a section is counted. This is not practical except for very small sections.

Stripping

This is a method of tallying unit squares by making successive marks on a strip of paper to measure unit strips, accumulating all unit strips on a cross-section, and converting to total cross-section area. This method is simple and rapid and keeps the chance of error to a minimum.

Computer Method

In this method, data from cross-sections (usually in coordinate form) is input into a computer program, which follows a program setup to finish areas and volumes.

CAD

Most plans are developed using computer aided design (CAD) programs. In these files, the earthwork calculations are detailed. Contact Production for these calculations.

Geometric Method

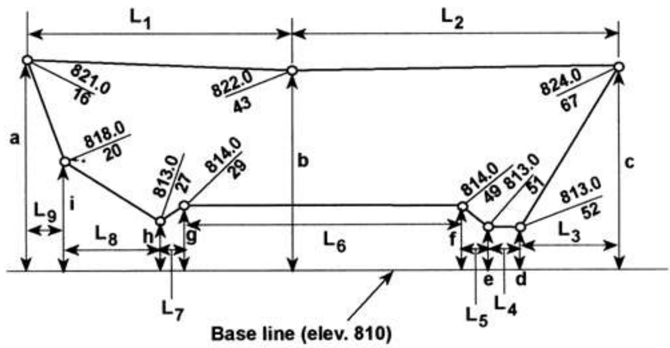
In this method, the section is broken into areas, such as triangles and trapezoids. Each area is then calculated by its geometry. The total area is found by summing the individual areas.

Arithmetic Calculation

This method calculates end area using a formula. Data for the formula is taken from a cross-section (or field notes) showing elevation and distance from a base line for each break in the cross-section line. A pocket calculator can be used for this calculation.

Determination of cross-section end areas by this method is exact and any two persons using the same information (field notes) will obtain the same answer, providing no errors are made in the calculator manipulation or arithmetic calculations. There is only one correct answer.

The two methods are described and illustrated in Figures 203.PP and 203.QQ.



Procedure: Select a base line either at or below the lowest elevation of the cross section. The equation for the area of the cross section for this example is as follows:

$$\textit{Exact Area} = L_1\frac{[a+b]}{2} + L_2\frac{[b+c]}{2} - L_3\frac{[c+d]}{2} - L_4\frac{[d+e]}{2} - L_5\frac{[e+f]}{2} - L_6\frac{[f+g]}{2} - L_7\frac{[g+h]}{2}$$
$$- L_8\frac{[h+i]}{2} - L_9\frac{[i+a]}{2}$$

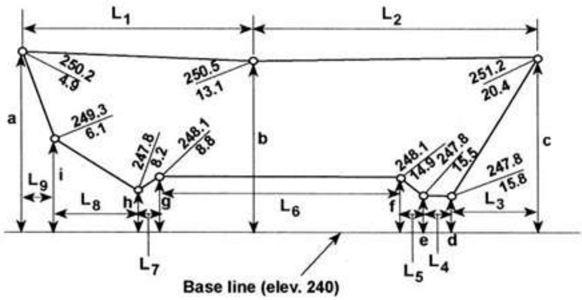
Using a base line of 810.0 the area is:

$$27\,\frac{[11+12]}{2} + 24\,\frac{[12+14]}{2} - 15\,\frac{[14+3]}{2} - 1\,\frac{[3+3]}{2} - 2\,\frac{[3+4]}{2} - 20\,\frac{[4+4]}{2}$$
$$-\,2\,\frac{[4+3]}{2} - 7\,\frac{[3+8]}{2} - 4\,\frac{[8+11]}{2}$$

Or: Exact Area = (27 x 11.5) + (24 x 13) - (15 x 8.5) - (1 x 3) - (2 x 3.5) - (20 x 4)

- (2 x 3.5) - (7 x 5.5) - (4 x 9.5) = $\boxed{\text{321.5 sq. ft}}$

Figure 203.PP – End Area Determination Method 1



Procedure: Select a base line either at or below the lowest elevation of the cross section. The equation for the area of the cross section for this example is as follows:

$$Exact\ Area = L_1\frac{[a+b]}{2} + L_2\frac{[b+c]}{2} - L_3\frac{[c+d]}{2} - L_4\frac{[d+e]}{2} - L_5\frac{[e+f]}{2}$$

$$- L_6\frac{[f+g]}{2} - L_7\frac{[g+h]}{2} - L_8\frac{[h+i]}{2} - L_9\frac{[i+g]}{2} =$$

Using a base line of 810.0 the area is:

$$= 8.2\ \frac{[10.2+10.5]}{2} + 7.3\ \frac{[10.5+11.2]}{2} - 4.6\ \frac{[11.2+7.8]}{2}$$

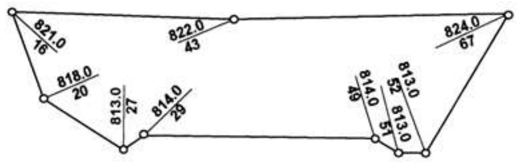
$$- 0.3\ \frac{[7.8+7.8]}{2} - 0.6\ \frac{[7.8+8.1]}{2} - 6.1\ \frac{[8.1+8.1]}{2} -$$

$$- 0.6\ \frac{[8.1+7.8]}{2} - 2.1\ \frac{[7.8+9.3]}{2} - 1.2\ \frac{[9.3+10.2]}{2}$$

$$= 8.2\ (10.35) + 7.3\ (10.85) - 4.6\ (9.5) - 0.3\ (7.8) - 0.6\ (7.95) - 6.1\ (8.1)$$

$$- 0.6\ (7.95) - 2.1\ (8.55) - 1.2\ (9.75) = \boxed{29.43\ m^2}$$

Figure 203.PP-M – End Area Determination Method 1 (Metric)



Procedure: Select the starting point, normally at the extreme left, and list the plotted coordinates in counter-clockwise sequence. For this example:

$$\frac{21}{16} \quad \frac{18}{20} \quad \frac{13}{27} \quad \frac{14}{29} \quad \frac{14}{49} \quad \frac{13}{51} \quad \frac{13}{52} \quad \frac{24}{67} \quad \frac{22}{43} \quad \frac{21}{16}$$

Multiply and accumulate the products of the denominator and the adjacent numerator to the right as follows:

(16 x 18) + (20 x 13) + (27 x 14) + (29 x 14) + (49 x 13) + (51 x 13)

(52 x 24) + (67 x 22) + (43 x 21) = <u>6257 sq. ft.</u>

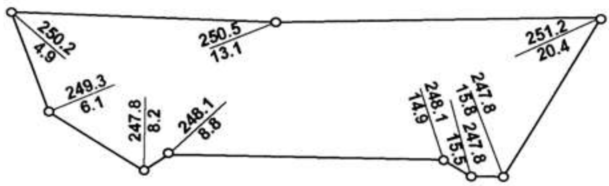
Multiply and accumulate the products of the denominator and the adjacent numorator to the left as follows:

(16 x 22) + (43 x 24) + (67 x 13) + (52 x 13) + (51 x 14) + (49 x 14)

+ (29 x 13) + (27 x 18) + (20 x 21) = <u>5614 sq. ft.</u>

$$\textit{Exact Area} = \frac{6257 - 5614}{2} = \boxed{321.5 \textit{ sq. ft.}}$$

Figure 203.QQ – End Area Determination Method 2



Procedure: Select the starting point, normally at the extreme left, and list the plotted coordinates in counter-clockwise sequence. For this example:

$$\frac{50.2}{4.9} \quad \frac{49.3}{6.1} \quad \frac{47.8}{8.2} \quad \frac{48.1}{8.8} \quad \frac{48.1}{14.9} \quad \frac{47.8}{15.5} \quad \frac{47.8}{15.8}$$

$$\frac{51.2}{20.4} \quad \frac{50.5}{13.1} \quad \frac{50.2}{4.9}$$

Multiply and accumulate the products of the denominator and the adjacent numerator to the right as follows:

4.9 (49.3) + 6.1 (47.8) + 8.2 (48.1) + 8.8 (48.1) + 14.9 (47.8) + 15.5 (47.8)

+ 15.8 (51.2) + 20.4 (50.5) + 13.1 (50.2) = 5300.75

Multiply and accumulate the products of the denominator and the adjacent numorator to the left as follows:

4.9 (50.5) + 13.1 (51.2) + 20.4 (47.8) + 15.8 (47.8) + 15.5 (48.1)

14.9 (48.1) + 8.8 (47.8) + 8.2 (49.3) + 6.1 (50.2) = 5241.89

$$\textit{Exact Area} = \frac{5300.75 - 5241.89}{2} = \boxed{29.43\ m^2}$$

Figure 203.QQ-M – End Area Determination Method 2 (Metric)

Volume Determination

The end areas of English plans are detailed in square feet (ft^2), while end areas on metric plans are detailed in square meters (m^2). Make the appropriate volume calculation shown below using the end area found in Figure 203.PP or 203.QQ.

Formula

For base lines and center lines on tangent, and for center lines on curves where the center line of the curve coincides with the center of mass (centroid) of the cross-sections, the formula for computing volume from end areas are as follows:

English Units

$$V = \left(\frac{A_1 + A_2}{2}\right) \times \frac{L}{27}$$

Where

V	=	volume in cubic yards (yd^3)
A_1	=	cross-section one end area in square feet (ft^2)
A_2	=	cross-section of other end area in square feet (ft^2)
L	=	distance between A_1 and A_2 in feet (ft)

Metric Units

$$V = \left(\frac{A_1 + A_2}{2}\right) \times L$$

Where

V	=	volume in cubic meters (m^3)
A_1	=	cross-section one end area in square meters (m^2)
A_2	=	cross-section of other end area in square meters (m^2)
L	=	distance between A_1 and A_2 in meters (m)

Table

Figure 203.RR shows a table for use in determining cubic yards (yd^3) from the sum of end areas for sections 100 ft. apart, and for conditions described above. This table cannot be used on metric projects.

CUBIC YARDS FOR SUM OF END AREAS

LENGTH OF PRISM 100 FEET

C.Y.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	C.Y.
0	0	54	108	162	216	270	324	378	432	486	540	594	648	702	756	810	864	918	972	0
2	1	55	109	163	217	271	325	379	433	487	541	595	649	703	757	811	865	919	973	2
4	2	56	110	164	218	272	326	380	434	488	542	596	650	704	758	812	866	920	974	4
6	3	57	111	165	219	273	327	381	435	489	543	597	651	705	759	813	867	921	975	6
7	4	58	112	166	220	274	328	382	436	490	544	598	652	706	760	814	868	922	976	7
9	5	59	113	167	221	275	329	383	437	491	545	599	653	707	761	815	869	923	977	9
11	6	60	114	168	222	276	330	384	438	492	546	600	654	708	762	816	870	924	978	11
13	7	61	115	169	223	277	331	385	439	493	547	601	655	709	763	817	871	925	979	13
15	8	62	116	170	224	278	332	386	440	494	548	602	656	710	764	818	872	926	980	15
17	9	63	117	171	225	279	333	387	441	495	549	603	657	711	765	819	873	927	981	17
19	10	64	118	172	226	280	334	388	442	496	550	604	658	712	766	820	874	928	982	19
20	11	65	119	173	227	281	335	389	443	497	551	605	659	713	767	821	875	929	983	20
22	12	66	120	174	228	282	336	390	444	498	552	606	660	714	768	822	876	930	984	22
24	13	67	121	175	229	283	337	391	445	499	553	607	661	715	769	823	877	931	985	24
26	14	68	122	176	230	284	338	392	446	500	554	608	662	716	770	824	878	932	986	26
28	15	69	123	177	231	285	339	393	447	501	555	609	663	717	771	825	879	933	987	28
30	16	70	124	178	232	286	340	394	448	502	556	610	664	718	772	826	880	934	988	30
31	17	71	125	179	233	287	341	395	449	503	557	611	665	719	773	827	881	935	989	31
33	18	72	126	180	234	288	342	396	450	504	558	612	666	720	774	828	882	936	990	33
35	19	73	127	181	235	289	343	397	451	505	559	613	667	721	775	829	883	937	991	35
37	20	74	128	182	236	290	344	398	452	506	560	614	668	722	776	830	884	938	992	37
39	21	75	129	183	237	391	345	399	453	507	561	615	669	723	777	831	885	939	993	39
41	22	76	130	184	238	392	346	400	454	508	562	616	670	724	778	832	886	940	994	41
43	23	77	131	185	239	393	347	401	455	509	563	617	671	725	779	833	887	941	995	43
44	24	78	132	186	240	394	348	402	456	510	564	618	672	726	780	834	888	942	996	44
46	25	79	133	187	241	395	349	403	457	511	565	619	673	727	781	835	889	943	997	46
48	26	80	134	188	242	396	350	404	458	512	566	620	674	728	782	836	890	944	998	48
50	27	81	135	189	243	397	351	405	459	513	567	621	675	729	783	837	891	945	999	50
52	28	82	136	190	244	398	352	406	460	514	568	622	676	730	784	838	892	946	1000	52
54	29	83	137	191	245	399	353	407	461	515	569	623	677	731	785	839	893	947	1001	54
56	30	84	138	192	246	300	354	408	462	516	570	624	678	732	786	840	894	948	1002	56
57	31	85	139	193	247	301	355	409	463	517	571	625	679	733	787	841	895	949	1003	57
59	32	86	140	194	248	302	356	410	464	518	572	626	680	734	788	842	896	950	1004	59
61	33	87	141	195	249	303	357	411	465	519	573	627	681	735	789	843	897	951	1005	61
63	34	88	142	196	250	304	358	412	466	520	574	628	682	736	790	844	898	952	1006	63
65	35	89	143	197	251	305	359	413	467	521	575	629	683	737	791	845	899	953	1007	65
67	36	90	144	198	252	306	360	414	468	522	576	630	684	738	792	846	900	954	1008	67
69	37	91	145	199	253	307	361	415	469	523	577	631	685	739	793	847	901	955	1009	69
70	38	92	146	200	254	308	362	416	470	524	578	632	686	740	794	848	902	956	1010	70
72	39	93	147	201	255	309	363	417	471	525	579	633	687	741	795	849	903	957	1011	72
74	40	94	148	202	256	310	364	418	472	526	580	634	688	742	796	850	904	958	1012	74
76	41	95	149	203	257	311	365	419	473	527	581	635	689	743	797	851	905	959	1013	76
78	42	96	150	204	258	312	366	420	474	528	582	636	690	744	798	852	906	960	1014	78
80	43	97	151	205	259	313	367	421	475	529	583	637	691	745	799	853	907	961	1015	80
81	44	98	152	206	260	314	368	422	476	530	584	638	692	746	800	854	908	962	1016	81
83	45	99	153	207	261	315	369	423	477	531	585	639	693	747	801	855	909	963	1017	83
85	46	100	154	208	262	316	370	424	478	532	586	640	694	748	802	856	910	964	1018	85
87	47	101	155	209	263	317	371	425	479	533	587	641	695	749	803	857	911	965	1019	87
89	48	102	156	210	264	318	372	426	480	534	588	642	696	750	804	858	912	966	1020	89
91	49	103	157	211	265	319	373	427	481	535	589	643	697	751	805	859	913	967	1021	91
93	50	104	158	212	266	320	374	428	482	536	590	644	698	752	806	860	914	968	1022	93
94	51	105	159	213	267	321	375	429	483	537	591	645	699	753	807	861	915	969	1023	94
96	52	106	160	214	268	322	376	430	484	538	592	646	700	754	808	862	916	970	1024	96
98	53	107	161	215	269	323	377	431	485	539	593	647	701	755	809	863	917	971	1025	98
C.Y.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	C.Y.

SUM END AREAS	C.Y.
2000	3704
3000	5556
4000	7407
5000	9259
6000	11111
7000	12963
8000	14815
9000	16067
10000	18519

EXPLANATION: Find sum of end areas in body of table. Then at top or bottom of vertical column find hundreds of cubic yards and at extreme right or left of horizontal line find cubic yards below 100.

EXAMPLE: $A_1 = 420^{ft^2}$, $A_2 = 472^{ft^2}$, Sum = 892^{ft^2}, which is found under 16 hundred and to the right or left 52.

ANSWER: 1652 cubic yards.

Figure not converted to metric

Figure 203.RR – Cubic Yards for the Sum of the End Areas

Earthwork Quantity Calculations

Figure 203.SS Earthwork Calculations depicts a form that can be used to summarize the earthwork calculations.

CA-EW-1
03/03/03

State of Ohio
Department of Transportation
Earthwork Quantity Calculations

Project No.: ____________ Co./Rt./Sec.: ____________ Date: ____________

Station	CUTS	Ref. No.:			FILLS	Ref. No.:		
	End Area Sq. Ft.	Avg. End Area Sq. Ft.	Length Ft.	C.Y.	End Area Sq. Ft.	Avg. End Area Sq. Ft.	Length Ft.	C.Y.
			Total Cuts:				Total Fills:	

____________ Calculated By ____________ Checked By

Figure 203.SS – Earthwork Quantity Calculations Form

Figure 203.TT shows a completed calculation form.

CA-EW-1
03/03/03

State of Ohio
Department of Transportation
Earthwork Quantity Calculations

Project No.: (01)0425 Co./Rt./Sec.: ATH 33 30.981 Date: 11/26/02

Station	CUTS Ref. No.: 18				FILLS Ref. No.: 19			
	End Area Sq. Ft.	Avg. End Area Sq. Ft.	Length Ft.	C.Y.	End Area Sq. Ft.	Avg. End Area Sq. Ft.	Length Ft.	C.Y.
351+50	25.68							
		37.64	50.00	69.70		0.00	50.00	0.00
352+00	49.60							
		102.81	50.00	190.38		0.00	50.00	0.00
352+50	156.01							
		222.23	50.00	411.54		0.00	50.00	0.00
353+00	288.45							
		239.58	50.00	443.66		0.00	50.00	0.00
353+50	190.70							
		143.88	50.00	266.44		12.94	50.00	23.96
354+00	97.06				25.88			
		70.87	50.00	131.24		68.50	50.00	126.84
354+50	44.68				111.11			
		22.34	50.00	41.37		154.22	50.00	285.59
355+00					197.33			
		0.00	50.00	0.00		136.99	50.00	253.68
355+50					76.64			
		0.00	50.00	0.00		54.22	50.00	100.41
356+00					31.80			
		0.00	0.00	0.00		15.90	0.00	0.00
		0.00	0.00	0.00		0.00	0.00	0.00
		0.00	0.00	0.00		0.00	0.00	0.00
			Total Cuts:	1554.33			Total Fills:	790.48

DOT-1619 Calculated By: Checked By:

Figure 203.TT – Completed Earthwork Quantity Calculations Form

Volume Determination on Curves

Where cross-sections are at right angles to curve center lines, and the center line is not located at the center of mass (centroid) of the cross-sections, corrections must be applied to volume calculations to obtain an accurate result. This is especially true for curves of short radius, such as those commonly used on ramps.

Inaccuracies of considerable magnitude may result unless proper corrections have been used in calculating earthwork volumes. General methods for determining accurate quantities in such cases are detailed in Section 1310.3.2 and Figure 1310-1 in the Location & Design Manual – Volume 3, *Highway Plans*. Links to the Location & Design Manual can be found on the Design Reference Resource Center on the Department's website.

Basis of Payment (203.10)

There are a multitude of statements that denote when the Department will and will not pay for earthwork quantities based on different field circumstances. The project should review this section. In this manual, we will focus on the final quantity measurements.

The GPS methods are not detailed in Section 203.09 or 203.10 of this manual. Electronic devices connected to graders or dozers are allowed in Item 623 in Section 623.02 of the C&MS.

Final Earthwork Quantities

Check measurements are made in areas where earthwork is being performed. A sufficient number of these checks must be recorded according to the instructions in this manual to provide a satisfactory record of the checks. The purpose of these measurements and records are:

1. To ensure that earthwork is being constructed to plan lines within specified tolerances.
2. To provide a simplified method of earthwork measurement so that payment may be based on corrected plan quantities.

This will result in the savings of engineering man-hours required to arrive at payment quantities and make it possible for the Contractor to receive prompt final payment after the completion of the work.

Measurement by Final Cross-Sections

Final cross-sections of roadway earthwork are usually 'not' required provided that the plan quantities are checked for accuracy and adequate checks have been made (and recorded) during construction. This establishes that plan quantities of earthwork have been performed within specified tolerances.

Final cross-sections may be called for by the Office of Construction where, by inspection or other knowledge of the project, it is indicated that measurement by final cross-section is necessary or desirable.

Procedure for Check Measurements and Check Calculations:

1. Before earthwork construction has begun, make a plan-in-hand inspection to verify the ground line shown on the plan cross-sections, and if significant changes in topography indicate the need for additional cross-

sections at intermediate locations. Where this inspection indicates the need, arrange for further checks by ground or aerial survey.

2. State in the project diary that this inspection has been made.
3. Ensure that slope stakes are set by the calculation method. The initial point for calculations should generally be a profile grade elevation.
4. Obtain a copy of the survey notes, whether the staking is done by a Department or Contractor survey crew, and plot horizontal and vertical locations of the slope stakes on the cross-section sheets. Check the accuracy of original plan ground cross-sections at slope stake locations. Record errors noted and correct plan sections promptly.
5. Check the accuracy of the original ground lines shown on plan cross-sections as follows:
    a. In order to verify the original ground lines shown on plan cross-sections, the Engineer shall field check cross-sections every 300 to 500 feet (100 to 150 meters) by either ground or aerial survey methods prior to the beginning of construction operations. If any appreciable variations from plan elevations are found, check sections must be taken at closer intervals in order to determine the extent of plan errors and amount of additional cross-sectioning required to provide accurate earthwork quantities. Use the corrected ground line where plan cross-section lines have been found in error.
    b. Plan quantities resulting from computations that have been properly documented and made a part of the project records are to be used as final pay quantities. Any additions to, or deductions from, plan quantities necessitated by change orders shall be computed by project personnel in order to determine final pay quantities for adjusted items.
    c. The Department will make revisions to the pay quantity for changes for the following:
        i. Total contract changes greater than $5000.
        ii. Two consecutive end areas varying by more than 5 percent.
        iii. Undercutting.
        iv. Foundation settlement.
        v. Changes in the grades or slopes.
        vi. Removing slides.
        vii. Arithmetic errors.
    d. Final pay quantities computed or adjusted by project personnel shall be checked, in the project office of the District office, by competent Department personnel who have been assigned to the project for construction control, supervision, etc.
    e. All computations of adjustments shall be properly validated by the signed initials or names of persons who computed the adjusted pay quantities and those who performed the checking operations. Also, the dates that these functions were performed shall be indicated. These adjustment computations shall be made a part of the official project records.

6. Where the plan quantities have been checked and validated on the plans, or on computation sheets provided by the design unit preparing the plans, it is not necessary during construction to make a detailed check of accuracy of plan earthwork quantities. If an error in validated plan quantities is noted, recalculate the end areas and volumes in question. Check all plan earthwork quantities for accuracy when plan quantities have not been checked and validated on the plans or on computation sheets provided by the design unit preparing the plans. Especially check locations where there are curves of short radius, such as ramps. Plan quantities are frequently in error by significant amounts at such locations. Where plan quantities are not correct, strike out the plan figures and write in the correct figures. Check the summary to see that quantities have been transferred accurately from cross-section sheets.
7. Make check measurements during construction to ensure work is being done within allowable field tolerances. Project personnel should perform these checks, supplemented by occasional use of the Department survey crew when needed. Make sufficient checks to ensure that the work is being performed within allowable tolerances. The frequency of these check measurements should be determined by the Engineer.
8. The Contractor is required to correct all deviations from plan lines in excess of allowable tolerances as determined by check measurements. During rough grading, it is acceptable to permit cuts and fills to exceed tolerances by an amount which will be corrected during fine grading by practical construction methods. In the case of fills, require prompt corrections of deviations inside allowable tolerances so that specified compaction of the outer edges will be obtained as the work progresses. In the case of deep cuts with steep slopes in rock or shale, prompt correction of deviations in excess of allowable tolerances is required, so that adjustments can be made as the work progresses while the slope areas in question are within reach of the equipment being used.
9. Record necessary check measurements in appropriate notebooks, inspectors report forms, or daily entry in the project diary. These notations should state the location where check measurements were made.
10. Maintain a set of plan cross-sections in the project office. Plot check measurements, changes, and errors in plan lines on these plans on all projects where there is authorized work beyond plan lines, such as excavation of soft subgrade in cut, measurements of this authorized additional work are required.

Borrow Pay Quantity

Specifying borrow happens rarely and only when the measurement in the final location is impractical. An example would be underwater or linear grading operations. Borrow will be specified by weight, when practical.

Natural Formations

Volume Measurement

When borrow is specified by the cubic yard, measurement may be taken in the borrow pit just as in regular embankment construction. Use the average end areas.

Only use Department personnel to make all measurements of the borrow material. Contractor's employees may be used to assist in check measurements and measurements of authorized excavations beyond plan lines where the quantity at each location is less than 2,000 cubic yards (yd^3) [1500 cubic meters (m^3)]. This assumes that project personnel only are responsible for collecting, plotting, and calculating of the data and quantities.

Weight Measurement

When borrow is specified by cubic yard, weight measurements may be used to calculate the payment quantity:

1. Take a series of density tests in the borrow areas, and average the test results. This value is the wet density, called WD (lbs/yd^3).
2. Calculate the total weight from the weight tickets. This value is called W (lbs).
3. Use the following equation to calculate the payment quantity.

$$\text{Payment quantity}\left(yd^3\right) = \frac{W}{WD}$$

This can be used as a check or if cross-sections are not available.

Other than Natural Formations

Volume Measurement

1. Take a series of density tests in place, and average the test results. This value is the wet density, called WD (lbs/yd^3).
2. Calculate the total weight from the weight tickets. This value is called W (lbs).
3. Use the following equation to calculate the payment quantity:

$$\text{Payment quantity}\left(yd^3\right) = \frac{W}{0.95 \times WD}$$

Weight Measurement for Borrow

When borrow is specified by weight use the following:

1. Weight tickets minus excess moisture.
2. Collect weight tickets according to C&MS 109.01.

Adjustment to Borrow Quantity

The quantity of borrow for payment is the measured quantity as detailed above minus:

1. Suitable excavation wasted.
2. Excess fill adjusted for shrinkage.
   a. The shrinkage factor used is detailed in Section 203.02 "Estimating Shrinkage and Settlement" of this manual.
   b. Use the following equation to calculate the payment quantity:

$$\text{Payment Quantity} = \text{SF} \times \text{Borrow Quantity}$$

Example 100,000 CY total borrow, 10,000 CY excess, borrow density is 110 lbs/ft^3 and embankment density 120 lbs/ft^3.

Solution:

Shrinkage Factor, SF=110/120= 0.92
100,000 - 0.92 (10,000) = 100,000 – 9,200= 90,800 CY

Explanation:

Borrow was measured at the borrow site. A larger amount of borrow fit into the embankment. Density is greater at the embankment location. Therefore, we subtract less borrow from the final pay.

Be careful about which way you apply the shrinkage factor.

Records

Record all check measurements and check calculations on the appropriate form, date and sign or initial the form, and place it in the project records.

Records of check measurements must be kept up-to-date at the project office during construction and will be reviewed by the Office of Construction during their routine visits to the project.

After completion of the earthwork, prepare a tabulation of earthwork pay items showing plan quantities where applicable, and listing appropriate measured quantities for all areas where there was deviation from plan lines beyond specified tolerances which affect the pay quantities, showing total quantities for payment.

This tabulation, together with records of check measurements, constitutes the earthwork report for the project. After processing, these reports shall be filed in the District Office.

Documentation Requirements - 203 Roadway Excavation and Embankment

1. Materials.
2. Verify plan cross-sections.
3. Cross-sections of borrow site, if required.

4. Classify suspect soils.
5. Foundation.
6. Lifts thickness and roller passes.
7. Equipment used.
8. Type of soils.
9. Take compaction tests according to S-1015.
10. Benching.
11. Verify final cross-sections.
12. Base estimate on yardage from cross-sections, load count or electronic grade control data.
13. Measure and Pay according to 203.09 and 203.10
14. Document on CA-EW-1, CA-EW-12 and CA-D-3. Do not duplicate the information on all forms unless necessary.

204 Subgrade Compaction and Proof Rolling

Importance

Over 25 million dollars of extra work was used to stabilize soft subgrades during the construction seasons of 2000 and 2001. This extra work has been minimized in recent years because of the construction and design criteria created since that time.

This section will help the project construct stable subgrades for pavement construction. Proper subgrade treatment ensures a constructible pavement, enhances pavement performance over its life, and ensures that the pavement design intent is carried through in the construction phase. This section is based on research performed by the Department from the 1960's through today. This section should not be used as the ultimate answer to solve all subgrade problems.

This section is detailed in such a manner so that construction personnel can easily apply information from the field and subsurface investigation to provide reasonable adjustments to the plan subgrade treatment.

Specification and Plan Requirements

Item 204 requires the top 12 inches of the subgrade to be compacted. Item 204 requires the subgrade to be proof rolled. If subgrade stabilization or undercutting is designed for the entire project, then proof rolling is only used to verify the undercut replacement material stability. If special subgrade treatment is provided in the plans at spot locations, proof rolling is specified to identify these areas and then performed afterwards to verify the undercut stability.

Proof rolling deflections and soil conditions that are observed during construction determine if the plan subgrade treatment must be adjusted. Adjustment of subgrade treatment to fit field conditions is essential and is the responsibility of the Project Engineer.

Subgrade Correction Prior to Proof Rolling

The Engineer must observe the effect of heavy equipment operating on the subgrade during rough grading. When rutting and deflection under heavy equipment indicates soft subgrade, the Engineer should authorize the correction. See "Elasticity and Deformation of Soils" in section 203.02 Materials of this manual.

Do not delay the correction until it can be checked by proof rolling. Investigate the extent of the problem by using the "Investigation" section of this Item. Be aware that the condition can be improved by time, drainage, and hauling as detailed in the section "Draining and Hauling" of this item.

If needed, make the correction by excavating and disposing of soft soil, and replacing it with suitable material as detailed in the section “Undercut Depth and Stabilization Determination” of this item.

Drainage and Hauling

Excess water in fine-grained soil is the principal cause of unstable soil conditions. The Engineer has a responsibility to ensure adequate drainage during construction. If the investigation indicates the need for underdrains or the cleaning of the existing underdrain outlets, then the Engineer must order the work as soon as possible.

Some examples of these conditions are as follows:

1. Existing underdrains with clogged outlets on rehabilitation projects.
2. Free water in the subgrade.
3. Saturated soils of moderately high permeability, such as sandy silt and silty clay of low plasticity.
4. Ground water seepage through layers of permeable soil.
5. Water seeping in the test pits.
6. Water seeping from higher elevations in cut locations.
7. Water flowing on the top of the rock or shale in subgrade undercuts.

Note: It is difficult to remove water from hard clay soils with PI’s greater than 20 with construction underdrains.

Subgrade stability can be significantly improved by cleaning out the existing underdrain outlets on rehabilitation projects and by adding construction underdrains on new or rehabilitation projects. Once the underdrain systems are in place and functioning, the drainage system can reduce the subgrade soil moisture content from 3 percent over optimum moisture to the optimum moisture content in 6 to 8 weeks. Moisture contents that exceed 3 percent over optimum must be dealt with by other means.

For rehabilitation projects, the Contractor should be instructed to unclog the underdrain outlets immediately. Try to perform this work in the time frame listed above. If the project consists of several phases, instruct the Contractor to perform the outlet cleaning for the entire project at the same time.

For new or rehabilitation projects, subgrade stability can be achieved by constructing the plan or construction underdrains as soon as the water problem is found. On new construction projects a longer period of time can be allowed for the underdrain system to work. Opportune times for this work are at the beginning of construction and before winter shut down.

The plan underdrains should be placed only when they will not be contaminated by further construction. If contamination is a concern then sacrificial or construction underdrains should be used on the project.

Item 605 in the C&MS details the construction underdrain construction. Construction underdrains are usually placed in the centerline of the roadway. They may also be placed in the ditch line if the water is coming in from a cut section at a higher elevation. The porous backfill is extended to the subgrade elevation. The outlets for the construction underdrain are the same pipe material and backfill as regular underdrains. The underdrains can be outlet to any convenient location such as catch basins, manholes, pipe, or ditches. The project should not be concerned with the contamination in the upper portion of the underdrain backfill. Construction underdrains are sacrificial underdrains that will continue to work throughout the life of the contract, and afterwards even though the upper portion is contaminated.

In Figure 204.A, the subgrade is saturated and the soil acts like a waterbed when the subgrade is Proof Rolled or hauled on. However, once the underdrains are in place and the soil is loaded, as shown in Figure 204.B, then the water has a place to go. As the soil is loaded or hauled on, the water is squeezed out and the subgrade conditions will improve.

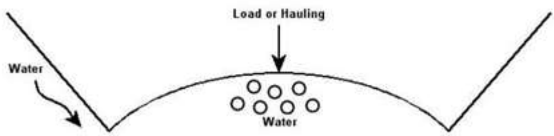


Figure 204.A – Water in the Subgrade without Drainage

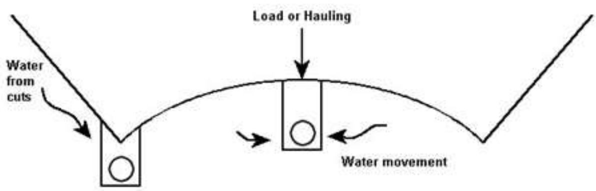


Figure 204.B – Water in the Subgrade with Drainage

By placing the drainage system prior to loading or hauling on the subgrade, the water is given a location to escape the subgrade system. If the drainage system is not in place before hauling or loading, the subgrade will rut or crack, and have a detrimental effect on the subgrade and not improve with loading.

Drainage and hauling can work together to correct soft subgrades under the above given guidelines.

Figure 204.C "Shale and Rock Undercuts" came from Figure 1009-10 in Location & Design Manual – Volume 2, *Drainage Design*. The specification requirements are detailed in 204.05. Shale and rock are cut 24 inches (610 mm) below the bottom of the pavement. This ensures that the pavement gets uniform support and good drainage. In addition, soft rock or shale can deteriorate due to the accumulation of water under the pavement.

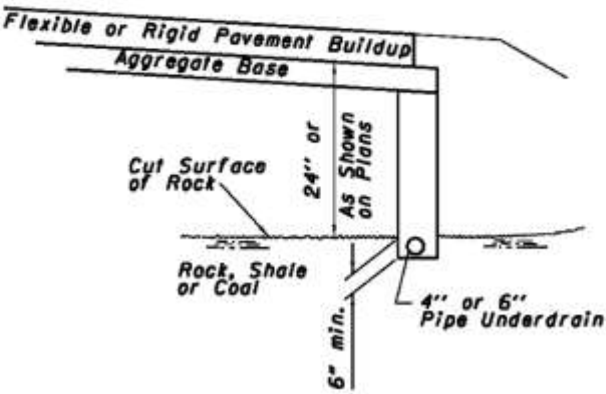


Figure 204.C – Shale and Rock Undercuts

The underdrains in these rock and shale cuts should extend at least 6 inches (150 mm) into the existing rock or shale formation. If the underdrains are too high, the water will accumulate at the rock and soil interface and cause subgrade instability.

Construction or rock underdrains can be placed in the ditches and other strategic locations in cut sections to minimize water coming under the pavement. Water under the pavement without drainage causes the subgrade to act like a waterbed. With drainage, the conditions improve and become more stable.

When to Proof Roll

For areas where subgrade appears to be stable without undercutting, proof roll after the top 12 inches (305 mm) of the subgrade meets the compaction requirements and after the subgrade has been brought to approximate shape within 0.1 to 0.2 feet (30 to 60 mm) required by plan lines.

For areas that are obviously unstable and require undercutting, do not proof roll unnecessarily to demonstrate that subgrade correction is required.

The proof rolling should be done immediately after the subgrade compaction operation, when the moisture content of the subgrade soil is near the optimum moisture content or at the moisture content that achieved compaction. This minimizes the subgrade becoming too wet or too dry for an effective proof rolling evaluation. If the subgrade is too wet, the material will displace and rut. If the subgrade is too dry, a hard surface crust may carry the proof roller over an undesirable soft wet underlying material without rutting or deflection, and the soft subgrade may not be detected.

Proof rolling may be done either before or after pipe underdrains are installed. If done after underdrains are installed, rolling should not be done directly over the underdrains. In C&MS 204.06, proof rolling must be performed at least 1.5 feet (0.5 m) away from the underdrains because of the potential damage to the underdrains.

Proof Rolling

CA-EW-2 "Proof Rolling Documentation Form" is used to document the proof rolling operation. It is imperative that the stations, deflections, weight of the proof roller, and comments are well documented. Digital photographs of subgrade distress are highly recommended.

The primary purposes of proof rolling are to locate soft areas, check the subgrade compaction, to carry out the intent of the design, and to provide uniform support for the pavement structure. Soft subgrade areas that are located will be corrected so that the subgrade density can be maintained throughout the construction. If done correctly, the pavement design intent will be carried through the construction process.

One trip with a proof roller is adequate to achieve satisfactory proof rolling results.

An over loaded proof roller for a soil type may cause satisfactory subgrade to become unstable during proof rolling. Conversely, soft areas will not be found if the proof roller is too light for the soil type.

Selection of Proof Roller Weights and Tire Pressure

In view of the many variations which must be expected in Ohio soil and moisture conditions, the Engineer is given authority to vary the weight and tire pressure of the proof roller to fit the conditions. The weights and tire pressures for the different soils are detailed in C&MS 204.06.

It is imperative that the project chooses the correct load for the type of soil on the project. These loads and tire pressures are soil type sensitive when evaluating the subgrade. For A-3, A-4, A-6, and A-7 soils, use a 35 ton (32 metric ton) roller with a tire pressure of 120 psi (820 kPa). This load and tire pressure is used on most projects because these are the most common soils found in the State of Ohio.

For granular soils, and soil, rock and granular mixtures, use a 50 ton (46 metric ton) roller with 150 psi (1030 kPa) tire pressure.

The goal of proof rolling is to maximize the load to locate soft subgrade. These soft soils could be 3 to 5 feet (1 to 2 m) deep. In rare cases, the soft soil may be deeper than 5 feet (2 m).

Close inspection throughout proof rolling is necessary to observe the rolling effects and to mark soft subgrade locations for correction or investigation. Inadequate stability is indicated by deflection, cracking, or rutting of the surface of the subgrade.

Failure Criteria

The failure criteria is used in this section to determine the locations from which to perform a detailed analysis. This detailed analysis consists of methods discussed later in this section such as rut depth, soil borings and test pits. If the subgrade deflects beyond the failure limits given in this section and the soil borings and test pits determine that the subgrade does not need to be undercut then the subgrade should be considered satisfactory. One additional area to evaluate is the moisture content of the soil. Some soils are more prone to rut at moisture contents greater than 3 percent below the optimum moisture content. In fill locations, the moisture content can be reduced to minimize this problem. If all of the above criteria are met then there is no reason the subgrade should not perform as anticipated. If there is any debate between the Department and the Contractor, especially if a warranty is involved, then further nondestructive or destructive testing can be used to resolve the issue.

The failure criteria for new construction and reconstruction projects are different because of the following reasons:

New construction projects

1. Longer construction time frames allow the subgrade to stabilize.
2. Haul roads to minimize the loading of the subgrade can be established for new construction projects.
3. Drainage and maintenance of these projects are much easier.
4. Even when rutting does appear during proof rolling, the material may be re-graded, hauled on, and re-compacted to meet the specifications.

Rehabilitation projects

1. The soil conditions under pavements are highly variable.
2. Water accumulates under the pavement because of the freeze thaw and wet dry cycles, high existing ditches and underdrain outlet clogging.
3. Construction time frames are limited.
4. Space limits the ability to dry the material in place.
5. Once the pavement is removed, all the drainage is toward the subgrade. This compounds an already poor drainage situation.
6. Alternate haul routes are limited or not available on rehabilitation projects.

The Criteria

In all situations, the maximum allowable rutting or elastic movement of the subgrade is the amount that allows the subgrade soil to maintain the specified density throughout the construction process. For example, if subgrade density can be maintained with 6-inch ruts, then this would be the allowable maximum.

The Contractor must be afforded reasonable use of the subgrade for hauling and for constructing the base material. If subgrade density cannot be maintained through reasonable use of the subgrade, then the allowable proof rolling rutting is too much. If the project conditions allows, areas other than the subgrade should be used as haul roads. For a Contractor 'to bid' to haul loaded trucks or scrappers endlessly across the subgrade throughout the life of the project is going above and beyond the reasonability test. At a minimum, the Contractor should be allowed the use of the subgrade to place the base material with vehicles of legal weight.

The following criteria have worked in the vast majority of the projects.

For new construction projects, permanent rutting in excess of 1 inch (25 mm) should be considered failure. In addition, elastic (rebound) movement or rutting in excess of 1 inch (25 mm) with substantial cracking or substantial lateral movement should be considered failure. Rutting and cracking greater than detailed above is considered "pronounced elasticity."

Elastic, rebound, or rolling movement is always associated with excess water in the subgrade system.

For reconstruction projects, permanent rutting greater than ½ inch (13 mm) should be considered failure. In addition, elastic (rebound) movement or rutting in excess of ½ inch (13 mm) with substantial cracking or substantial lateral movement should be considered failure. Rutting and cracking greater than detailed above is considered "pronounced elasticity."

When deflections are greater than these criteria, there is no assurance that overlying pavement construction will not damage the subgrade compaction. Although subgrade density and stability can be maintained during the proof rolling, the repetitive loading, hauling of materials, and base and pavement construction can destroy the subgrade compaction.

See Figures 204.D, 204.E and 204.F.

In Figure 204.D, the soil has been compacted in the top foot of the subgrade and the conditions are good for the top 3 feet (1.0 m). However, there is a soft layer at a lower elevation. The soft layer has no detrimental effect on the subgrade density during the subgrade compaction.

Figure 204.D - Stage 1 Compaction of Subgrade

In Figure 204.E the proof roller deflects because of the soft soils. The subgrade density may or may not be affected by the proof rolling. The loss of subgrade density is proportional to the amount of rutting or elasticity during proof rolling and subsequent construction operations. The severity of the overall subgrade condition can be measured by the amount of the deflection and elasticity on the surface.

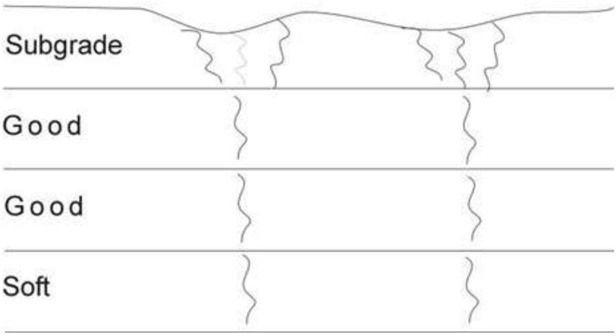


Figure 204.E - Stage 2 Proof Rolling

In Figure 204.F, when the deflections exceed the failure criteria, the proof rolling, repetitive loading, and pavement construction can destroy the top layers of the subgrade.

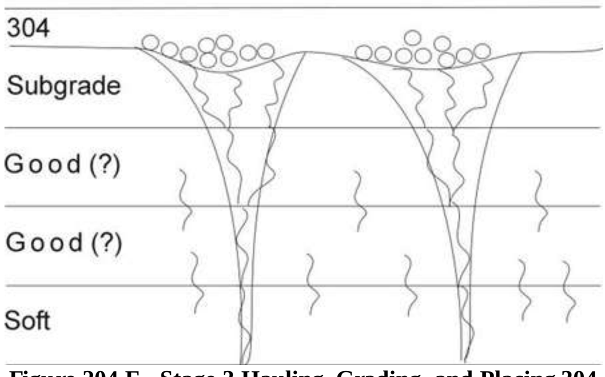


Figure 204.F - Stage 3 Hauling, Grading, and Placing 304

In actual field conditions, this soft layer can be just a few inches thick and at any elevation from the top 1 foot (0.3 m) to as deep as 5 feet (2 m). In addition, it may be an indication of an overall soil condition that is just over optimum for the entire 5-foot (2 m) depth of the subgrade. The field excavation is used to identify the layer or layers causing the surface distress is detailed in the section "Investigation" of this Item. Therefore, it is imperative that these conditions are correctly identified.

As shown in Figure 204.H "Subgrade Treatment Chart" subgrade constructability is suspect at curve locations to the left of the triangles. Further details are given in the section "Undercut Depth and Stabilization Determination" in this Item.

Crusting is a condition when the subgrade surface appears to be dry and there is substantial cracking on the surface with or without rutting. This indicates a need for further investigation and usually indicates soft or wet underlying soil with the top foot or so of the subgrade being very dry.

Variations in the Proof Rolling Results

The project should not be concerned with occasional or nominal deflections in excess of the above failure criteria. If the density is checked and the investigation shows that good soil extends throughout the top 5 feet of the subgrade, then the design intent will be fulfilled and the project can be constructed. All soils will occasionally deflect under these loads.

The pavement design is based on an average CBR. The CBR value was directly correlated to soil density many years ago. By using the average CBR (Density) value, the pavement design accounts for a 30 percent, or one standard deviation variation, in the subgrade strength from the design CBR; 15 percent is expected to exceed this value and 15 percent is expected to be less than this value. Therefore, some variation in the subgrade condition is already accounted for in the pavement design.

Another consideration is the fact that these proof rolling loads and tire pressures are about 10 times the final in-place stresses once the pavement is constructed. The proof rolling tire pressures are between 120 to 150 psi (820 to 1030 kPa) and the stresses once the pavement is constructed are about 8 psi (55 kPa) for a thin asphalt pavement and 4 psi (27 kPa) for a thick concrete pavement. Therefore, these loads are the largest loads that the subgrade will encounter.

If the project can be constructed while maintaining subgrade density, then the subgrade design intent will be fulfilled.

The project should not be concerned with the "Pavement Warranty" issues that Contractors often bring up. If the project follows theses guidelines and properly documents the subgrade work, Central Office can defend the warranty issue.

Once failure is established based on the proof rolling results, then the responsibility for the correction of the failure should be determined.

Responsibility for the Soft or Failed Subgrade

If soft or failed subgrade locations are found, take compaction tests to determine if the specifications are met in the top 12" (300 mm). The Engineer should instruct the Contractor to correct any deficiencies found in these locations.

The Department is responsible when the soft or failed subgrade is encountered in:

1. Cuts.
2. On rehabilitation projects.
3. In shallow fill locations where the soft material is found under the contract fill.

4. When the soft material is found at lower elevations than the project contract work.

Subgrade stability may not be possible by compacting the upper 12 inches (0.3 m) because of conditions at these lower elevations.

It is the Contractor’s responsibility to correct all failed or soft locations in fills. If the Contractor built the fill correctly, the proof rolling will do nothing but verify specification work. If the fill fails then the proof rolling will determine the location of the deficient specification work.

If the Contractor fails to maintain the subgrade, then the Engineer should instruct the Contractor to repair the failed areas. See C&MS 203.04.A for the Contractor’s responsibility to drain and maintain the subgrade.

Investigation

Investigate the causes of failed locations quickly to expedite the corrective treatment. Three pieces of information are needed to make the most economical subgrade treatment:

1. Rut Depth
2. Soil Boring Information
3. Test Pit Data

At this point the rut depth has already been determined.

Soil Boring Information

For rehabilitation projects or cut sections, the soil borings can be examined to determine an estimated undercut depth or stabilization methods.

Evaluate standard penetration test (SPT) results from soil borings in the failed subgrade locations. The standard penetration test (SPT) is an indicator of the soil consistency or strength, and measures the number of blows per foot (N) required to drive the soil sampler through the soil. The soil data on the boring logs are presented as the number of blows required to drive each 6-inch (150 mm) increment. The first 6 inches (150 mm) of the run is ignored because the sampler may not be seated in the borehole or may be driven through cuttings. For example, standard penetration data shown as 1/2/3 has an N value of 5 blows per foot.

When investigating the need for undercutting or stabilization in failed locations, look at the borings in those locations in the upper 5 feet (1.5 m) of the subgrade. At each location, pick the lowest N value when multiple N values are taken in the top 5 feet (1.5 m) of subgrade.

Average the N value along the failed locations. This value provides one part of the information needed to determine the undercut depth or stabilization methods.

Test Pits

Once the soil borings have been evaluated, construct test pits by excavating 3 to 5 feet (0.6 to 1.5 meter) into the subgrade using the Contractor's excavation equipment. Excavate at least two test pits that represent the failed area. Use judgment for long areas; usually about two to four test pits per mile is sufficient. Construct the test pits across the width of the subgrade in the failed locations. Pick locations with the highest deflections to evaluate the most severe locations.

Warning: These trenches may collapse on the construction personnel. The Department offers an 8 Hour Construction Safety Class to evaluate the trench collapse risk. In addition, there is a trench safety class offered by the Bureau of Workers Compensation, Division of Safety and Hygiene. These classes are given statewide all year around. (614-466-5563)

An examination of the soil and moisture conditions in these test pits provides valuable information to make the appropriate correction. Once the pits are excavated, the Engineer must examine the trench sidewalls and the bottom of the cut.

Record the test pit information on CA-EW-3, "Subgrade Test Pit Investigation" form shown in Figure 204.G. The soil conditions vary with depth and must be quantified. By examining the sidewalls, the Engineer can determine the soil type, layer thickness, soil condition, and soil strength by using a hand penetrometer.

CA-EW-3 Subgrade Test Pit Investigation

Subgrade Elevation:	Date:
Station:	Evaluation Stations:
Rut Depth:	Tire Pressure:

Unconfined Compressive (ton/SF) From Penetrometer		Soil Layer
U1		Layer Type:
U2		Layer Thickness:
U3		Soil Condition:
Uavg		Comments:
U1		Layer Type:
U2		Layer Thickness:
U3		Soil Condition:
Uavg		Comments:
U1		Layer Type:
U2		Layer Thickness:
U3		Soil Condition:
Uavg		Comments:
U1		Layer Type:
U2		Layer Thickness:
U3		Soil Condition:
Uavg		Comments:
Soil Type (see section 203.02): Clay, Silt, Sand Gravel, Sandstone, Shale, Rock, Combination		
Soil Condition: Wet, Dry, Organic, Roots, Water seepage, Soup, Jell-O, Hard or Soft Peanut Butter		
Critical Later/ Design layer = U:		
Inspector Signature:		

Figure 204.G – Form CA-EW-3 Subgrade Test Pit Investigation

The Engineer must field classify the soil. See 203.02 Materials, "Identifying Soil and Granular Materials in the Field" for help in the classification.

Added soil conditions are described on the bottom of the test pit form. These conditions are stated in commonly-known consistencies, so that the non-geotechnical reader can relate to the soil conditions. They are listed on the bottom of the form. No explanation is needed for these terms.

Hand Penetrometer Readings

A hand penetrometer can be used to further classify the soil and to estimate its strength. A hand penetrometer can be obtained from a test lab supply company for less than $100. Hand penetrometers can be obtained from the following companies:

Gilson	Model # HM-500	Phone 800-444-1508
ELE	Model # E129-3729	Phone 724-864-3364
Humboldt	Model H-4200	Phone 800-444-7220

The exact instructions come with the hand penetrometer. In summary:

1. Push the hand penetrometer slowly into the soil at right angles.
2. Record the reading when the hand penetrometer penetrates the soil to the ¼-inch groove mark.
3. Record the readings to the nearest 0.25 tons per square foot (tsf).
4. Take at least three different readings in each soil layer.

Use CA-EW-3 “Subgrade Test Pit Investigation” form to record the readings. Average the readings once three readings are taken for the soil layer. Also evaluate the bottom of the test pit; this is extremely valuable information. Once the averages are determined, record the lowest average unconfined reading on the bottom of the form. This would be the most critical soil layer.

Average the unconfined readings (U) of all the test pits in the failed locations. Use this number to further evaluate the undercut depth or stabilization methods.

Consider the following when evaluating the sidewalls of a trench:

1. Different layers of a natural formation or cut are more noticeable than fill materials.
2. High unconfined numbers may be obtained with high deflections or rolling at the surface. This is an indication of soft soil at a lower elevation than 5 feet (2 m) or a subgrade soil that is just too wet.

Undercut Depth and Stabilization Determination

Once the proof rolling rut depth (in inches), soil boring information (N), and unconfined data from the test pits (U) are obtained, use the “Subgrade Treatment Chart” in Figure 204.H to determine the undercut depth requirements. The input values (rut depth, N and U) are on the horizontal axis. The two curves denote the type of project under construction. The left vertical scale shows the undercut depth in feet of granular material. The right vertical scale shows the stabilization depth required in inches of lime or cement.

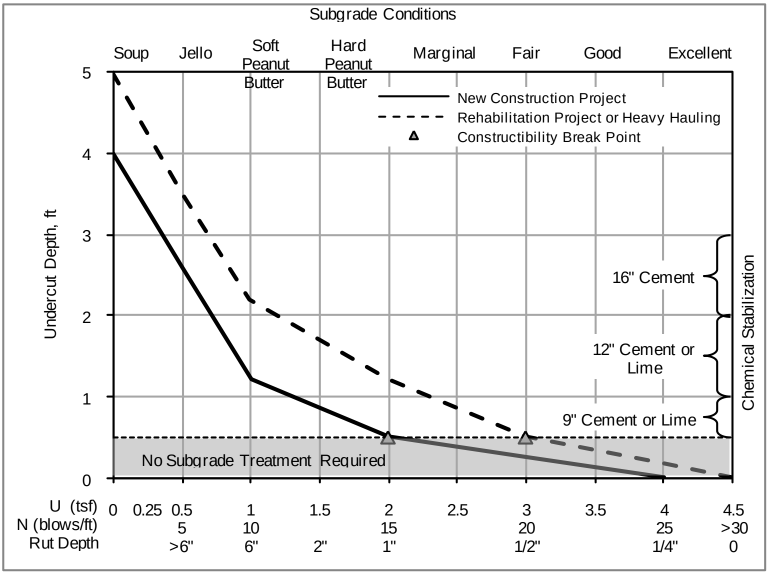


Figure 204.H - Subgrade Treatment Chart

The horizontal dashed line at about ½ foot indicates that treatment is not required for results below this line. The top portion of Figure 204.H details the general subgrade condition.

Figure 204.H takes into account the standard deviation of test results, anticipated truck loading, and type of project under construction.

Use the rut depth, N values, and unconfined strengths (U) from a hand penetrometer to draw a vertical line to the curve for the type of project under construction. At that intersection draw a horizontal line to the left and right. This determines the granular undercut depth or stabilization needs.

The undercut chart gives the required stabilization method to obtain stability when the undercut or stabilization is completed.

It would be rare to see a perfect alignment in the results from all three inputs. In some cases, one or two of these inputs may not be available. In other cases, some judgment is needed to redesign the most economical undercut that will work. In order of hierarchy, use the test pit data, then the N values, and then the rut depth. The rut depth is the least reliable indicator of undercut need because it cannot determine which soil layer is causing the deflection.

There will be cases where the N values and unconfined values are all high but the subgrade is rolling and cracking, and rut depth is greater than allowable. In this case use the rut depth as a guide to redesign the undercut. See the last example in the example section.

There is an example in Figure 204.I.

Given: 5 mile long Rehabilitation Project
Average N value was 12
U= 1.4 tsf
Average Rut Depth was 2-4 inches.

Answer: Use an undercut depth of 2.0 feet (0.6m) or stabilize with 12-16 inches of cement or lime. Since this is a long project, give serious consideration to the stabilization method. It will be more cost effective.

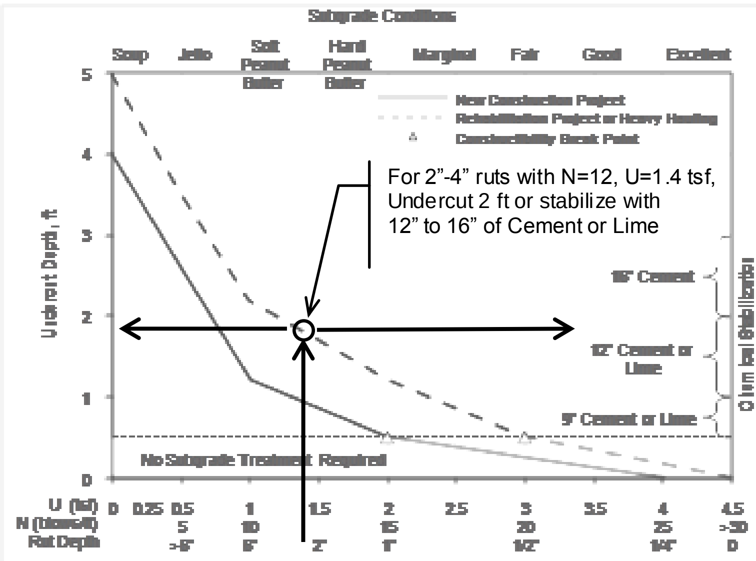


Figure 204.I - Example using the Subgrade Treatment Chart

After making the undercut, this depth may need to be adjusted to meet the actual conditions. See the section, “Implementation during Construction” of this manual.

General Rules

On new construction projects, if all of the soft material can be removed and the bottom of the test pits or cuts are stable, then soil may be used as replacement material. For reconstruction projects, soil is usually not available in large quantities and the bottoms of the cuts are highly variable. Therefore, soil undercuts are less effective solutions on reconstruction projects.

If the bottom of the test pit is unstable, when conditions are highly variable, or for rehabilitation projects then use granular material, rock, geotextile, or lime or cement stabilization, rather than soil.

Undercuts should be used in small locations or in areas where spot locations are identified. Consider cement or lime stabilization for long areas greater than one mile.

Only the most unusual cases require removal to depths greater than 3 feet (1 meter). Seventy five to ninety percent of subgrade problems can be solved with a one-foot treatment of granular material and geotextile or stabilization with lime or cement. Use stabilization methods for projects with long areas to stabilize or when the undercut depth is greater than 1.0 foot.

If a project or section of a project undercut locations are more than 30% of the total area, undercut or stabilize the entire area. If you do not undercut the entire area, these locations will grow and the construction will be inefficient as the construction proceeds. The Department pays a higher cost at a reduced final quality by undercutting a high percentage of the subgrade throughout the project. ODOT would not repair a bridge deck or pavement with this high a percentage of repairs.

Stabilization methods speed construction because of the ability to work immediately after a rain. Estimates indicate that the construction production is increased by at least 50 percent by using stabilization methods.

Examples

The following table shows some example solutions. The types of material refer to 703.16.C and Item 206.

Given	Solution
Rehabilitation Project with Silty A-4a material with N=15 or U=2.0 tsf Rut Depth>1"	1.5 feet of Granular Material Type B, C or D with geotextile or 12 inches of stabilization with cement
Rehabilitation Project with Deep, weak, and wet A-4 with N = 12 or U=1.4 tsf Rut Depth = 2"	2.0 feet of Granular Material Type B, C, or D, with geotextile or 12-16 inches of stabilization with cement
New Construction, Deep, weak & wet A-4, A-6 or A-7-6 combination with N = 10 or U=1.0tsf. Rut Depth = 4"	1.5 feet of Granular Material Type B C or D with geotextile or 12 inches of stabilization with lime or cement. (Check the PI of the soils. Use the stabilization type according to the PI's of the soil.)
New Construction Jell-O like consistency soil with N = 5 or U=0.5 tsf. Rut depth > 6"	2.5 feet of Granular Material Type B, C, or D, with geotextile or 16 inches of stabilization with cement. (Check the PI of the soil.)
Any Project with soup like consistency soil with N = 2 or U=0.25 tsf Rut Depth = Buried equipment	5 feet of Granular Material Type B, C, or D, with geotextile. (May need two layers of geotextile, Use type D Granular Material if available)
Reconstruction Project Sandy, A-4a, A-6a soil, PI < 20, N = 8 or U=1.0 tsf Rut Depth = 6". (Long Project)	Cement Stabilized Subgrade 16" deep at 6%
New construction A-7-6 clay soil, PI > 20 N = 11 or U=1.2 tsf Rut Depth =3". (Long Project)	Lime Stabilized Subgrade 12" deep at 5%

Given	Solution
Reconstruction Project A-6a silty clay PI < 20, N=30 and U>4.5 tsf Rut depth > 2" and rolling The key here is the rolling. Probably caused by high moisture content of the soil at a depth. If the subgrade is rolling with one pass of a proof roller then the subgrade condition can rapidly deteriorate during construction.	16" of Cement at 6% or 2.5 foot undercut with Granular Material Type B, C, or D, with two layers of geotextile. Use Type D material if available.

Type of Undercut Materials

Use Granular Material Types B, C, D, E, and F. They are cheaper than 304.

Type B is a well-graded aggregate with the gradations of Items 304, 411, or 617. Type C has a top size of 3 inches and type D has a top size of 8 inches. Both C and D are well-graded materials. The larger top size material will bridge the soft material better that the smaller size material.

Use Granular Material Type E when water levels are high or cannot be drained. The Type E materials are very porous. Always choke the Granular Material Type E with Granular Material Type B or geotextile fabric.

There is a potential for piping of soil into the Granular Material Type E as shown in Figure 204.J. In the upper detail, when the open material is placed on soft fine graded soil, the soil pipes into the open graded material during construction or by loading. In the lower detail, the geotextile fabric blocks the material from entering the open graded material. Geogrids will not work for this application.

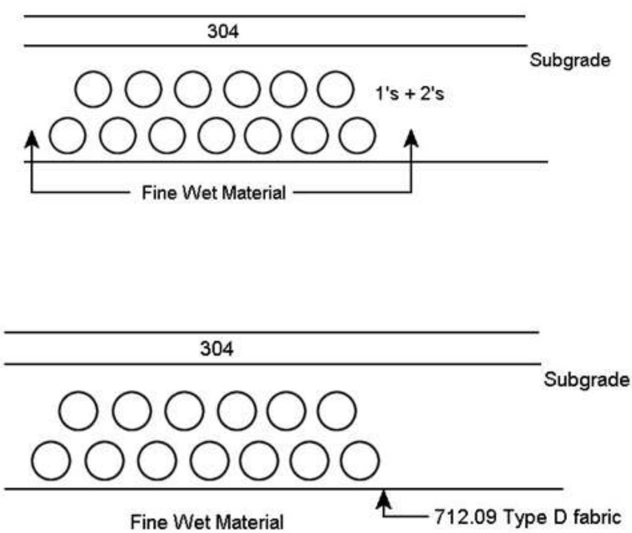


Figure 204.J - Soil Piping in Open Material

Underdrains cannot be placed through Granular Material Types D, E, or F or geotextile fabric. Use Granular Material Type B in the locations of the underdrains. Always drain the undercut to an underdrain, catch basin, or pipe.

Always use 712.09 Geotextile Fabric Type D. The cost is around $1.00 per square yard. In the case of deeper undercuts, multiple layers can be used at a 12-inch vertical spacing if needed.

Cement and Lime Stabilization of the Subgrade

Item 206 Chemically Stabilized Subgrade can be used to treat unstable subgrades. Lime or Cement can be used to stabilize the subgrade.

Lime is used for A-6b (silty/clay) or A-7-6 (clay) soils which have a plasticity index of 20 or greater. Use 5 percent lime by dry weight of the soil assuming a dry weight of 110 pounds per cubic foot.

Cement can be used to treat unstable subgrades consisting of A-3 (fine sand, coarse and fine sand), A-2-4 through 7 (gravels), A-4a (sand silt), A-6a (silt and clay), A-6b (silty clay), or A-7-6 (clay) which have a plasticity index less than 20. Use 6 percent cement by dry weight of the soil assuming a dry weight of 110 pounds per cubic foot.

See Item 206 Chemically Stabilized Subgrade of this manual.

Implementation during Construction

Once they type of stabilization treatment has been chosen, constant monitoring of the construction is required to adjust the treatment to meet the field conditions. Soil conditions always vary; they vary the most on rehabilitation projects or in cuts.

If the undercut option is chosen, the project should monitor the bottom of the cut and evaluate the condition. Take hand penetrometer readings at the bottom of the cuts and compare them to the initial test pit or soil boring information. If the condition changes from the earlier evaluation of the test pits or the soil borings, then adjustments to the undercut depth are required.

In addition, for undercuts that are two feet deep or greater, give consideration to placing multiple layers of geotextile fabric. The need for additional layers of geotextile can be determined by placing about ½ of the undercut depth. Load the undercut with a fully loaded truck. If the area is unstable, then place another layer of geotextile and continue to fill the undercut.

Once the undercut or stabilization is complete, proof roll the area to ensure that the final subgrade meets the rut depth and density requirements as detailed earlier in section “Failure Criteria”.

Constant vigilance is needed in order to make the most economical correction. It is easy to over-excavate unnecessarily and waste money. It is more difficult to make the right economical choice to stabilize the subgrade and to meet the design and construction needs.

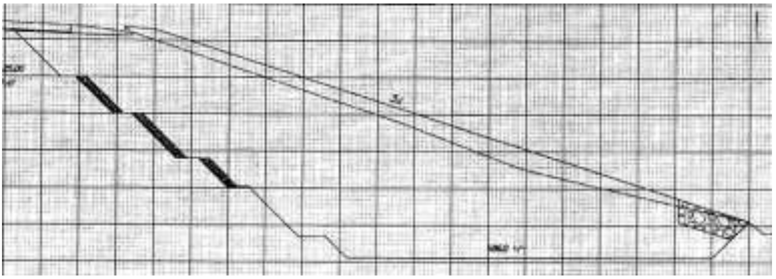
Documentation Requirements - 204 Subgrade Compaction and Proof Rolling

1. Materials.
2. Compaction according to S-1015.
3. Lift thickness and roller passes.
4. Equipment used.
5. Type of soils.
6. Verify square yardage.
7. Verify subgrade line and grade.
8. Proof Roll and make corrections.
9. Subgrade Test Pit Investigations.
10. Undercut measurements.
11. Document on CA-EW-1,CA-EW-2,CA-EW-3, CA-EW-8, CA-EW-12 and CA-D-3. Do not duplicate the information on all forms unless necessary.

205 Chemically Stabilized Embankment

Uses of Chemically Stabilized Embankment

Chemically stabilized embankment is generally used to repair landslides, such as shown in the following figure. This situation involves the removal of wet soil, treating it with cement or lime, and then using the treated soil to rebuild the embankment. Notice the addition of drainage to the slide repair.



Typical Use of Chemically Stabilized Embankment to Repair Landslide

There are primarily two types of chemicals used to treat soil: cement and lime.

Cement is most effective in treating soils with a plasticity index (PI) less than 20, such as sandy and silty soils like A-3a, A-4a, A-4b, A-6a, and some A-6b soils. Use cement stabilized subgrade to treat areas with N values (SPT blow counts) as low as 5, and unconfined strengths (hand penetrometer) as low as 0.5 tsf.

Lime is most effective in treating soils with a PI greater than 20, such as A-7-6 and A-6b soils. Use lime stabilized subgrade to treat areas with N values (SPT blow counts) as low as 10, and unconfined strengths (hand penetrometer) as low as 1.0 tsf.

Materials (205.02)

If using cement, use Type 1 cement according to 701.04. If using lime, there are two types of lime used for soil stabilization: quick lime and hydrated lime. Quick lime is used most of the time. Quick lime must all pass through the No. 4 (4.75 mm) sieve. Lime must come from a supplier listed on the QPL.

Lime kiln dust is another material that can be used for soil stabilization. The Department has limited experience with lime kiln dust for soil stabilization, so it is generally not included in the plans. However, the contractor may propose to use it in a value engineering change proposal. Lime kiln dust must conform to 712.04.C.

Limitations (205.03)

Chemical stabilization should not be performed when the temperature is below 40 ºF (5 ºC) or the ground is frozen. In order to stabilize the soil, the lime or cement needs to react with the water in the soil. It cannot do that if the water is frozen. If it is raining, then the free water will react with the lime or cement instead of the water in the soil.

Spreading lime and cement creates some dust. For this reason, the chemical stabilization should not be performed when it is windy, as this will spread the dust outside of the project area.

Construction (205.04)

Spreading (205.04.A)

The amount of chemical applied to each lift is based on a percentage of the dry weight of the soil that will be treated. The percentage is typically 4 to 10 percent for cement and 4 to 8 percent for lime. If the Contractor Designed Chemically Stabilized Embankment pay item is included in the plans, the contractor will determine the appropriate percentage of chemical based on a testing program. If the pay item for the contractor designed subgrade is not included in the plans, then use the percentage given in the plans or the percentage given in 205.04.A.

When lime is shown on the plans, the quantities and percentage of lime are based on the use of hydrated lime. If the contractor chooses to use quick lime and the percentage is not determined from the Contractor Designed Chemically Stabilized Embankment test program, adjust the percentage to account for the fact that hydrated lime is not being used (typically this means using 4 percent quick lime rather than 5 percent hydrated lime).

To calculate the spreading rate (number of pounds of the chemical per square yard), use the following equation.

$$C = 0.75 \times T \times D \times P$$

where:

C = spreading rate for chemical (pounds per square yard)

T = thickness of embankment lift (inches)

D = average dry density of soil (110 pounds per cubic foot)

P = percentage of chemical, expressed as a decimal
(e.g. 5% = 0.05)

0.75 is a unit conversion factor ($9\ ft^2 / 1\ yd^2 \times 1\ ft / 12\ in$)

For example, if using 4% of a chemical and an 8-inch embankment lift:

$$C = 0.75 \times 8\text{ in} \times 110\text{ lb/ft}^3 \times 0.04 = 26.4\text{ lb/yd}^2\text{ of chemical}$$

The contractor must submit a spreading plan or report two days before the work that indicates how the contractor will achieve the required spreading rate. After the spreading operation, check the contractor’s spreading rate by taking the total weight of chemical spread and dividing it by the area that was treated.

For slide repair work a loader is sometimes used to spread the chemicals. The exact amount of chemical in each lift of soil is not as critical as it is in subgrade stabilization work.

When a mechanical spreader is used, dusting is minimized by using a shroud around the spreader bar that extends to the surface. A distribution bar with a maximum height of 3 feet (1 m) above the subgrade can be used. The chemical should not be spread if wind conditions are such that blowing dust exceeds the limits in 107.19.

Spreading cement with a shroud around the spreader bar

Mixing (205.04.B)

The contractor should mix the chemical into the soil immediately after spreading the chemical. The contractor may use a spring tooth harrow, a disk harrow, or a power driven rotary mixer which looks like a big rotary tiller. However, if the area is beneath a pavement or paved shoulder, then the contractor must use the power driven rotary mixer.

Rotary mixer for chemical stabilization

If using a power driven rotary mixer, mix the soil and chemical until all the soil clods are reduced to a maximum size of 2 inches (50 mm). Add water if necessary to bring the mixture to at least the optimum moisture content if using cement or hydrated lime and to at least 3 percent above optimum moisture content if using quick lime. Quick lime reacts more strongly with water and the additional water prevents future expansion problems. Determine the optimum moisture content from the moisture-density curves developed in the test program from the Contractor Designed Chemically Stabilized Subgrade, or by using the Ohio Typical Moisture Density Curves and the one point proctor method in Supplement 1015.

Disk harrow

If using a spring tooth or disk harrow, break up the soil with the harrow before spreading the chemical. Mix the chemical into the soil and add water as described above. During mixing, use at least 20 passes of the harrow; 10 in one direction and

10 in a direction perpendicular to the first 10. Reduce all the soil clods to a maximum size of 1 inch (25 mm). The harrows do not do as good a job mixing in the chemical as the rotary mixer, so more effort is required with the harrow to mix the chemical and soil.

Note that for Chemically Stabilized Embankment the mixing is the same for both cement and lime. This is different from Chemically Stabilized Subgrade.

Compaction (205.04.C)

Compact to 98 percent of the maximum dry density and use the one point proctor method in Supplement 1015 to determine the maximum dry density. In some cases, the test section method or the moisture-density curves developed by the contractor may be used to determine the maximum dry density.

Contractor Designed Chemically Stabilized Embankment (205.05)

If the pay item for Contractor Designed Chemically Stabilized Embankment is included in the plans, then the contractor uses the testing program described in Supplement 1120 to determine the spreading rate for the chemical. Different mixtures of the soil and chemical are tested for unconfined compressive strength. The results are used to determine the percentage of chemical used in the field. The common increase in strength ranges from 20 psi to 100 psi with lime and from 50 psi to 200 psi with cement.

Method of Measurement (205.06)

When lime is shown on the plans, the quantities and percentage of lime are based on the use of hydrated lime. If the contractor chooses to use quick lime, the quantity of lime measured for payment is increased by the equation in 206.07. This is done because generally less quick lime is required than hydrated lime to have the same soil improvement.

Documentation Requirements - 205 Chemically Stabilized Embankment

1. Materials per 205.02
2. Check contractor designed lime or cement percentage.
3. Verify cross sections.
4. Temperature must be 40 °F (4 °C) or above and the soil cannot be frozen
5. Document the Construction: Spreading, Mixing, and Compaction.
6. Perform the compaction testing according to Supplement 1015.
7. Measure and pay according to 205.06 and 205.07
8. Final cross sections.

9. Document on CA-EW-1, CA-EW-12 and CA-D-1, and CA-D-3. Do not duplicate the information on all forms unless necessary.

206 Chemically Stabilized Subgrade

Uses and Application for Chemically Stabilized Subgrade

Use chemically stabilized subgrade for improving long sections of subgrade, generally more than a mile. It is generally not cost effective for short spot locations. If the chemical stabilization is not in the plans and is being added to the project in order to address a subgrade problem, use the Subgrade Treatment Chart in Figure 204.H to determine the appropriate depth of chemical stabilization. If the chemical stabilization is in the plans, the designer used Geotechnical Bulletin 1, *Plan Subgrades*, from the Office of Geotechnical Engineering to design the chemical stabilization.

There are primarily two types of chemicals used to treat soil: cement and lime.

Cement is most effective in treating soils with a plasticity index (PI) less than 20, such as sandy and silty soils like A-3a, A-4a, A-4b, A-6a, and some A-6b soils. Use cement stabilized subgrade to treat areas with N values (SPT blow counts) as low as 5, unconfined strengths (hand penetrometer) as low as 0.5 tsf and to remove ruts up to 12 inches (300 mm) deep.

Lime is most effective in treating soils with a PI greater than 20, such as A-7-6 and A-6b soils. Use lime stabilized subgrade to treat areas with N values (SPT blow counts) as low as 10, unconfined strengths (hand penetrometer) as low as 1.0 tsf and to remove ruts up to 6 inches (150 mm) deep.

Materials (206.02)

If using cement, use Type 1 cement according to 701.04. If using lime, there are two types of lime used for soil stabilization: quick lime and hydrated lime. Quick lime is used most of the time. Quick lime must all pass through the No. 4 (4.75 mm) sieve. Lime must come from a supplier listed on the QPL.

Lime kiln dust is another material that can be used for soil stabilization. The Department has limited experience with lime kiln dust for soil stabilization, so it is generally not included in the plans. However, the contractor may propose to use it in a value engineering change proposal. Lime kiln dust must conform to 712.04.C.

The curing coat can consist of a rapid setting emulsified asphalt prime coat or a curing compound. The prime coat may be specified by plan note to discourage traffic on the subgrade during the curing period. The prime coat remains tacky, so equipment operators tend to stay off of it.

Limitation (206.03)

Chemical stabilization should not be performed when the temperature is below 40 ºF (5 ºC) or the ground is frozen. In order to stabilize the soil, the lime or cement needs to react with the water in the soil. It cannot do that if the water is frozen. If it is raining, then the free water will react with the lime or cement instead of the water in the soil.

Spreading lime and cement creates some dust. For this reason, the chemical stabilization should not be performed when it is windy, as this will spread the dust outside of the project area.

Test Rolling (206.04)

If chemical stabilization is specified in spot locations, use test rolling with a proof roller to locate areas that require the chemical stabilization. If rutting is significant, (greater than 6 inches for cement, greater than 4 inches for lime) investigate the subgrade by digging test pits. After the chemical stabilization is complete, proof roll the stabilized areas.

If chemical stabilization is specified throughout the project, do not test roll before stabilization, but do perform proof rolling after the chemical stabilization work is complete.

Construction (206.05)

Spreading (206.05.A)

The amount of chemical applied to the subgrade is based on a percentage of the dry weight of the soil that will be treated. The percentage is typically 4 to 10 percent for cement and 4 to 8 percent for lime. If the Contractor Designed Chemically Stabilized Subgrade pay item is included in the plans, the contractor will determine the appropriate percentage of chemical based on a testing program. If the pay item for the contractor designed subgrade is not included in the plans, then use the percentage given in the plans or the percentage given in 206.05.

When lime is shown on the plans, the quantities and percentage of lime are based on the use of hydrated lime. If the contractor chooses to use quick lime and the percentage is not determined from the Contractor Designed Chemically Stabilized Subgrade test program, adjust the percentage to account for the fact that hydrated lime is not being used (typically this means using 4 percent quick lime rather than 5 percent hydrated lime).

To calculate the spreading rate (number of pounds of the chemical per square yard), use the following equation.

$$C = 0.75 \times T \times D \times P$$

where:

C = spreading rate for chemical (pounds per square yard)

T = thickness (or depth) of stabilization (inches)

D = average dry density of soil (110 pounds per cubic foot)

P = percentage of chemical, expressed as a decimal
(e.g. 5% = 0.05)

0.75 is a unit conversion factor (9 ft^2 / 1 yd^2 × 1 ft / 12 in)

For example, if using 5% of a chemical and a 12 inch depth of treatment:

$$C = 0.75 \times 12 \text{ in} \times 110 \text{ lb/ft}^3 \times 0.05 = 49.5 \text{ lb/yd}^2 \text{ of chemical}$$

The contractor must submit a spreading plan or report two days before the work that indicates how the contractor will achieve the required spreading rate. After the spreading operation, check the contractor’s spreading rate by taking the total weight of chemical spread and dividing it by the area that was treated. To check the spreading rate during the work, take a pan and place it on the prepared surface in front of the spreading truck (the pan will have to be placed in a small depression to keep the shroud from knocking it over). Once the spreader has passed and filled the pan with the chemical, weigh the filled pan. Determine the weight of the chemical by subtracting the weight of the pan. Calculate the spreading rate by dividing the weight of the chemical by the area of the pan (remember to convert the area of the pan to square yards).

Example: Weight of pan and chemical = 7.3 lb

Weight of pan = 2.8 lb

Pan is 9 in × 13 in

$$\frac{7.3\text{ lb} - 2.8\text{ lb}}{9\text{ in} \times 13\text{ in}} \times \frac{1296\text{ in}^2}{1\text{ yd}^2} = 49.8\,{}^{\text{lb}}\!\big/_{\text{yd}^2}$$

When a mechanical spreader is used, dusting is minimized by using a shroud around the spreader bar that extends to the surface. A distribution bar with a maximum height of 3 feet (1 m) above the subgrade can be used. The chemical should not be spread if wind conditions are such that blowing dust exceeds the limits in 107.19.

Spreading cement with a shroud around the spreader bar

Mixing (206.05.B)

The contractor should mix the chemical into the soil immediately after spreading the chemical. The specifications require a power driven rotary mixer which looks like a big rotary tiller.

Mixing Cement

The specification describes a two step process for mixing cement into the soil, but a single mixing is allowed if the contractor can add water through the mixer and obtain the required gradation with the single mixing. For cement, at least 80 percent of the mixed soil must be smaller than the openings in a No. 4 sieve and all of the soil clods must be smaller than 1 inch (25 mm). Any stones in the soil that would be retained on the No. 4 sieve are not considered when calculating the percentage. If necessary, add water until the soil-cement mixture is at optimum moisture content. Determine the optimum moisture content from the moisture-density curves developed in the test program from the Contractor Designed Chemically Stabilized Subgrade, or by using the Ohio Typical Moisture Density Curves and the one point proctor method in Supplement 1015. To ensure thorough mixing, check the mixture for uniform color.

Rotary mixer for chemical stabilization

Mixing Lime

Lime stabilization requires two separate mixings with a mellowing period in between the mixings. During the initial mixing, all the soil clods are reduced to a maximum size of 2 inches (50 mm) and water is added if necessary to bring the mixture to at least the optimum moisture content if using hydrated lime and to at least 3 percent above optimum moisture content if using quick lime. Quick lime reacts more strongly with water and the additional water prevents future expansion problems. Determine the optimum moisture content from the moisture-density curves developed in the test program from the Contractor Designed Chemically Stabilized Subgrade, or by using the Ohio Typical Moisture Density Curves and the one point proctor method in Supplement 1015.

After the initial mixing, lime stabilized subgrade is allowed to sit undisturbed (mellowed) for at least 24 hours, but not more than 7 days. During the mellowing period, the clumps of lime break down and the lime reacts with the soil, breaking up the soil clods. After the second mixing at least 60 percent of the mixed soil must be smaller than the openings in a No. 4 sieve and all of the soil clods must be smaller than 1 inch (25 mm). Any stones in the soil that would be retained on the No. 4 sieve are not considered when calculating the percentage. To ensure thorough mixing, check the mixture for uniform color.

Compaction (206.03.C)

Chemically stabilized subgrade should be compacted immediately after the shaping and final mixing. For cement the compaction needs to be completed within 2 hours of adding water. Compaction is performed with a vibratory, footed roller weighing at least 10 tons (9 metric tons). However, the final rolling is performed with a smooth drum roller without any vibration.

For the compaction testing criteria, use 98 percent of the maximum dry density and use the one point proctor method in Supplement 1015 to determine the maximum dry density. In some cases, the test section method or the moisture-density curves developed by the contractor may be used to determine the maximum dry density.

Check the depth of the stabilization by digging a hole. Apply phenolphthalein or dilute hydrochloric acid to the side of the hole to check for the presence of lime or cement. Phenolphthalein will turn purple and dilute hydrochloric acid will fizz.

Checking depth of soil stabilization with phenolphthalein

Curing (206.03.D)

The chemically stabilized subgrade must cure for at least 5 days. The surface of the chemically stabilized subgrade is covered with an emulsified asphalt (prime coat) or curing compound to retain moisture in the subgrade during the curing period. However, before the curing coat is applied, the surface must be wet. If the surface has dried out (turns white) before the curing coat is applied, then the contractor needs to add more water to the surface.

The curing coat must uniformly cover the surface of the chemically stabilized subgrade. The following photos show an example of good coverage and poor coverage using a curing compound.

Example of good coverage with curing compound

Example of poor coverage with curing compound

Curing coats can leach off the subgrade if not cured completely prior to a rain event. During the curing period, all equipment should stay off the subgrade.

Proof Rolling (206.03.E)

Proof roll the chemically stabilized subgrade after the cure period. If the stabilization was performed properly and the planned depth of stabilization was adequate, there should be no deflection or rutting.

Fine Grading (206.03.F)

The chemically stabilized subgrade is constructed an inch high. This top inch is often dry and unsuitable. It is removed during the fine grading.

The aggregate base needs to be placed within 60 days of the fine grading.

Contractor Designed Chemically Stabilized Subgrade (206.06)

If the pay item for Contractor Designed Chemically Stabilized Subgrade is included in the plans, then the contractor uses the testing program described in Supplement 1120 to determine the spreading rate for the chemical. Different mixtures of the soil and chemical are tested for unconfined compressive strength. The results are used to determine the percentage of chemical used in the field. The common increase in strength ranges from 20 psi to 100 psi with lime and from 50 psi to 200 psi with cement.

Method of Measurement (206.07)

When lime is shown on the plans, the quantities and percentage of lime are based on the use of hydrated lime. If the contractor chooses to use quick lime, the quantity of lime measured for payment is increased by the equation in 206.07. This is done because generally less quick lime is required than hydrated lime to have the same soil improvement.

Documentation Requirements - 206 Chemically Stabilized Subgrade

1. Materials per 206.02
2. Check contractor designed lime or cement percentage.
3. Verify subgrade line and grade.
4. Verify subgrade stability with proof roller, if variable locations.
5. Document the Construction: Spreading, Mixing, and Compaction
6. Perform the compaction testing according to Supplement 1015.
7. Proof Rolling results.
8. Measure and Pay according to 206.07 and 206.08
9. Document on CA-EW-2, CA-EW-12, CA-D-1, and CA-D-3. Do not duplicate the information on all forms unless necessary.

207 Temporary Sediment and Erosion Controls

SS 832 Temporary Sediment and Erosion Controls

Description (832.01)

SS 832 replaces C&MS 207 and SS 877. At the time of this publication revisions to SS 832 were under committee review and not yet finalized. The information contained in this MOP section is an interpretation of the proposed revisions. SS 832 as discussed, includes the latest OEPA NPDES permit (OHC000003). Projects which involve one (1) acre or more of earth disturbing activity are required to have an NPDES Permit. This permit pertains to both the work within the project work limits and related support activities.

1. The Contractor is required to furnish a fully executed Co-permittee form.
2. The Contractor is required to furnish site specific Storm Water Pollution Prevention Plan (SWPPP) that is compliant with the NPDES Permit (see SS832 Appendix E).
3. The Contractor is required to locate, furnish, and maintain all TSEC BMP as identified in the Contractors SWPPP.
4. Project personnel are required to read the permit, SS832 Appendix E, and should inform the Contractor of any non-compliant permit conditions known on the construction site.
5. If stream or river crossing (causeway) provisions are not specifically included in the contract documents, the Contractor must obtain the proper permit to construct a stream or river crossing. **Fording streams, rivers or waterways is not permitted.**

Definitions (832.02)

Co-Permittee: The Contractor is required to file the co-permittee form to OEPA. This form notifies OEPA that the Contractor is an “Operator”. Both ODOT and the Contractor are identified as “Operators” in the NPDES Permit. As a result both ODOT and the Contractor are required to keep the construction activity in compliance with the NPDES Permit. ODOT contractually holds the Contractor responsible for compliance and provides compensation for the Contractor’s efforts. ODOT cannot knowingly allow a permit violation to exist without taking corrective measures. If a permit violation or deficiency is identified, the Contractor should be notified and reminded of his contractual responsibility to maintain permit compliance.

Standard Construction Drawing Reference (832.03)

The Standard Construction Drawings (SCD) provide detailed information describing the materials, construction and installation requirements for most of the TSEC BMP. The SCDs are referenced in SS 832; however they are often overlooked by the Contractor's crews performing the work. The SCDs should be brought to the Contractor's attention as early in the project as possible and preferably at or before the preconstruction meeting. Project staff should use the SCDs when inspecting and measuring TSEC BMP for payment.

Requirements (832.04)

Post construction NPDES Storm Water Management Requirements are not included in this specification. Post construction controls are not considered "Temporary" and therefore are addressed in the project plans. *Project staff should be familiar with the Post Construction BMPs, where they are located in the plans and on site. OEPA may specifically inspect these BMPs during a field visit.*

Provisions (832.05)

The "Provisions" portion of the specification identifies how the ODOT contract handles storm water enforcement actions resulting from non-compliance. The NPDES permit holds the "operator" responsible for compliance. **BOTH** ODOT and the Contractor are identified as Operators. If a non-compliant condition results in OEPA enforcement action the Contractor agrees to:

1. Make all necessary corrections resulting from an incomplete or inadequate SWPPP.
2. Reimburse ODOT for any fine penalty assessment damage judgment or expense resulting from non-compliance regulatory action.
3. Indemnify and hold the Department harmless for any fine penalty assessment damage judgment or expense resulting from non-compliance regulatory action.
4. If a stop work order is issued resulting from an incomplete or inadequate SWPPP and or TSEC BMPs the Department will find the Contractor in default.
5. Failure to correct non-compliant site conditions may result in suspension of the work and/or removal of the project superintendent.

When notifying the Contractor of non-compliance matters, the provisions portion of the spec should be referenced.

EDA Requirements (832.06)

ODOT Maintenance projects involving less than 5 acres of maintenance work activity are exempt from the NPDES permitting requirements. For a project to be eligible for this exemption it is required that ALL work activity included in the project falls under the OEPA approved list of "Maintenance Activities". The approved list can be found at:

http://www.epa.state.oh.us/dsw/storm/routine_maint.html

If the Contractor elects to work outside of the project limits (typically areas for borrow, waste, staging or storage) and the EDA is greater than 1 acre, then the Contractor is required to obtain the NPDES General Construction permit.

Work outside the project work limits

If the project has identified any EDA within the project limits (even less than one acre Project EDA), ODOT will compensate the Contractor for the installation of appropriate TSEC BMP within the project limits. For projects with more than one (1) acre of EDA, the Contractor is required to specifically identify all work areas located outside of the project work limits on his SWPPP. The cost for expanding the SWPPP coverage outside of the project work limits is included in the lump sum price bid for SWPPP. See 107.19 for general environmental protection requirements. It is important to note that the Contractor EDA may be on ODOT R/W but outside of the project work limits.

Jurisdictional Waters may include Waters of the State or Waters of the US. In either case, a permit may be required (See107.19). Placement of fill in these regulated waters (i.e. streams, ponds, lakes, waterways etc.) without a permit is illegal. The Contractor is required to furnish the proper permit for any area affected by his operation that is outside of the project work limits. This may include temporary work pads, stream crossings, causeways or placement of any fill in "Jurisdictional Waters" that are not otherwise identified in the plans.

The Contractor is required to furnish spill response equipment for all operations working next to a body of water. (See 107.19).

The Contractor is required to furnish water handling controls that are capable of preventing sediment-laden water from being discharged from the site. This is an important consideration when working in and around water areas on drilled shafts, cofferdams, dewatering operations etc. (See 107.19.)

The Contractor is required to provide a location to properly wash out cement or concrete trucks. Concrete washdown water is toxic and can cause a fish kill or other serious environmental impact. Concrete truck washdown BMPs must be located away from all bodies of water. The Contractor is required to locate the concrete washout BMP(s) on the SWPPP.

TSEC BMP Materials (832.07)

The Standard Construction Drawings referenced on the plan title sheet contain details that are often overlooked by the Contractor. The SCDs have been revised to address the latest version of the storm water permit. Earlier SCD versions may reference sediment and erosion controls that are no longer recognized by OEPA as viable BMPs.

Furnish the materials as outlined below:

1. Furnish commercial fertilizer, seed, and mulch material that meet 659.
2. Furnish filter fabric material for ditch checks that meets standard drawing DM-4.4. It is important to note that this BMP includes the installation of an aggregate component to prevent high flows and sediment accumulation from collapsing the fabric fence.
3. Furnish rock material for ditch checks that meets standard drawing DM-4.4.
4. Furnish filter fabric material for inlet protection that meets standard drawing DM-4.4.
5. Furnish filter fabric material for perimeter controls that meets standard drawing DM-4.4.
6. Furnish filter fabric material or hay or straw bale material for bale filter dikes that meets standard drawing DM-4.3.
7. Furnish excavation and embankment material for sediment basins and dams that meets the capacity and 48 hour draw down requirements described in the NPDES Permit.
8. Furnish pipe material for slope drains that meets standard drawing DM-4.3.
9. Furnish rock channel protection material that meets standard drawing DM-4.3.

Furnish and Locate TSEC BMP (832.08)

The NPDES Permit requires that the SWPPP identify the type, location and size of all sediment and erosion controls installed or proposed on the project site. The Contractor is required to keep the SWPPP current with the controls installed and maintained on site SS832 Appendix E Part III.C.2.D.

Figure 832.A- Sediment Settling Pond with Construction Fence and stream Perimeter Filter Fabric Fence

Figure 832.A2 Perimeter Filter Fabric Fence

Perimeter Controls (SS 832.08 A)

Apply perimeter control practices to protect the disturbed area from offsite runoff and to prevent sediment from discharging off site to areas below the construction site. Sediment and runoff barriers surrounding the area disturbed by construction activity prevents runoff from moving offsite and impacting surface waters downstream

1. Perimeter controls must be placed and identified in the SWPPP before or concurrent with any clearing and grubbing operation.
2. The perimeter controls should be dated on the SWPPP along with the dates of the clearing and grubbing.
3. Perimeter controls BMP are detailed in standard drawing DM-4.4.
4. Perimeter controls (typically dikes) can effectively divert water away from the project and, when designed properly, can separate watersheds into smaller drainage areas reducing the need for large sediment settling ponds.
5. Perimeter controls should be used to protect all water bodies (ponds, streams, wetlands, etc.) and any areas shown on the plan which may be adversely affected by construction surface drainage.

Figure 832.A3 Perimeter Control, Water Body Protection

Filter Fabric Fence

Filter Fabric Fence is used to control sheet flow (not concentrated flow). The application of Filter Fabric Fence is limited by the steepness of the slope and the size of the surface area draining toward the fence. The regulatory limitations for Filter Fabric Fence are outlined in the NPDES Permit see SS832 Appendix E, Part III.G.2.d.

It is critical that Filter Fabric Fence be installed in accordance with standard construction drawing DM 4.4. The fabric must be installed in a 6 inch X 6 inch trench and backfilled with compacted earth. Placement of the fence along the ground surface and shoveling fill on top of the lower edge of the fabric is NOT acceptable.

Filter Fabric Fence is a filter. It should be installed down gradient of EDA to filter sediment from sheet flow. Do not install silt fence above EDA areas.

When Filter Fabric Fence fails in the field it is typically caused by one or more of the following:

1. Improper burial depth
2. Drainage area exceeds the capacity of the fence
3. Fence is not parallel to the surface contours
4. Poor maintenance

Dikes

Dikes can be used as a perimeter control. Dikes function best by collecting and concentrating sheet flow then directing it to an appropriate controlled outlet or other BMP which does not allow the discharge of sediment.

Inlet Protection (SS 832.08 B)

Place Inlet Protection as outlined below. The location and date of placement, maintenance or removal should be identified on the SWPPP. It is recommended that all inlet protection be numbered and dated both in the field and on the SWPPP.

Figure 832.B - Inlet Protection

1. If Inlet Protection is being used as a TSEC BMP it is required that they be located on the SWPPP
2. Inlet Protection should be dated on the SWPPP.
3. Inlet protection should be used around Catch Basin inlets and/or any structure that conveys storm water.
4. Inlet protection requirements are detailed on standard drawing DM-4.4.

5. When Inlet Protection fails in the field it is typically caused by one or more of the following:
    a. Improper burial depth
    b. Inadequate height of fence above inlet invert
    c. Improper lap of fabric
    d. Poor maintenance

Construction Seeding and Mulching (SS 832.08.C)

Seed and mulch all disturbed areas that have been idled, in particular, before winter shut down.

Figure 832.C - Construction Seeding and Mulching

Figure 832.C2 - Winter Seed and Mulch, with mulch crimped in place

1. The rate furnished for straw mulch is 3 tons per acre. (0.5 metric ton/1000 m²)
2. The rate furnished for fertilizer is ½ the rate found in Item 659.
3. Do not place construction seed on frozen ground.
4. Install Construction Seed and Mulch on disturbed areas that work will be suspended during the winter. Standard Construction Seed and Mulch should not be installed between October 15 and March 15.
5. Winter Seed and Mulch is the standard erosion control practice for EDA occurring between October 15 and March 15. This BMP includes mulch crimped in place or a Bonded Fiber Matrix capable of providing sufficient protective cover to comply with the NPDES Permit. The cost for installing BFM mulch is typically greater than crimped mulch. The BFM mulch is better suited for limited area applications on steep slopes or areas where crimping implement access is limited. The use of other seed and/or mulch materials in this time period requires Department approval.
6. Temporary cover such as Construction Seed and Mulch, Construction Mulch or Winter Seed and Mulch should be installed as the construction progresses and not when a “big enough” area is exposed to the elements. Temporary cover requirements address the allowable time that disturbed earth may remain exposed. It is important that temporary cover installation keeps up with construction progress.
7. The date of construction seed placement should be recorded on the SWPPP and corresponding NPDES inspection reports.

Slope Protection (SS 832.08.E)

Fill Slopes that are greater than 8 feet (2.5M) and have had no filling activity for three weeks.

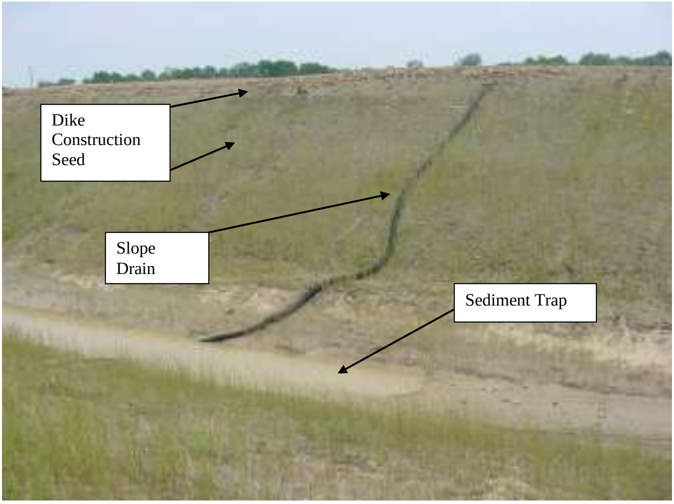


Figure 832 E - EC Items Required For Slope Protection

1. If dikes are being used as a TSEC BMP it is required that they be located on the SWPPP
2. Dikes should be dated on the SWPPP along with the date of the slope construction.
3. Dike and slope drain construction requirements are outlined on standard drawing DM-4.3.

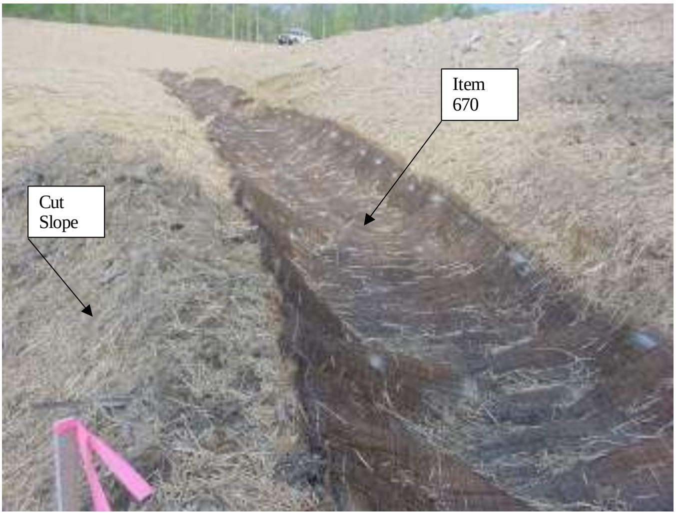


Figure 832 E2 - Item 670 Recommended for Cut Slope construction

When constructing cut slopes, a surface water control ditch should be installed before the slope excavation begins.

1. The ditch should be constructed at the top of the cut slope.
2. If the ditch is being used as a TSEC BMP it is required that it be located on the SWPPP.
3. It is important that the ditch is constructed with sufficient grade to prevent water from saturating the underlying soils and causing slope instability problems.

Ditch Checks and Ditch Protection (SS 832.08.F)

Figure 832 F1- Filter Fabric Ditch Check

1. Construct Filter Fabric Ditch Checks as soon as ditch is cut.
2. Ditch checks shall be placed per the SWPPP or as required.
3. Ditch checks are TSEC BMP and are required to be recorded on the SWPPP along with the ditch construction.
4. Filter fabric ditch checks construction requirements are detailed on the standard drawing DM-4.4.
5. Filter Fabric Ditch Checks are limited to drainage areas of 2 acres (0.8 ha) or less.
6. Filter Fabric Ditch Checks include #1 thru #4 aggregate component. The Engineer may waive the aggregate requirement when ditch checks are needed in the clear zone. The aggregate should be replaced with straw bales staked in place against the filter fabric as detailed on standard construction drawing DM-4.4 (see Figure 832 F2).
7. It is important that ditch checks be in place by the end of the day if working on the ditch.

Figure 832 F2- Filter Fabric Ditch Check with Straw Bale Backing

Figure 832 F3 - Rock Ditch Check

1. Rock Ditch Checks shall be placed per the SWPPP or as required.
2. If Rock Ditch Checks are used as TSEC BMP they should be recorded on the SWPPP.
3. Rock Ditch Checks should be installed as soon as the ditch is cut.
4. Rock Ditch Checks construction requirements are detailed on the standard drawing DM-4.4.

5. Rock Ditch Checks are limited to drainage areas between 2 and 5 acres (0.8 and 2.0 ha).
6. It is important that ditch checks be replaced by the end of the day if working on the ditch.

Bale Filter Dike (SS 832.08.G)

OEPA no longer recognizes Bale Filter Dikes or Bale Ditch Checks as acceptable BMPs.

Filter Fabric Ditch Checks that are installed in the clear zone may use straw bales in lieu of the aggregate backing (see DM 4.4) **when allowed by the Engineer**.

Sediment Basins and Dams (SS 832.08.H)

Place Sediment Basins and Dams as outlined below and as required by the NPDES Permit.

Figure 832 H - Sediment Settling Pond

1. Sediment basins and dams are required to be placed within 7 days after completion of grubbing and constructed before grading begins.
2. Sediment basins and dams should be installed as per the SWPPP and as required by the NPDES Permit.
3. Sediment basins are a TSEC BMP and are required to be recorded on the SWPPP and routinely inspected.
4. Concentrated flow discharging from areas containing EDA is required to pass through a Sediment Settling Pond.
5. Typical field locations include: the bottom of a ravine, culvert inlets and outlets, at the end of a ditch, and any concentrated water exit point.

6. Sediment Settling Ponds, Basins or Dams should never be constructed in a body of water.
7. Sediment Basins and Dams should be sized to retain 67 cubic Yards (125 cubic meters) of water for every acre of drainage area. The latest version of the OEPA NPDES General Construction Permit requires that the basin volume described above be designed to have a minimum 48 hour draw down time. Sediment storage ponds are required to include an additional volume specifically designed for sediment storage. The sediment storage portion of the pond consists of 34 cubic yards per acre of disturbed earth in the watershed. The SWPPP designer is required to attach the computations for sediment settling pond design to the Acceptance submittal (832.10).
8. Construction requirements for Sediment Basins and Dams are detailed on the standard drawing DM-4.3.
9. Install Construction fence as needed for safety considerations.

River, Stream, and Water Body Protection (SS 832.08.I)

All rivers, streams, and water bodies must be protected from all sediment-laden or turbid water. 832 items are provided to ensure the protection of all rivers, streams, and surface waters.

Figure 832 I - Stream Protection

Stream Relocation (SS 832.08.J)

Fully stabilize any temporary-relocated waterway before the water is diverted as outlined below. Examples are temporary run-arounds to constructed culverts, temporary ditches, or any temporary waterway constructed by the Contractor to build the project. General and/or specific permits may be attached part of the special provisions shown in the plan. Some individual or specific permits may include requirements in addition to what is required under the general NPDES Permit.

Figure 832 J - Temporary Channel

Temporary Channel

1. Temporary channels require stabilization with rock channel protection, Item 670 Erosion Protection or a stand of grass at least 70% established.
2. Temporary channels are required to be stabilized before any flow is diverted into the channel.
3. If the Temporary channel is a 404/401 permit requirement, costs associated with constructing maintaining and removing the temporary channel are incidental to the work taking place within the footprint of the 404/401 permit area.

Causeways and Access Fills (Stream and River Crossings and Fills) (SS 832.09).

Equipment can cross a waterway only by means of a permitted crossing or causeway. Regulatory permits are required prior to any disturbance to the waterway. Place Stream or River Crossings (Causeways) as outlined below and date the placement on the SWPPP.

Figure 832 K - Stream Crossing

1. Ensure the causeway is a height of 1 foot (.3m) above the Ordinary High Water Mark (not necessarily the "normal water elevation").
2. The causeway should be as narrow as practical to provide for passage of the equipment while preventing the movement of any fill into the water.
3. Furnish culvert pipes if filling more than one-third of the waterway. Pipes may be specifically required per the terms of the 404/401 permit.
4. Only clean dump rock (non-erodible fill) is permitted for use in the waterway. Broken concrete can be used as a Temporary Fill if all exposed rebar has been removed.
5. Furnish 50 feet (15m) approach drive of dump rock (non-erodible fill) on both sides of the causeway.
6. When a high water event impairs the contractor's ability to work and causes a delay, the Department will allow an excusable non-compensable delay. The Department will compensate the Contractor for required repairs to the causeway and access fills that were damaged as a result of the high water event.

Causeways and Access Fills Construction and Payment (SS 832.10).

Typically Causeways and Access Fill environmental protection costs are incidental to the work contained within the 404/401permit boundary. In some cases, Causeways and Access Fills are paid as a separate item. It is important to note that all environmental controls within the 404/401 permit boundary are incidental to the work conducted within that boundary. The Sediment and Erosion Control Prices (SS 832 Appendix F) should not be used as compensation when BMPs are installed within the 404/401 permit boundary.

Figure 832.11 L - Required Maintenance

Maintenance (SS 832.11).

1. The Contractor is required to maintain all TSEC BMP throughout its functional life on the project.
2. All TSEC BMP are required to be sized and designed to withstand a minimum ½ inch rainfall event.
3. The cost for maintaining TSEC BMP is included in the price paid per unit of BMP. Compensation is provided for TSEC BMP replacement and or repair required as a result of a rainfall event greater than ½ inch. The Contractor is required to inspect, record and report all impacts to the TSEC BMPs that require maintenance and/or replacement. TSEC BMP must be inspected weekly and within 24 hours of a ½ inch or greater rainfall event.
4. Sediment that accumulates at the TSEC BMP requires removal and proper disposal as part of the Contractor's responsibility for maintenance. Safeguards must be in place to prevent the release of sediment into waters of the state during the BMP maintenance effort. Disposal of accumulated sediment must be compliant with C&MS 107.19.
5. Routine maintenance and repair of TSEC BMP is required to be conducted within 3 days of the inspection which identified the need. Sediment settling ponds must be repaired and or maintained within 10 days of the inspection. If deficiencies or violations have been identified on site, the Contractor is required to correct and mitigate the conditions within 48 hours of notification by the Department or regulatory agency SS832.05.G.
6. TSEC BMP should not be removed until the Earth Disturbing Activity has been completed and a "uniform perennial vegetative cover with a density of at least 70% has been established" on all unpaved areas. If silt fence is removed to accommodate the final grading and seeding operation it should be replaced after the seeding work is completed, or other perimeter control BMPs should be installed to provide appropriate protection. OEPA recommends the installation of sediment basins down gradient as an appropriate control measure when perimeter controls are removed for final grading and seeding.

TSEC BMP Maintenance Requirements

Routine maintenance on TSEC BMP is required when repairs are needed and when:

1. Rock Ditch Checks have sediment covering ½ the height of the rock.
2. Perimeter Filter Fabric Fence, Filter Fabric Ditch Checks and/or Inlet Protection have sediment covering ½ the height of the fabric.
3. Sediment Settling Ponds require sediment remove maintenance when the required sediment settling zone is full.
4. Bale Filter Dikes have sediment covering ½ the height of the bale.

5. Erosion Control Mats require replacement when they are torn and or displaced.
6. Construction Seeding and Mulching has been displaced and re-application is needed.

Permanent stabilization must be achieved before the project is accepted. Once the project is "permanently stabilized" see SS832 Appendix G, Part VII.H all TSEC BMP must be removed and resulting debris disposed of appropriately.

Storm Water Pollution Prevention Plan (SS 832.12).

1. The Department requires that the SWPPP be designed by an Engineer (P.E.) that has attended and completed the CPESC Exam Review Course. The effective date of the CPESC training requirement is July 1, 2006. The designer's CPESC training record will be made available for confirmation by the project.
2. The SWPPP must show the location of the TSEC BMP for all areas with EDA related to the project. This includes borrow, waste, staging and storage areas that experience EDA.
3. It is important that the SWPPP identify the watersheds and the area disturbed by the construction in each watershed (SS 832.12 G). This provides the project and Contractor with the location of all drainage outlets from the project. This information is helpful in conducting appropriate inspections (see SS 832.14 below).
4. If the Contractor is proposing BMPs other than those identified on the standard BMP pricing schedule, the SWPPP needs to describe the proposed BMPs for the Engineers approval particularly if compensation is a consideration.

SWPPP Acceptance (SS 832.13).

The intent of "acceptance" is to determine if the SWPPP developed by the Contractor is a reasonable reflection of the site conditions and identifies reasonable controls that will uphold compliance with the NPDES permit. Acceptance is not regulatory approval. If the SWPPP is accepted, the Department is recognizing that the Contractor has developed what appears to be an appropriate plan to comply with NPDES. Sections A through G of Part III in the NPDES permit is a checklist that identifies the minimum SWPPP elements that the Contractor must have on his plan. If the SWPPP is not accepted by the project and the Contractor is requesting assistance from the project to develop an acceptable SWPPP, guidelines are available in the form of a checklist from OEPA. The checklist is titled: *SWPPP Checklist for Construction Activities* and it can be found at: *http://www.epa.state.oh.us/dsw/storm/construction_index.html*. Project staff can and should make recommendations to the Contractor to facilitate permit compliance. It is important to note that the Contractor's responsibility and liability related to NPDES compliance is reduced when he is **directed** to perform compliance work by the Department. The Contractor is required to tailor his operation in such a way to comply with the NPDES permit. The underlying point is that the purpose of this submittal is to demonstrate compliance with the contract documents. If the contractor intends on using the submittal as a mechanism to alter the contract requirements, he is required to "prominently call attention to the proposed deviation from the contract in the submittal.

Inspections and Updates (SS 832.14).

Inspections are a requirement of the SWPPP. The NPDES permit requires that all controls (BMPs) and all surface water outfalls on the site are inspected at least once every 7 calendar days and within 24 hours of any storm event greater than one-half inch as per SS832 Appendix E part III.G.2.i. The storm Water inspection report is a document of record that carries legal liability. The Contractor has the contractual responsibility to conduct the inspections by or directly under the supervision of the SWPPP designer who sealed the SWPPP. At least monthly the SWPPP designer is required to sign off on the inspection report with the following standard Certification language:

> *"I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations."*

SS832 Appendix E part III.G.2.i describes the minimum components of an inspection report.

It is important that the inspection specifically include all discharge locations. If erosion is occurring or sediment is accumulating at a discharge location along the boundary of the project, immediate action needs to be taken to document and correct the problem. For situations where off site sediment is mixing with surface water from the project, care should be taken to separate the flows and divert the offsite water away from the site (when possible). In many instances the separation and diversion of offsite surface water is not possible. In these cases the contractor should monitor the in-coming surface water and document the conditions as part of the routine inspection effort. In the event that OEPA or others identify an NPDES permit violation, the remedy and/or corrective action can be identified and implemented quickly and additional enforcement actions can often time be avoided.

OEPA refers to the SWPPP as a "living breathing document". The intent of the SWPPP requirement of the permit is to plan the work in advance and incorporate the BMPs in such a way that prevents the discharge of pollutants to waters of the state. The permit requires that the SWPPP be kept current with the site conditions and document the addition removal and maintenance of the BMPs on the SWPPP see SS832 Appendix E, part III.D. The Department requires that the contractor perform the required inspections. The inspector must be CPESC Trained. When modifications to the SWPPP are needed the inspector is required to get approval of the SWPPP design Engineer. The SWPPP design Engineer approval is documented as part of the routine inspection report provided to the project at least monthly. The Contractor's Erosion Control Inspector is required to provide the project with a weekly certification that the site is compliant with the permit. If the project is not receiving the weekly certifications, SS 832.05 should be enforced and the Contractor should be notified in writing. The certification requirement provides the project with the ability to track compliance issues and stay current with the required documentation.

Documentation Requirements – SS 832 Temporary Sediment and Erosion Controls

Documentation requirements include the entries in the "Inspector's Daily Reports" that reflect the inspectors observations relative to the sediment and erosion control compliance of the site. A BMP Inventory form is furnished in SS 832 Appendix A to assist in documenting and recording the BMP quantities for payment. **<u>The BMP inventory form in Appendix A is not a substitute for the inspection report described above.</u>**

The Contractor is required to provide the Engineer with an inspection report every 7 days and within 24 hours of a 0.5 inch (13 mm) or greater rainfall event throughout the life of the contract. Inspection requirements can be reduced to once a month, if the SWPPP Engineer certifies that the entire project has been "Temporarily Stabilized" and the construction activity will be suspended over the winter.

Include the following in the inspection report;

- The OEPA NPDES Permit inspection checklist information (see appendix E, Part III.G.2.i),
- A map identifying all BMPs needed, installed, maintained or removed since the last inspection report.
- Certification that all construction activities are compliant with the SWPPP and the signature of the CECI responsible for the inspection,
- The signature of the Professional Engineer who sealed the SWPPP is required as part of the inspection report, on a monthly basis or when modifications to the SWPPP design are made,
- Include the certification requirements according to OEPA NPDES Permit Part V.H with all reporting sign offs.

208 Rock Blasting

General Information

This section only covers the basic concepts of rock blasting. The topic is covered in more detail in the FHWA manual *Rock Blasting and Overbreak Control*, FHWA-HI-92-001. Many of the figures and specification concepts originated from this manual. The manual is available on the FHWA website:

www.fhwa.dot.gov/engineering/geotech/library_listing.cfm

There used to be a training course from NHI for Rock Blasting and Overbreak Control, but unfortunately this course is no longer available from NHI.

Rock Blasting Basics

Rock blasting consists of drilling holes in the rock at depths, in diameters, and at spacing so that the ANFO (which is a mixture of Ammonium Nitrate [fertilizer] and Fuel Oil [diesel fuel]) can fracture the rock in a controlled manner. The rock must fracture enough to displace it and break it down to the size of the intended use.

The specifications limit the way blasting contractors can blast so that rock or blast vibrations do not harm people or adjacent property.

Blasting Free Body Diagram

The basic geometry for rock blasting is shown in Figure 208.A.

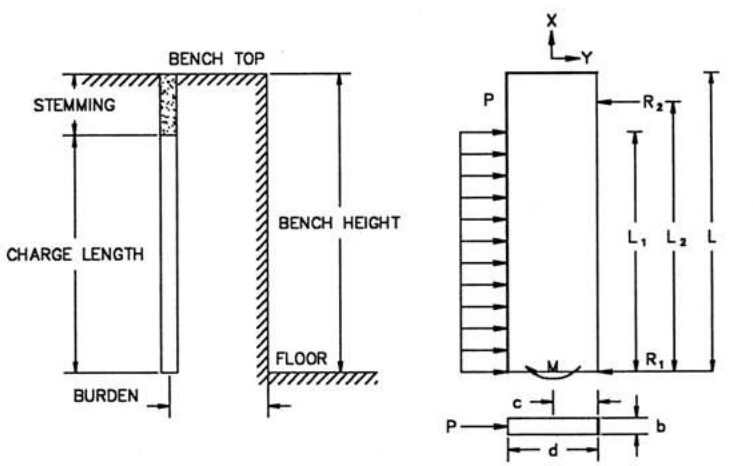


Figure 208.A – Rock Blasting Free Body Diagram

Holes are drilled to the required depth to remove the rock, and filled with ANFO (the charge length). The charge is topped off with stemming that helps hold the blast down. The free body diagram in the right-hand side of Figure 208.A shows the explosive pressure P and moment M from the blast.

The blaster and blasting consultant can arrange the geometry of the blast for optimal breakage. This is done so that P and M do not exceed the amount needed to break the rock. Excessive P and M causes flyrock and excessive air blast and vibrations that can cause damage and injury.

Blasting Geometry and Symbols

Figure 208.B further defines the rock blasting geometry.

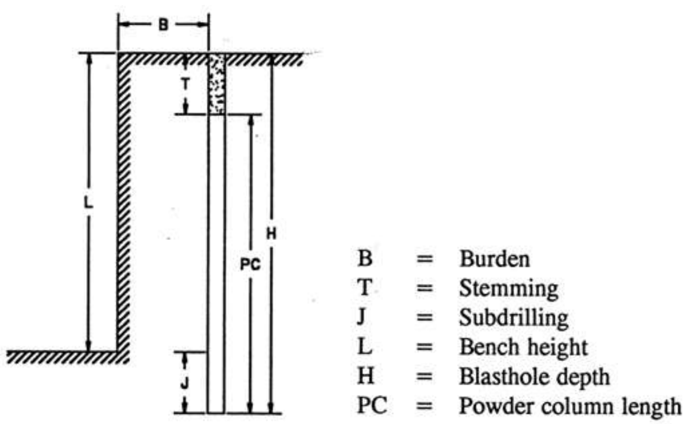


Figure 208.B – Rock Blasting Geometry and Symbols

Figure 208.B illustrates the following blast geometry parameters:

- B (Burden) is the distance between the free face and the first hole.
- T is the stemming (the inert material in the hole).
- L is the length of the bench height.
- H is the hole depth.
- PC is the Powder Column Length. (ANFO).
- J is the subdrill depth or the depth the hole extends below the planned cut.

Two main parameters to remember here are the L/B ratio and the stemming height.

Hole Spacing and Timing

The top view of the rock blasting geometry is shown in Figure 208.C. Notice the distance B is still the distance to the free face. The distance, S, or spacing of the holes is a function of the burden.

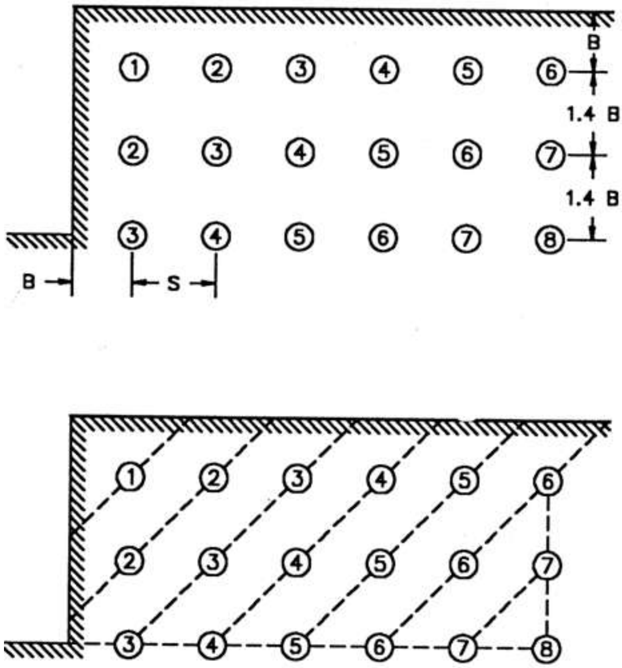


Figure 208.C – Rock Blasting (top view)

The spacing of the holes and the timing (or delay) of the holes are part of the blasting design. The bottom illustration in Figure 208.C shows how the blast is delayed by the sequencing numbers. Each hole may be blasted milliseconds apart to control the blast. The row-to-row shots are certainly time delayed.

An initiation system transfers the detonation signal from hole to hole at precise times. Plastic shock tubes or electric caps using a timing system are generally employed. A shock tube is non-electric, instantaneous, and has a thin reactive powder that propagates the shock wave signal.

The timing or delay minimizes the pounds of explosive per delay period. This can significantly control noise and vibration effects. It would be a disaster if all the holes went off at the same time.

The design variables of burden, stemming, subdrill length, spacing, and timing are selected to maximize fragmentation and to minimize excessive vibration, air blast, and flyrock.

Effects of L/B Ratio

Figure 208.D shows what happens when the ratio between the distance L (Bench Height) and the Burden (B) is changed. Potential blasting problems are decreased as the ratio is increased. As this ratio is decreased, these problems are increased.

Stiffness Ratio (L/B)	1	2	3	4
Fragmentation	Poor	Fair	Good	Excellent
Air Blast	Severe	Fair	Good	Excellent
Flyrock	Severe	Fair	Good	Excellent
Ground Vibration	Severe	Fair	Good	Excellent
Comments	Severe backbreak & toe problems. Do not shoot. REDESIGN!	Redesign if possible.	Good control and fragmentation	No increased benefit by increasing stiffness ratio above 4.

Figure 208.D – Potential Problems as it Relates to Stiffness Ratio L/B

The specifications in 208.06.C require this ratio to be greater than one. ODOT blasters design the correct timing, hole spacing and stemming, and have not had problems with designs having a L/B ratio near one. Local blasters are also very familiar with local geology.

Generally, a ratio near one maximizes the rock blasting production. The main problem with designing a ratio that is near one is that the rock generally fractures in large chunks. This can pose problems for the Contractors when trying to use the material for fill.

When the ratio is increased, it can decrease the particle size of the rock. This allows the material to be used as fill easier.

Proper Burden

In order to ensure that the blaster is using the proper burden, follow this rule of thumb: the burden is usually 24 to 30 times the production hole diameter. For example:

If the production holes have a diameter of 6 inches (0.5 feet) then the burden should be:

$$24 \times 0.5 \text{ ft} = 12 \text{ ft} \qquad \text{or} \qquad 30 \times 0.5 \text{ ft} = 15 \text{ ft}$$

The burden for the shot should be between 12 and 15 feet.

Effects of Stemming

The specifications in 208.06.E require that the stemming depth (T) of inert material be at least 0.7 times the burden (B). This helps control the air blast.

Figure 208.E depicts the effects of stemming. If effective, the blast direction is lateral. If the stemming is ineffective, the blast can blow upward and cause excessive air blast. Notice that in the example, the blast cuts back into the cut slope. This is an obvious problem.

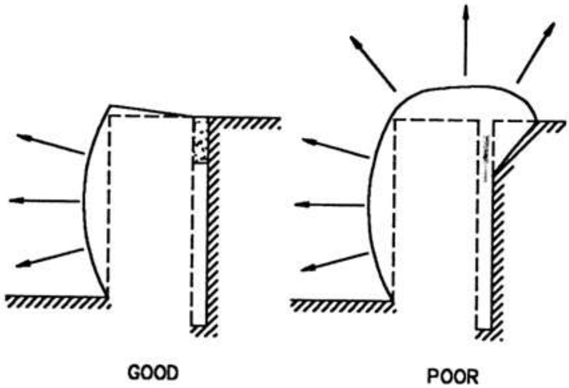


Figure 208.E – Stemming Effects

Drill cuttings are normally used for stemming. However, when blasting in water-filled production holes, or when blasting within 200 feet of a structure, the stemming material is changed to prevent problems. For holes less than 4 inches in diameter, crushed No. 8 stone is required. For holes 4 inches in diameter or larger, No. 57 stone is required. This helps hold the blast down better.

Effects of Timing

Timing the blast is another important parameter. Figure 208.F depicts the effects of poor and good timing.

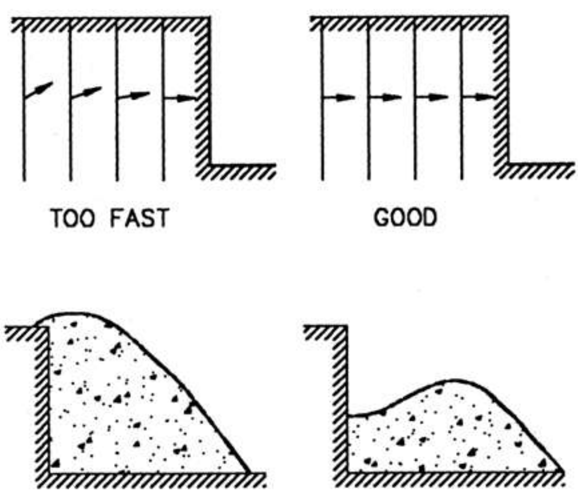


Figure 208.F – Timing Effects

With correct timing, the blast has a distinct lateral movement. With poor timing, the movement is more upright and has potential problems.

Vibration and Air Blast Monitoring

The blaster is required to design the burden, stemming, subdrill length, spacing, and timing to minimize excessive vibration, air blast, and flyrock. The blaster must monitor the air blast and vibration for every shot at the nearest structure. Seismographs are used to monitor the vibration.

Specialized equipment is used to monitor the air blast. The maximum air blast, in 208.16.A, is required to be under 134 dB. The air blast limit may need to be lower to prevent damage.

A typical vibration criterion is given in Figure 208.G. This is from the US Bureau of Mines.

To lower the air blast, check the stemming height and type of material used for the stemming. Thin or thick areas of the burden may create excess air blast and even flyrock. Measure the burden to the free face to ensure a uniform burden.

To lower the vibration everything needs to be checked. This includes the blast design and layout of the blast holes.

APPENDIX B.—ALTERNATIVE BLASTING LEVEL CRITERIA

Safe blasting vibration criteria were developed for residential structures, having two frequency ranges and a sharp discontinuity at 40 Hz (table 13). There are blasts that represent an intermediate frequency case, being higher than the structure resonances (4 to 12 Hz) and lower than 40 Hz. The criteria of table 13 apply equally to a 35-Hz and a 10-Hz ground vibration, although the responses and damage potentials are very much different.

Using both the measured structure amplifications (fig. 39) and damage summaries (figs. 52 and 54), a smoother set of criteria was developed. These criteria have more severe measuring requirements, involving both displacement and velocity (fig. B–1).

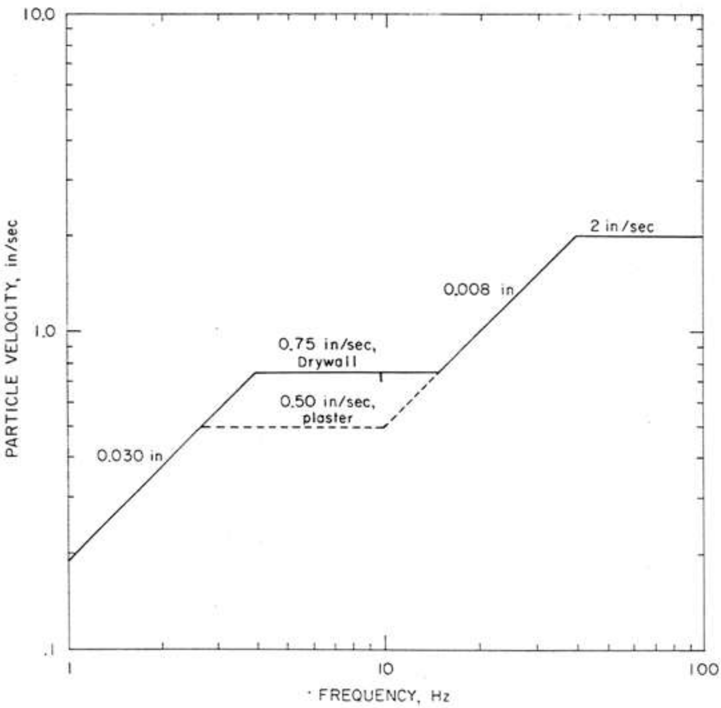


Figure B–1.—Safe levels of blasting vibration for houses using a combination of velocity and displacement.

Figure 208.G – Typical Vibration Blasting Criteria

Each blast has a particle velocity and frequency. The project can plot these values on the chart in Figure 208.G. If the point is lower than the plotted line, then the blast is within limits that are considered to be safe.

Presplitting (208.09)

Presplitting is a very effective method of controlling the final appearance of steep slopes; it can result in a clean sheared face. Presplitting is required when the slope is steeper than 1H:1V and deeper than 5 feet.

Specialized presplit blasting explosives are used. Hole diameters are about 3 inches, and the presplit holes are blasted prior to the production blast. The presplit hole spacing is started at 36 inches. This is adjusted to obtain a good shear face of the rock.

Documentation Requirements - 208 Rock Blasting

1. Accept preblast survey.
2. Verify the experience of the Blasting Specialists.
3. Accept and verify the blasting plan.
4. Ensure that the Item CA-EW-10 Item 208 Blasting Drilling Log is prepared by the Driller.
5. Review the blasting area for blasting plan dimensions with the blasting consultant.
6. Control Blasting is used on cut slopes steeper than 1:1 and deeper than 5 feet (1.5 m). Techniques are outlined in Section 208.10.
7. Production blasting is for widely spaced production holes in the main excavation
8. Review the regulations of explosives as outlined in Section 107.09
9. Blasting plan is required at least 2 weeks before drilling begins.
10. Review the detailed blasting plan of test shots.
11. Document test sections and drilling patterns.
12. Document safety procedures as outlined in 208.08. Ensure that the CA-EW-11 Item 208 Rock Blasting Site Security Plan is prepared by the Blaster.
13. Witness all shots. Inspect all shots using the CA-EW-9 Item 208 Rock Blasting Field Inspection Form.
14. Check vibration, air blast and flyrock for all blasts.
15. Check monitoring wells with Hydrologist.
16. Check the presplit face and requirements.
17. Measure presplit areas.
18. Monitor blasting consultants' hours.
19. Review contractor's record keeping for explosives and blasting logs.
20. Review monthly blasting report.
21. Document on the CA-EW-9, CA-EW-10, CA-EW-11 and the CA-D-2. Do not repeat information on other forms listed unless necessary.

209 Linear Grading

Because of the simplicity this item of work, no detailed explanation of the item is required in this manual.

Documentation Requirements- 209 Linear Grading

1. Verify plan dimensions.
2. Verify materials.
3. State method of excavation (grader, milling machine, etc.)
4. Statement as to how excavated material is disposed
5. Construct the embankment and subgrade.
6. Areas graded too much must be filled with material used for reconditioning shoulders (C&MS 617) at the Contractor's expense.
7. Measure and pay per 209.08.
8. Check completed work.
9. Measure borrow, if required. Document on CA-EW-1.
10. Measure pay according to 209.08 and 209.09.
11. Document on CA-D-2 and CA-EW-12. Do not duplicate the information on these forms unless necessary

250 Pavement Repairs

251 Partial Depth Repair

Description (251.01)

This work consists of partial depth removal of existing pavement in areas exhibiting surface deterioration, applying tack coat, and placing and compacting asphalt concrete.

Removal of Existing Pavement (251.02)

Mark the areas in rectangular shapes. Unless specified, the pavement should be removed to the full width of the traffic lane at transverse joints and along the longitudinal joint. Ensure pavement is removed to the depth shown in the plans and that adjacent pavement is not damaged. If the adjacent pavement is damaged, remove all loose pavement to the depth specified in the plans.

Removed pavement shall be disposed of in accordance with 202.02. The Inspector shall determine and document where and how pavement is being disposed by the Contractor.

Placement of Asphalt Concrete (251.03)

The exposed surfaces must be thoroughly coated with 407.02 material to fill all cracks and joint openings. The approved 448 asphalt concrete must be placed and compacted in as many lifts as necessary to finish flush with the adjacent pavement surface.

The final lift must be compacted using a Type I pneumatic tire roller that conforms to 401.13. At least 18 passes should be made over all points on the entire surface of the repair area. A pass is defined as one movement of the roller over the surface of the patch. As the rolling progresses, additional patching material may need to be added, as necessary, to produce a smooth surface flush with the existing pavement surface.

Each lift shall be continuously compacted while the material is in a workable condition throughout the depth of the lift.

Unless the repair area is scheduled to be covered with an asphalt overlay within 60 days, trim the limits of the repair area to form a vertical face 1.5 inches (38 mm) deep from the surface before placing the final asphalt concrete layer adjacent to the existing pavement.

If the Contract does not include resurfacing, seal the perimeter surface of the repaired areas with a 4” (100 mm) wide strip of approved 702.04 asphalt material, RS-1, RS-2, CRS-1, CRS-2, or 702.01 approved PG binder.

Documentation Requirements - 251 Partial Depth Pavement Repair

1. Mark and record areas to be repaired in rectangular shapes.
2. Document the removal of deteriorated pavement to a suitable depth as specified by plan or as directed by the Engineer.
3. Document the disposal of removed pavement.
4. Document that the area was cleaned and tacked with 407 tack coat.
5. Document the placement and compaction (number of lifts and compaction method) of approved 448 Type I asphalt.
6. Document the location of repairs, measurements, and calculations, and pay per 251.04.
7. Show documentation on CA-D-6 or other approved form.

252 Full Depth Rigid Pavement Removal And Flexible Replacement

Description (252.01)

This work consists of the full-depth removal of existing rigid pavement in areas exhibiting deterioration, correcting the subgrade, placing and compacting asphalt concrete, and restoring the shoulders.

Removal of Existing Pavement (252.02)

Pavement Sawing

The Engineer marks the limits of the areas to be repaired. The minimum longitudinal length of a repair is 6 feet (1.8 meters). All pavement repairs are the full lane width unless otherwise detailed by the plan.

The existing pavement is sawed full-depth at the limits established by the Engineer with a diamond saw blade. All diamond saw cuts shall be perpendicular to the surface of the pavement. Normally, the existing concrete pavement thickness is given in the plan. There may be older projects where the existing pavement was built thicker than specified in the new repair plan. Concrete sawing and removal depths may be as much as 1 inch (25 mm) greater than indicated on the repair plan without additional compensation to the Contractor.

If there is an existing asphalt overlay on the concrete pavement, the Contractor may elect to saw full-depth through the asphalt concrete and the Portland cement concrete. Depending on the thickness of each material, the Contractor may not be capable of sawing through both courses and may elect to make an offset saw cut through the asphalt course and remove enough asphalt to allow room for a diamond saw that would saw full-depth through the concrete pavement. If the Contractor elects to make offset cuts to facilitate the removal, the offset cut will not be measured for payment; only full-depth saw cuts that are made at the limits of the removal are measured for payment. Intermediate saw cuts made by the Contractor to facilitate removal by the lift out method are not measured for payment.

During hot weather, it may be necessary for the Contractor to saw only at night or morning when cooler temperatures prevail. Concrete pavement heats up and expands as temperatures rise during hot summer days. Diamond saw blades could be pinched and locked up during sawing by the expanding pavement slabs. Some contractors use a carbide-tipped saw to cut through the pavement within the repair area. This is permitted provided the Contractor does not damage the base under the pavement to be removed. All perimeter saw cuts must be made with diamond saws.

Pavement Removal

Removal of the concrete follows the full-depth sawing operation. The lift out method is required in order not to disturb the base under the pavement and to minimize the damage to the adjacent pavement that is to remain. Holes are drilled within the removal area and lift pins are inserted. The slab or portion of the slab is then removed by lifting the slab vertically with a crane or large backhoe. After lifting, loose debris left behind is removed by hand methods.

Removed pavement shall be disposed of in accordance with 202.02. The Inspector shall determine and document where and how pavement is being disposed by the Contractor.

The use of a pavement breaker and backhoe for removal is not permitted unless the Engineer determines that the lift out method is not practical because of extensively deteriorated pavement, existence of asphalt concrete full-depth repairs, or old concrete pavement repairs which are extensively cracked and deteriorated. There will be no additional compensation for removal of the existing pavement with a pavement breaker and backhoe.

Correction of Subgrade (252.03)

Prior to placing the asphalt concrete in the removal area, any base or subgrade that is disturbed below the level of clean out is removed. The repair area must be compacted to the satisfaction of the Engineer. All vertical faces shall be cleaned and coated with asphalt material according to 401.14.

Placement of Asphalt Concrete (252.04)

The pavement replacement is constructed by placing and compacting Item 301 or 448 Type 2 material in two or more lifts according to 401.16. Note that the plans for the project may specify the use of another material. The first lift, and all intermediate lifts, must be thoroughly and uniformly compacted using suitable mechanical compaction equipment operated over the entire replacement area.

The final lift must be compacted using a pneumatic tire roller that conforms to 401.13. At least 18 passes should be made over all points on the entire surface of the repair area. A pass is defined as one movement of the roller over the surface of the patch. As the rolling progresses, additional patching material may need to be added, as necessary, to produce a smooth surface flush with the existing pavement surface.

Each lift shall be continuously compacted while the material is in a workable condition throughout the depth of the lift.

If an overlay is not scheduled to be placed within 60 days of the repair, the perimeter of the repair shall be trimmed vertically 1.5 inches deep from the surface before placing the final lift of asphalt concrete.

If the Contract does not include resurfacing, the perimeter surface of the repaired areas must be sealed with a 4” (100 mm) wide band by applying approved 702.04 asphalt material, RS-1, RS-2, CRS-1, CRS-2, or 702.01 approved PG binder.

After completing repairs, the existing shoulders must be repaired to the condition that existed prior to the repair work.

Documentation Requirements - 252 Full-Depth Rigid Removal and Flexible Replacement

1. Locate, mark, and record all areas to be repaired.
2. Measure and record saw cuts. Full-depth saw cuts are an additional pay item paid by the linear foot.
3. Document removal of deteriorated pavement. Note condition of existing adjacent pavement.
4. Document the disposal of removed pavement.
5. Document preparation of subgrade.
6. Document that the area was cleaned and tacked with 407 tack coat.
7. Document the placement and compaction (number of lifts and compaction method) of approved 301 or 448 Type 2 asphalt, or other as specified by plan.
8. Document the location of repairs and saw cuts, measurements, and calculations, and pay per 252.06.
9. Show documentation on CA-D-6 or other approved form.

253 Pavement Repair

Description (253.01)

This work consists of removing existing asphalt concrete, brick, Portland cement concrete or aggregate pavement courses; shaping and compacting the exposed material; and placing new asphalt concrete pavement or aggregate and asphalt concrete pavement courses.

The plans show details about the repairs and replacement material.

Removal of Existing Pavement (253.02)

The Engineer shall mark all areas for removal. The pavement shall be cut at the limits marked and removed. Ensure that the pavement is removed to full depth or to the depth shown in the plans and that adjacent pavement is not damaged during removal. If the adjacent pavement is damaged, remove all loose pavement to full depth or to the depth specified in the plans.

Removed pavement shall be disposed of in accordance with 202.02. The Inspector shall determine and document where and how pavement is being disposed by the Contractor.

Placement of Asphalt Concrete (253.03)

The exposed underlying material must be shaped and compacted. The asphalt material shall be as specified in the plans. Before placing asphalt concrete, all vertical faces of the existing pavement must be cleaned and coated with asphalt material according to 401.14. The replacement material must be placed in appropriate lifts. Each lift must be thoroughly and uniformly compacted using suitable compaction equipment. The final lift must be flush with the existing pavement surface.

Compact the final lift using a pneumatic tire roller that conforms to 401.13. The final lift should be compacted with at least 18 passes over all points on the entire surface of the repair area. A pass is defined as one movement of the roller over the surface of the patch. As the rolling progresses, add additional patching material, as necessary, to produce a smooth surface flush with the existing pavement surface.

Continuously compact each lift while the material is in a workable condition throughout the depth of the lift.

If an overlay is not scheduled to be placed within 60 days of the repair, the perimeter of the repair shall be trimmed vertically 1.5 inches deep from the surface before placing the final lift of asphalt concrete.

If the Contract does not include resurfacing, the perimeter surface of the repaired areas must be sealed with a 4” (100 mm) wide band by applying approved 702.04 asphalt material, RS-1, RS-2, CRS-1, CRS-2, or 702.01 approved PG binder.

After completing repairs, the existing shoulders must be repaired to the condition that existed prior to the repair work.

Documentation Requirements - 253 Pavement Repair

1. Locate, mark, and record all areas to be repaired.
2. Document removal of deteriorated pavement. Note condition of existing adjacent pavement.
3. Document the disposal of removed pavement.
4. Document preparation of subgrade.
5. Document that the area was cleaned and tacked with 407 tack coat.
6. Document the placement and compaction (number of lifts and compaction method) of approved 301 or 448 Type 2 asphalt, or other as specified by plan.
7. Document the location of repairs, measurements, and calculations, and pay per 253.05.
8. Show documentation on CA-D-6 or other approved form.

254 Pavement Planing

Description (254.01)

This work consists of planing the existing pavement and disposing of the cuttings, and if specified in the Contract, patching the planed surface. The pay description indicates the predominant type of pavement.

Equipment (254.02)

The equipment used must be self-propelled and have sufficient power and stability to consistently and efficiently meet the requirements of 254.05 and the plans. Equipment can have grinding, sawing, or milling type cutters. The cutters have to be mounted rigidly to the carrier and must be adjustable to control the depth of cut and cross-slope. Longitudinal planing action shall be accomplished by using equipment with a suitable carrier wheelbase or with an automatic control system having an external reference. Ensure that cross-slope adjustments or automatic controls are capable of producing a variable and a constant cross-slope, as required.

For small or confined areas, the Contractor may use suitable supplemental equipment or methods approved by the Engineer.

Planing (254.03)

The engineer should mark the locations of signal loop detectors and notify the maintaining agency before starting the planing operation.

The Contractor may make one or more planing passes, as necessary, over the designated area to obtain the depth specified in the plans. Where establishing new pavement surface elevation or cross-slope remove irregularities such as bumps, corrugations, and wheel ruts as required.. Ensure that all cuttings are removed from the surface following each pass.

Before opening the completed area to traffic, the surface shall be thoroughly cleaned of all loose material that would create a hazard or nuisance, or would redeposit into the surface texture.

Cuttings shall be disposed of in accordance with 202.02. The Inspector shall determine and document where and how cuttings are being disposed by the Contractor.

Monitor and control dust, pavement contamination, and the scattering of loose particles during planing and cleaning operations to acceptable levels.

If damage occurs to the adjacent pavement by planing operations, repair the damaged area by matching the adjacent pavement with the planed area in terms of smoothness and mix type.

Surface Patching (254.04)

After planing mark areas of spalled or dislodged unsound pavement. Before patching, the areas shall be clean of loose materials and coated with 407.02 asphalt material. The area shall be patched with Item 448, Type 1 asphalt. Patched areas shall be compacted to be flush and level with adjacent pavement.

Surface Tolerances (254.05)

The surface shall be planed free from grooves, ridges, gouges, or other irregularities detrimental to the safe operation of vehicles on the planed surface.

If the Contract specifies planing without resurfacing, the surface shall be planed to a smoothness of 1/8 inch in 10 feet (3 mm in 3 m). If the Contract specifies resurfacing after planing, the surface shall be planed to a smoothness of 1/4 inch in 10 feet (6 mm in 3 m). The surfaces shall be matched at the edges of adjacent passes within 1/8 inch (3 mm). Ensure that the cross-slope of the planed surface is within 3/8 inch in 10 feet (10 mm in 3 m) of the specified cross-slope.

Method of Measurement and Basis of Payment (254.06, 254.07)

Measure the quantity of planing and patching and convert to square yards for payment.

Payment will not be made for repairs due to damage caused by the planing operation.

If the depth of the planed surface is increased by more than 3/8 inches (9.5 mm), the Department will recalculate the surface area for payment by multiplying the surface area measurement by a factor that equals the new depth divided by the plan depth. Additional depth will only be paid for with prior approval.

Documentation Requirements - 254 Pavement Planing

1. Document the location and/or stations of work.
2. Note locations of all loop detectors for traffic signals and notify the proper authority before removing.
3. Document the type of equipment used.
4. Record the depth of cut and cross slope grade.
5. Document the final disposition of cuttings.
6. Document method of removal (air hammer, bobcat, hand tools, etc.) around manholes, water-stops, catch basins, curb drains, etc.
7. Measure and pay as per 254.06.
8. Document on CA-D-1A or 1B or other approved form.

255 Full Depth Pavement Removal and Rigid Replacement

General

During the life of concrete pavement, it is sometimes necessary to make repairs to arrest progressive deterioration and to maintain serviceability. Timely repairs restore quality and provide the rideability and life expectancy for which the pavement was designed.

Problems may occur at various stages of the pavement life; it is important that these problems are corrected as the need arises. Corrections are often necessary during construction, and these repairs must be of the highest standard in order to achieve the anticipated pavement life. This section establishes a standard repair procedure and provides uniform application for repairs. These standards are also applicable at any time throughout the pavement life.

Generally, concrete pavement repairs are classified as full-depth pavement replacement and thin-bonded patching. Full-depth replacement applies when the damage is more extensive than surface scaling or spalling, and requires removal and replacement for the full depth of the slab. Thin-bonded patching applies to surface scaling and spalling, spalling at edges and joints, and other surface deterioration that does not extend below the pavement mesh. Compliance with all the provisions of the following standards is necessary to assure durable repairs and to permanently restore the quality of the pavement.

Description (255.01)

When this item is called for, Standard Construction Drawing BP-2.5 Rigid Replacement applies to the work. The basic process of full-depth repair includes the following:

1. Full-depth diamond blade sawing
2. Removing the existing pavement full-depth
3. Removing base material if specified
4. Compaction of base material
5. Drilling dowel bar or tie bar holes
6. Furnishing and grouting dowel bars and tiebars
7. Installing mesh when required
8. Placing, consolidating, finishing and curing concrete
9. Sealing of repaired surface perimeter
10. Restoring affected shoulders

Materials (255.02)

Concrete

The concrete to be used must be 499 Class C, S, FS, or MS and it will be called out in the pay item description.

Curing Materials

The curing material to be furnished and used must be white-pigmented liquid membrane forming compounds meeting 705.07. The shipping containers must be equipped with mechanical agitators to agitate the material prior to use.

Non-shrink Non-metallic Grout

The dowels and tiebars must be anchored with non-shrink, non-metallic grout material, and must set up within 30 minutes. Item 705.20 provides the requirements for grout. The Inspector should check to ensure the proposed grout is on ODOT's Qualified Products List.

Reinforcing Steel 709.00

Reinforcing steel for dowel bars, basket assemblies, deformed bars, tiebars, hook bolts, wiggle bolts, and couplings must be epoxy coated steel.

Welded Steel Wire Fabric

Welded steel wire fabric, also called steel mesh, must comply with Item 709.00.

Dowel Bars and Basket Assemblies

Dowel bars may be epoxy coated steel 709.13or fiber reinforced polymer (FRP) bars 705.01. Basket assemblies must be epoxy coated steel.

Removal of Existing Pavement (255.03)

The Engineer must mark the limits of the areas to be repaired. The minimum longitudinal length of a repair is 6 feet (1.8 meters). All pavement repairs must be the full lane width unless otherwise detailed by the plans.

The existing pavement is sawed full-depth at the limits established by the Engineer with a diamond saw blade. Normally, the existing concrete pavement thickness is given in the plans; however there may be projects where the existing pavement was built thicker than shown in the repair plan.

Picture 255.03 A - Full Depth Diamond Blade Saws

Concrete sawing and removal depths may be as much as 1 inch (25 mm) greater than indicated on the repair plan without additional compensation to the Contractor.

If there is an existing asphalt overlay on the concrete pavement, the Contractor may elect to saw full-depth through the asphalt concrete and the Portland cement concrete. Depending on the thickness of each material, the Contractor may not be capable of sawing through both courses and may make an offset saw cut through the asphalt course; remove enough asphalt to allow room for a diamond saw; then make a full depth saw cut through the concrete pavement. If the Contractor elects to make offset cuts to facilitate removal, the offset cut will not be measured for payment; only full-depth saw cuts that are made at the limits of the removal are measured for payment. Any intermediate saw cuts made by the Contractor to facilitate removal by the lift out method are not measured for payment.

During hot weather, it may be necessary for the Contractor to saw only at night or morning when cooler temperatures prevail. Concrete pavement heats up and expands as temperatures rise during hot summer days. Diamond saw blades could be pinched and lock up during sawing by the slab expansion. Some contractors use a carbide-tipped saw to cut through the pavement <u>within</u> the repair area. This is permitted provided the contractor does not damage the base under the pavement to be removed. However, all perimeter saw cuts must be made with diamond saws.

Picture 255 B – Pavement Removal by the Lift-out Method

Removal of the concrete follows the full-depth sawing operation. The lift out method is required in order to not disturb the base material under the pavement and to minimize damage to the adjacent pavement that is to remain. Holes are drilled within the removal area and lift pins are inserted. The slab or portion of the slab is then removed by lifting the slab vertically with a crane or large backhoe. After lifting, loose debris left behind is removed by hand. The removed pavement is disposed of in accordance with Item 202.02.

The use of a pavement breaker and backhoe for removal is not permitted unless the Engineer determines that the lift out method is not practical because of extensively deteriorated pavement, existence of asphalt concrete full-depth repairs, or old concrete pavement repairs which are extensively cracked and deteriorated. There will be no additional compensation for removal of the existing pavement with a pavement breaker and backhoe.

Regardless of the method used to remove the pavement, if the face of the pavement to remain is damaged by the sawing or removal operations, an additional full-depth saw cut is required for the full width of the lane or lanes at a distance from the first cut that includes the damaged pavement. The additional pavement repair area and the additional saw cut is not measured for payment.

After pavement is removed from the area to be repaired, an additional saw cut must be made if the face of the remaining pavement or shoulder is deteriorated on the bottom to a height greater than 1/4 of the pavement thickness. The additional saw cut should encompass the deteriorated areas. The additional saw cut and repair area is measured for payment.

Removed pavement shall be disposed of in accordance with 202.02. The Inspector shall determine and document where and how pavement is being disposed by the Contractor.

Correction of Subgrade (255.04)

Prior to placing the concrete in the removal area, and before installing dowels or tiebars, shape and compact the base or subgrade material. Any area that has been over-excavated must be filled with concrete.

Picture 255.C - Debris Remaining After Removal by the Lift-out Method is Removed by Hand Methods

Picture 255. D - Compaction of Base

If undercut joints at the limits of the repair areas are specified the Contractor must be careful when removing the base material to create the undercut section. The undercut section is the void created by removing the base material from underneath the existing remaining pavement. This undercut will be filled with concrete when placing the new pavement repair. Refer to Standard Construction Drawing BP-2.5 for undercut joint details. Damage to the bottom of the slab that is to remain cannot be tolerated. Any damage caused by the Contractor's operations requires additional removal and replacement at no additional cost If a backhoe bucket plate is used, exercise care (or use hand methods) to excavate under the existing slab. Undercut work is incidental and included in the pay item.

Drilling Transverse Dowel or Tiebar Holes (255.05)

Dowels could be smooth or deformed steel bars depending on the type of joint (transverse contraction or transverse tied) Smooth dowels are 1-1/2 inch (38 mm) in diameter by 14 inches (355 mm) in length. Fiber-reinforced polymer dowel bars may be used in lieu of smooth steel dowels. Deformed bars are No. 11 (#35M) by 14 inches (355 mm) in length. Refer to Standard Construction Drawing BP-2.5 for details on tied and contraction joints requirements.

Holes for dowels and tie bars are drilled in the existing concrete slab using hydraulic or electric drills. Drilling is to be done in a manner that will not spall or damage the existing concrete. Pneumatic drills are not to be used. Holes must be drilled with a device that allows independent adjustment of all drill shafts in the horizontal and vertical direction. The device must be capable of drilling a minimum of three holes at one time.

Holes for dowel and tie bars are to be centered at mid-slab within a tolerance of plus or minus 1/2 inch (13 mm). Dowels are spaced starting at 12 inches (300 mm) from the outside edge of pavement; are spaced at 12-inches (305 mm); and stop 24 inches (600 mm) from the adjacent lane to avoid hitting existing tiebars at the longitudinal joint. This will result in ten (10) bars in each 12-foot lane. The Contractor must drill dowel holes parallel to the pavement surface and the centerline otherwise the smooth dowels will not perform properly when the pavement expands and contracts.

Picture 255 D - Hole Drilling Equipment

Holes for dowels or tiebars must be 1-5/8 inches (41 mm) in diameter and a minimum of 7 inches (178 mm) deep into the concrete.

Longitudinal Joints

Full-depth repairs that are greater than 10 feet (10 meters) in length will require a tied longitudinal joint using No. 5 X 24” (# 16M X 600) tiebars or hook bolts spaced at no more than 30 inches (760 mm) and not less than 24 inches (610 mm). Refer to Standard Construction Drawings BP-2.1 and BP-2.5 for more details.

Holes for longitudinal tiebars must be ¾ inches (19 mm) in diameter and a minimum of 12 inches (300 mm) deep into the concrete.

Grouting Dowels or Tiebars

This section details the requirements for transverse dowels and tiebars. The requirements for tied longitudinal joints are the same, however the bar dimensions differ. All dowels and tiebars must be grouted into place with a non-shrink non-metallic grout material. Prior to injecting grout, the holes must be blown clean with oil-free compressed air. The hole must be dry and frost free before grouting dowels or tiebars.

The grout must be injected pneumatically into the back of the hole and the dowel or tiebar inserted 7 inches (178 mm) into the hole. A nylon or plastic washer (called a grout retention disc) is then pushed flush against the saw cut after the bar is installed to keep the grout in the hole. Grout retention discs must be clear or opaque white in color. Sufficient grout must be used to completely fill all voids around the bar, including any spalling at the face of the saw cut. Grout should extrude through the slot in the grout retention disc after filling and inserting the dowel or tiebar. Other methods of installing dowels or tiebars are not permitted.

Picture 255.E - Typical Grout Injection Equipment

Picture 255.F - Pneumatic Injection of Grout into Hole Prior to Installing Dowel Bar with Grout Retention Disc

Most Contractors pump the resin and hardener from separate pressure pots; the two materials are mixed immediately before being injected into the hole through a baffled mixing tube. In cooler temperatures, it may be necessary to heat the grout materials to promote flow and to allow set up in the required 30 minute time period. Dowels or tiebars must be held in proper alignment until the grout has hardened.

Picture 255.G - Insert Steel Rods w/ Grout Discs in Place

Picture 255.H - Using a Spud Bar to Push Steel Rod into Place

Placement of Portland Cement Concrete (255.06)

Placement of the concrete can begin when the grout around dowels or tiebars has hardened. Smooth dowels must be coated with new light form oil before concrete is placed. Rigid forms are required at the outside edge of the full-depth repair. The concrete must be placed in a continuous operation and consolidated with internal vibration.

Picture 255.I - Rigid Forms Installed at Shoulders

Full-depth repairs that are greater than 10 feet (3.0 meters) in length or will be opened to traffic within 24 hours of placement require W8.5 or D8.5 wire fabric reinforcement. The clearance from the end of the wire fabric to the edge of the pavement or new transverse joint is 4 ± 2 inches (100 mm ± 50 mm). Refer to Standard Construction Drawing BP-2.5 for details.

Picture 255.J - Screeding of Repair Area

Picture 255.K - Bull Floating the Repair Area

Specifications require that repairs less than 12 feet (3.7 meters) in length be screeded parallel with the centerline. If the repair is over 12 feet (3.7 meters) or longer in length the screed must be perpendicular to the centerline. After screeding and floating is completed, the surface must be tested with a 10 foot (3.0 meter) straightedge before the concrete hardens to assure that the transition on and off the repair meets a tolerance of 1/8 inch in 10 feet (3 mm in 3.0 m). Any high or low areas must be corrected and the surface rechecked to assure compliance.

The surface finish of the concrete repair must match the adjacent concrete. If the adjacent pavement is smoothed with a burlap drag, the patch should have the same finish. If the patch texture is different, it may be very noticeable when traveling over the patch at normal traffic speed.

After finishing and straightedge checking is completed, the concrete must be cured with white pigmented curing membrane as per 705.07, Type 2. A uniform coverage of membrane is required at an application rate of 150 square feet per gallon (1 liter per 3.7 square meters).

Wearing Course Replacement (255.07)

If asphalt was removed from the top of the existing pavement, it must be replaced with either 301 or 448 Type 2 material as shown in the plans. Compact these mixtures as approved by the Engineer using any of the roller types specified in 401.13. Prior to placing the hot mix asphalt concrete; apply a tack coat on the repaired surface per 407.

Trim to vertical all transverse joints 1.5 inches (38 mm) minimum before placing the final asphalt concrete layer adjacent to the existing pavement.

Seal the perimeter surface of repaired areas 4inches (100 mm) wide by applying approved 702.04 asphalt material, RS-1, RS-2, CRS-1, CRS-2, or 702.01 approved PG binder.

Shoulders must be restored to the original line and grade with aggregate or asphalt concrete as the Engineer directs or as shown in the plans. Fill low areas and compact them flush with the surrounding shoulder.

Opening to Traffic (255.08)

Full depth repairs can be opened to traffic when the concrete attains a modulus of rupture of 400 psi (2.7 Mpa). The time to obtain this strength will vary depending on the class of concrete used and the atmospheric conditions.

When traffic is maintained adjacent to the lane being repaired, the Contractor must schedule his work so that slab replacements are completed within 48 hours after removing the existing pavement. At the end of a daily work shift, unfilled repairs 10 feet (3.0 meters) and less in length must be covered with steel plates at the end of the work shift.

The Contractor must plan work so that no repairs are left unfilled when work is suspended for holidays or weekends. If the Contractor has removed pavement and is unable to complete the repairs in the above time, he must fill the areas with a suitable temporary patch material to the satisfaction of the Engineer. These areas must be maintained by the contractor.

Method of Measurement (255.09)

The Department will measure the quantity of full-depth pavement removal and rigid replacement by the number of square yards (square meters) repaired in the completed and accepted work.

Full-depth pavement sawing is measured by the number of feet (meters) of perimeter full-depth saw cuts made in the completed and accepted work. The Department will not measure any offset cuts, pressure relief cuts, or other saw cuts made to facilitate pavement removal.

Basis of Payment (255.10)

Payment is full compensation for all work specified in this item. Payment for accepted quantities of the full-depth pavement removal and rigid replacement item is at the contract price per square yard (square meter).

Payment for the full depth pavement sawing item is at the contract price per linear foot (meter).

The Department will not pay for additional work to repair damage caused by pavement sawing or pavement removal.

The Department will include tack coat in the cost of the asphalt concrete. The Department will pay for asphalt concrete according to Item 301 or Item 448.

Documentation Requirements - 255 Full Depth Pavement Removal and Rigid Replacement

1. Locate, mark, and record areas to be replaced.
2. Document removal of existing pavement and note if damage occurred due to removal operation.
3. Document the disposal of waste material.
4. Measure and record saw cuts. Full depth saw cuts are an additional pay item paid by the linear foot.
5. Document any damage to existing base material or subgrade during pavement removal operation.
6. Document preparation and compaction of base material or subgrade.
7. Document type of equipment used for drilling holes for dowel bars; depth of holes; holes blown clean before dowel bars placed.
8. Document dowel and tiebar sizes, spacing, and alignment; approved grout, method of grout placement; use of grout retention discs.
9. Document placement of concrete placed in accordance with 451.06 and direction of screeding.

10. Document surface tolerance checks with straightedge and any corrections made.
11. Calculate and document curing compound used and required.
12. Document times and results of beam breaks.
13. Measure and pay as per 255.10.
14. Show documentation on CA-D-6 or other approved form.

256 Bonded Patching of PCC Pavement

General

The success of a thin-bonded patch depends on complete removal of all unsound or damaged material, adequate bond between old and new concrete, use of "low slump" air-entrained concrete, and proper curing. Successful patching depends on strict adherence to all these requirements.

Description (256.01)

This work involves bonded patching of Portland cement concrete pavements in areas designated by the Engineer and includes:

1. Marking repair areas using aerosol spray paint; minimum payment is 2 square feet (0.2 m^2) for each area.
2. Saw cutting the perimeter of all areas marked for repair.
3. Removing loose and unsound concrete and asphalt patching materials from within the repair area.
4. Removing sound concrete to obtain a minimum depth of 1 ½ inch (38 mm).
5. Preparing the surface by cleaning bonding surfaces using abrasive blasting.
6. Applying a bonding grout for Type A, B, or C patches.
7. Mixing, placing, finishing, and curing of Type A, B, or C patch material.
8. Checking surface for trueness using 10-foot (3 m) straightedge.

Materials (256.02)

Portland Cement

Type A patches require high early strength cement, 701.05. Type B patches require quick setting concrete mortar, 705.21 Type 1 or 2. Type C patches require quick setting concrete mortar, Type 2.

Fine Aggregate

Fine aggregate must meet the requirements for concrete aggregate specified in 703.02.

Coarse Aggregate, No. 8 Size

Coarse aggregate must meet the requirements for concrete aggregate specified in 703.02 and be No. 8 size.

Curing Compound

Curing compound must meet the requirements of 705.07

Air-entraining Admixture

Air entraining admixtures must conform to 705.10.

Quick Setting Concrete Mortar

Prepackaged mortar material must conform to the requirements of 705.21.

Equipment (256.03)

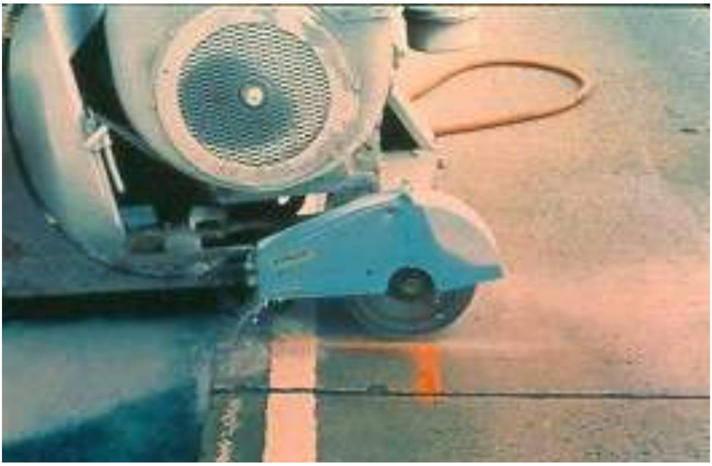
Equipment must be milling machines, concrete saws, jackhammers, or other approved equipment that is capable of removing the existing surface material. The chipping hammers used may not be heavier than 35-pound (16 kg) class.

Oil and moisture free compressed air is required to clean and abrasive blast prepared areas.

An on-site concrete mixer with a minimum capacity of 2-cubic feet (0.06 cubic meters) is required to mix the patching material.

Removal of Unsound Concrete (256.04)

Picture 256.A - Areas to be Repaired are Marked by the Engineer



Picture 256.B - Perimeter of the Repair is Saw Cut a Minimum of 1 Inch Deep

The limits of the damaged area must first be determined and the repair area established beyond the deteriorated area and into sound concrete. A steel rod or steel chain may be used to "sound" the surface to determine hollow and deteriorated concrete. The Engineer marks the limits of all bonded patches with spray paint provided by the Contractor.

Picture 256.C – Pavement Removal with Jackhammer

Picture 256.D - Pavement Removal by Milling Machine

The repair area should be square or rectangular. The perimeter should be outlined by sawing to a vertical depth of approximately 1 inch (25 mm) to avoid feathered edges that usually spall. Additional saw cuts within the outlined area aid the breakup and removal operation. The Contractor must remove all unsound concrete materials and all loose or disintegrated concrete within the marked area. Sound concrete must be removed to the minimum required depth within the patch area. Concrete removal may be by jack hammering or milling. The minimum depth of a repair is 1-1/2 inch (38 mm) except for the perimeter saw cuts that require 1 inch (25 mm) minimum. During removal operations, remove any reinforcing steel within the patch area by cutting or with a torch.

Picture 256.E - Abrasive Blasting of Repair Areas

Preparation of Patch Area (256.05)

After removal of pavement within the repair area the area must be cleaned of all loose material, dirt, dust, asphalt, etc., by abrasive blasting and blowing out with oil and moisture free compressed air. If water is used for cleaning, it must be mopped out thoroughly before abrasive blasting. Abrasive blasting of the bonding surfaces must be done after the area has dried. The contractor must comply with all State, regional and local government agency requirements regarding control of dust generated by the abrasive blasting operation.

Type B and C patching materials that do not use water as an activator may require additional surface preparation. Check the manufacturer's instructions to ensure surface preparation is done correctly.

If a bonded patch area is adjacent to a transverse or longitudinal joint, the joint must be re-established by using a joint board or form that extends below the level of the patch and is as wide as the joint. This board is to be removed about an hour after placing the patching material.

Picture 256.F – Adjacent Joints are Formed Prior to Placing the Patching Material

Bonding Grout Installation (256.06)

For Type A patches, prepare a grout of equal parts by volume of Portland cement, sand and water to a consistency of a thick paint or slurry. The grout should be brushed and scrubbed into the dry and clean bonding surfaces of the exposed concrete. Grout should be placed immediately prior to placing the patching material. Excess grout should not be allowed to collect in low spots. Ideally the grout should have a uniform thickness of 1/16 to 1/8 inch.

For Type B and C patches the bonding grout should be mixed and applied per the manufacturer's requirements.

Picture 256.G - Portable Mortar Mixer used to Mix Bonding Grout and Patching Material

Picture 256.H - Bonding Grout is Brushed into the Dry Patch Area

Placement of Patch Material (256.07)

The plans will specify the type of patching material to be used. In all cases, after placing the patching material, screed patches 12 feet and less in length parallel with the centerline and patches longer than 12 feet perpendicular to the centerline.

While the patch material is still plastic, the surface of the patch should be checked with a 10-foot straightedge to ensure the final surface is flush with the edges of the adjacent pavement. The straightedge is to be placed parallel with the centerline and drawn across the patch checking for any high or low areas across the patch. High or low spots that exceed 1/8 inch in 10 feet are to be immediately corrected. After making any corrections, recheck the surface to ensure there are no variations more than 1/8 inch high or low in 10 feet.

The surface of the completed patch is to be textured in the same manner as the adjacent pavement.

Type A Patch

Type A patching material is to be mixed in the field using 701.05 high-early-strength cement (Type III). Ready mixed concrete is not permitted. The principal requirements are the use of only enough water to make it cohesive and sufficient air entrainment. One part of cement is combined with 1 ½ parts of sand and 1 ½ parts No. 8 size coarse aggregate and enough water to obtain a slump practical to place in the patch area. Only a minimum amount of water is to be used and the slump must not exceed 4 inches. A low slump mix will reduce shrinkage of the patch and ensure a good bond to the surrounding concrete. An air entraining admixture is used to obtain 8 ± 2% air content.

Place the patching material while the grout is still wet, and vibrate the concrete in place after the patch area is slightly overfilled. Strike off the concrete to the elevation of the adjacent concrete.

Type B Patch

This type of patching material is a quick-setting mortar that comes prepackaged. The patching material must be pre-approved and must comply with 705.21 as Type 1 or 2 material.

Mix and place the material according to the manufacturer's directions. Add coarse aggregate, as needed, according to the manufacturer's instructions. Place the mortar mixture in the patch area. If the manufacturer's requirements specify using bonding grout, place the mixture while the bonding grout is still wet. Slightly overfill, vibrate, and strike off the concrete.

Picture 256.H - Patching Material Placed and Consolidating with an Internal Vibrator

Picture 256.I – Patching Material Screeded Off Flush with Surrounding Pavement

Type C Patch

This type of patching material is also a quick-setting mortar that comes prepackaged. The patching material must be pre-approved and must comply with 705.21 as Type 2 material. Mix and place the material according to the manufacturer's directions. Add coarse aggregate, as needed, according to the manufacturer's instructions. Place the mortar mixture in the patch area. If the manufacturer's requirements specify using bonding grout, place the mixture while the bonding grout is still wet. Slightly overfill, vibrate, and strike off the concrete.

Picture 256.J – Application of Curing Compound to New Bonded Concrete Patch

Picture 256.K – Completed Bonded Patches

Curing and Loading (256.08)

Type A patches must be cured with a white-pigmented liquid membrane-forming compound conforming to 705.07 and applied at a rate of 150 square feet per gallon (1 Liter per 3.7 square meters). The amount of curing required and used is to be documented. A modulus of rupture of 400 psi (2.8 Mpa) must be obtained prior to opening to traffic. Record times and results of all beam breaks.

Cure Type B and Type C materials according to manufacturer's directions.

Method of Measurement (256.09)

Project personnel must measure the repair areas and calculate the area in square feet (square meters) of completed and accepted work. If a measured area is less than 2 square feet (0.2 square meters) the Engineer will increase for pay to 2 square feet (0.2 square meters).

Basis of Payment (256.10)

Pay the contract price for accepted quantities per square feet (square meters) of Item 256, Bonded Patching of Portland Cement Concrete Pavements, Type A, B, or C.

Documentation Requirements - 256 Bonded Patching of Portland Cement Concrete Pavement

1. Locate, mark, and record areas to be replaced.
2. Document method of removal of the existing surface material and of unsound concrete, size of jackhammers, depth of repair area, removal of reinforcing steel, method of cleaning.
3. Document type of grout, mixing, and application.
4. Document type of patch material, mixing, placement, screeding, surface check, texturing, curing.
5. Document times and results of beam breaks.
6. Measure and calculate the area of the repair for payment.
7. Document on CA-D-6 or other approved form.

257 Diamond Grinding Portland Cement Concrete Pavement

Description (257.01)

This work consists of diamond grinding a rigid concrete pavement normally the full width of the lane to eliminate transverse cracking and transverse joint faulting. The work results in a longitudinal "corduroy" texture. If done properly the ride of the finished pavement surface will be improved and the skid resistance enhanced.

Final acceptance of a diamond ground pavement is done by surface measuring equipment that is passed over the completed pavement and measures the surface profile. This equipment is called a non-contact profilometer or a profiler.

Equipment (257.02)

Figure 257.A - Types of Diamond Grinding Equipment

Figure 257.A - Types of Diamond Grinding Equipment

Equipment requirements for diamond grinding:

- Must be power driven, self-propelled machine specifically designed to smooth and texture Portland cement concrete pavement with diamond blades or diamond impregnated cylinder rings
- Diamond blades or diamond impregnated cylinder rings must be mounted on an arbor head that is a minimum of 3 feet long
- Must be capable of grinding the surface in the longitudinal direction without causing spalling or other damage at cracks, joints and other locations
- Must be capable of correcting the pavement profile and providing proper transverse cross slope
- The effective wheelbase must be at least 12.0 feet (3.6 m) a set of pivoting tandem bogey wheels at the front of the machine and at the rear wheels that travel and track in the fresh cut pavement must be provided
- The center of the grinding head must not be further than 3.0 feet (0.9 m) forward from the center of the back wheels
- Must be configured such that it does not encroach on traffic movement outside of the work area in adjacent lanes
- Must be designed to remove all grinding residue; grinding residue is not permitted to flow across lanes being used by the traveling public

Requirements for surface measuring equipment (profiler):

- A non-contact surface measuring device conforming to Supplemental Specification 1058 along with software must be to develop an IRI.
- All necessary supplies must be provided to fully operate and graph the smoothness test results on the diamond ground pavement.

Contractors doing diamond grinding work use water trucks to provide water to the grinding heads of each grinder to cool the diamond blades.

Construction (257.03)

The plans will designate the areas to be diamond ground. Bridge decks, bridge approach slabs and roadway shoulders are not normally diamond ground unless indicated on the plans or required to provide drainage. Diamond grinding must eliminate crack or joint faults while providing positive lateral drainage by maintaining a constant cross-slope between grinding limits in each lane. Adjacent ramp lane grinding must be transitioned as required from the mainline edge to provide positive drainage and an acceptable riding surface.

The diamond grinding operation must result in pavement that conforms to the typical cross-section and the requirements specified for the final surface finish. It is the intention of this specification that faulting at joints and at cracks be eliminated and the overall riding characteristics restored within the limits specified. To accomplish the smoothness required, diamond grinding may not be required on 100 percent of the existing pavement surface.

In faulted pavement the rear slab will be lower than the forward slab (in the direction of traffic) creating a "step" or bump. Therefore Contractors will typically grind the pavement in the opposite direction of normal traffic flow so the "step" is cut first and the remainder of the slab can be feathered out. During initial grinding operations, the profiler must be used to test the pavement surface as soon as the concrete has been ground full lane width. This initial testing is to aid the Contractor in evaluating the grinding methods and equipment being used. Subsequent to the initial testing, the contractor must run daily profiles of each day's grinding the next working day.

All dust and residue generated as a result of grinding must be immediately removed. Dust cannot be allowed to blow across traffic lanes, into gutters or drainage structures.

Final Surface Finish

The final surface finish produced should be a longitudinal corduroy-type texture. The peaks of the ridges of this corduroy-type texture are to be approximately 1/16 inch (1.5 mm) higher than the grooves. There must be 53 to 57 evenly spaced grooves per foot (174 to 187 per meter).

Figure 257.B - Surface Texture Left by Diamond Grinding

The pavement surface must be tested by the Contractor with an approved profiler device that provides electronic copies of the pavement profiles compatible with ProVAL software. The contractor must produce a riding surface that does not exceed an IRI of 95 inches per mile or any localized surface deviations in excess of 0.4 inches in 25 feet.

The Engineer is to witness testing of the pavement's wheel paths. Wheel paths are to be located 3 feet (0.9 m) measured transversely inside all lane edges and parallel to the centerline. The profiler is to be maintained at the wheel path at all times when testing the pavement.

Figure 257.C - Profile Measuring Device

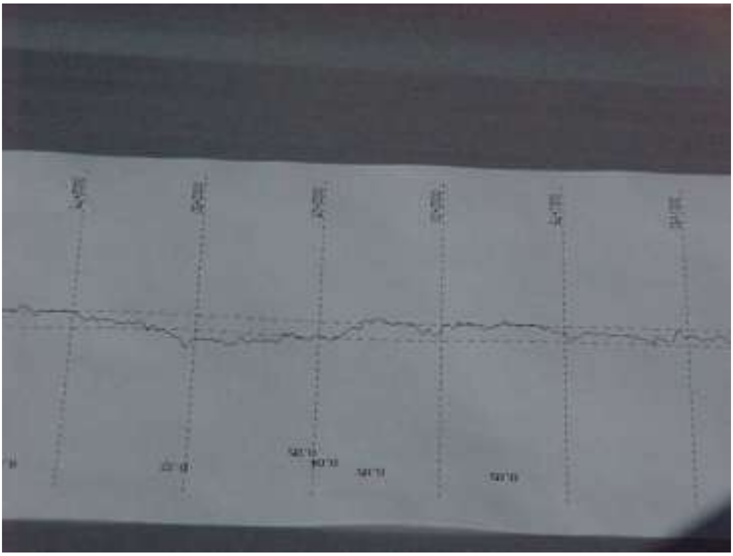


Figure 257.D - Typical Profile Trace

The Contractor must regrind any 0.10 mile section of pavement with an IRI greater than 95 inches per mile.

The contractor must provide traffic control and survey stationing necessary for all profiling. Profile measuring equipment is to stop within 1 foot (0.3m) of any existing pavement not ground, any pressure relief joint or any approach slab to a bridge.

Inspection should include spot testing the pavement to verify that transverse joints and cracks are flush with the adjacent pavement. If opposite sides of a joint or crack are within 1/16 inch of each other, it is considered flush. The cross slope should be checked with a 12-foot straightedge for deviations greater than ¼ inch. Straightedge requirements do not apply to areas that have not been ground.

Method of Measurement (257.05)

Measure pavement grinding by the square yard (square meter) of pavement ground and accepted. The quantity of pavement grinding will be determined by multiplying the width specified on the plan by the total length of the finished pavement surface measured in the field, excluding bridge decks, approach slabs and other areas designated by the Engineer.

Basis of Payment (257.06)

Payment is full compensation for furnishing all labor, materials, tools, equipment and incidentals for doing all work involved in grinding the existing surface, removing residue, cleaning the pavement, and testing with a profiler conforming to the plans and specifications.

Documentation Requirements - 257 Diamond Grinding Portland Cement Concrete Pavement

1. Check and document pavement grinding equipment prior to use to assure compliance as to width of diamond grinding head, number of grooves per foot, vacuum system, etc.
2. Check and document pavement smoothness testing equipment for compliance. Obtain ODOT certification of the equipment from the contractor.
3. Perform and document spot testing of ground pavement for surface tolerances.
4. Obtain and document profiling test results.
5. Measure length of ground pavement and use the plan width to calculate area for pay.
6. Document area calculations on CA-D-3A, CA-D-3B, or other approved form.

258 Dowel Bar Retrofit

General

This is a rehabilitation technique that is normally specified to restore load transfer at faulted transverse cracks in older concrete pavements. It has also been used in new construction when dowel bar installing equipment on a concrete paving machine inadvertently fails to install dowels at contraction joints. Standard Construction Drawing BP-2.6 Dowel Bar Retrofit is to be followed when constructing this item of work.

Description (258.01)

The work involves the following:

1. Sawing the proper size slots across transverse cracks.
2. Cleaning the slots.
3. Injecting a silicone caulking filler to seal the crack and filler board as specified.
4. Placing a smooth dowel bar 1-1/2 inch in diameter with appropriate dowel chairs, expansion caps and ½ inch thick filler board in each slot.
5. Filling the slot with one of the specified cementitious patching materials.
6. Consolidating, finishing and curing the cementitious patching material.
7. Establishing a joint by sawing.

Equipment (258.03)

Equipment for sawing slots in the pavement must be power driven, gang type, assemblies with diamond saw blades that are capable of sawing a minimum of three slots at a time. Saws must not damage the existing pavement.

Picture 255.A – Slot Sawing Equipment

Jack hammers used to remove concrete from the sawed slots must be less than a 30 pound (13.6 kg) class.

Abrasive blast equipment used to clean debris from the slots must be capable of removing the saw slurry and other foreign material from the exposed surfaces of the sawed slot leaving a clean, newly exposed concrete surface free of spalls, laitance, and all contaminants detrimental to achieving an adequate bond. If wet blasting is used, ensure water blasting pressure with abrasives in the water is 10,000 psi (690 bar) or less.

Construction (258.04)

The Engineer must mark the transverse cracks to be retrofitted with dowels. The Contractor will provide the spray paint. The Contractor must position the slots as shown in Standard Construction Drawing BP-2.6 Dowel Bar Retrofit.

The sawing must done to the specified width of 2-½ inches (65 mm) and to a length as needed to allow the centering of the dowel at the transverse crack. The slot must be sawed deep enough to assure that the dowel, when installed with a ½ inch tall prefabricated chair, is level and located at mid-depth in the concrete slab. The slots must be parallel to the centerline of the pavement. The contractor may make multiple parallel saw cuts within the 2 ½ inch width to facilitate removal of concrete, and to provide a level surface for the feet of dowel bar chairs. Six slots are to be cut in each lane at each crack, three slots at one foot (0.3 m) centers in each wheel path, as shown in BP-2.6.

Picture 258.B - Saw Cuts for Three Slots

Picture 258.C - Concrete Removal by Light Weight Jack hammer

Once sawing is complete, the concrete is removed carefully from the 2-½ inch slot using lightweight jack hammers (30 pounds (13.6 Kg) or less). Once concrete is removed, traffic must be kept off of the slots until the patching material is placed and cured.

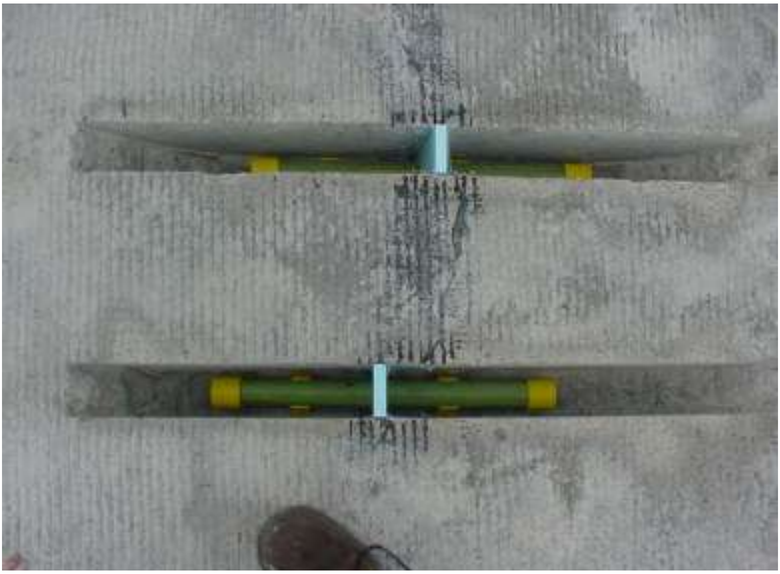
It is permissible to do all of the sawing within an area and open the pavement for a period of time, but once the concrete is removed traffic must be prohibited from using the pavement.

Once concrete is removed from the sawed slots to the proper depth, cleaning of the slots can begin. Inspection should include checking the slot depth to ensure the bottom of the slot is level and to the proper depth. Cleaning must be done by approved abrasive blasting (wet or dry) which will produce a rough surface on the sawed faces of the slots. The Contractor’s abrasive blasting operation must not damage the surrounding pavement. Do not allow the Contractor to begin abrasive blasting operations unless reasonably available engineering controls are implemented to limit fugitive dust. The Contractor must conform to state, regional, and local government agency requirements regarding control of dust generated by the blasting operation.

Picture 258.D – Dry Abrasive Blasting

Picture 258.E – Blowing Out Slots - Air Blast

After cleaning the slots, caulk cracks at the bottom and sides of the slot with silicone material. The purpose of the caulking is to keep the patching material from entering the crack when placed in the slot. The caulking material must be forced into the crack under pressure. Care must be taken to be neat and not contaminate the cleaned slot face in adjacent areas.



Pictures 258.F - Dowels Installed in Prepared Slots at Transverse Cracks

Next dowel bars are placed into the prepared slots. Inspectors must ensure the Contractor follows these dowel placing requirements:

Dowels must be 1-½ inch (13 mm) in diameter and 18 inches (460 mm) long. The dowel is to be centered on the crack. Dowels must be epoxy coated steel or fiber reinforced polymer.

Coat each dowel with a thin coating of new light form oil just prior to installation in the slot.

Place an expansion cap on each end of the dowel prior to placing it in the slot.

Two dowel bar chairs are required for each dowel bar. The chair is to be placed parallel to the pavement surface. Normally the two dowel chairs are attached to each dowel prior to installation into the slot. These dowel chairs must firmly hold the dowel bar centered in the slot at the proper elevation of ½ inch (13 mm) from the slot bottom. Inspectors must reject any chair design that allows movement of the dowel bar during placement of the patching material.

The dowel must have the 1/2 inch (13 mm) thick preformed filler board centered on the dowel to maintain the crack across the slot, as shown in BP-2.6. This filler board must fit tight around the dowel and extend to the bottom and to the edges of the slot. The filler board must be maintained in a vertical position and be tight to all edges during placement of the patching material. Use the silicone caulking material on the bottom of the preformed filler to keep the patching material from flowing under it. The filler board must extend from the bottom of the slot to the surface of the pavement. If the filler board shifts during placement of the patching material the Contractor must redo the installation at no additional cost.

Once the dowels are in place at the proper location the Contractor must make several passes of an air blast throughout each slot to provide a dust free slot for adequate bonding of the patch material.

Next the patching material is mixed, placed, and cured per the material manufacturer's directions. The patching materials specified are prepackaged, proprietary, cementitious materials which may allow the use of a certain amount of aggregate of a certain grading to be blended with each bag. The contractor must provide one of the approved patching materials listed on the Department's Qualified Products List (QPL).

Picture 258.F - Portable Mortar Mixer

Picture 258.G - Filling Slots with Patching Mix

The patching materials are mixed in the field in a portable mixer. When the material is placed into the prepared slot it must be consolidated with an internal vibrator approved by the Engineer. The excess patching material is screeded off flush with the adjacent pavement. The surface is cured per the manufacturer's directions however a minimum cure time of 4 hours is required before placing any vehicle loads on the repair, or as directed by the Engineer.

Picture 258.H – Internally Vibrating Patch

Picture 258.I – Patches Cured with Spray Cure

Method of Measurement (258.05)

The Department will measure the quantity of Retrofit Dowel Bars by the actual number in the complete and accepted work.

Basis of Payment (258.06)

Payment is full compensation for furnishing all materials including paint; sawing and cleaning the slots; installing dowel chairs, dowels, bond breaker material, dowel bar end caps, sealant/caulking material, filler material, and patching material.

Documentation Requirements - 258 Dowel Bar Retrofit

1. Mark and document the locations of dowel bar retrofit.
2. Check and document equipment for compliance prior to commencing work.
3. Check and document all dowels (diameter, length and epoxy coating) and dowel hardware (expansion caps, dowel chairs and ½ inch wide preformed filler board) for compliance.
4. Document all materials used (sealant, patching material).
5. Document compliance to specification requirements (slot location, width and depth of slot, cleaning, dowel placement, chair placement, patch mixing and placement, curing, etc.).

6. Document the number of slots performed each day for payment.
7. Pay the unit bid price for Dowel Bar Retrofit.

300 BASES

301 Asphalt Concrete Base

Description (301.01)

This work consists of constructing a base course of aggregate and asphalt binder, mixed in a central plant and spread and compacted on a prepared surface.

The requirements of Item 401 apply, except as modified by this specification.

Composition (301.02)

The Contractor shall furnish aggregate for the mix that conforms to the following gradation:

Sieve Size	Total Percent Passing
2 inch (50 mm)	100
1 inch (25.0 mm)	75 to 100
1/2 inch (12.5 mm)	50 to 85
No. 4 (4.75 mm)	25 to 60
No. 8 (2.36 mm)	15 to 45
No. 16 (1.18 mm)	10 to 35
No. 50 (300 µm)	3 to 18
No. 200 (75 µm)	1 to 7

The Contractor may use a maximum of 50 percent of reclaimed asphalt concrete pavement (RAP) as per 401.04. The Laboratory will establish the JMF according to 401.02.

Asphalt concrete is sampled and tested by the Contractor at the asphalt plant. Contractor tests are used for pay if they are verified by District testing. See 403.06 for sampling details.

Spreading and Finishing (301.04)

The Contractor must notify the Engineer at least 24 hours before starting paving. Spreading equipment must conform to 401.12 specifications. Ensure that the paver is approved by the Office of Materials Management. The maximum compacted thickness of any one lift is 6 inches. The uncompacted thickness will be greater than 6 inches.

The minimum air temperature required for paving 301 base is 40 °F (5 °C). The minimum mixture temperature when delivered to the paver is 250 °F (120 °C).

When using warm mix asphalt the minimum temperature is 230 °F (110 °C). The mixture temperature should be checked at a minimum, 4 times per day and more if required. The temperature should be documented in the project records.

Hauling

Hauling must conform to specification 401.11.

The Contractor must use trucks for hauling asphalt concrete that have tight, clean, smooth metal beds from which the entire quantity of mixture is discharged smoothly into the spreading equipment.

If transporting hot asphalt concrete at prevailing air temperatures below 50 °F (10 °C) or if the length of haul exceeds 20 miles (32 km), ensure that all truck beds are insulated to maintain workable mix temperature, and that all covers are fastened to exclude the wind. Do not exceed a distance of 50 miles (80 km) from the asphalt concrete plant to the paving site except by specific permission of the Department.

Compaction

Compaction must conform to specification 401.16

Compact the mixture uniformly using a combination of both steel and Type I pneumatic tire rollers conforming to 401.13. Do not use a spreading rate that exceeds the total of the specified capacities of the rollers in use. A pneumatic tire roller is required for compaction of base mixes. The type and number of rollers must be documented in the project records.

Ensure that the maximum compacted depth of any one layer is 6 inches (150 mm) and the temperature of the mixture when delivered to the paver (not to the job site) is a minimum of 250 °F (120 °C).

Example: Roller Capacity and Placement Rate

A contractor is using 1 three-wheel roller, 1 vibratory roller with 66-inch drums (both vibrating) and 1 Type I pneumatic tire roller to compact a mat 5 inches thick using material with a Laboratory conversion factor of 2.0 tons per cubic yard.

From Table 401.13-1 the following is the capacity of the rollers the contractor will use:

- Three wheel = 700 *sq yd/hr*
- Vibratory roller = 2 *drums* x 66 *in* x (15 *sq yd/in* of width) = 1980 *sq yd/hr*
- Type I Pneumatic Roller = 1000 *sq yd/hr*
- Maximum roller capacity = 700 + 1980 + 1000 = 3680 *sq yd/hour*

[(3360 *sq yd/hr)* X (9 ft^2/*sq yd*) X (5 *in*) X (1 *ft*/12 *in*)] X (1 yd^3/27 ft^3) = 511.11 yd^3/*hr*.

511.11 yd^3 X 2.0 *tons/*Yd^3 = 1022.22 *tons per hour* maximum placement rate.

Spreading and Surface Tolerances (301.05)

Spread the mixture at the rate calculated using the specified thickness, the compacted width of the pavement course being placed, and the weight-to-volume conversion factor established in 401.21. Maintain the actual rate of spreading the mixture within a tolerance of $\pm$5 percent.

Do not exceed 3/8 inch (10mm) in surface variation from the edge of a 10-foot (3 m) straightedge. Surface variations include bumps and depressions. If using Item 301 Asphalt Concrete Base as a subbase for a rigid pavement or base, do not exceed a variation of ¼ inch in 10 feet. (6 mm).

Example: Determining the Required Placing Rate per Station (RPRS)

A contractor is placing a 5 inch uniform mat of asphalt concrete pavement whose Laboratory conversion factor is 2.0 tons/cubic yard. The required placing rate (RPRS) in tons of material per station for a 12 ft wide mat is:

RPRS = [Volume of asphalt in cubic yards] x [Lab Conversion Factor]

= [{100 *ft per station* X 12 *ft* X (5 *in* ÷ 12 *in/ft*)} ÷ 27 ft^3/ yd^3] X 2.0 *tons/*yd^3

= 37.04 tons/station

Documentation Requirements - 301 Asphalt Concrete Base

1. Document condition of base material at the time of paving (example: primed 304, clean and dry concrete, etc.).
2. Obtain JMF for the project.
3. Determine and document if paver is on approved list.
4. Document tack or prime used along with source and quantity used versus required.
5. Document surface and air temperatures.
6. Write location (station), date, and time on asphalt plant tickets. Tickets should be totaled daily, initialed, with the calculator tape attached.
7. Document lift thickness, mat width, weather conditions, surface tolerance checks, equipment problems, mat problems (segregation, tearing, tenderness, etc), spreading rate, roller coverage, and any other issue or observations made during paving operations.

8. Obtain and document temperature of the mix at project site and place this information on ticket of load checked. This should be done a minimum of four times daily or any time temperature is in question.
9. Document the kind of rolling equipment and maximum tons per hour allowed. See Example Roller Capacity and Placement Rate.
10. Calculate and document the quantity of material placed for payment.
11. Document on form CA-FP-4 or other approved forms as needed.

302 Asphalt Concrete Base

Description (302.01)

This work consists of constructing a base course of aggregate and asphalt binder, mixed in a central plant and spread and compacted on a prepared surface. This item is similar to 301 and requires the same level of field inspection and documentation.

The requirements of Item 401 apply, except as modified by this specification.

Composition (302.02)

The contractor shall furnish aggregate for the mix that conforms to the following gradation:

Sieve Size	Total Percent Passing
2 inch (50 mm)	100
1 1/2 inch (37.5 mm)	85 to 100
1 inch (25.0 mm)[1]	68 to 88
3/4 inch (19.0 mm)[1]	56 to 80
1/2 inch (12.5 mm)[1]	44 to 68
3/8 inch (9.5 mm)[1]	37 to 60
No. 4 (4.75 mm)	22 to 45
No. 8 (2.36 mm)	14 to 35
No. 16 (1.18 mm)	8 to 25
No. 30 (600 µm)	6 to 18
No. 50 (300 µm)	4 to 13
No. 200 (75 µm)	2 to 6

[1] Provide aggregate to retain a minimum of 7 percent of the material on each of these sieves. This requirement applies to the gradation of the JMF and the mix production according to Item 403.

The Contractor may use a maximum of 40 percent of reclaimed asphalt concrete pavement per 401.04.

Asphalt concrete is sampled and tested by the Contractor at the asphalt plant. Contractor tests are used for pay if they are verified by District testing. See 403.06 for sampling details.

Spreading and Finishing (302.04)

The Contractor must notify the Engineer at least 24 hours before starting paving. Spreading equipment must conform to 401.12 specifications. Ensure that paver is approved by the Office of Materials Management. The maximum compacted thickness of any one lift is 6 inches. The uncompacted thickness will be greater than 6 inches.

The minimum air temperature required for paving 301 base is 40 °F (5 °C). The minimum mixture temperature when delivered to the paver is 250 °F (120 °C). When using warm mix asphalt the minimum temperature is 230 °F (110 °C). The mixture temperature should be checked at a minimum, 4 times per day and more if required. The temperature should be documented in the project records.

Hauling

Hauling must conform to specification 401.11.

The Contractor must use trucks for hauling asphalt concrete that have tight, clean, smooth metal beds from which the entire quantity of mixture is discharged smoothly into the spreading equipment.

If transporting hot asphalt concrete at prevailing air temperatures below 50 °F (10 °C) or if the length of haul exceeds 20 miles (32 km), ensure that all truck beds are insulated to maintain workable mix temperature, and that all covers are fastened to exclude the wind. Do not exceed a distance of 50 miles (80 km) from the asphalt concrete plant to the paving site except by specific permission of the Department.

Compaction

Compaction must conform to specification 401.16.

Compact the mixture uniformly using a combination of both steel and Type I pneumatic tire rollers conforming to 401.13. Do not use a spreading rate that exceeds the total of the specified capacities of the rollers in use.

Ensure that the maximum compacted depth of any one layer is 6 inches (150 mm) and the temperature of the mixture when delivered to the paver (not to the job site) is a minimum of 250 °F (120 °C).

Example: Roller Capacity and Placement Rate

A contractor is using 1 three-wheel roller, 1 vibratory roller with 66-inch drums (both vibrating) and 1 Type I pneumatic tire roller to compact a mat 5 inches thick using material with a Laboratory conversion factor of 2.0 tons per cubic yard.

From Table 401.13-1 the following is the capacity of the rollers the contractor will use:

- Three wheel = 700 *sq yd/hr*
- Vibratory roller = 2 *drums* x 66 *in* x (15 *sq yd/in* of width) = 1980 *sq yd/hr*
- Type I Pneumatic Roller = 1000 *sq yd/hr*
- Maximum roller capacity = 700 + 1980 + 1000 = 3680 *sq yd/hour*

$[(3360\ sq\ yd/hr) \times (9\ ft^2/sq\ yd) \times (5\ in) \times (1\ ft/12\ in)] \times (1\ yd^3/27\ ft^3) = 511.11\ yd^3/hr$.

$511.11\ yd^3 \times 2.0\ tons/Yd^3 = 1022.22$ *tons per hour* maximum placement rate.

Spreading and Surface Tolerances (302.05)

Spread the mixture at a rate calculated using the specified thickness and the compacted width of the pavement course being placed, and the weight-to-volume conversion factors established in 401.21. Maintain the actual rate of spreading the mixture within a tolerance of $\pm$5 percent.

Do not exceed 3/8 inch (10mm) in surface variation from the edge of a 10-foot (3 m) straightedge. Surface variations include bumps and depressions. If using Item 302 Asphalt Concrete Base as a subbase for a rigid pavement or base, do not exceed a variation of ¼ inch in 10 feet. (6 mm).

Example: Determining the Required Placing Rate per Station (RPRS)

A contractor is placing a 5 inch uniform mat of asphalt concrete pavement whose Lab conversion factor is 2.0 tons/cubic yard. The required placing rate (RPRS) in tons of material per station for a 12 ft wide mat is:

RPRS = [Volume of asphalt in cubic yards] x [Lab Conversion Factor]

$= [\{100\ ft\ per\ station \times 12\ ft \times (5\ in \div 12\ in/ft)\} \div 27\ ft^3/\ yd^3] \times 2.0\ tons/yd^3$

= 37.04 tons/station

Documentation Requirements - 302 Asphalt Concrete Base

1. Document condition of base material at the time of paving (example: primed 304, clean and dry concrete, etc.).
2. Document tack or prime used along with source and quantity used versus required.
3. Write location (station), date, and time on asphalt plant tickets. Tickets should be totaled daily, initialed, with the calculator tape attached.
4. Document lift thickness, mat width, weather conditions, surface tolerance checks, equipment problems, mat problems (segregation, tearing, tenderness, etc), spreading rate, roller coverage, and any other issue or observations made during paving operations.

5. Obtain and document temperature of the mix at project site and place this information on ticket of load checked. This should be done a minimum of four times daily or any time temperature is in question.
6. Document the kind of rolling equipment and maximum tons per hour allowed. See **Example** Roller Capacity and Placement Rate.
7. Calculate and document the quantity of material placed for payment.
8. Document on form CA-FP-4 or other approved form.

304 Aggregate Base

Materials (304.02)

All of the material requirements for 304 are located in section 703.17. This section allows the use of the following five material types:

1. Crushed carbonate stone (CCS)
2. Crushed gravel
3. Crushed air cooled blast furnace slag (ACBFS)
4. Granulated slag (GS)
5. Open hearth slag (OH)

Crushed Carbonate Stone (Limestone) Used for 304

If crushed carbonate stone (CCS) is used, the material must meet the gradation and physical requirements in 703.17. In rare cases, these materials become soft after a rain event or over the winter.

Crushed Gravel Used for 304

If crushed gravel is selected for use as aggregate base, it must be manufactured from material retained on the ½ inch (12.5 mm) sieve. It must meet the gradation and physical requirements shown in 703.17. At times, this material is missing some fine material and can become unstable.

Crushed Air Cooled Blast Furnace Slag Used as 304

If air cooled blast furnace slag is selected for use, ensure that the material meets the requirements of Supplement 1027. This material can cause environmental concerns. The gradation and physical requirements are detailed in 703.17.

Granulated Slag Used for 304

If granulated slag is selected for use, the material must meet the requirements of 703.08.

Open Hearth Slag Used as 304

If open hearth slag is selected for use, ensure that the material meets the gradation and physical requirements of 703.17 and the requirements of 703.14 which include:

1. Deleterious Substances
2. Identification of OH Slag
3. Verification of Tufa Performance
4. Aging and Stockpiling Requirements
5. Expansion Testing

Prior to Spreading (304.03)

1. Sample the material to be used.
    a. Develop a moisture density curve per Supplement 1015.
2. Material Moisture
    a. The material must have reasonably uniform moisture content
    b. Use a moisture content not less than 2 percent below optimum moisture prior to spreading.
    c. Add water to the stockpile, if required.
3. Minimize segregation.
    a. If segregation occurs, mix or re-grade the stockpile.

Spreading (304.04)

The 2008 C&MS contains an incorrect version of 304.04. See Supplemental Specification 800 (Boilerplate) for the correct version.

1. Do not spread on frozen surfaces.
2. Do not use frozen material.
3. Do not exceed a compacted lift thickness of:
    a. 8 inches (200 mm) when using vibratory rollers greater than 12 tons (11 metric tons).
    b. 6 inches (200 mm) with vibratory rollers weighing 10 to 12 tons (9 to 11 metric tons).
    c. 4 inches (100 mm) with no vibratory roller. If the contractor is compacting with a vibrating plate compactor, the maximum lift thickness is 4 inches. If the contractor is compacting with a roller without any vibration, the maximum lift thickness is 4 inches.
    d. Can use a lighter roller with equivalent centrifugal force.
    e. Centrifugal force is the weight with vibration.
    f. Contractor needs to document the roller weight requirements are met.
4. Place in equal lifts when the specified thickness exceeds 8 inches (200 mm).
    a. Example: if 12-inch lift is specified, place in two 6 inch lifts.

Spreading 304 with a Dozer and Spreader Box

Spreading 304 with an Asphalt Paver

5. Use self-propelled spreading machines.
    a. Capable of placing the 304 material true to line and grade.
    b. Use a dozer with a spreader box or an asphalt paver.
        i. This operation prevents segregation.

ii. If an area appears to be segregated, take in place gradation tests according to Supplement 1090.

iii. Contractor is only allowed to use dozers without spreader boxes or graders or hand-placing methods when the total area of the aggregate base is 2000 square yards or less, or in small areas. Do not take in-place gradation tests in small areas.

Spreading 304 with a Dozer May Result in Segregation

Spreading 304 with a Grader May Result in Segregation

Compaction (304.05)

Adding Water to 304 Prior to Compaction

Compacting 304 with Vibratory Roller

1. Add water or dry out the material.

   a. To bring material to within 2 percent of the optimum moisture content.
   b. Add water or dry the 304 prior to compaction.
      i. Material is too dense to add water after compaction.
   c. Maintain moisture during compaction.
   d. Uniformly apply water throughout the lift.
   e. Reduce when unstable.
2. Compact immediately after spreading.

Construct a Test Section

Perform the Compaction Tests

3. Construct a short test section.
    a. Compaction testing according to Supplement 1015.
    b. Use a minimum of eight passes in the test section.
        i. Minimizes getting a false maximum.
4. Use and adjust the vibration.
    a. Maximize density and stability.
    b. When vibration at maximum can make any material unstable.
5. Use 98 percent for the acceptance in the production area.
    a. Take 3 tests in the lot for acceptance.
    b. Use the average of the results.
6. Use at least:
    a. Same number of passes and compactive effort used to obtain the test section maximum density for the production material.
        i. Increases passing results in the production area.
7. At a minimum, use eight passes in the production area.
    a. Increases passing results.
8. Reduce minimum passes if detrimental.
    a. Do not over roll it may cause cracking.
9. Construct a new test section when.
    a. Material changes.
    b. Supporting materials change (e.g. Go from natural soil to cement stabilized subgrade).
10. Check production material density.
    a. Before or after the finishing operations.
11. Maintain the surface
    a. So that the texture is:
        i. Reasonably uniform.
        ii. Aggregate firmly keyed.
        iii. Hauling on the 304 will 'Un-key' the material.
12. Scheduling 304 operations
    a. Cover the aggregate base with the next pavement layer prior to the end of the construction season.
    b. If the contractor doesn't pave before the end of the construction season, then the Contractor is responsible for contamination, damage and instability of the base, subgrade and underdrains.
13. Provide drainage and maintain the material according to 203.04.A.
    a. Maintain the cross slope.
    b. If it rains or material sits over the winter.
        i. Dry the 304 and subgrade.
        ii. Obtain and maintain stability and density.

Finished Surface (304.06)

1. Finished surface so that does not vary:
    a. More than 3/8 inch (10 mm).
        i. From a 10-foot (3 m) straightedge parallel to the centerline.
    b. Or more than 1/2 inch (13 mm).

            i. From a template conforming to the required cross-section.
2. Contractor to furnish straightedges, templates, or other devices.

Checks of the Depth (304.06)

1. At the beginning of the spreading operation.
    a. Contractor must adjust the spreader.
        i. Produce sufficient loose depth to meet plan compacted thickness.
            1. Determined after compaction.
        ii. Make occasional checks.
            1. During the spreading to ensure uniform depth after compaction.
    b. Purpose is to control spreading.
        i. Need not be recorded.
2. After fine grading:
    a. Make depth checks.
        i. At 500 ft. (150 m) intervals.
        ii. Extended to 1,000 ft. (300 m) if depth is consistent and meets plan depth.
    b. Some variation in depth is expected.
        i. Tolerance of 3/4 in. (19 mm) between individual measurements.
    c. If consistently less by any amount.
        i. Requirements have not been met.
        ii. Take corrective action.
    d. If individual measurement.
        i. Less than 3/4 in. (19 mm) of plan depth.
            1. Make measurement within 100 ft. (30 m).
            2. If greater than plan thickness.
                a. Satisfactory.
            3. If less than plan thickness.
                a. Make checks at additional locations.
                b. Define deficient area.
                c. Require correction.
    e. Record all depth measurements.
        i. With station locations.
        ii. Place in the project records.

Checks of the Width (304.06)

1. Measurements of the width of base.
    a. Need not be made prior to placement of overlying courses because the width of base can readily be verified.
2. After the overlying pavement is placed make a visual verification of the base width.

a. If it conforms to or exceeds the plan width. File a statement in the project records.

Documentation Requirements - 304 Aggregate Base

1. Materials
2. Roller weights
3. Record lift thickness
4. Segregation.
5. Roller passes
6. Perform the compaction tests according to S-1015
7. Verify cross section and thickness.
8. In place gradation tests according to S-1090, if required.
9. Obtain weight ticket, if required. Tickets should be totaled with initialed and dated tape attached. Convert to cubic yards (cubic meters) as per 304.07 of the C&MS
10. Pay and measure according to 304.07 and 304.08
11. Document on the CA-EW-12 and CA-D-1 and CA-D-2. Do not duplicate the information on these forms unless necessary.

305 Portland Cement Concrete Base

Construction

When constructing this item, the requirements of 451 apply with the following exceptions:

1. Reinforcing mesh required by 451.07 is not required in concrete base.
2. The curing application rate for the membrane forming curing compound for concrete base is 200 square feet per gallon (5 square meters per liter) instead of what is specified for 451 and 452 pavement described in 451.10.
3. Provide dowels at transverse contraction joints in mainline pavement, ramps, acceleration/deceleration lanes, or collector/distributor lanes. Dowels are not required in shoulders for mainline pavement, ramps, acceleration/deceleration lanes, or collector/distributor lanes unless the transverse contraction joint is located within 500 feet of a pressure relief joint.
4. Construction joints are NOT to be placed within 6 feet of another parallel joint.
5. The surface finish for concrete base is broom dragged in either the longitudinal or the transverse direction to provide a uniform, gritty surface texture to the satisfaction of the Engineer. Transverse grooving per 451.09 is not required.
6. Surface smoothness variations for concrete base are not to exceed 1/4 inch in 10 feet (6 mm in 3 m).
7. Station numbers as required in 451.09 are not required for concrete base.

Method of Measurement

The concrete base must be field measured and the area of pavement placed calculated for payment in square yards (square meters). The area is determined the same as for 451 or 452 pavement.

The pavement width for payment will be based on the plan typical cross-section plus any additional widening that has been directed by the Engineer. The length will be field measured along the centerline of the roadway or ramp.

Basis of Payment

Pay a reduced price for base found deficient in thickness according to 451.17. There is no additional payment for a concrete base thicker than that shown in the plans. Pay for accepted quantities at the contract price per square yard (square meter).

Documentation Requirements - 305 Portland Cement Concrete Base

1. Document thickness checks of forms (where applicable) and of the plastic concrete during placement.
2. Document condition of base material prior to placement.
3. Document type, alignment, grade, and condition of forms.
4. Document placement of transverse contraction joints including dowel basket anchoring, dowel alignment and depth, joint spacing, oiling of dowels, removal of assembly wires.
5. Document placement of tiebars or hook bolts for longitudinal joints.
6. Document weather conditions; beginning and ending temperatures, rain, wind, etc.
7. Document type of equipment used.
8. Document results of required concrete tests.
9. Document any issues or observations during placement operations.
10. Document surface tolerance checks.
11. Document curing type and quantity required and used.
12. Measure and document width and length for payment.
13. Provide documentation on CA-D-3A, CA-D-3B, or other approved form(s).

308 Asphalt Treated Free Draining Base

This Item was removed from the 2008 Construction and Materials Specifications. Refer to the 2006 Construction Inspection Manual of Procedures for information on this Item.

320 Rubblize and Roll

Description (320.01)

This work consists of breaking up existing rigid concrete pavement using a rubblize and roll method to provide a base material for the placement of new asphalt concrete pavement.

Materials (320.03)

Filler material may be needed to correct grade after the concrete pavement has been rubblized. The contractor must furnish materials conforming to Item 304 to fill depressions 1 inch (25 mm) or greater in depth.

Equipment (320.03)

The contractor must use a self-contained, self-propelled unit of either the resonant frequency type or the multiple head breaker type for rubblizing the exposed concrete pavement. There are specific equipment requirements for each type of breaker. The Contractor must provide documentation showing that the proposed equipment meets those requirements. Refer to C&MS 320.03 for specific details.

A vibratory roller is required and must have a total weight of at least 10 tons. The Contractor must provide documentation for the roller if needed by the project to verify total weight.

Construction Details (320.04)

Saw Cutting

The Contractor must make a full depth saw cut to cut load transfer devices at existing joints on ramps or on the mainline pavement where the rubblizing abuts concrete pavement or approach slabs that are to remain in place permanently or temporarily for maintenance of traffic.

Test Section

The Contractor is required to rubblize a test section before beginning full scale operations. The Engineer will designate the test section area. The Contractor will rubblize the test section per the specification requirements. At the direction of the Engineer, the Contractor will excavate a test pit to check the particle sizes of the rubblized concrete throughout the depth of the slab. Based on the Engineer’s determination the rubblizing operation may proceed or additional test sections and test pits may be required to obtain the required particle sizes.

The test pit can be refilled using the excavated material and additional 304 aggregate as needed to bring the final surface to the required grade. The test pit can be rolled at the completion of the test section or later during full operation.

The Engineer may require additional test pits as necessary, throughout the rubblizing operation.

Control and Operating Speed

The Contractor is required to adjust the speed of the rubblizing operation to maintain the correct particle sizes. If the Contractor is not consistently obtaining the specified particle sizes, the Engineer may require another test section, test pit, or additional passes to ensure compliance. The correct particle size is of critical importance to obtaining a suitable base material.

Proper Particle Size

Particles sizes should range from sand sized to pieces not exceeding 6 inches (150 mm) in their largest dimension. The majority being a nominal 1 to 2 inches (25 to 50 mm) in size.

Reduce the portion of the concrete slab above the reinforcing steel to 1 to 2 inches (25 to 50 mm) in size.

Filling & Compacting

Leave steel reinforcement in place in the rubblized pavement. Reinforcing steel may rise to the surface during either the rubblizing or rolling operations. However cut off any exposed steel reinforcement to below the surface and remove it from the site.

The rubblized pavement must be compacted with two passes of the vibratory roller operated in the vibratory mode and at a speed not to exceed 6 feet (1.8 m) per second.

Depressions 1 inch (25 mm) or more in depth below the immediate surrounding surface, that form as a result of rubblizing, compaction, or steel reinforcement removal, must be filled with filler aggregate conforming to Item 304.

Excess filler material must be leveled off such that is level with the surrounding area. Compact filled depressions with the same roller and compactive effort previously described.

Restrictions

Traffic is not allowed on the rubblized pavement before the initial asphalt concrete base and intermediate courses are in place.

The Contractor must structure operations such that not more than 48 hours elapse between rubblizing the pavement and placing the initial asphalt concrete course. In the event of rain during the 48 hour period, the Engineer may waive this time limitation to allow sufficient time for the rubblized pavement to dry to the Engineer's satisfaction.

If the Engineer waives the time limitation, cease rubblizing the pavement until the Engineer allows paving to resume.

Method of Measurement (320.05)

The Engineer will measure Rubblize and Roll by the number of square yards (square meters).

The Engineer will use the actual width of the existing concrete pavement and will measure the length along the centerline of each roadway or ramp.

The Engineer will measure the Filler Aggregate by the number of cubic yards (cubic meters) furnished, placed, and compacted.

Documentation Requirements - 320 Rubblize and Roll

1. Document that equipment being used meets the specifications.
2. Document the location and particle size determination for the test section. Include any additional test sections and results.
3. Document where rubblizing is being performed (station to station), particle sizes obtained, cutting of reinforcing steel, addition of filler aggregate, roller speed and passes, and any other observations or issues during the operation.
4. Measure the width of the actual existing pavement and the length along the centerline of each roadway and calculate square yards for payment.
5. Measure the filler aggregate and calculate the number of cubic yards placed and compacted.
6. Document using form CA-D-3A or other approved form(s).

Item 321 Cracking and Seating Existing Plain Concrete Pavement

Description (321.01)

This work consists of breaking up an existing non-reinforced concrete pavement using a cracking and seating method to provide a stable base for the placement of new asphalt concrete pavement.

Equipment (321.02)

The Contractor must use equipment that is capable of producing the desired crack pattern without extensive spalling or excessive shattering. Extensive spalling is considered at depths of greater than 1-1/4 inches.

Whip hammers cannot be used.

The Contractor must use a 50 ton pneumatic tire roller that also conforms to the requirements of 204.06 (Proof Rolling) to seat the cracked concrete slabs. Additionally pneumatic tire towing equipment is required to move the roller forward and backward along predetermined lines. The Contractor shall provide information to verify the roller meets the specification requirements.

Construction Details (321.03)

The Contractor should provide positive provisions in addition to 107.07 to contain any flying debris during cracking operation.

The contractor must demonstrate to the Engineer the ability of the selected equipment and procedure to produce the desired crack pattern by cracking at least three, but no more than five existing concrete slabs. The Contractor shall furnish and apply water to dampen the cracked concrete to enhance visual determination of the crack pattern during the test section process. The contractor must make adjustments to the energy or striking pattern to maintain the crack pattern desired.

The Contractor must provide a crack pattern of 4 feet by 4 feet (1.2 m X 1.02 m) segments.

There may be instances where the existing slab is already cracked into segments by age and traffic. In these cases the Contractor must further crack the slabs to obtain maximum 5 feet and minimum 3 feet dimensions, both transversely and longitudinally.

The breaking equipment shall not be allowed to affect slabs within 1 foot of another break line, a joint, or the edge of the concrete slab.

Once a day (minimum) the Contractor must apply water to a check section to allow verification of a satisfactory crack pattern. When the crack pattern differs from required, the Contractor must make adjustments to the operation to bring the crack pattern into compliance.

The Contractor must roll the cracked pavement until the all of the concrete pieces are seated with at least two roller coverages. The seated pieces cannot rock or move after seating.

The Engineer will determine the maximum number of coverages of the roller on the test section to ensure proper seating of segments without damage to the concrete.

Before placing asphalt concrete the Contractor must remove all loose pieces of concrete that are not fully seated. All voids must be repaired by applying 407 tack coat, filling with asphalt concrete and compacting, as directed by the Engineer,

Traffic is not allowed on the cracked concrete before the initial asphalt concrete base and the intermediate courses are in place.

Documentation Requirements - 321 Cracking and Seating Existing Plain Concrete Pavement

1. Document that equipment being used meets the specifications.
2. Document the location and crack pattern obtained from the test section. Include any additional test sections and results.
3. Document where cracking and seating is being performed (station to station), segment sizes obtained, roller coverages, addition of tack and asphalt to fill voids, and any other observations or issues during the operation.
4. Measure the width of the actual existing pavement and the length along the centerline of each roadway and calculate square yards for payment.
5. Document using form CA-D-3A or other approved form(s).

400 FLEXIBLE PAVEMENT

400-401 Asphalt Concrete Pavements – General

General

General requirements for mix production and construction of asphalt concrete pavement courses are included in Item 401. Other specific requirements for flexible pavement production, quality control and mix design are included in Item 402 *Asphalt Concrete Mixing Plants*; Item 403 *Asphalt Concrete Quality Control and Acceptance*; and Item 441 *Contractor Mix Design and Quality Control - General*. Requirements for the specific pavement courses are found in the specifications under the contract item designation (301, 442, 446, 448 etc.).

Asphalt concrete is a mixture of aggregate and asphalt material. The asphalt material used in these mixtures has a relatively high viscosity at normal temperatures. Because of this, it is necessary to heat the aggregate and asphalt material to permit mixing, placing, and compacting.

Asphalt concrete may be used in new construction as the entire pavement structure or it may be used with other materials in a layered pavement structure. Extensive use of asphalt concrete is also made for rehabilitating existing pavements by resurfacing, or widening and resurfacing. Asphalt concrete is particularly adaptable to this type of work, where disruption of normal traffic flow must be kept to a minimum. Although written with reference to new construction, the instructions contained herein also apply to rehabilitation construction.

Asphalt concrete mixtures are produced in a central proportioning and mixing plant. At the plant, aggregate is dried and heated to the mixing temperature and combined with the specified asphalt material. On completion of mixing, the asphalt mixture is discharged directly into trucks, or conveyed to a surge bin from which trucks are loaded, for transport to the project.

Asphalt concrete is placed by use of various types of mechanical pavers. After it is placed, the mixture must be compacted using the proper compaction equipment before it cools and becomes unworkable.

Field Inspection

The Inspector assigned to the placing of asphalt concrete should observe closely the placing of the initial production of each type of mixture for indications of deficiencies in the mixture composition. If the mixture appears to be deficient in any of the following respects, notify the District plant monitor and the Contractor immediately, and note on the Inspector's Daily Report. The Engineer should be consulted when there are mix deficiencies that need addressed. In some cases, production should cease immediately.

Segregation

The coated aggregate particles should appear to be uniformly graded in size from coarse to fine behind the paver in the finished mat. Notify the plant monitor.

Mixture Consistency

The mixture should have sufficient cohesion to remain mounded in the vehicle during hauling, but should flow freely from the vehicle when the load is dumped.

Stability

The mixture should have sufficient stability for compaction without excessive displacement and movement.

PG (Asphalt) Binder Content

The mixture should contain enough PG (Asphalt) binder (which binds the aggregate particles together as the mixture is compacted) without producing a glazed or flushed appearance.

Temperature

Variations in the temperature of asphalt concrete loads can often be detected simply by comparative observation, and then substantiated by actual temperature measurement. In extreme cases, a hot load will give off a blue smoke while a cold load will be partially congealed (change from a fluid to a solid state) and will not flow freely. By close observation of the flow of the asphalt concrete from the truck bed into the paver hopper, the Inspector can learn to judge the temperature of the material quite accurately. However the Inspector should monitor and record the mix temperature.

Mixture Proportions

Excessive fluctuations in PG binder content, changes in the proportion of the coarse and fine aggregate, and non-uniform mixing can be detected by observation. Notify the plant monitor.

Moisture

Variations in the moisture content of the aggregate fed to the plant or an erratic production rate may result in an excess of moisture in the asphalt concrete mixture. This can cause slumped or flattened loads, accompanied by considerable bubbling or steaming of the mixture. In extreme cases, the PG binder material may separate from the aggregate and collect in a film over the surface of the load. This condition is unacceptable and is sufficient cause for rejection of the load. Excess moisture may also cause streaks of excess PG binder material to appear as the mixture is spread. These streaks should be eliminated immediately by remixing the material using a rake. The District plant monitor should be notified of this condition.

Contamination

An asphalt concrete mixture can become unsatisfactory due to contamination of the PG binder material, the aggregate, or the mixture itself. Contamination of the PG binder material, either in shipment or in storage at the plant, usually has the most serious effects. Contamination of the PG binder material may remain undetected until a quantity of mix is produced, at which time a marked change in the odor, consistency, or appearance of the mixture in the truck or in the paver hopper indicates that such contamination has occurred. When these changes are noted, observe the mixture carefully as it is being placed and compacted. If the mixture is unusually soft and unstable or tends to flush, the material is unsatisfactory and must be removed and replaced with acceptable material.

Contamination of small portions of the asphalt concrete mat may occur due to bed hoist leakage, spillage of fuel or lubricants, or foreign matter on the surface. These areas should be corrected by removing the contaminated material and replacing it with acceptable material.

As the placing of the asphalt concrete progresses, the Inspector should continue to observe the mixture being delivered to the paver since irregularities in proportioning, mixing, and temperature control may occur. The results of such irregularities may not be detected at the plant and an unsatisfactory load of asphalt concrete may arrive at the paver. Mixture in the hauling vehicle that is out of specification limits must be rejected in borderline cases.

Material may be placed with acceptance based on the appearance of the material under the action of the compaction equipment. If the mixture is unsatisfactory, it must be removed and replaced with acceptable material. When the field Inspector rejects a load of material, this action must be recorded on the plant ticket form, along with the reason for rejection. Also, the District plant monitor and Contractor's quality control technician should be informed of the quantity of the material rejected and the reasons for rejection.

Requirements for Mix Design, Quality Control and Mix Plants (401.02 through401.05)

A Job Mix Formula (JMF) is submitted by the Contractor using the contract mix specifications for the contract asphalt concrete (446, 448, etc.). The Laboratory must provide conditional approval of all JMFs before production of any asphalt concrete. The JMF provides the proportions of the aggregates and Reclaimed Asphalt Pavement (RAP); binder content, along with the optimal compaction temperature for the asphalt mix. This information is used in quality control for production and in field inspection. The Contractor quality control requirements for asphalt concrete are provided in Item 403.

Laboratory personnel must inspect and approve the mixing plant that will be used by the Contractor prior to the production of any asphalt concrete. Specification Item 402 provides detailed requirements for asphalt mixing plants.

Weather Limitations (401.06)

There are specific requirements for air and surface temperatures in Item 401.06 that must be met before paving can start. In all cases the existing surface to be paved must be dry and weather conditions that allow proper handling placement and compaction. Table 401.06-1 provides minimum surface temperature requirements based on the thickness of the course being placed.

The air temperature must be 40°F for all surface courses. For Type 1H asphalt and any surface course using a polymer modified asphalt binder the surface and air temperature must be at least 50°F.

Regardless of weather conditions Type 1H asphalt or any surface course with a polymer modified binder cannot be placed after November 1.

Table 401.06-1

Course Thickness	Minimum Surface Temperature	
3.0 inches (75 mm) and over	36 °F[1]	(2 °C[1])
1.5 to 2.9 inches (38 to 74 mm)	40 °F	(5 °C)
1.0 to 1.4 inches (25 to 37 mm)	50 °F	(10 °C)
Less than 1.0 inch (25 mm)	60 °F	(16 °C)
Variable Intermediate, 0 to 3.0 inches (0 to 75 mm)	40 °F	(5 °C)

[1] Instead of 36 °F (2 °C), use a minimum air temperature of 40 °F (5 °C) if paving on an aggregate base or subgrade.

Surface temperature measurements should be taken using the following procedures:

1. When taking a reading in the sun, place the thermometer on the pavement and then shade that area with a clipboard, cardboard, or other available shading material. Then take the temperature reading after approximately 3 minutes. The intent is not to shade the area to allow it to cool, but to protect the thermometer from obtaining a false reading due to direct exposure to the sun.
2. The surface temperature should not be taken under the only shade tree or at the only sunny (unshaded) spot on the project. The surface temperature should be taken at a representative area.
3. The surface temperature should be taken in the lane to be paved and not the adjacent berm.
4. On Portland cement concrete pavements where flexible repairs have been performed, the surface temperature of the Portland cement concrete will be the governing temperature.
5. A new surface temperature should be taken when the existing pavement surface material changes (asphalt concrete to portland cement concrete or Portland cement concrete to asphalt concrete) to ensure that the new surface meets the minimum temperature specification. If this specification is not met, paving operations must be discontinued until the

surface reaches specification temperature. Or, paving operations may be moved to a different area of the project where the surface meets minimum specification temperature.

Placing thin surface courses at temperatures near the applicable limit may require the Contractor to employ special precautions to produce a satisfactory surface. These precautions include avoiding paver stops, keeping the rollers close to the paver, and providing proper insulation for the truck hauling the material.

It is the Inspector's responsibility to instruct the Contractor to stop paving operations in the event of rain. It is the Contractor's responsibility to stop plant production. A load of material in the process of being dumped into the paver may be placed, with the requirement that the rollers follow closely behind the paver and a construction joint is formed at the end of the run. Loads waiting to be dumped, however, must not be allowed to be placed. The material in the waiting trucks will retain sufficient heat for proper placing and compacting for an hour or more depending on the ambient temperature. Water can be kept from accumulating on the covers of the trucks and draining into the asphalt mixture by raising the truck beds slightly. These loads may be placed when conditions improve if the asphalt temperature is acceptable and the surface being paved is in a reasonably dry condition.

Notification (401.07)

The Contractor should notify the Engineer at least 24 hours before starting paving on a project. It is a recommended practice for the Engineer to call for a meeting to discuss material and equipment to be used.

Hauling (401.11)

Included in the specifications (401.11) are the requirements concerning the condition of the vehicles used to haul asphalt concrete mixtures and the distance the mixture may be transported.

The Inspector should check the trucks for compliance with the specifications as they arrive at the paving site. In particular, the Inspector should observe the following:

1. The bed tarp is in good condition.
2. Small portions of the load are not isolated from the mass on projections such as extensions over cabs.
3. The load is discharged evenly, without surging in the paver hopper, and without jogging the vehicle when it is in contact with the paver.
4. As the bed is raised, it does not come in contact with the rigid parts of the paver.
5. Uniform contact between the truck and the paver is maintained as the paver pushes the truck during unloading.
6. Excess coating material is not being used on the truck bed.
7. Diesel fuel is not being used as a coating material.

8. When insulation is required, check to see that all trucks are properly insulated and permit only approved trucks to be loaded.

The Inspector should notify the Contractor when deficiencies are found. When corrections are not satisfactory and difficulties persist, the vehicle in question should be removed from the project.

Spreading Equipment (401.12)

Asphalt pavers shall be self-propelled mechanical spreading and finishing equipment, provided with a screed or strike-off assembly capable of distributing the material to the full width of the lane being paved. The type of equipment suitable for spreading asphalt concrete depends on the particular paving operation to be performed, mainline, widening, berm, intersections, and whether the pavement course to be placed is base, intermediate, or surface. Spreading equipment requirements are stated in 401.12.

The Contractor should use means and methods approved by the asphalt spreader manufacturer consisting of, but not limited to any combination of chain curtains, deflector plates, or other such devices that will eliminate segregation.

The Contractor should inform the Office of Materials Management of all asphalt spreader equipment purposed for use on ODOT projects. Information should include the spreader make, model, serial number and manufactured year. The list of the approved spreaders will be posted on ODOT web site. The Inspector must check that the paver used on a project has been approved by the Laboratory.

Certain pavers require modifications. The Contractor must submit to the Engineer a certification statement stating that the paver to be used is modified and approved as per 401.12.

Pavers that leave ridges, indentations or other marks in the surface shall not be used. The Engineer shall determine whether a paver is providing an acceptable asphalt mat that is ready for compaction.

The basic types of pavers found in current practice are described in the following paragraphs:

Floating Screed Asphalt Paver

A standard asphalt paver consists of a tractor with a receiving hopper, a conveying and distributing system, and a floating screed. The screed is essentially a rectangular trowel which floats on the surface of the asphalt mixture. The tractor pulls the screed by means of two shafts or arms hinged to each side of the tractor. The thickness of placed material is regulated by adjusting the angle of the screed with respect to the arms. This adjustment causes the screed to rise or fall until a condition of equilibrium is reached. Vibrating or tamping devices on the screed maintain a uniform flow of mixture under the screed. A heating system is provided to bring the screed to operating temperature at the beginning of work and to maintain proper screed temperature in cool weather.

The paver must have an automatic control system that maintains the screed in a constant position relative to grade, profile, and cross slope references. These references must be capable of controlling the screed position independent of irregularities in the underlying surface and the paver operation.

When paving in excess of the nominal paver width, only a screed extension with full auger extensions and the ability to heat should be used. Strike-off plates may be used on adjacent berm areas.

Off-Set Blade Strike-Off Paver

Spreading equipment having a hopper from which material is conveyed to a side-mounted blade strike-off is used to place asphalt concrete for pavement widening, berm paving, and other applications where a relatively narrow width is to be placed. The tractor to which the hopper is attached operates on the surface adjacent to the area being paved. The blade is attached to the tractor and is adjustable as to width, elevation, and cross slope.

Motor Grader

The standard motor grader, when properly equipped to contain the material within the required width; places asphalt concrete satisfactory in patching, spot leveling, and in crown correction work.

Approval of any of the previously described spreading equipment for use on asphalt concrete construction should be based mainly on observation of the quality of previous work completed and current performance. The following items should be observed when considering approval:

1. Equipment must have sufficient size, power, and stability to receive the asphalt concrete material without erratic operation.
2. Equipment must be capable of placing the material accurately in regard to line and grade.
3. Asphalt concrete must be fed uniformly across the width of the screed or strikeoff without surges (which produce corresponding roughness in the finished surface).
4. Asphalt concrete mixture behind the screed or strike-off must have a uniform appearance across the full width of the course.

It is the Contractor’s responsibility to make any necessary adjustments in the paver operation. The Inspector, however, should be familiar with the working of the paver, the effect of wear on paver operation, and the effect of various paver adjustments on the placing operation.

Rollers (401.13)

Compaction of asphalt concrete is governed by 401.16, 446.05 or 448.05 depending on the contract item designation. Item 446 is accepted by density testing and the roller selection is at the discretion of the Contractor and not governed by 401.13.

This is also the case for 448 when it is accepted by field density testing using Supplemental Specification 1055. Acceptance by density testing allows the Contractor to select the type and number of rollers needed to obtain proper compaction and thus receive full compensation. When compliance with 401.13 is not required, rollers must be inspected for general working condition, leaks, and suitability. The Department retains the right to reject the use of rollers which are not in good repair, or are not designed to do the work required fully and satisfactorily.

Where Item 448 is not accepted by density testing, and for Items 301 and 302 Asphalt Concrete Base; the requirements of 401.13 apply.

For asphalt concrete items requiring compliance with item 401.13 all rollers must be inspected for conformance with the specifications before paving begins.

Steel drums and wheels should have the necessary accessories to prevent adhesion to the mixture; they should be kept properly moistened with water, water containing a detergent, or water containing an approved additive. Excessive use of liquid should be prohibited.

Pneumatic tire rollers must be self-propelled, reversible units with vertical oscillation on all wheels on at least one axle.

The Contractor should determine the tire inflation pressure necessary to meet the specified minimum contact area and contact pressure requirements.

The Contractor should furnish the tire manufacturer's charts or tabulations to the Engineer for verification of the required inflation pressure.

Tire inflation pressure should be maintained within 5 pounds per square inch (35 kPa) of the required pressure.

Approval of specialized equipment proposed for compaction in areas inaccessible to the specified rollers should be based on obtaining equal results.

TABLE 401.13-1 ROLLER CAPACITY

Roller Type	Maximum Capacity Square Yards per Hour (m^2/hr)
Tandem	700 (600)
Three-Wheel	700 (600)
Trench	15 per inch width (13 per 25 mm width)
Pneumatic Tire, Type 1	1000 (850)
Pneumatic Tire, Type 2	700 (600)
Vibratory, Vibrating Roll	15 per inch width (13 per 25 mm width)
Vibratory, Static Roll (not vibrating)	3 per inch width (3 per 25 mm width)

TABLE 401.13-2 STEEL WHEEL ROLLERS

Roller Type	Three-Wheel	Tandem	Vibratory Static	Trench
Total weight, tons (metric tons)	10 (9)	8 to 12 (7 to 11)	8 to 12 (7 to 11)	-
Compression rolls, pounds per inch width (kN/m), minimum	300 (53)	200 (35)	120 (21)	300 (53)

TABLE 401.13-3 PNEUMATIC TIRE ROLLERS

Type I	
Tire size, minimum	9.00 × 20 in (229 × 508 mm)
Wheel load, minimum	5000 lb (2250 kg)
Average tire contact pressure, minimum	85 psi (590 kPa)
Type II	
Tire size, minimum	7.50 × 15 in (191 × 381 mm)
Wheel load, minimum	2000 lb (900 kg)
Average tire contact pressure, minimum	55 psi (380 kPa)

Preparation of the Surface (401.14)

Cleaning the Surface

The surface on which an asphalt concrete course is to be placed must be free from material accumulations that would contaminate the mixture, prevent bonding, or interfere with placing operations. The surface of the existing pavement should be inspected before the paving operation begins, and should be cleaned of all foreign material, in accordance with 401.14. The surface also should be checked a short distance in front of the paver to assure that the surface has not become contaminated during the construction operation. A dirty or very dusty surface reduces the ability of the tack coat to bond, resulting in a potential slippage plane between the existing surface and the asphalt overlay.

Maintenance of Previously Constructed Surfaces

Prior to placing asphalt concrete on a pavement course constructed under the same contract, the condition of this previously-approved work should be observed. Where the approved subgrade or pavement course has become loosened, rutted, or otherwise defective, the deficiency must be corrected before the placing of a subsequent course is permitted. Hauling of materials over an asphalt concrete base course, for example, may cause cracking when there is not sufficient pavement to carry such loads or where excessive deflection occurs over soft areas developed in the subgrade. Where cracking of the pavement occurs in such a case, the strength due to slab action is destroyed, and the affected material must be removed and replaced after correcting the cause of the failure.

Coating Vertical Faces

The specifications require all vertical faces, with which the asphalt concrete will come in contact, to be coated with asphalt material of a type specified in 401.03. The purpose of this requirement is to provide some additional asphalt material to improve the bond of the asphalt concrete to other structures, such as gutters, curbs, catch basins, and all existing pavements. Because of the small quantity of material involved, approval of the asphalt material for this purpose may be based on field inspection. The results of this inspection are recorded on the Inspector's Daily Report, with the material identified as to type, grade, manufacturer, and use.

Before placing a surface course on an intermediate course, apply a tack coat to the intermediate course according to 407.06.

Correcting Existing Surface Irregularities

In contracts which include rehabilitation of the existing pavement by resurfacing, a quantity of asphalt concrete is usually provided in the plans for making spot corrections or for placing a continuous intermediate course to correct the cross-slope and profile of the existing pavement, as directed by the Engineer. The placing of this corrective material should be controlled closely to assure that the best possible riding quality is obtained in the completed pavement.

Spot corrections, when provided for in the plans, are made to correct irregularities in the existing pavement which would not be corrected satisfactorily due to their magnitude during the placing of the intermediate or surface course. Deficiencies in the existing surface requiring spot correction should be located, and the Engineer should notify the Contractor of the required corrective measures. In making these spot corrections, the mixture should be alternately placed and compacted until the profile and cross-slope conforms to the surrounding pavement. Interior edges of these patches may be irregular, but outside edges must conform to the specified edge alignment. All spot corrective work must be completed to the satisfaction of the Engineer before the intermediate or surface course may be placed.

An intermediate course of asphalt concrete, when specified, is used to correct minor irregularities in the existing pavement surface. As mentioned above, spot correction may be needed prior to placing the intermediate course since this course cannot be expected to cover or correct major deficiencies. The paver used to place the intermediate course has a self-leveling action that tends to correct these small irregularities. In addition to this action, automatic control of the paver screed compensates for these irregularities. Inspect the placing of the intermediate course to assure that all deficiencies have been corrected satisfactorily. For intermediate courses where the profile or cross-slope is not specified on the plans, the profile of the new course should provide for a smooth riding surface, and the cross slope should be uniform on all tangent sections and should vary uniformly in transition sections into superelevated sections. For an intermediate course where the profile or cross-slope is specified, the new course should conform to the required profile and cross-slope, within the specified limits. The procedure for checking the profile and cross-slope is given in Section 401.19.

Checking Spreading Methods

Inspection of the asphalt concrete spreading consists primarily of observing the methods and practices being used by the Contractor. It is the Inspector's responsibility to assure that these methods are producing the intended results and to require any corrective measures necessary if unsatisfactory results are obtained. Regardless of the method of placing used, mechanical or hand, the following conditions should be checked closely:

1. Uniformity of the mixture and any evidence or segregation
2. Surface texture of the mixture
3. Temperature of the mixture
4. Edge alignment of the material

The Inspector should observe the spreading operation for any signs of segregation of the mixture. The accumulation of coarse aggregate in pockets across the width of the spread mixture is undesirable; particularly when these pockets occur along the edges. Methods or practices causing segregation must not be permitted to continue.

Hand placing and leveling tend to segregate the mixture by working the coarse aggregate particles to the surface. Surface courses placed by hand must be given particular attention because of appearance and the fact that the segregated areas are very susceptible to raveling. Only a dense, uniform surface texture is acceptable. Since an unsatisfactory surface texture may not be evident until after a roller pass, the Inspector must insist that workers and material are available during rolling of hand-placed areas to make any needed correction. Segregated areas should be corrected by placing additional material and raking out the coarse particles, leaving the fine particles to form a dense surface.

Disturbance of the paver operation, due to bumping of the paver by the hauling vehicle or uneven flow of material into the paver hopper, can cause irregularities in the surface being placed. The hauling vehicle should come in contact with the paver with as little shock as possible and, if the hauling vehicle is pushed by the paver during unloading, a constant contact pressure should be maintained in order to avoid jerking the paver. The asphalt concrete should flow uniformly from the truck into the hopper with the quantity in the hopper being maintained at a constant level. Sudden surges of material affect the position of the strike off, causing surface irregularities.

The mixture should have a uniform appearance across the width placed. Streaks of differing texture and pulling or tearing of the mixture generally indicate the need for adjustments to the paver screed or strike off, or that differential wear has occurred in these parts. This also may be due, however, to low temperature or to mix deficiencies.

The placing of asphalt concrete mixtures, particularly in a thin surface course susceptible to rapid loss of heat, must be done in such a manner that compaction can follow before the mixture cools below a workable temperature. Lower compaction temperatures are directly related to an increase in air void content, which decrease the strength of the pavement. Even with a perfect mix design, if the mix is not properly compacted in the field, the final product will not last for its intended length of time.

This is important especially in small areas where the mixture is placed by hand. In these areas, heating of the underlying surface with torches or radiant heaters helps reduce the loss of heat from the mixture to this surface. Although not a recommended practice, heat can also be applied to the material being placed in order to maintain the mixture at a workable temperature. This practice must be controlled carefully to prevent damage to the mixture. Any mixture that cools before it can be compacted properly must be removed and replaced.

The Inspector should use a straightedge to check the surface of the loose material cross slopes.

The Inspector should calculate the required spreading rate in tons per station and ensure that the actual spreading rate is within ±5%. See Example in 301.05.

Nighttime Paving

When nighttime paving is allowed, no work can proceed without an approved and operating lighting system. This work consists of furnishing, installing, operating, maintaining, moving, and removing night time lighting to illuminate construction work areas for night work. Night work is defined as work performed from 30 minutes before sunset to 30 minutes after sunrise.

An illuminated zone at specific luminance is required around all paving equipment in the immediate vicinity and at 25 feet. Item 401.15 provides these specific requirements. The engineer must approve the lighting system based on measured luminance readings. The Contractor must provide a photometer that can measure the luminance levels at the specified foot-candles with measurements taken at 20 inches above the roadway.

Luminance measurements can be required by the Contractor at any time as requested by the Engineer. The Contractor must provide luminance readings at any change in the approved lighting configuration. Any corrections and deficiencies must be made within one hour or the Engineer is required to shut down the construction.

Light sources shall be positioned such that they do not interfere with, impede, or cause glare for motorists. Light cannot be pointed at adjacent properties. Luminaires must be kept clean and bulbs replaced immediately. Asphalt pavement placed during nighttime operations should be reviewed and inspected in the daylight for mat problems like segregation, smoothness, etc. The results and observations of daylight reviews should be used to make corrections and adjustments to the paving procedures in order to correct and prevent substandard operations and unacceptable asphalt pavement.

Compaction (401.16)

The compaction of asphalt concrete mixes is currently governed by one of two types of specifications. A method specification is used by some asphalt concrete (301, 302, and 448 – by 2005 specification and older), while most mix types (446 and 448 – by 2008 specification) are governed by a density requirement (446.05 and 448.03).

The Job Mix Formula (JMF) provides the optimal compaction temperature for the design. The mixture should be checked frequently to ensure the asphalt is being compacted at, or near that temperature. For asphalt concrete base pavements refer to Items 301 and 302 for minimum allowed mix temperature. In all cases the mixture should not be allowed to cool below a workable temperature for adequate compaction (175° F to 275° F) and the majority of compaction should be accomplished before the temperature reaches 225° F.

Compaction (Method)

This section applies to all mixes without a density specification. Compaction of an asphalt concrete mixture using the method specification is performed by using the rollers and methods specified in 401.13 and 401.16.

The number and type of rollers proposed for use by the Contractor should be checked for compliance with 401.13. The calculation for the roller capacity (tons per hour) should be made by the project personnel. See the example in 301.04. Documentation of the calculations and the tire manufacturer's charts or tabulations furnished by the Contractor should be kept in the project files. As the work progresses, the placement rate should be checked to assure that it does not exceed the combined capacity of the rollers in use. If the placement rate does exceed the roller capacity, the Contractor must either reduce the rate or use additional rollers.

For compacting base mixtures, the specifications require at least one steel wheel and one Type 1 pneumatic tire roller. This requirement must be met even though the placing rate may indicate the need for only one roller. The intent is to assure that each layer of base mixture will be subjected to the traffic conditioning effects of pneumatic tire rolling while the mixture has sufficient retained heat to respond without fracturing.

Compaction (Density Acceptance)

This section applies to mixes accepted based on a density specification. The Contractor is responsible for determining the correct roller train to ensure compaction.

For 446, and 448 accepted by density testing, the requirements of 401.16 are modified and only the last 4 paragraphs of 401.16 are applicable to 446 and 448 accepted by density testing.

General Compaction Inspection

This section pertains to the compaction of asphalt concrete mixes using either the method specification or the density acceptance specification (described above). The Inspector should refer to the last four paragraphs of 401.16 to review the common part of both compaction specifications.

The optimum compaction conditions are present immediately behind the paver, and the greatest increase in density per roller pass occurs in this area. It is important, therefore, that the initial or breakdown roller follows the paver as closely as possible. When an intermediate roller is used, it should follow the initial roller closely in order to provide the required overlapping coverage. The timing of the final rolling, required for removal of any roller marks, depends on the condition of the mixture. Regardless of their position in the compaction sequence, however, the rollers should be in continuous operation during the spreading process except for necessary stops for fuel and water. The specified roller pattern should be repeated uniformly, without abrupt stops or changes in direction, and the reversing points at the end of the roller runs should be staggered to reduce the possibility of forming transverse bumps.

Asphalt pavement joints can be confined or unconfined. Confined joints occur when the asphalt mixture is placed directly against a previously placed asphalt pavement or an existing pavement, while unconfined joints are not. The unconfined edges of the mat should be rolled first using a steel drum roller with the roller drum hanging out in air around 6 inches from the unconfined joint.

Longitudinal joints occur where two lanes are, or will be, joined together. For an unconfined or confined longitudinal joint, best results are obtained by using a drum vibratory roller operated in the vibratory mode with the frequency set at maximum. Pneumatic tire rollers should not be used to do the first pass of an unconfined longitudinal joint.

The Inspector must not hesitate to require correction of any defects which appear during the compaction operation. Deficiencies can be corrected with better results and with less effort during the compaction operation, while the mixture is still hot, than after final compaction and cooling of the mixture.

Joints (401.17)

Longitudinal Joints

Longitudinal joints in the top layer shall correspond with the edges of proposed traffic lanes. Longitudinal joints in lower layers shall be offset as per Standard Construction Drawing BP-3.1 alternating each side of the edges of traffic lanes not less than 6 inches (150 mm).

Proper longitudinal joint construction requires the loose asphalt mixture to be set up an extra 25% thickness above the adjacent material to allow for roll down and with a 1 inch to 1½ inch overlap to permit proper compaction. If the joint is being made against a sawed or milled vertical edge, the overlap must be around ½ inch.

The height of the new asphalt mixture over the joint must be sufficient to permit full compaction of the material being placed before the weight of the roller begins to be carried on the adjacent construction. This pre-compaction height must be maintained uniformly, particularly on surface courses where raveling of an unsound joint is likely to occur. Height uniformity is achieved by continuous manual control or by automatic control of the strike off height.

The paver should be operated in a straight line to provide a mat with a straight edge that can be consistently overlapped. Excessive deviations of the edge line from a straight line are unacceptable and require trimming the edge before the adjacent material is placed. With a good edge and proper control of the placing operation, little or no hand work is needed to form a good longitudinal joint. The Contractor should not continuously rake the joint. On surface courses, the Inspector must be sure that the hand raking process does not produce an irregular surface texture.

The specified time limit for making a longitudinal joint in the surface course when traffic is maintained is intended to reduce distortion and sealing over of the exposed face. When the Contractor fails to meet this requirement due to unforeseen conditions such as weather or equipment failure, the joint face should be inspected and special precautions taken to assure that a dense, well bonded joint still can be constructed. Trimming of the joint face may be necessary in some cases.

All cold longitudinal joints are required to be sealed as specified in 401.17 using a certified PG binder or Rubberized Asphalt Emulsion to provide 100 percent coverage of the joint.

Transverse Joints

Transverse joints occur at any time the paving operation is stopped for the day (or night). When placing the last load of asphalt concrete for the day, the paver should move forward until all material is spread. This leaves an irregular end that should be squared off by hand to form the joint. This joint edge should be compacted thoroughly, with the rollers passing over the edge even though this may cause some rounding or even displacement of the material in the process.

When the paving operation resumes, locate the point where the rounding or other departure from the profile begins, and continue the paving operation from that location in order to assure a smooth transition from one section to the other. In some cases, trimming the joint face may be necessary. For all surface courses, the transverse construction joint is required to be formed or cut to vertical. All cold transverse longitudinal joints are required to be sealed as specified in 401.17 using a certified PG binder, Rubberized Asphalt Emulsion to provide 100 percent coverage of the joint, or with a certified 702.04 asphalt material at a rate of 0.25 gallon per square yard (1 L/m^2).

The Contractor must have workers and hot material available during construction of the transverse joint; utilize alternate rolling, a 10 foot straightedge, and the addition or removal of material to produce a uniform profile. Paving operations should not be permitted to continue until a satisfactory joint has been obtained.

Checking Pavement Tolerances (401.19)

Checking Line

In new construction, asphalt concrete mixtures are placed on top of a prepared subgrade, subbase, or base course. The placing must be controlled accurately so that the new pavement will conform to the required plan lines. The Contractor sets line and grade stakes prior to the paving operation to aid in placing control and to provide inspectors with reference points to check the conformity of the asphalt surface to the plan profile grades. The Contractor will use sensors and long skis gliding over the surface to be overlaid to control the mat thickness and provide a smooth surface. Sometimes when matching bridge approach slabs, the Contractor will use a guide or string line as a reference. The paver follows this string line to provide a smooth transition.

Paver with Ski on Adjacent Lane

The edge of the existing pavement may be used as the required reference if it is straight and uniform. If the edge is unsatisfactory for this purpose, the contractor should propose a method satisfactory to the Engineer.

Checking Longitudinal Profile

For all new construction, and some rehabilitation construction, the required profile grade and pavement elevations are given in the plans. Where a profile grade is not specified for rehabilitation construction, the profile of the finished pavement surface depends upon the profile of the existing pavement surface. The plans may require profile correction prior to placing an overlay pavement; however, profile elevations may or may not be specified.

For construction where a profile grade is specified, the Contractor is required to set grade stakes in order to provide a reference for controlling the elevation and grade at which the asphalt concrete is placed. These grade stakes should be set at intervals of not more than 50 feet (15 m) on tangents and not more than 25 feet (7.5 m) on vertical curves and transition lengths of superelevated curves. The stakes should be placed on both sides of the pavement to permit easy checking of the grade; intermediate stakes should be provided as needed in areas of greater than normal width.

The specifications require the completed pavement profile to be parallel to the plan-proposed profile within the tolerance specified in 401.19. The difference in pavement elevation may be obtained by methods such as profile levels or differences in rod readings. Prior to placing the surface course, the Contractor must check the profile of the preceding course at 50 feet intervals and submit a tabulation of the results to the Engineer for approval. The results should be tabulated in a convenient form, listing the following:

1. Station
2. Pavement elevation
3. Plan elevation
4. Difference

The Engineer must evaluate the Contractor's profile check. Approval of the profile and permission to place the surface course should be based on satisfactory completion of any corrective work needed for compliance with the profile requirement. The approved profile check will be part of the project record.

Checking Cross-Slope (Transverse Slope)

For all new construction and some rehabilitation construction, the required cross, or transverse, slope of the asphalt concrete pavement is given either as crown or as superelevation in the plans. Where a cross-slope is not specified for rehabilitation construction, the cross-slope of the finished pavement depends on the cross-slope of the existing pavement surface.

For construction where the cross-slope is specified, the pavement cannot vary more than 3/8 inch in 10 feet. The Contractor should check the cross-slope of the pavement course being placed during the spreading operation. The Inspector should observe this operation regularly to assure that the pavement course is being constructed substantially within the specified cross-slope limits.

Particular attention should be given to the checking of the cross-slope on the asphalt concrete course preceding the surface course. Where observation of the Contractor's checking or additional checking by the Inspector reveals substantial deviations from the specified limits, corrections must be made to bring the asphalt concrete course within the specified cross-slope limits before the surface course can be placed.

Checking Surface Smoothness

The required smoothness of asphalt concrete pavement courses is specified in terms of an allowable tolerance from the testing edge of a 10 foot (3.0 m) straightedge. The Contractor is required to provide a straightedge that is satisfactory to the Engineer. The Contractor should check the course being placed while the Inspector observes. The frequency of checking depends on the nature of the work being done. No checks of the smoothness need to be made when the paving operation is progressing uniformly and no evidence of bumps, divots, depressions, etc. are observed. The surface smoothness should be checked closely when a transverse joint is being made, when erratic paver operation occurs, or when hand placing is required in the construction of a transverse joint.

The completed intermediate or surface course shall not vary by more than 1/4 inch in 10 feet.

Acceptable methods for the correction of irregularities are given below.

Special Requirements for Surface Course

Construction Requirements

Before placing a surface course on the intermediate course, a coat of tack must be applied to the intermediate layer.

Where the surface course has been damaged due to inadequate bonding, it must be removed and a tack coat applied before the surface placing is continued.

On projects where traffic is maintained, the longitudinal joints between adjacent lanes of surface course pavement must be completed within 24 hours. Where this time limit is exceeded, the joint should be inspected, and if the joint appears to be excessively rounded or displaced, necessary corrections should be made as provided in 401.17. This action should be recorded in the project records.

Traffic should not be permitted on a completed surface course until the mixture has cooled sufficiently to prevent glazing or the drawing of asphalt material to the surface of the pavement due to tire action.

Where the completed surface course is placed directly against an adjacent curb face, the surface course should be sealed along the gutter line. When sealing is required, the operation should be inspected and the use of an excessive quantity of asphalt material or sloppy application should not be permitted. Only the quantity of asphalt material necessary to fill the surface voids should be used. The material should be applied at a uniform rate, approximately 4 inches (100 mm) in width. The asphalt material used for the seal shall be asphalt binder as directed by the Engineer. Because of the small quantity of material involved, the approval of the asphalt material to be used for this purpose may be based on field inspection, and the results of the inspection recorded on the Inspector's Daily Report, with the material identified as to grade, manufacturer, and use.

Correction of Surface Course

The specifications require that irregularities and defects be corrected in a manner satisfactory to the Engineer. The following methods will produce satisfactory results when the work is properly performed by sufficiently skilled workers.

Where removal of defective material is required, removal limits should be defined by cutting or sawing to neat lines. After the defective material has been removed, the area and the edges should be given a uniform coating of tack coat material. The replacement material should then be placed and compacted to conform to the surface of the surrounding material.

Minor segregated areas in which there is insufficient fine aggregate at the surface can be corrected by a squeegee application of a commercial sealer containing asphalt material of the same type as was used in the mixture. An emulsion of the asphalt material along with added fine aggregate is also effective. Careful use of the squeegee is necessary to fill the surface voids without leaving a surplus of the sealer on the surface.

Where additional surface course mixture must be added to correct a low area in the surface, correction area limits should be defined by cutting or sawing to neat lines followed by removal of material as necessary to permit replacement at not less than 0.5 inch (12.5 mm) thickness. The surface of the area to be corrected and the face of the butt joint should be given a coating of tack coat material. The replacement mixture should then be placed and compacted as required to effect the needed correction.

Where material must be removed to correct high areas in the surface, satisfactory correction often can be accomplished by using a surface grinder or a cutter planer. Removal and replacement of the surface course and a portion of the underlying material may be necessary in extreme cases.

Method of Measurement (401.21)

Conversion Factor Established by the Laboratory

Asphalt mixture is delivered to the project based on weight in tons for each load. Payment is made in cubic yards. Therefore a conversion from tons to cubic yards is required. The laboratory provides a conversion factor (unit weight/volume) for the specific JMF being used. This conversion factor is given in tons/cubic yard (tons/yd^3). The conversion factor for the mix can be obtained from the "BCJMF" screen in the TAS portion of CMS.

Control of Quantity Placed

For a given course the Required Placement Rate per Station (RPRS) is calculated in tons per station. Every 500 feet (150 m), at the end of a full load the exact length of the section should be measured and a check should be made to ensure that the placement rate is within $\pm$5%.

To establish the required placement rate, the laboratory conversion factor (tons/yd^3) is multiplied by the required volume of the asphalt pavement per station. One station is equal to 100 feet. The placement rate, in tons per station is given by the following equations:

Calculate Required Placement Rate per Station, RPRS:

RPRS = [Volume of asphalt in cubic yards (yd^3)] x [Lab Conversion Factor, CF (ton/yd^3)]

= [{100 *ft per Station*) x Lane Width (*ft*) x Mat Thickness (*ft*)} ÷ 27 ft^3/yd^3] x C.F. ($tons/yd^3$)

= tons/station

Calculate the Actual Placement Rate, APR:

APR = [Material Used (*Tons*) ÷ (Test section length (*Ft*) ÷ 100 per Station)]

= tons/station

Where:

RPRS is the required placement rate per station

APR is the actual placement rate per station

C.F. is the lab conversion factor (*tons/*yd^3)

Examples:

Roller Capacity and Placement Rate

A contractor is using one three-wheel roller, one vibratory roller with 66-inch drums (both vibrating) and one Type 2 pneumatic tire roller to compact a mat 3 inches thick using material with a Laboratory conversion factor of 2.0 tons per cubic yard (*tons/*yd^3).

From Table 401.13-1 the following is the maximum capacity of the rollers the contractor will use:

- Three wheel = 700 *sq yd/hr*
- Vibratory roller = 2 *drums* x 66 *in* x (15 *sq yd/hr/in* of width) = 1980 sq *yd/ hr*
- Type II Pneumatic Roller = 700 *sq yd/hr*
- Maximum roller capacity = 700 + 1980 + 700 = 3380 *square yards/hour*

3380 yd^2/hr x (3 *in* ÷ 36 yd^3/in^3) = 281.67 yd^3/hr.

281.67 yd^3 x 2.0 *tons/*Yd^3 = 563.34 *tons per hour* maximum placement rate.

Determine the Required Placing Rate per Station (RPRS)

A contractor is placing a 5 inch uniform mat of asphalt concrete pavement whose Laboratory conversion factor is 2.0 tons/cubic yard (*tons/*yd^3). The required placing rate (RPRS) in tons of material per station for a 12 ft wide mat is:

RPRS = [Volume of asphalt in cubic yards] x [Lab Conversion Factor]

= [{100 ft/station x 12 ft x (5 in ÷ 12 in/ft)} ÷ 27 ft^3/yd^3] x 2.0 $tons/yd^3$

= 37.04 tons/station

This rate should be rounded off to two digits after the decimal for control purposes.

In order to construct courses for uniform thickness in new full-depth or base-widening construction, the Contractor is required to maintain the calculated rate of placing within a specified tolerance of plus or minus 5 percent. The Inspector must check this placement rate, using the plant weight tickets which must accompany each load of material, and the area covered by a given number of loads. The area to be used for the check should not be greater than 500 feet (150 m) in length and should be measured from the start of a full load of asphalt concrete to the end of a full load. The results of these checks should be recorded on Form CA-FP-4, Bituminous Concrete Inspection, or the Inspector's Daily Report. If Form CA-FP-4 is not being used or is not available, a suggested format for the check is:

Location of Test Section	
Plan Thickness	
Required Placement Rate (A)	
Length of Test Section	
Width of Test Section	
Actual Placement Rate (B)	
Specification Tolerances (A ± 5%) = B ÷ A	

When variations greater than ±5% of the required rate are calculated, the Inspector should address the variance with the Contractor to determine a cause. The Contractor should adjust the paver operation accordingly to bring an unwarranted variation back into tolerance. The Inspector should immediately check the actual spreading rate when changes are made to the paving operation. All variations in tolerance should be recorded in the Inspector's daily report.

Depending on the nature of the material being placed and quality of the placing operation, one to four placement rate checks per day normally will represent the material placed with a given paver. When the work involves a series of small areas, the use of partial loads at each location makes the check impractical. In such cases, the Inspector should determine plan thickness is being obtained.

The placing of asphalt concrete should be closely controlled and kept as near as possible at the specified rate. Even for a well-controlled operation, however, both positive and negative variations will occur and are to be expected. The Contractor should not place the material at a rate greater than that required since this would result in an overrun of plan quantity for which the Contractor would not be paid. As stated in 401.21 Method of Measurement, the pay quantity is limited to the total weight of the item placed, converted to cubic yards (cubic meters), with no payment made for the quantity of material placed which exceeds that calculated from plan lines and dimensions.

Basis of Payment (401.22)

Acceptance Sampling

With the exception of 446 core samples, remaining asphalt concrete is sampled and tested by the Contractor at the asphalt plant. Additional field density field testing may be required for 448. Contractor tests are used for pay if they are verified by District testing. Item 446 core samples are determined and marked by the Engineer, cut by the Contractor, and tested by the District. See 403.06 for sampling detail. See the specific asphalt concrete item in this manual for additional sampling information.

Cutting Pavement Samples

On occasion cut pavement samples are obtained when additional tests are needed on the finished asphalt concrete pavement to determine whether specifications have been met.

The location of a cut pavement sample is selected in a random manner, as specified in Supplement1035. The cut pavement sample should be 12 inches × 12 inches (305 mm × 305 mm). If the cut pavement sample breaks while it is being removed from the pavement, take care to obtain all of the pieces.

After a cut pavement sample is obtained, it should be packaged and identified in accordance with current District or Laboratory policy. The sample should be shipped to the District lab as soon as possible. Most District labs are not able to test cut pavement samples, so the District will forward the sample to the Laboratory for testing.

Cut pavement samples are usually tested to determine the gradation and binder content of the asphalt concrete mix.

Quantities for Payment

Summarizing Quantities

A plant ticket form approved by the Laboratory must accompany each load of asphalt concrete delivered to the project and accepted for placement. When the load is accepted at the paving site, the paving Inspector records the placement location and validates the ticket in the space provided.

A daily summary by item and location should be made of the weight of asphalt concrete placed.

When the placement of asphalt concrete items has been completed, a final summary of the weight placed must be made for use in the determination of the pay quantity for each item. The final summary should be broken down by separate pavement areas. In general, separate pavement areas are defined as separate contract parts, separate participation codes, physically separate roadways, and pavement areas having differing design sections. The total weight summarized is converted to cubic yards (cubic meters) using the applicable conversion factor.

Converting to Cubic Yards (Cubic Meters)

After the total weight of material used in a pavement section has been determined, it must be converted to cubic yards (cubic meters) using the applicable conversion factor established in accordance with 401.21. In 401.21, the Laboratory establishes the conversion factor when a mix design is approved for the project. The conversion factor of a mix can be obtained from the District test lab and from the "BCJMF" screen in the TAS portion of CMS. The total weight of material used in a pavement section can be converted to cubic yards (cubic meters) as follows:

$$\text{Cubic Yards} = [TW \div CF]$$

Where:

TW = total weight of asphalt placed (*tons*)

CF = conversion factor (*tons/yd*^{3}) or (*tons/m*^{3})

This volume should be rounded off to the nearest cubic yard (cubic meter).

Pay Quantity - New Construction

Where asphalt concrete is placed on a subgrade, subbase, or base constructed under the contract, the plan depth is uniform and the pay quantity is the quantity placed providing it does not exceed the quantity calculated using plan lines and dimensions. Quantities placed in excess of the plan quantity are not eligible for payment.

However, where a pavement consists of more than one item for example (301, 448 type II and 448 Type I), an excess in the quantity of one item may be transferred to offset a deficiency in the quantity of another item. Payment for the transferred quantity should be made at the lower unit bid price. Such transfer of quantities should not be made from the summary for one separate pavement section to another. Separate pavement sections are defined as separate contract parts, separate participation codes, physically separate roadways, and pavement areas having differing design sections.

No transfer should be made to offset a deficiency in the quantity of a surface course item.

Pay Quantity - Minor Rehabilitation

Where one to two courses of asphalt concrete is placed on an existing pavement for the correction of the profile and cross section, the depth is variable and the pay quantity is the quantity placed as directed by the Engineer in accordance with the intent of the plans. Placement rate checks, as described in Section 401.21, should be used to verify that the Contractor is meeting the intent of the plans.

Pay Quantity - Major Rehabilitation

Where multiple courses (three or more) of asphalt concrete are placed as part of a major rehabilitation of a pavement section, part of the asphalt concrete may be used for the correction of the profile and cross section of the rehabilitated pavement, as described above, and the rest of the asphalt concrete placed at a uniform depth, as described in Section 401.21 Pay Quantity – New Construction.

For the course(s) used to correct the profile and cross section, the pay quantity is the quantity placed as directed by the Engineer in accordance with the intent of the plans. Once the Engineer has determined the profile and cross section have been corrected, the rest of the courses should have a uniform depth and the pay quantity is the quantity placed providing it does not exceed the quantity calculated using plan lines and dimensions, in accordance with Section 401.21 Pay Quantity – New Construction.

Documentation Requirements - 401 Asphalt Concrete Pavements-General

This section contains general requirements for inspecting and documenting asphalt concrete pavement operations. In all cases the Inspector should record all observations regarding the placement of the asphalt mixture in addition to the following requirements.

1. Obtain JMF for the project.
2. Determine and document if paver is on approved list.

3. Check and document roller capacities as outlined in 401.13 if required by the specification item.
4. Document pavement surface condition, preparation, and surface and air temperatures.
5. Document tack or prime used along with source and quantity used versus required.
6. Document lift thickness, mat width, weather conditions, surface tolerance checks, equipment problems, mat problems (segregation, tearing, tenderness, etc), spreading rate, roller coverage, and any other issue or observations made during paving operations.
7. Observe and document trucks hauling material:
    a. Check for secured waterproof cover.
    b. Check for insulated truck beds for temperatures below 50° F (10° C) and/or if the haul exceeds 20 miles (32 km).
    c. Observe the asphalt mix in the truck and note any slumping, drain down, or blue smoke.
8. Determine compliance with compaction requirements as per 401.16.
9. Record asphalt mixture temperatures in the paver hopper and on the mat at the time of compaction.
10. Determine and record required and actual placement rates and variance.
11. Write location (station), date, and time on asphalt plant tickets. Tickets should be totaled daily, initialed, with the calculator tape attached.
12. Take samples, cores, or density readings as required by item 446 or 448.
13. Record luminance readings for night paving operations
14. Determine plan quantity for payment
15. Document on CA-FP-2 through 4 or other approved forms as needed.

407 Tack Coat

Description (407.01)

The tack coat is an application of liquid asphalt material on an existing pavement surface, used as an aid in bonding a new asphalt concrete course to the existing pavement surface. Proper application of tack coat is a key factor in producing a quality asphalt paving project. Tack coat promotes bonding between asphalt layers to achieve a maximum strength of the pavement structure. Proper tack coat application prevents separation or movement of asphalt layers and provides a long-lasting quality pavement.

Materials (407.02)

Tack coat used should be RS-1, SS-1, SS-1h, CRS-1, CSS-1 or CSS-1h and conforms to the application requirements of 702.

When paving over a concrete pavement the tack coat used should be rubberized asphalt emulsion conforming to 702.13.

Emulsions are classified as rapid setting (RS or CRS), medium setting (MS or CMS), or slow setting (SS or CSS). The letter "C" in front of an emulsion type (CRS, CMS, or CSS), denotes a cationic (positively charged) emulsion. If the emulsion type is followed by an "h" (SS-1h) it means the emulsion was made from harder base asphalt cement.

Equipment (407.03)

The inspection and approval of asphalt distributors used to apply tack coat material are governed by the ability to fulfill 407.06 and 407.03. The distributor must be capable of applying the tack coat at the rate specified by the plans. The distributor must have a tachometer, pressure gauges, and an accurate volume measuring device or a calibrated tank. A thermometer is required to monitor temperature of the tack. The spray system must by fully circulating and the spray bar must be adjustable both laterally and vertically. The Contractor must provide charts or other information that shows truck and pump speeds required to obtain the application rate.

Mechanical sweepers and other related hand equipment may be of any type that will accomplish the required results.

Weather Limitations (407.04)

The tack coat should not be applied when the surface temperature of the existing pavement is below the minimum placement temperature for the asphalt pavement course to be placed. The minimum placement temperatures are specified in 401.06. The surface temperature is to be recorded on the Inspector's Daily Report.

Preparation of Surface (407.05)

The pavement surface must be dry and free of any material accumulations that might hinder the bond of the tack to the pavement. Excessive use of tack coat should never be a substitute for proper cleaning of pavement. Excessive tack coat can act as lubricant creating a slip plane between pavement layers.

Remove all dust, loose aggregate, soil, leaves, and pieces or lumps of other foreign material deposited on the surface. Cleaning may require brooming, handscraping, and perhaps power blading of heavy accumulations. Special attention should be given to the edges to assure proper coverage of the full width intended.

Although emulsified tack coat could be applied to a damp pavement; this practice is discouraged. Damp pavement will require additional cure time that is indicated by a change in color from brown to black. If allowed by the Engineer there should be no standing or flowing water on the surface of the pavement to be tacked. The time to cure should be closely monitored to ensure the tack application has completely set before paving begins.

Application of Asphalt Material (407.06)

Protection and Control of Traffic

When the contract requires traffic to be maintained, tack coat application should not be allowed to start until the provisions of the traffic maintenance item have been met. Alternate movement of one-way traffic must be in place before the distributor is brought into the starting position. Give special attention to the Contractor's operation relative to traffic movement. Every reasonable effort should be made to keep "pick up" of the asphalt material prior to paving to a minimum. This may involve tacking in sections and allowing time for curing.

Application of Asphalt Material

Only asphalt material meeting the requirements of 407.02 can be used. Tack is shipped under ODOT's Asphalt Materials Certification Requirements as detailed in Supplement 1032. Weight tickets will be provided for the loads of asphalt material delivered to the project. A weigh-back ticket must be provided to accurately determine the quantity of tack used based on weight. This weight will have to be converted to gallons based on the appropriate conversion factor for the tack. Although the distributor is required to have an accurate volume measuring device, payment must be made using the weight tickets.

The Inspector must make a general inspection of the distributor to become familiar with the particular equipment and to detect any variance from the specifications. In particular, the Contractor must demonstrate the use of the required volume measuring device, thermometer, and application controls. Work should not be permitted to start if this equipment is unsatisfactory. In addition, the approval of the distributor is based on observation of the operation and check measurements of the actual application rate, performed as described in the following paragraphs.

For large areas, the application rate is determined by the application of a given quantity of an asphalt material over a known area. The rate is calculated using the gallons (liters) indicated by the volume indicating device on the distributor, the known length of the distributor run, and the measured width covered. The rate of application is considered acceptable when measured application rate is within ±10 percent of the required rate and the tack is uniformly applied. The application rate for small areas, where volume measurement is not practical, may be judged visually. Note that for payment, the quantity used is based on weight tickets not the volume measuring device on the distributor.

The elevation of spray bar should be maintained at a sufficient height and the nozzles should be angled 15º to 30º from the axis of the spray bar, to produce fully developed fan of bituminous material that will overlap with the fan from the adjacent nozzle.

The operation of the distributor is judged by visual observation. The quantity of material flowing from each nozzle should appear to be uniform. The angle of each "fan" of material with the spray bar should appear to be the same; the particular angle is specified by the manufacturer. The material should be applied uniformly across the width of the spray bar with no visible streaks and with no apparent variations in thickness from the beginning to the end of the run.

The results of the foregoing observations and check tests are recorded for each distributor proposed for use together with a means of identification (license plate or equipment number) and indication of approval or non approval. This information is entered in the project record as a supplement to the Inspector's Daily Report.

The asphalt material should be sprayed uniformly on the pavement surface. The application must be uniform without streaking, thin lines or dribbles. Streaking is caused by faulty distributor adjustment or operation, resulting in the asphalt material being placed in ridges. Contrary to popular belief, these ridges will not “flow” together. The result is insufficient asphalt material between the ridges to bond the new asphalt paving course to the existing pavement surface. Applications with streaking, thin lines, ridges, etc. are not acceptable. The Contractor must be notified to make corrections by adjusting the distributor and the operation to obtain a uniform and consistent application of material across the entire width of the area to be paved.

Example of Good Application

Example of Good Application

Example of Bad Application

Example of Bad Application

Application of Cover Aggregate (407.07)

To maintain a safe construction zone, traffic should not be allowed over tacked surfaces at any times unless aggregate cover is used to provide friction and prevent tack pick-up. Cover aggregate is required to be sufficiently dry to permit adhesion of liquid asphalt. When the cover aggregate is placed on an asphalt emulsion tack coat, the aggregate may be moist, but not to the extent that free water drains from the truck bed.

For all types of asphalt materials, the cover aggregate should be placed as close behind the distributor as is practical.

The Contractor is required to apply only the quantity of cover aggregate needed to prevent "pick up" by traffic. A typical rate for applying cover aggregate is 4 to 8 lbs/yd^2.

Quantities for Payment (407.08)

Determine gallons (liters) from weight tickets or weighed partial loads. For weights or volumes that are questionable or unknown a volume-measuring device is required before accepting the material. Cover aggregate is included in the bid price for the tack coat.

Documentation Requirements - 407 Tack Coat

1. Measure and document surface temperature
2. Document surface preparation (sweeping, cleaning) and condition of surface just prior to tack application
3. Document the temperature of material as delivered to the project
4. Document equipment used and conformance to specifications
5. Calculate and document rate of application and comparison to required rate
6. Document the use of any cover aggregate
7. Document any issues with application (streaks, lines, ridges) and actions taken to correct
8. Calculate and document for pay number of gallons applied per 407.08, 407.09 and 109.01
9. Use form CA-FP-6 and other approved forms to document the tack application and calculations.

408 Prime Coat

Description (408.01)

Construction requirements for prime coats are included in 408. An asphalt material having low viscosity is required for a prime coat. This material is intended to penetrate a prepared granular surface prior to the placement of an asphalt concrete mixture. The purpose is to bind the granular particles together for some depth below the surface to provide additional stability.

Asphalt Material (408.02)

One of the following types of asphalt material can be used 702.02 MC-30, MC-70, or MC-250; or 702.03 Primer 20.

Cover Aggregate (408.03)

Cover aggregate must conform to No. 9 size or gradation requirements of 703.05 or 703.06.

Weather and Moisture Limitations (408.04)

Prime coat cannot be used on a wet surface.

Do not apply prime coat for asphalt concrete paving or surface treatment work when the air temperature is below 50 °F or when the air temperature in the last 24 hours has been 40 °F or lower.

Do not apply prime coat on stabilized or granular base courses when the air temperature is below 40°F.

Equipment (408.05)

Equipment requirements for the application of tack coat are the same as detailed in 407. These requirements include the use of tachometer, pressure gauges, and an accurate volume measuring device or a calibrated tank. A thermometer is required to monitor temperature of the tack. The spray system must by fully circulating and the spray bar must be adjustable both laterally and vertically. The Contractor must provide charts or other information that shows truck and pump speeds required to obtain the application rate.

The spreading of the cover aggregate, when required, can be accomplished by any approved method, depending upon the specific job conditions. When sweeping is required, the brooms approved for use should produce a uniform surface without causing damage.

Preparation of Surface (408.06)

The surface to be primed should meet all requirements for the particular specification item (i.e., subgrade, aggregate base, stabilized subgrade, etc.). Irregularities in the subgrade, subbase, or base material in excess of specified tolerances must be repaired prior to priming. These include, but are not limited to ruts, corrugations, and high and low areas. Mud, clumps of dirt, and other foreign material must be cleaned from the surface to be primed.

Application of Asphalt Material (408.07)

The specified application rate for the asphalt material is an estimated rate suitable for average conditions. Open textured surfaces may permit an increase, while dense surfaces may require a reduction in the estimated rate. The application rate should be such that the prime will be absorbed by the material within 24 hours.

The asphalt material must be applied uniformly over the entire width of the area to be primed. The distributor must meet the same requirements of 407.03. If excess material is applied, the Contractor should squeegee the excess from the surface. Any deficient or skipped areas must be coated.

Prime is shipped under ODOT’s Asphalt Materials Certification Requirements as detailed in Supplement 1032. Weight tickets will be provided for the loads of asphalt material delivered to the project. A weigh-back ticket must be provided to accurately determine the quantity of tack used based on weight. This weight will have to be converted to gallons based on the appropriate conversion factor for the tack. Although the distributor is required to have an accurate volume measuring device, payment must be made using the weight tickets.

Application of Cover Aggregate

When traffic must use the primed area where the material has not penetrated completely, cover aggregate must be applied to absorb any excess material.

Quantities for Payment (408.09)

Determine gallons (liters) from weight tickets or weighed partial loads (weigh-back). For weights or volumes that are questionable or unknown, a volume-measuring device is required before accepting the material. Cover aggregate is included in the bid price for the prime coat.

Documentation Requirements - 408 Prime Coat

1. Measure and document air temperature
2. Document surface preparation (sweeping, cleaning) and condition of surface just prior to prime application
3. Document the temperature of material as delivered to the project

4. Document equipment used and conformance to specifications
5. Document the use of any cover aggregate
6. Document any issues with application (excess, deficiency) and actions taken to correct
7. Calculate and document for pay number of gallons applied per 409.09, 408.10 and 109.01
8. Use form CA-FP-6 and other approved forms to document the tack application and calculations.

409 Sawing and Sealing Asphalt Concrete Pavement Joints

Materials (409.02)

Be sure approved materials are used per 409.02 requirements. These include joint sealant and backer rod.

Construction Details (409.03)

Check that the following operations are proceeding properly per 409.03:

1. Saw cut the intermediate course if the surface course is not placed within 5 days. Saw cut is 1/8 inch wide by ¼ the depth of the intermediate course over contractor joints. At expansion joints the saw cut is ½ inch wide by ¼ the depth of the intermediate course.
2. Saw cut the surface course no later than 48 hours after paving.
3. Accurately locate saw cuts over joints with pins or stakes before paving The Engineer shall approve the method of joint marking before any resurfacing operations begins.
4. Final saw cuts shall be 2 inches deep with a sealant reservoir that is 3/8 inch wide by 3/4 inch and is recessed 1/8 below the surface.
5. Dry cut joints shall be cleaned using compressed air using an air compressor with a minimum rated capacity of 100 psi. Wet cut joints require water blast cleaning followed by drying with a propane torch or lance unit (409.03 has details on lance unit requirements).
6. The saw cut shall extend over the full pavement width including paved shoulders.
7. The joint is to be kept clean until sealing and traffic is not permitted to damage the joint before sealing. Damaged saw cuts must be repaired prior to sealing
8. The sealer is to be heated per the manufacturer's directions.
9. The first gallon of material that flows out of the applicator wand at the start of the day is to be discarded and not used.

Prior to sealing a backer rod must be placed in the clean joint and the liquid sealant immediately placed in the joint using a nozzle that is inserted into the joint and reservoir completing filling the joint. The sealant level after cooling should be not more than 1/8 inch below the pavement surface.

Documentation requirements - 409 Sawing and Sealing Asphalt Pavement Joints

1. Document when the saw cuts are made with respect to paving
2. Review, approve, and document method for locating joints

3. Measure and document depth and width of saw cuts. Document joint cleaning methods, placement of backer rod, and installation of sealant.
4. Document measurements on CA-D-2 or other approved form(s)

410 Traffic Compacted Surface

Because of the simplicity this item of work, no detailed explanation of the item is required in this manual.

Documentation Requirements - 410 Traffic Compacted Surface

1. Materials
2. Subgrade condition.
3. Document location where material was used on the ticket.
4. State if all load was used; if not, be sure to get a weigh back
5. Blading operation.
6. Maintenance.
7. Weigh tickets should be totaled with an initialed and dated tape attached. Convert to cubic yards as per 410.06 of the C&MS.
8. Pay and measure according to 410.06 and 410.07.
9. Document on CA-D-1 and CA-EW-12. Do not duplicate the information on these forms unless necessary.

411 Stabilized Crushed Aggregate

Because of the simplicity this item of work, no detailed explanation of the item is required in this manual.

Documentation Requirements - 411 Stabilized Crushed Aggregate

1. Materials.
2. Document location of where material was placed and lift thickness.
3. Roller weights.
4. Lift thickness.
5. Roller passes.
6. Use a rubber tire roller for the final compaction.
7. Perform the compaction tests according to S-1015.
8. Weigh tickets should be totaled with an initialed and dated tape attached. Convert to cubic yards as per 411.04 of the C&MS.
9. Pay and measure according to 411.04 and 411.05
10. Document on CA-D-1 and CA-EW-12. Do not duplicate the information on these forms unless necessary.

421 Microsurfacing

Description

This item of work is used to provide a cold laid polymer modified emulsified asphalt pavement course to fill ruts, depressions, and to provide a leveling course. It can also be used as a surface course over existing pavements. The mixture includes the use of crushed aggregate, mineral filler, water, polymer modified emulsified asphalt binder, and other additives.

Materials (421.02)

Materials used in the mixture and the completed mix are approved by the Laboratory prior to beginning work. The Contractor must provide a certificate of analysis and statement of compliance from the manufacturer with each load of binder.

Proportioning (421.03)

Verify job mix formula (JMF) approval by the Laboratory.

Weather Limitations (421.04)

The mixture cannot be placed when it is raining.

Allow microsurfacing if:

1. Surface temperature is 40 °F (5 °C) or above.
2. Air temperature within 24 hours of placement is NOT forecast to be below 32°F.
3. Surface temperature is 50 °F (10 °C) or above between September 30 and May 1.

Mixing Equipment (421.05)

Mixing equipment must conform to the specifications. Equipment must be self-propelled, front feed, with continuous loading system conveyor system. A gear pump must accurately proportion aggregate and asphalt emulsion.

Mineral filler must be dropped into the aggregate before reaching the pug mill. A spray bar must pre-wet the aggregate with water and additive before the addition of asphalt emulsion and before as it drops into the pub mill.

The pug mill must be continuous flow type and a minimum of 49 inches long.

The equipment must have driving stations on both sides. The back mixing station must have forward speed control to allow the mixing operator to control speed and the level of mixture in the paver.

A water pressure system with spray nozzles that can spray water ahead of the spreader box may be required.

The Contractor can use truck-mounted machines with a conveyor belt delivery system when project segments of less than 15,500 square yards or for spot repairs.

Equipment Calibration (421.06)

Witness the calibration of the mixing equipment before start or for any mix design change. Obtain documentation of individual materials calibrations from the equipment calibrator. After the initial calibration no further changes or adjustments to the mixing equipment can be made without the Engineer’s approval.

Spreading Equipment (421.07)

The spreading equipment must apply the mixture uniformly. A standard spreader box is allowed when placing a leveling course or surface course. For surface courses a secondary strike-off must be attached to the spreader.

If a rut fill course is required, the Contractor must use a V-shaped rut filling spreader box equipped with a steel strike-off.

Either spreader box must be attached to the mixer and must be equipped with adjustable paddles that continuously agitate and mix the materials throughout the box. Check for excessive build up and settling in the spreader box and have the Contractor correct.

Burlap or other drags are allowed for use to provide the desired surface finish.

Surface Preparation (421.08)

Be sure the surface is thoroughly cleaned before application. Apply a tack coat consisting of 1 part asphalt emulsion and 3 parts water and apply at a rate of 0.06 to 0.12 gallons per square yard. Apply tack in accordance with 407.

Raised pavement markers are to be removed according to 621.08 and depressions filled with the same material being used for the microsurfacing.

Pavement markings and all other paint must be removed using an abrasion method.

Test Strip (421.09)

A 1000 feet test strip must be constructed for evaluation by the Engineer. The test must include all courses specified and must be constructed at the same time of day as the scheduled full scale production. For example, if the Contractor plans night work, the test strip must also be done at night.

The test strip will be evaluated by the Engineer after traffic has been on it for 24 hours. Full scale operations can only begin after the Engineer accepts the test strip.

If work is schedule after May 1 and before September 30 AND the Contractor has constructed a test strip with the same JMF and materials in the same construction season, the test strip may be waived.

Application (421.10)

During application the following items should be closely checked and monitored:

1. Uniform and complete coverage that fills cracks, potholes, and surface irregularities.
2. No skips, lumps, or tears are allowed in the material placed.
3. No unmixed aggregate is allowed.
4. In a rut fill material must fully fill ruts without excess overfilling that creates a crown of 1/8 inch after 24 hours of traffic compaction.
5. Rut fill must be applied in 5 to 6 feet passes in each wheel path.
6. Restore the design profile of the pavement cross section.
7. Leveling course must be applied at 14 ± 2 pounds per square yard (7.6 kg/m2).
8. Surface course must be at 16 ±1 pounds per square yard (8.7 kg/m^2) when placed on another microsurfacing course.
9. Surface course must placed at a minimum 18 pounds per square yard (9.8 kg/m^2) when not placed on another microsurfacing course.
10. Surface courses must be wide enough to cover rut fill and leveling courses.
11. Straights lines must be maintained along curbs and shoulders, and at intersections.
12. Stop placement if excessive streaking or other problems develop.
13. Contractor must use a rubber tire roller if the material is not under traffic within 48 hours.
14. The pneumatic roller must meet 401.13 and a tire pressure of be 40 to 60 psi (275 to 400 kPa) is required.
15. Squeegees are required where hand spreading and finishing is needed.

Acceptance (421.11), Measurement (421.12), Payment (421.13)

Accept microsurfacing based on the Engineer’s summary of quantities for each day provided the proportion of binder to dry aggregate is maintained within 2 gallons per ton (8.5 L/metric ton) and all other control requirements for proportioning and spread rate are in conformance with the specifications.

The final pavement surface must be free from excessive scratch marks, tears, rippling, streaks, and other surface discontinuities. Longitudinal joints and transverse joints must be neat and straight.

Microsurfacing (surface and leveling course) is measured and paid by the square yards completed and accepted. The pavement width is as shown on the plans, specified in these specifications, or as directed by the Engineer. Length is measured along the centerline of the roadway.

Rut fill course will be measured and paid by the number of tons of dry aggregate used and accepted based on ticket weights.

The test strip will be paid based on the acceptance at the individual bid prices for each course placed. For example if the plans require a leveling and surface course, the test strip must be constructed using these courses and would be paid on the measured quantities for both of these items.

Tack coat is not paid separately and is considered incidental to the work.

Documentation Requirements - 421 Microsurfacing

1. Check for certificate of analysis and compliance from the manufacturer of the binder and document for each load of binder.
2. Check and document surface and forecast for next 24 hours.
3. Verify and record conformance to specifications for the mixing equipment.
4. Verify that an approved JMF is being used.
5. Document equipment calibration.
6. Document construction of test strip and the evaluation and any changes implemented.
7. Document surface preparation and tack coat application.
8. Document placement operation regarding uniformity, rut filling, leveling, pounds per square yard used, construction of straight lines, roller compaction if required, issues and corrections made.
9. Document acceptance, method of measurement, and calculations for pay.
10. Document onCA-D-3A or other approved form(s).

422 Chip Seal With Polymer Binder

Description (422.01)

Chip seal consists of the application of polymer modified asphalt emulsion covered by an aggregate course. It is applied as a single or double chip seal for use as a surface course on all types of pavements and on paved berms. Chip seal can also be used as an intermediate course for a hot mix asphalt surface course.

The purpose of a chip seal is to seal and protect the underlying course from weathering and from wear by traffic. A coating of asphalt material helps seal existing pavement cracks and joints and the cover aggregate provides a skid-resistant surface.

When applied on berms, the cover aggregate provides delineation of the traffic lanes from the berms by a change in surface color and texture.

A Chip Seal Operation

Equipment (422.03)

Distributors

The Inspector must make a general examination of the distributor to ensure compliance with the requirements of this specification and 407.03. The equipment used for the application of a tack coat is the same as used for the application of the polymer binder for chip seal but must include a computerized rate control that automatically adjusts the binder pump to the unit ground speed. This control must have a gauge or meter (in gallons) that is easily read. The spray nozzles must be appropriate for the material and rate specified. In addition, the approval of the distributor is based on observation of the operation and check measurements of the actual application rate, performed as described in the following paragraphs. The Inspector should have the Contractor demonstrate the use of the required volume measuring device, thermometer, and application controls. Work should not be permitted to start if this equipment is unsatisfactory.

The operation of the distributor is judged by visual observation. The quantity of material flowing from each nozzle should appear uniform. The angle of each "fan" of material with the spray bar should appear to be the same; the angle is specified by the manufacturer. The material should be applied uniformly across the width of the pavement with no visible streaks and with no apparent variations in thickness from the beginning to the end of the run.

Distributor with Improperly Aligned Nozzles (at Different Angles)

Streaking or ridging will not be tolerated when applying polymer binder for chip seal work. This type of defect is generally caused by nozzles that are not all at the same angle in respect to the spray bar. The Inspector must approve or prohibit use of a particular distributor accordingly.

The results of the foregoing observations and the results of the test section are recorded for each distributor proposed for use, together with a means of identification (license plate or equipment number) and indication of approval or non-approval. This information is entered in the project record as a supplement to the Inspector's Daily Report.

After the initial inspection, continued approved status of a given distributor depends on continued satisfactory results determined visually or by additional checks when deemed advisable.

Asphalt Distributor Applies the Polymer Binder

Rollers

Only Type II pneumatic rollers conforming to 401.13 are permitted for embedding the cover aggregate, however the maximum capacity shall not apply.

Type II Pneumatic Tire Rollers

Aggregate Spreaders

The aggregate spreader must be self propelled with a variable width aggregate hopper (8 to 16 feet) and shall conform to specification 422.03. The spreader must produce a uniform application of aggregate without gaps or ridges at the rate specified. Spreaders must have pneumatic tires, a screen to prevent oversized material from passing through to the roadway, revolving cylinders, and adjustments.

Aggregate Spreader Spreads the Aggregate on top of the Polymer Asphalt Binder

Brooms

Rotary brooms are used for the initial surface preparation to sweep the roadway prior to the application of the polymer binder. After the cover aggregate application a rotary broom or sweeper is required to sweep excess aggregate from the completed surface without dislodging the embedded aggregate. Be sure that aggregate is not being swept onto adjacent lawns.

Rotary Broom

Weather and Moisture Limitations (422.04)

For chip seals, the weather limitations are specified in 422.04. This section requires a minimum pavement and air temperature of 60 °F (16 °C). Work should not begin if temperatures are forecast to be below 50 °F (10 °C) within 24 hours from the start of work. Do not place the chip seal if the existing pavement temperature is 140 °F (60 °C) or above. This work is not to be done before May 1 or after September 1.

Test Strip (422.05)

The Contractor is required to provide a test strip to demonstrate that the equipment and operations can meet the requirements of the specifications. Do not waive the test strip.

The test strip must be 1000 feet long by one lane width wide. The test strip must be continuous. The test strip is used to determine the binder application rate, the aggregate application rate, and the aggregate gradation.

During the test strip the aggregate spreader will calibrated by applying aggregate to a piece of cardboard of a known size (generally 1 square yard). The material is collected from the cardboard and weighed to determine the application rate (pounds/square yard). Based on acceptance of the test strip this will be the rate of cover aggregate application.

The proper binder application rate will be determined. Initially the binder should be applied at the target rate specified. The depth of embedment of the aggregate will be checked visually. A good rate of application will provide an average of 2/3 embedment of the chip in the binder after rolling. The Engineer will make adjustments to the rate as needed to obtain the proper embedment. The rate will be calculated using the test strip dimensions and the number of gallons used as measured by the distributor gauge or meter (gallons/square yard).

The Engineer will review the test strip the following day. The acceptance criteria of 422.11 will be used to determine acceptance of the test strip. These criteria include proper chip embedment; binder streaking, ridging, and flushing; loss of cover aggregate; and joint construction. The Engineer may require another test strip if there are problems with the application.

Preparation of the Surface (422.06)

Before a chip seal is applied to an existing surface, all material accumulations, debris, foreign objects, dust, leaves, soil etc. that would interfere with the adhesion of the asphalt material must be removed. Proper cleaning of the surface requires power brooming and may necessitate hand scraping and power blading of heavy accumulations. Hand brooming may be necessary. Special attention should be given to the edges of the roadway to assure proper coverage of the width intended.

Application of Asphalt Material (422.07)

Only asphalt binder materials meeting the requirements of 422.07 are permitted. Check the specifications for project conformance. Asphalt binder is shipped under ODOT's Asphalt Materials Certification Requirements as detailed in Supplement 1032. Ensure that the material used on the project is from a certified source.

A uniform application in the transverse and in the longitudinal direction is important. Continued application should not be permitted when visible defects occur. Where it is demonstrated that distributor results are erratic, discontinue use of the equipment until the problem is corrected.

The binder must be maintained at 150 to 185 °F (65 to 85°C) during application and at the beginning of the day. Binder is not to be reheated at a rate faster than 25 °F (14°C) per hour when it has been allowed to cool to below 150 °F (65 °C).

With all other conditions being equal, the application rate of asphalt material depends on the average size of the cover aggregate particles. In a good chip seal, the average size aggregate will be embedded for approximately 2/3 of its height after thorough seating by rolling. This can be checked by pulling out chips by hand and visually inspecting how much of the chip is coated. When the binder application rate is too heavy, the particles may become totally embedded, resulting in a flushed or bleeding surface. When the application rate is too light, the particles may not be held with sufficient firmness to resist dislodging by traffic, and a loss of cover aggregate will result.

The binder application rate required to produce proper embedment for a given particle size also may depend upon the porosity, absorption, and firmness of the surface to be sealed. The rate required by the specifications may need field adjustment depending upon the actual nature of the surface. Considerable judgment is required to determine the proper application rate and to avoid undesirable effects of bleeding or raveling. If proper stone embedment is not obtained, the Engineer must be notified and the application rate adjusted and documented.

The binder application must be started and stopped on a removable protective cover of paper, cardboard, metal or other material that protects the adjacent pavement or previous chip seal from being coated. The use of the protective cover allows the binder to be applied at the full rate at each ending and beginning point but does not allow the binder to be applied to existing pavement or over applied on a previously constructed chip seal. The binder application must not be lapped, such as where one day's production meets the next. The protective cover must be removed immediately after use.

Chip Seal Prior to Rolling

Application of Cover Aggregate (422.08)

Only aggregate that has been approved is permitted for use. Collect the weight tickets when the material is received at the paving site.

The previously established spreading rate of aggregate must be verified using a 1 square yard of cardboard, weighing, and determining pounds per square yard. The Contractor must make adjustments to the spreader as necessary to meet the test section calibrated rate.

The aggregate must be sufficiently free from dust and moisture to permit immediate adhesion of the asphalt material. Material delivered to the site with water running from the bed of the truck must be rejected.

Application of cover aggregate in excess of requirements for complete coverage and that would be considered a nuisance to the public will require the work to be stopped. It is unacceptable to rely on brooming or vacuuming to remove excess aggregate. The spreading operation requires recalibration in these cases.

Construction Operation (422.09)

General Considerations

The Contractor must establish stations for the project at 1000 feet intervals before placing any material. The stationing must be clearly marked and be maintained throughout the project. Stationing is typically provided using wooden lath along the roadway and the markings should be easy to read.

The binder distributor, aggregate spreader, and rollers must be as close to each other as possible. The binder distributor cannot be more than 150 feet ahead of the aggregate spreader.

The longitudinal joint must be placed on a lane line or as the Engineer directs. For double chip seals, the longitudinal joint for the first course is to be placed 6 inches off the centerline and the second course is to be placed on the centerline.

Where a double chip seal is required by the plans, the first course must be cured, swept and capable of withstanding construction traffic. Any deficiencies or damage must be corrected before placing the second course of chip seal.

Rolling

Rolling of the chip seal cover aggregate is required to begin immediately behind the aggregate spreader. Three rollers minimum are required. Do not allow the aggregate to go unrolled for more than 5 minutes. This is to ensure that the aggregate particles will be embedded in the asphalt binder before the binder sets up. If the binder sets up before the aggregate is rolled the result will be loose stone that must be removed. That section of roadway would be unacceptable and would require rework.

The specifications require a minimum of two complete roller passes of the cover aggregate. A single complete pass is forward and back over the same area. Each new pass must be overlapped by ½ of the roller width. While making these passes, the speed of the roller must be slow enough, not greater than 5 miles per hour (8 km/h), to avoid displacing or dislodging the aggregate particles from the asphalt. If stone is being picked up by the rollers, have the Contractor adjust the speed.

Sweeping and Opening to Traffic

After the binder sets up for a single or double chip seal the new surface must be swept within 4 hours using a power broom or pickup sweeper to remove all loose aggregate. The Contractor cannot reuse this aggregate in the double chip seal course. There may be issues that do not allow the Contractor to sweep within the 4 hour timeframe like stone moisture, high humidity slow binder cure rate, rain, etc. In this case the Engineer may suspend the operation until the problem is resolved or more favorable conditions prevail that allow sweeping within 4 hours.

Make sure sweeping extends 1 foot beyond the edge of the roadway to remove any loose aggregate that could migrate back to the roadway.

Before opening the road to traffic, the contractor must place "Loose Stone" and "35 MPH" signs on the same post spaced at 0.5 mile intervals. Signs must conform to Item 614.

Where traffic is using the chip seal on two lane roads in the work area, the Contractor must provide a pilot vehicle at 25 mph to guide traffic through the work zone.

The Contractor is responsible for all damage claims that result from his operations and the chip seal surface until the application of the final pavement markings or the application of a fog seal if it is required.

Quality Control (422.10)

The Contractor is required to provide quality control of the chip seal process and must stop placement and notify the Engineer and DET if any of the parameter tolerances are exceeded. The Contractor must identify and correct problems and receive permission from the Engineer to restart the chip seal operation. Additionally the Department can obtain samples at any time. Aggregate samples can be taken from the stockpile or from the spreader to test for conformance. If Department testing shows out of compliance material, work can be stopped.

The Contractor is to provide an asphalt binder sample on a daily basis for the Department.

The binder application rate cannot exceed ±0.02 gallons per square yard from the established application rate.

Aggregate must meet a specific moisture content and gradation as provided in 422.10. The Contractor is required to reject material that does not meet these requirements. If water is seen running from the truck bed when aggregate is brought to the job it must be rejected.

The Contractor must provide a daily quality control report to the Engineer that includes the specific information as listed in 422.10.

Acceptance (422.11)

Acceptance of the final product depends on daily inspection of the six items listed in 422.11 and final inspection after 25 – 35 days for the defects listed in 422.11.

Daily Inspection and Acceptance

1. The finished surface shall have no more than four tears or untreated areas greater than 1 inch wide and 4 inches long in any 120 square yard area.
2. Joints are neat and uniform; there is no buildup, uncovered areas, or other unsightly appearance.
3. Longitudinal joints have less than a 2 inch overlap

4. Transverse joints have no more than ¼ inch difference in elevation as measured across the joint using a 6 foot straightedge.
5. The edge of the chip seal does not vary more than 2 inches in any 100 feet along a shoulder or edge.
6. Typical stone embedment is 2/3 of a typical chip

Final Project Acceptance

Deficiencies in chip seal construction often do not show up until the surface has been under traffic for a period of time. The Engineer and Contractor will review the completed chip seal in 25 to 35 days after placement. Surface patterns that show streaking or ridging; bleeding/flushing; and loss of cover aggregate are to be specifically evaluated. The Contractor is required to perform corrective work when any one defect exceeds 20% of any 120 square yard area. The following are descriptions of these defects and likely causes.

Surface Patterns (Ridges and Streaking)

Streaking is caused by faulty distributor adjustment or operation, resulting in the asphalt being placed in ridges. Contrary to popular belief, these ridges will not "flow" together, particularly when the cover aggregate is applied immediately after the application of asphalt material as required by the specifications. Streaking results in insufficient asphalt material between the ridges to hold the aggregate in place. This aggregate is loose and will be “kicked up” by traffic. This leaves only the aggregate that was embedded in the ridged asphalt producing a streaked appearance.

Streaking and Ridging in Completed Chip Seal

Bleeding/Flushing

Bleeding and flushing is defined as a migration of asphalt material to the surface, completely or almost completely submerging the cover aggregate. Continuous bleeding is likely the result of too high a rate of application. Spotty bleeding usually is the result of variations in the surface of the existing pavement. Bleeding at tie-ins between distributor loads is the result of an overlap of the previous run.

Bleeding or Flushing of a Chip Seal

Loss of Cover Aggregate

Loss of cover aggregate is the detachment, loosening or stripping away of the aggregate material from the asphalt binder leaving behind a black shiny surface. This is a serious form of chip seal failure because of the traffic hazard created by the exposure to the slippery film of uncoated asphalt binder material and loose aggregate particles. It may be caused by one or more of the following:

1. Too light an application of the asphalt material
2. Penetration of the asphalt material into the underlying surface
3. Use of an improper grade of asphalt material for existing conditions
4. Delay in spreading the aggregate on the asphalt emulsion (binder has set up)
5. Excess aggregate application
6. Lack of adequate rolling
7. Use of wet or dirty aggregate
8. Opening the roadway to traffic before adequate curing has taken place

Loss of Cover Aggregate

Documentation Requirements - 422 Chip Seal with Polymer Binder

1. Inspect and document all equipment as to its suitability based on the specification requirements (distributor, aggregate spreader, rollers).
2. The results of the test section must be documented including calibration of the aggregate spreader, adjustments to binder application rate, and the Engineer's review comments.
3. Bills of lading for the binder and aggregate must be included in the project records.
4. During chip seal placement document air and pavement temperatures; binder and aggregate application operations; rolling procedure; brooming; traffic control procedures including all signing and use of pilot car.
5. The Contractor must provide a Quality Control report with the information listed in section 422.10 of the specifications.
6. Inspect and document the completed chip seal for initial and daily acceptance.
7. Inspect and document the completed chip seal for final acceptance within 25 to 35 days after placement.
8. Measure and calculate for payment accepted chip seal using the actual width of placement and the length along the centerline of the roadway. Payment is in square yards.

423 Crack Sealing, Hot Applied

Description

This work consists of cleaning and preparing pavement cracks and placing a hot crack joint sealant.

Materials (423.02)

The hot applied crack sealer must be the type specified on the plans and meet the requirements of 423.02. Crack sealants are known as Type I, Type II, Type III, or Type IV.

Type I crack sealant must be approved by the Laboratory before shipping to the project. Type II and III joint sealants are mixed on the project and require the use of PG 62-22 binder and fibers. Binder is accepted based on a certification program while the fiber manufacturer must be on the Qualified Product List. Type II can be a premixed and prepackaged sealant. This type of sealant requires certified test data.

Type IV sealant is a prepackaged and preapproved mixture that requires the fiber manufacturer's representative be present during the application to ensure proper application. The Contractor must submit a 10 pound sample of the base binder and 10 pounds of fiber to the Laboratory for approval.

Equipment (423.03)

All equipment used for crack sealing must meet the Engineer's approval and the requirements of 108.05.

Type I sealant must be heated in a kettle or melter constructed as a double boiler. The space between the kettle and outer shell must be filled with oil or other heat-transfer fluid. The melter must have temperature control of the oil; have a mixing vat, mechanical agitation, and recirculation pump. Heat cannot be applied directly to the sealant.

Type II, III, and IV sealants must be heated in a double boiler as described above for Type I sealant but there must be separate thermometers for the oil and the mix vat. A full sweep agitator and a minimum 2-inch recirculation pump must be used in the kettle. Heat cannot be applied directly to the sealant.

For all sealant types a mechanical applicator wand with a flow shutoff valve is required. Nozzles on the wand must be shaped to penetrate the crack.

Air compressors are used to clean out the cracks prior to placing the sealant and must be a minimum of 100 psi. Air compressors must have water and oil traps.

Water cleaning equipment must deliver water at 2000 psi to the crack being cleaned.

A propane lance that produces hot air and operates at 1000 °F with a gas velocity of 2000 feet per second must be used to dry the crack.

Routing and sawing equipment must be mechanical and power driven and capable of following the path of the crack and widening the crack to a desired dimension with causing spalling and damage to the adjacent pavement. Saw blades must be diamond and 8 inches or less in diameter.

Weather Limitations (423.04)

The pavement surface must be dry (no visible moisture of any kind) and at least 45 °F (7 °C).

Preparation (423.05)

The Engineer determines the cracks to be sealed.

If routing is required for cracks of less than 3/4 inch wide, rout cracks to an opening 3/4 inch wide by 1 inch deep. This is the reservoir for the joint sealant

If sawing is required saw cracks to 3/4 to 7/8 inch wide by 7/8 to 1 inch deep. The slivers of asphalt concrete left behind that are less than 1 inch wide along the sides of the crack must be removed. The Contractor can use hand tools or a light weight chipping hammer. Just before sealing the crack it must be sandblasted to remove contaminants and to provide a rough face so the sealant adheres to the walls of the crack. If the crack below the saw cut is greater than 3/8 inches a backer rod has be pushed into the crack to form a bottom.

All cracks must be cleaned using an approved method and can include water blasting and air blasting. All dust, dirt, debris, moisture, and vegetation must be removed from the crack. The prepared crack must be kept clean and dry prior to sealing.

Mixing Type II and Type III (423.06)

Determine the proper proportion of fiber and binder to blend by using weigh tickets. Check for thorough mixing. Check the sealant temperature against the manufacturer's recommendation and do not let it exceed this temperature. Be sure the temperature of Type III sealant does not exceed 295 °F (146 C) at any time.

Application of Sealant (423.07)

Fill cracks within 250 feet (76 m) of the cleaning operation.

Seal cracks that are wide enough to allow injection of the sealant. Tight cracks less than ¼ inch wide are to be sealed only if they are raveling or spalling. Do not seal cracks greater than 1 inch wide. Do not seal spalls and cavities greater than 4 inches wide.

For Type I and IV sealants fill the entire crack reservoir from the bottom to about 1/16 above the pavement surface. The surface must be scraped immediately with a V-shaped or U-shaped squeegee to smooth the sealant at the surface. The band that remains on the surface after smoothing must be less than 2 inches wide. Wider bands must be rejected.

For type II and Type III sealant, the width of the band should be 2 to 4 inches but never over 4 inches. Do not accept the work if the band is too wide and, or the thickness of the sealant on the pavement surface is more than 3/16 inches (5mm).

Opening to Traffic (423.08)

Do not allow traffic on fresh sealant until it has cured and will no long pick up and track under traffic. The Engineer may allow the use of an anti-tracking material if traffic must use the roadway.

Method of Measurement and Payment

Crack sealing is measured by the number of pounds of hot applied crack sealant in place and accepted.

Documentation requirements - 423 Crack Sealing Hot Applied

1. Document that the materials are on an approved list, have certified test data, and, or have been sampled as required.
2. Document type of sealant used (Type I, Type II, Type III, Type IV) and mixing methods
3. Document the proper crack preparation procedures including routing, sawing and cleaning.
4. Document pavement conditions and air temperature.
5. Document when the pavement is opened to traffic and any observations regarding sealant pick up or tracking. Document and determine weight of sealant for pay. Use weight tickets only.

424 Fine Graded Polymer Asphalt Concrete

General

This specification is intended to be used for pavement preventive maintenance but may have other applications as well. The specification includes two mixture compositions, Type A and Type B. Both mixtures are required to use a polymer binder.

Composition

Type A material is a very fine graded mix composed primarily of natural sand and contains a very high polymer binder content (8.5 %). This is a recipe mix. It is designed to give a very long life but generally is not for high truck traffic situations. A Type A mix is normally specified as a 5/8 inch (16 mm) mat thickness.

Type B material is a fine graded mix composed of more angular materials and contains less binder content than the Type A mix (minimum of 6.4 %). This mix is designed by the Marshall Mix Design Method for light, medium or heavy traffic. The Type B mix is designed to be more rut resistant than Type A. The Type B mix can be placed on medium and high volume roads, including most interstate applications. A Type B mix is normally specified as a ¾ inch to 1 inch (19 to 25 mm) mat thickness.

Item 424 (Type A and Type B) Mix Compositions

Equipment

The equipment requirements of 401 apply to this work.

Materials (424.03)

Both types of mixtures under this specification are to use a polymer binder. Either a PG 76-22M asphalt binder or a PG 64-22 asphalt binder modified by the addition of 5.0 $\pm$ 0.3 % styrene butadiene rubber (SBR) can be used.

The use of reclaimed asphalt pavement is not permitted in a Type A mix.

Fine aggregate for use in this specification is required to have at least 50% silicon dioxide by weight. This special requirement assures proper skid resistance for both mix types.

Coarse aggregate used in the Type B mix is required to have 10 % two-faced crushed aggregate by weight for medium traffic applications and 100 % two-faced crushed aggregate for heavy traffic applications.

Mixing (424.04)

When these mixtures are discharged from the plant, the mix temperature must be between 335° F and 370° F (168° C to 188° C).

Mix Texture for Type A, Item 424

Mix Texture for Type B, Item 424

Weather Limitations (424.05)

The placement of either Type A or B material cannot be placed if the exiting pavement temperature is less than 60°F or the ambient air temperature is less than 60° F (16° C).

Spreading and Finishing (424.06)

Either mixture is to be placed and compacted per the requirements of 401; a three-wheel roller is required in the breakdown position behind the paver. Do not use vibratory rollers when the mat thickness is less than 1.5”

Traffic is not allowed on the compacted surface until it has cooled enough to prevent damage.

Surface tolerances are to be checked and must be in conformance with 401.19 for transverse slope and surface smoothness. The transverse slope cannot vary more than 3/8 inch in 10 feet. The surface smoothness cannot vary more than 1/4 inch in 10 feet. Ensure that the finished surface is within these tolerances as the paving progresses.

Acceptance (424.08)

Type A mixtures are to be accepted using Item 301 procedures (see Item 403) and Type 2 materials are to be accepted according to Item 448 procedures.

Documentation requirements - 424 Fine Graded Polymer Asphalt Concrete

1. State condition of base (example: primed 304, clean and dry concrete, etc.)
2. Write location on tickets where material is placed
3. Mark on ticket time unloaded
4. Obtain temperature of the mix at project site and place this information on ticket of load checked. This should be done a minimum of four times daily or any time temperature is in question.
5. State kind of rolling equipment and maximum tons per hour they are allowed to cover. See **Example Roller Capacity and Placement Rate**
6. Calculate and document the required placement rate (Tons/Station)
7. Document on form CA-FP-4
8. Lift thickness if required
9. Tickets should be totaled with initialed and dated tape attached

442 Superpave Asphalt Concrete

Description (442.01)

This item is a gyratory mix design specification to produce an asphalt concrete that is used for an intermediate or surface course. Known as Superpave this asphalt concrete is used for higher traffic routes and can be either a 446 or 448 asphalt concrete pavement. Superpave mix design requires the use of special equipment, material properties, and design procedures. Superpave asphalt concrete requires inspection and documentation as per the requirements of 401, and 446 or 448.

Acceptance Sampling and Testing (442.07)

Superpave items are accepted per 448 or 446 requirements, as specified. See those sections for details.

Documentation Requirements - 442 Superpave Asphalt Concrete

1. Obtain the approved JMF for the project.
2. Determine and document if paver is on approved list.
3. Document pavement surface condition, preparation, and surface and air temperatures.
4. Document tack or prime used along with source and quantity used versus required.
5. Check and document roller capacities as outlined in 401.13 if required by the specification item.
6. Document lift thickness, mat width, weather conditions, surface tolerance checks, equipment problems, mat problems (segregation, tearing, tenderness, etc), spreading rate, roller coverage, and any other issue or observations made during paving operations.
7. Observe and document trucks hauling material:
    a. Check for secured waterproof cover.
    b. Check for insulated truck beds for temperatures below 50° F (10° C) and/or if the haul exceeds 20 miles (32 km).
    c. Observe the asphalt mix in the truck and note any slumping, drain down, or blue smoke.
8. Determine compliance with compaction requirements as per 401.16.
9. Record asphalt mixture temperatures in the paver hopper and on the mat at the time of compaction.
10. Determine and record required and actual placement rates and variance.
11. Write location (station), date, and time on asphalt plant tickets. Tickets should be totaled daily, initialed, with the calculator tape attached.
12. Take samples, cores, or density readings as required by item 446 or 448.
13. Record luminance readings for night paving operations.

14. Determine plan quantity for payment.
15. Document on CA-FP-2 through 4 or other approved forms as needed.

446 Asphalt Concrete

Description (446.01)

This item includes placing a surface or intermediate course asphalt concrete that is accepted based on the level of density obtained. This type of specification is based on performance and not on method. Under this specification a Contractor can be rewarded for providing a better product than required by the minimum specification, or can be penalized for not meeting the minimum requirements. The requirements of 401 apply unless noted.

Density Acceptance (446.05)

Item 446 is accepted by density testing and the roller selection is at the discretion of the Contractor and not governed by 401.13. Additionally the requirements of 401.16 that detail compaction operations are waived except the last four paragraphs. These last four paragraphs describe how requirements for the rolling pattern to obtain compaction. The Inspector should observe the rolling pattern for conformance.

Density of the asphalt concrete is based on cores that are cut from the completed mat (asphalt pavement placed at the design thickness). The core locations are determined by the Engineer as detailed in 446.05. Ten cores are required to be cut per lot. A lot is considered one day of production with provisions for combining a small production day (<400 tons) with the next day. Each lot is divided into five equal sublots and 2 cores are cut from each sublot. Core locations are determined on a random basis using a random number selection process. That process will be used for all lots.

Core Procedure

Cores are required to be cut within 48 hours of placement. To allow the contractor to core the same day determine core locations prior to the end of work by estimating production based on production rate and contractor expectations. *However* these locations are not be given to the Contractor before the end of the day’s production. The Department does not intend to bias the Contractor’s operations by specifying where the cores will be taken.

If a cold longitudinal joint is made between the mainline and shoulder, include the shoulder in the lot for coring. If a hot joint is made, be sure the same equipment and rolling pattern is used on the shoulder. If the contractor does not adhere to this requirement, include the shoulder in the lot for coring.

There are additional specific requirements for cold longitudinal joint cores. In each lot three cores are to taken from the cold longitudinal joint in the first and last lots and randomly from one of the middle three lots. Joint cores are to be 3, 4 or 6 inches from the cold joint depending on its construction type. All other cores are to be located at least 12 inches from the edge of pavement.

Form TE-217 provides a standardized method for sublot lay out and random selection of core locations (transversely and longitudinally). The form is located on ODOT's Construction website and is available as either an Excel spreadsheet that automatically calculates core sample locations or as a manual-use (non-electronic) form.

If using the Electronic TE-217 form enter all required information as indicated by the yellow highlighting. After entering the beginning and ending stations for the lot, press key F9 and the computer automatically generates the random numbers. The form automatically calculates the core sample locations as shown in the orange highlighted boxes. Use these locations to lay out the cores on the completed asphalt mat.

For the Non-electronic TE-217 form all calculations are done manually. The selection of random numbers must come from a table. This table is included with the Non-electronic TE-217 on the ODOT website as well as instructions for selecting random numbers. The same method should be used consistently on the form. When this form is completed use the calculated locations to lay out the cores on the completed asphalt mat.

The Engineer will physically mark the core locations on the mat using aerosol paint. Be sure coring takes place where marked. This can be ensured by observing each coring operation or by painting the core location with a small diameter circle with an "X" or other marking. The Contractor must be instructed to cut the core within this circle. The cut core should be examined to verify there is paint on the surface which indicates the core was cut at the selected location. If the Contractor takes "sister" cores make sure they are cut within 4 inches longitudinally of the Department's cores. For joint cores, use a different paint color than for the mainline cores. This provides assurance that joint cores are cut from the locations selected by the project.

There have been isolated incidents where cut cores have been "switched out" with other cores that presumably would provide better density test values. Project personnel must provide thorough oversight of the core cutting operation such that the cores being testing for payment are from the locations selected by the project through the random selection process. Substitution of cores by cutting in other locations or by replacing cut cores with others is absolutely prohibited and cannot be tolerated.

Core holes are required to be filled by the next workday using the same asphalt mixture used to place the mat. The holes must be dry and coated with tack meeting the requirements of 707.02. The asphalt must be compacted adequately and finished flush with the completed asphalt mat.

After core samples are obtained, package and identify in accordance with current District or Laboratory policy. The District test lab may have specific requirements for labeling the core samples. The samples should be shipped to the District lab as soon as possible. Care should be taken not to damage the core by dropping it, throwing it, or exposing it to excessive heat. Cores should not be stacked in any way.

Documentation Requirements - 446 Asphalt Concrete

1. Obtain JMF for the project.
2. Determine and document if paver is on approved list.
3. Document the number and types of rollers being used.
4. Document pavement surface condition, preparation, and surface and air temperatures.
5. Document tack or prime used along with source and quantity used versus required.
6. Document lift thickness, mat width, weather conditions, surface tolerance checks, equipment problems, mat problems (segregation, tearing, tenderness, etc), spreading rate, roller coverage, and any other issue or observations made during paving operations.
7. Observe and document trucks hauling material:
    a. Check for secured waterproof cover.
    b. Check for insulated truck beds for temperatures below 50° F (10° C) and/or if the haul exceeds 20 miles (32 km).
    c. Observe the asphalt mix in the truck and note any slumping, drain down, or blue smoke.
8. Determine compliance with compaction requirements as per 401.16.
9. Record asphalt mixture temperatures in the paver hopper and on the mat at the time of compaction.
10. Determine and record required and actual placement rates and variance.
11. Write location (station), date, and time on asphalt plant tickets. Tickets should be totaled daily, initialed, with the calculator tape attached.
12. Record luminance readings for night paving operations
13. Determine plan quantity for payment
14. Determine and mark core locations for each day of production using Form TE-217
15. Document on CA-FP-2 through 5 or other approved forms as needed.

448 Asphalt Concrete

Description (448.01)

This item includes placing a surface or intermediate course asphalt concrete that is accepted based on plant testing and verification; or on plant testing and verification with field density testing. The requirements of 441 apply to this item except as noted.

In the event of a mix problem the Engineer or DET may require plate sampling at the project. Hopper samples are no longer typically taken. However, in the event of a mix problem the Engineer or DET may require hopper sampling.

Acceptance (448.04)

The District lab and Monitoring Team conducts verification acceptance of the Contractor's quality control procedures based on lots. The Monitoring Team may require that the Contractor provide split samples of a random sample for Laboratory testing.

In the event there are workmanship or quality control problems at the plant the Monitoring Team may require a sample taken from the road in accordance with Supplement 1035. If the pavement mat is less than 1.25 inches the sample would be taken from the paver hopper. After a plate or hopper sample is obtained, it should be packaged and identified in accordance with current District or Laboratory policy. The sample must be shipped to the District lab as soon as possible or as directed by the Engineer or DET. Samples obtained by plate sampling are tested to determine the gradation and binder content of the asphalt concrete mix.

In addition to plant sampling and verification for acceptance the Contract may require the use of density gauge testing according to Supplement 1055. When field density testing is required the roller selection is at the discretion of the Contractor and not governed by 401.13. The requirements of 401.16 are also waived except the last four paragraphs. These applicable paragraphs detail the compaction operation and sequence.

Field density testing is used to determine compaction and whether a deduction to the Contractor's pay will be made for inadequate compaction. There is no increase in pay for this item based on the density results.

Refer to Supplement 1055 for the details of density testing requirements. The Inspector should understand and monitor the testing for compliance.

Documentation Requirements - 448 Asphalt Concrete

1. Obtain JMF for the project.

2. Determine and document if paver is on approved list.
3. Document the number and types of rollers being used.
4. Document pavement surface condition, preparation, and surface and air temperatures.
5. Document tack or prime used along with source and quantity used versus required.
6. Document lift thickness, mat width, weather conditions, surface tolerance checks, equipment problems, mat problems (segregation, tearing, tenderness, etc), spreading rate, roller coverage, and any other issue or observations made during paving operations.
7. Observe and document trucks hauling material:
    a. Check for secured waterproof cover.
    b. Check for insulated truck beds for temperatures below 50 °F (10 °C) and/or if the haul exceeds 20 miles (32 km).
    c. Observe the asphalt mix in the truck and note any slumping, drain down, or blue smoke.
8. Determine compliance with compaction requirements as per 401.16.
9. Record asphalt mixture temperatures in the paver hopper and on the mat at the time of compaction.
10. Determine and record required and actual placement rates and variance.
11. Write location (station), date, and time on asphalt plant tickets. Tickets should be totaled daily, initialed, with the calculator tape attached.
12. Record luminance readings for night paving operations
13. Determine plan quantity for payment
14. Determine random locations of quality assurance testing, witness, and initial the test results.
15. Document on CA-FP-2 through 5 or other approved forms as needed.

450 RIGID PAVEMENT

Portland cement concrete pavement must be constructed so that it provides a smooth-riding surface satisfactory to the traveling public and is durable when subjected to natural weathering, traffic abrasion, and chemicals used for snow and ice control. It must be capable of sustaining the traffic that it is intended to carry and be of sufficient skid resistance to eliminate slippery conditions when wet.

While the quality of the riding surface is the chief construction element by which the public either approves or condemns a pavement, this element is not more important than durability and structural strength. All desirable elements of a good pavement are a product of the workmanship of the Contractor and the engineering and inspection personnel assigned to the work.

Every step of construction, from the preparation of the subgrade and base through concrete curing and opening to traffic, has a definite effect on the rideability, durability, and structural integrity of the finished pavement.

451 Reinforced Portland Cement Concrete Pavement

Description (451.01)

This item includes the construction of a Portland cement concrete pavement that contains reinforcing steel

Materials (451.02)

Concrete

The concrete specified for use in reinforced Portland cement concrete pavement is Class C concrete as defined in Item 499 (Table 499.03-3). The Contractor may provide Class C concrete with one of three proportioning options specified in 499.04. If Class C with Proportioning Option 1 or Option 3 is selected, they can only be used between April 1 and October 15, unless authorized by the Director. These options allow the use of fly ash or ground granulated blast furnace slag respectively, which slows the strength gain of the concrete This characteristic is desirable during hot weather but is not desirable during cool months.

The coarse and fine aggregate used in the Class C concrete for exposed concrete pavements (Item 451 and 452) have additional requirements found in 703.02.A. The fine aggregate used in the concrete must be natural sand; therefore, sand manufactured from stone is not permitted. Coarse aggregate must be provided in accordance with 703.13 in addition to the requirements of 703.02.

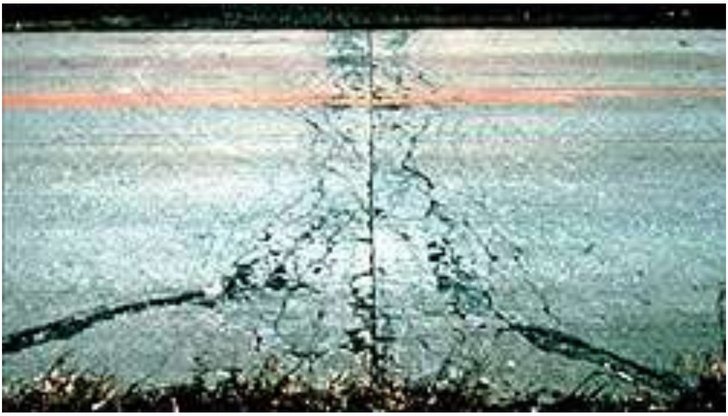
Coarse Aggregate

In addition to the requirements of 703.02, the following aggregate requirements apply per 703.13.

Where gravel, crushed ACBFS, or limestone is selected and the total combined quantity of the listed items is greater than 10,000 square yards (8000 m^2), the coarse aggregate must be No. 57 or 67 size. If the total combined quantity of the listed items is less than 10,000 square yards (8000 m^2), the coarse aggregate must be one of the following sizes: No. 7, 78, 8, 57, or 67. If gravel or limestone No. 57 or 67 size is used in either of the above cases, the coarse aggregate must meet 703.02 and must be tested according to ASTM C 666, Procedure B.

Freeze-thaw resistance testing is required for all coarse aggregate used in 451 to help eliminate the concrete pavement's potential for D-cracking.

D-cracking is cracking caused by freeze-thaw deterioration of the aggregate within the concrete. This type of cracking can be observed as early as 7 to 10 years after construction of concrete pavement. D-cracks are closely spaced cracks parallel to transverse and longitudinal joints which multiply outward from the joints toward the center of the pavement panel. D-cracking is a function of the pore properties of certain types of aggregate particles and the environment in which the pavement is placed. Due to the natural accumulation of water under pavements in the base and subbase layers, the aggregate may eventually become saturated. Then with freezing and thawing cycles, cracking of the concrete starts in the saturated aggregate at the bottom of the slab and progresses upward until it reaches the wearing surface. This problem can be reduced either by selecting aggregates that perform better in freeze-thaw cycles or, where marginal aggregates must be used, by reducing the maximum particle size. Also, installation of effective drainage systems for carrying free water out from under the pavement may be helpful.



D-cracking in Portland Cement Concrete Pavement

Joint Sealer

Expansion joint sealer must be a 705.04 hot-applied joint sealer conforming to ASTM D 6690, Type II.

Curing materials 705.05, 705.06, 705.07 Type 2

These curing materials are burlap cloth, sheet-curing materials, and liquid membrane-forming compounds. The liquid membrane-forming compounds used on the project must be on the Department's Qualified Products List.

Tie Bar Steel, Epoxy Coated

Tie bar steel used in the longitudinal joints in concrete pavement must meet the epoxy coated reinforcing steel requirements of 709.00.

Reinforcing Steel

The steel reinforcing steel must comply with 709.09, 709.10, and 709.12

Dowel Bars and Basket Assemblies

Dowel bars and basket wires used to support the dowels at the proper position must be coated with a fusion-bonded epoxy coating conforming to AASHTO M 254 with the exceptions listed in 709.13.

Equipment (451.03)

Reinforced Portland cement concrete pavement is placed by a series of equipment called a paving train. A paving train normally consists of a concrete spreading machine, a mesh cart, a mesh depressor, a finish paving machine, a work bridge and a cure/texture machine.

The riding qualities of a pavement depend largely on the proper operation of mechanical finishing equipment. The equipment must be in correct adjustment. It is almost impossible to use hand finishing to correct a poor surface left by the equipment. Frequent checking and minor adjustments to compensate for changing conditions, will do much to eliminate surface irregularities.

The Contractor is responsible for equipment adjustments. Department personnel are not expected to adjust or advise the Contractor on how to adjust and maintain mechanical equipment, but they are expected to observe the checking of all equipment. The Inspector should be able to recognize when such equipment is out of adjustment or is not coordinated with the balance of the paving train. The following information on spreaders and finishing equipment is given to provide some knowledge on the operation of the equipment.

General Equipment Requirements

The equipment used must be self-propelled spreading and finishing machines that are capable of consolidating and finishing the concrete; and producing a finished surface meeting the requirements specified. The specifications give the Contractor the option of using slip-form or fixed-form pavement construction methods.

Vibrators are used for the full width and depth of the concrete slabs to provide consolidation of the fresh concrete. They must be internal type, using a tube or multiple spuds. Internal means the vibrators must be immersed in the fresh concrete. External vibration is not allowed. Vibrators may be attached to the spreader or the finishing machine; or may be mounted on a separate carriage. They must not come in contact with the joint load transfer devices, subgrade, reinforcing mesh or side forms. Multiple spuds should not be spaced further apart than 2 1/2 feet (0.76 m). Therefore, a minimum of 10 spuds is required for a full 24 feet (7.2 meter) width paving.

Internal vibrators must operate at frequency of 7,000 to 11,000 impulses per minute. The vibrators should be connected to an electronic monitoring device equipped with an automatic recorder. The monitoring device should display the operating frequency of each internal vibrator. The readout display should be located near the paving operator's controls and must operate continuously when paving and display all vibrator frequencies with manual or automatic sequencing between individual vibrators. The automatic recorder must record the following information each 25 feet (8 m) of paving or every 5-minute time interval:

- the time of day
- station location
- paving machine track speed
- the frequency of each vibrator

If the monitoring system is not equipped with an automatic recorder, the contractor must manually record the above information every 30 minutes. The Contractor must provide a record of the data to the Engineer each paving day.

Vibration is required for all concrete pavements. Small irregular areas require vibration by hand-held or machine-mounted equipment to assure that adequate consolidation for the full depth and width is achieved without segregation.

Vibrators must be connected such that they turn off when the machine on which they are mounted stops.

Transit Mix and Central Mix Equipment

Concrete plants and hauling units must be checked for proper condition prior to paving operations, and at regular intervals during paving. Water and admixture metering devices should be checked to assure proper calibration within specified tolerances.

Transit Mix Trucks used for Concrete Delivery

Transit mixers should be checked to determine that the counters are functioning properly. After having been mixed for not less than 70 revolutions at mixing speed, the mixer should contain concrete of uniform consistency and be able to discharge the batch without segregation. Since this determines acceptability, mixers that do not perform in this manner should not be used, and discontinued if encountered. Sources of trouble are badly-worn mixing blades and leaky valves which prevent mixers from producing uniform concrete. They should not be used until corrected.

Non-Agitation Concrete Delivery Units - Dump-Crete Truck

Non-Agitation Concrete Delivery Units Dump Truck

Central mix plants should be checked to see that the mixer drum is capable of uniformly mixing and discharging the large volume of concrete. During paving, the Contractor or ready mix supplier must keep mixer blades free from concrete build up and excessive wear.

When the concrete is transported to the paving site in dump trucks or other non-agitating units, check the bodies to see that they are water-tight and free of objectionable corners or internal ribs where concrete may accumulate. Canvas covers to shield concrete from sun and wind shall be provided when required by the Engineer.

Concrete Batch Plants

Aggregate stockpiles should be placed on areas which are paved, prepared by using sheet metal, wood plank, etc., or they may be placed directly on the ground. When building stockpiles on existing ground, the area should be firm, cleaned of foreign material, and shaped to provide drainage. No aggregate is to be removed from the stockpile within one foot of the ground until the final clean up. Aggregate within this area should be processed to meet specifications before permitting its use.

Stockpiles should be built in such a manner that different types or sizes of aggregate do not become mixed and the aggregate does not become segregated.

In building the stockpiles of coarse aggregate, exercise continual care to prevent segregation through improper handling. A clam bucket operated by a crane of sufficient size so that the center of the pile can be reached from the edge is best for this work. In depositing the aggregate, the bucket should be lowered close to the level where the aggregate is to be deposited before releasing the aggregate. This prevents the larger aggregate from rolling to the bottom of the pile causing segregation. As the pile increases in height, each layer of aggregate should be benched back to form tiers that will help limit rolling and segregation.

Other equipment may be used in conjunction with a clam bucket. If the Contractor uses front-end loaders to build the pile, they must have clean rubber tires. As with the clam bucket, the drop should be as short as possible when depositing the aggregate. Once on the pile, the front-end loader should not be permitted to move on and off of the pile as this may cause contamination.

Pushing of large aggregate with a bulldozer is not permitted, as this causes segregation. Use of steel treads on the pile is not permitted as they tend to crush the aggregate.

Small aggregate does not segregate as easily as large aggregate because the smaller pieces are less likely to roll down the side of the pile.

Any operation which might result in segregation, degradation, or contamination is not permitted. When these conditions appear evident, run a gradation test and, if substantiated, adjust the operation.

Materials should be placed in the batch plant bins by dumping into the middle of the bin with as short of a drop as possible. Keeping the drop to a minimum reduces the chance for segregation in handling aggregate, as well as in handling concrete.

The Specifications require that concrete materials be measured by weight. The scales shall be checked for accuracy with standard test weights as outlined in Item 499.

Fixed Form Construction (451.03.A)

This construction method requires that the Contractor furnish equipment that will spread, screed, and consolidate concrete using one or more machines operating on previously placed side forms. There must be enough equipment with capacity to perform the work at a rate equal to the concrete delivery rate. The equipment must uniformly distribute and consolidate the concrete without segregation.

The equipment must either operate on two side forms, on an adjacent lane and one side form, or on two adjacent lanes as necessary. When operating the equipment on adjacent lanes, the adjacent lanes must be protected from damage from the equipment.

Forms for use on ODOT projects must meet the following requirements:

- made of steel
- straight and must not be less than 10 feet (3 m) in length
- have a depth equal to the pavement thickness specified
- have a horizontal joint and base width equal to the depth of the forms
- forms that are bent or damaged are not permitted

Sections of Steel Concrete Paving Forms

Fixed Forms in Place Ready for Paving

Forms must be cleaned and oiled each time they are used. If the radius of the pavement edge is 100 feet (30 m) or less, flexible or curved forms may be used as approved by the Engineer.

The Contractor must provide methods and devices that securely set forms and withstand paving equipment operation. Built up forms must not be used unless constructing less than 2,000 square yards (1,650 square meters) of pavement for the entire project. All forms must have adequate joint locks to tightly join the ends of abutting sections together.

Transverse Finishing Machines for Fixed Form Construction

The transverse finishing machine should first be checked for its operating condition. The bearings, especially those of the cranks actuating the oscillating screeds, should fit snugly so that the screed reverses direction without slap (which would rack the forms).

The end plates that slide on the forms should be inspected for wear and reversed or replaced if necessary. The screed should be checked for straightness or crown if one is required. Perform this check by placing a block on the forms under each end of the screeds and stretching wires at both front and back across from form to form. Check the crown by measuring the offsets from the wire to the screed. Adjusting bolts can be loosened or tightened to secure proper adjustment.

The exact tilt required in each screed cannot be determined until construction begins. However, at the start of paving operations, the front edge of the forward screed should be titled about 3/16 inch (5mm) and the rear screed set level. Adjustments can be made readily by end bolts provided for this purpose.

Springs are used as shock absorbers to prevent slap at the end of the stroke. These should be checked to insure that they are in compression at all times. The screed lift chains must be long enough so that they are not tight at the end of the stroke; otherwise, the screed will be lifted off the forms at every oscillation.

Finally, the wheel scrapers should be tightened so that they will be sure to keep the wheels clean.

Operation of Transverse Finishing Machine

The work of the transverse screed is an intermediate step in the process between placing and distribution of the concrete and the final mechanical finishing. The work performed by the screed should be as nearly complete as possible, so that smoothing and floating is the only operation required by any following equipment.

As the transverse screed begins work, the concrete before it must be distributed to approximately the correct surface level, either by mechanical concrete spreaders or by hand methods. The requirements for correct transverse screed operation are the same regardless of the method of prior distribution, except that local grading by hand work will be more irregular and will require more care in the screeding operation.

The transverse screed must leave the surface with a uniform texture and a uniform, correct elevation for final finishing. Good finish cannot be obtained if the screed does not perform this function. Deep or irregular corrugations behind the screed indicate improper operation.

Satisfactory results depend upon several critical factors. These factors must be considered at all times, and variations in the adjustments or in the operation of the screed must be made, as occasion demands, to keep the factors always in balance.

The head of concrete carried in front of the forward screed must be maintained at a uniform height, about 4 to 10 inches (100 to 250 mm), and in uniform quantity across the full width of the lane.

The concrete head carried in front of the rear screed must be uniform and about 2 to 4 inches (50 to 100 mm) high. The material being moved ahead by the rear screed should roll, not flow or tear, and the mix and timing of operations must be controlled to satisfy this requirement.

The height and tilt of the screeds must be adjusted to compact the particular mix being used and to permit a uniform amount of surge.

The traction speed, screed speed, and length of screed stroke are controlled independently. These must be combined in the proper relation to obtain optimum results. As conditions on the project vary, these relationships should be varied to produce a consistent surface.

The forms and wheels must be kept clean. If the wheels ride on an irregular surface, the concrete will show corresponding roughness. The screeds must be kept clean, so that they do not leave streaks in the concrete and do not drop lumps of hardened concrete on the fresh surface.

The amount of concrete being carried ahead of the screeds (both forward and rear) controls the amount of surge past the screeds for any given mix. If the head of concrete is too high, an excess will pass under the screed and leave an overload for following equipment. If there is a deficiency of concrete at any point in front of the screed, a low spot develops. If the head varies continually, the surge will also vary and a wavy or rough surface will be left. Therefore, a uniform roll of concrete must be maintained along the front edge of the screeds to provide a uniform amount of surge. At the beginning of a day’s work, a small amount of concrete should be placed in front of the forward screed to provide a working supply for filling in low areas. This accumulation should not be allowed to build up as the work progresses, but should be maintained uniformly. If excess builds up, the excess should be screeded off or a second pass made.

The Inspector should insist on coordination of distribution and transverse screeding to obtain continuous, acceptable results. The forward screed should compact the concrete level with the top of the form allowing for a very small amount of settlement that usually occurs before the following finisher passes. The difference in the requirements at the two screeds accounts for the difference in the size load each should carry.

Inspectors on transverse screeding work must remember that the finishing machine is not intended for heavy duty. The surface left by this work must be uniform and satisfactory. The transverse screed is capable of meeting these requirements. The

Inspector should insist that the operator make full use of the machine's capabilities in order to obtain a complete and proper integration with the entire paving process.

If one pass of the screed does not result in satisfactory surface conditions, a second pass is necessary. It is preferable that preceding operations be controlled so that a second pass is not required at intermittent points. The Contractor may elect to use two screeds or to pass over the entire area twice with one machine. Different amounts of screeding will result in variable surface conditions and are to be discouraged.

Screeds should be operated with the screed wearing plates working directly on the forms. A straight screed with no tilt results in a concrete surface at or below form level, except for surge. Adjustments in screed elevation and tilt may be required to work certain mixes properly. If the concrete mix is extremely stiff, the screeds normally will tear the surface and leave insufficient mortar for finishing. Under these conditions, the front or first screed should be tilted so that the forward edge is raised slightly. This compacts the concrete as the screed passes and forces a small amount of mortar to the surface. Extremely stiff mixes usually demonstrate an absence of surge which, with combined tearing, leaves the surface below the top of forms. The center of the screed then should be raised slightly by adjusting end screed hanger bolts, leaving the end plates to work on the forms with the remainder of the screed raised. This permits the required amount of concrete to pass the forward screed. The rear screed always should be straight along the rear edge and work directly on the forms.

The amount of tilt of the screeds must be worked out for the particular job conditions. As a starting guide, the following information will be of assistance. With standard Portland cements and with air-entrained concrete of relatively stiff consistency, less than 2-inch (50 mm) slump, the forward screed will likely require a tilt of 1/4 inch (6 mm) or less and the rear screed a tilt of 1/16 inch (0 to 2 mm).

The combination of traction speed and screed motion depends on the concrete mix and consistency, and on the grade or super elevation of the pavement. With stiff mixes, the screed speed should be rapid with a long stroke and the traction should be slow in comparison to more workable mixes. This aids in compaction and in providing enough mortar at the surface for finishing. With more fluid mixes, the screed action should be decreased; both in speed and length, and the traction speed should be increased. This will prevent over working or excessive agitation of the concrete, which might cause flowing to the low side of the forms, excessive surge past the screeds, or a pooling of wet mortar on the top. The relation of traction and screed speeds is very important. In most machines, the controls are independent and the proper combination can be made by trial without any difficulty. A change in speed of either screed or traction requires only shifting of a lever. The change of length of screed stroke requires a work stoppage and readjustment of the screed drive, but this change should not be required very often unless control of the concrete mix is poor. Poor control of the concrete mix should not be tolerated.

The screed wearing plates are rubbing continuously on the forms or on completed concrete lanes. They are made of abrasion-resisting steel, but may wear rapidly. As they wear, they have the effect of lowering the entire center portion of the screed by the amount of wear. Furthermore, the wear may not be the same for the full length of screed stroke, and may change the strike-off elevation of the screed. They should be checked at the beginning of each job. Adjustments for up to 1/8 inch (3 mm) in wear can be taken care of by adjusting the screed bolts. The plates should be replaced when wear exceeds this amount.

Exercise care when operating the finishing machine over expansion joints to avoid displacing or damaging the preformed expansion material. Any method of operation that does not interfere with the expansion material will be permitted.

Combination Float Finisher

The combination float finisher is commonly used to provide the final mechanical finish on a pavement. The machine consists of two screeds and a float and is designed for use on a 24-foot (7.2 m) pavement.

The front screed of the machine is a conventional reciprocating screed that rides the forms. The rear screed and float, however, are suspended from an approximately 16 foot (4.9 m) beam platform and do not receive any support from the forms. The elevation of both the rear screed and the float is determined by adjustment of the hangers that connect them to the platform. As a result, variations in forms do not significantly affect the plane of operation of either the rear screed or float. The key to smooth finishing with this machine is the rear screed since it is the final screeding tool and operates from a 16 foot (4.9 m) straightedge essentially free from influence of deviations in the forms.

Spring-loaded shoes are fastened to both ends of the rear screed to keep the screed in contact with the forms. The springs are sufficiently strong so that the rails will be kept clean, but not so strong that they will cause the screed to raise when an undetected highpoint in the forms is being traversed.

The float does not oscillate but moves forward with the machine providing a smooth trowelled surface. It is approximately 30 inches (0.7 m) in length and rides on the slab between the forms. Both of the screeds and the float are provided with devices which permit rapid changes in crown. These devices make it possible to change crown at superelevated sections without delay.

Operation of Combination Float Finisher

The combination float finisher serves both as a conventional transverse and longitudinal finisher. The transverse screeding is accomplished through the two screeds (front and rear) and the longitudinal finishing by the suspended finishing pan that rides on the slab surface.

Several details must be adhered to closely in order to obtain the best possible finish when the machine is used for the final mechanical finishing operations. These items are described in the following paragraphs.

The concrete must be accurately fed to the machine. Better results are obtained when spreaders and auxiliary screeds (when used), operating ahead of the machine, leave just enough concrete so that a uniform roll of 4 to 6 inches (100 to 150 mm) is carried on the front screed. When this condition does not exist, the equipment operating ahead of the float finisher should be adjusted so that such a concrete roll is obtained.

The screeds and float must be set accurately. Both front and rear screeds should be set flat. When the front screed is flat and carries a 4 to 6 inch (100 to 150 mm) roll, it passes sufficient concrete to form about a 2-inch (50 mm) roll on the rear screed. When this 2-inch (50 mm) roll reduces in size, fresh material should be carried back and placed to obtain a uniform roll. It is essential to keep the roll in front of the rear screed uniform for optimum results.

The rear screed cuts off any excess concrete and leaves the pavement surface at the desired crown and grade. When set to proper crown without tilt, the float just makes contact with the surface and trowels it smooth and free of screed marks. Occasionally, it is desirable to leave the front of the float about 1/16 inch (2 mm) high when greater compaction is desirable. This practice, however, generally leaves deeper transverse marks than are considered desirable.

The finishing machine is designed primarily for a one-pass operation. If all operations prior to the pass of the machine are as they should be, it is rarely necessary to make more than one finishing pass. If the forward speed is adjusted properly, the machine moves forward at a uniform rate, eliminating frequent stops that cause variations in the surface. It is true with this machine, as with other types of finishing equipment, that continuous operation provides smoother pavement.

The machine must be kept clean. The bottoms of the screeds and the pan must be absolutely smooth. Accumulations of hardened concrete (or oil and grease) that might drop on the pavement must be cleaned off continually. The machine should be cleaned thoroughly every day.

Slip Form Construction (451.03.B)

This method of construction permits pavement placement without the use of fixed side forms. In lieu of forms, the paving machine vibrates, tamps, compresses, and strikes off the concrete within the machine's moving forms, and extrudes the consolidated concrete slab. Consolidation is such that the vertical sides of the slab retain their shape and position after leaving the paving machine. Trailing side forms are needed only to protect the slab edges during hand straight-edging operations. The slip form paver/finishing machine has three main components: augers, vibrators, and a profile pan. The augers spread the concrete across the width of the area to be paved. The vibrators provide consolidation of the concrete as it passes under the paver. The profile pan, located at the rear of the paver, trims the concrete to the proper elevation and provides a smooth surface.

The base must be constructed as outlined in the specifications. Stability of the base is critical for slip form construction. The base must be graded to the plan elevation by a properly designed machine. The track area for the paving train may be brought to grade using a form grader, with a subgrader on crawlers used to grade the area under the pavement. An automatic subgrader operating from a preset grade line is ideal for slip form construction and does not require the use of a form grader.

Stabilization in the paving machine track area to provide traction is permissible, provided the area is scarified after pavement construction, to avoid interference with lateral drainage of the subbase. Any method of stabilization proposed by the Contractor must be approved by the Engineer.

An approved slip form paving machine or combination of paving machines must be used to spread, consolidate, screed, and finish the concrete in one pass. The machine(s) must consolidate the full width and depth of pavement being placed, to provide a dense homogeneous pavement slab, requiring a minimum of hand finishing. Two machines may be used with the leading machine striking off the bottom course for placement of the mesh. The width of the bottom course may be 6 inches (150 mm) narrower than plan width so as not to interfere with the second paving machine.

Slip Form Construction

Preset grade lines are required for slip form paving equipment to assure acceptable riding quality of the pavement. Paving equipment must have controls that trace the grade line and automatically adjust the screeds. String lines offset from and parallel with the edge of pavement are used most often. Sensors on the paver follow the string line and automatically adjust the screed.

The use of string lines will not assure riding quality. All lines, grades, and controls should be frequently checked to avoid obvious errors. The electronic controls of the slip form paving equipment are not capable of sensing grading errors and will therefore duplicate those errors in the pavement surface. When a string line is used, the string line should be supported at intervals that eliminate sagging of the string under its own weight. Supports every 25 feet (8 m) produce the most desirable results. In addition to the intervals between supports, the stringline tension must also be taut enough that excessive sag does not occur.

The concrete slump should not exceed 3 inches (75 mm) and the nominal range is 1 to 3 inches per 499. If the slump exceeds 3 inches (75 mm), the edges may be subject to settlement after the forms have passed. Slump less than about 1-1/2 inches (40 mm) may result in an open textured surface requiring excessive hand finishing. Therefore, the slump should be maintained between 1-1/2 and 3 inches (40 and 75 mm) for best results.

Good construction results are achieved by operating the paving machine with a continuous forward motion with a minimum of starting and stopping. When the paving machine stops, all vibrating, tamping and oscillating elements must stop also.

The slip form machine must not be used like a dozer to push large quantities of concrete piles out in front of it. Therefore, some means of depositing and striking off the concrete must be used to permit smooth uninterrupted operation of the paving machine(s). The use of spreader boxes, a concrete spreader, or any technique that provides a uniform distribution of concrete is permissible.

At the end of the day’s production, pavement at construction joints may be reduced approximately 2 inches (50 mm) in overall width. This allows the Contractor to use an insert just inside each moving side form so that the paving machine(s) can be positioned at the joint when production is resumed. The trailing side forms do not bind and spall the slab edges when this leeway is provided on each side.

Inspection of slip form paving should include checking the pavement edges. Since no forms are used to screed against or to hold the edge in place, the edge can slump downward or tilt out. A straightedge can be placed perpendicular to the edge to check transversely. In addition, the straightedge can be placed longitudinally at the pavement edge to check in that direction. Areas that do not meet the tolerance must be corrected while the concrete is plastic.

Where pavement will be placed against an edge, the pavement must not vary more than 1/4 inch (6 mm) below the typical section.

Where pavement will not be placed against an edge (outside edge) the pavement must not vary more than 1/2 inch (13 mm) from the typical section.

All pavement edges must be nearly vertical with no projections or keyways exceeding 1/2 inch (13 mm). If edge projections exceed 1/2 inch (13 mm) concrete must be removed by hand methods and the edge should be troweled smooth.

Setting Forms

Forms are a potential source of trouble because they serve as the “tracks” for the paving equipment in addition to serving as forms for the concrete. Since developments in paving equipment have provided heavier equipment, the forms play an increasingly important role in the construction of smooth pavements.

Before any forms are set on a project, they must be inspected to see that they comply with specification requirements. In addition, they must have sufficient pin pockets for setting securely so that they will withstand the operation of the paving equipment. Forms are to be set such that that they do not vary more than 1/8 inch in 10 feet (3 mm in 3 m) on the top face; or more than 1/4 inch in 10 feet (6 mm in 3 m) on the vertical face. If they cannot be reset or repaired to meet this tolerance they cannot be used. Forms are reused continuously. Therefore, inspection of forms must be continuous. Any time forms are found out of tolerance, they must be rejected. Forms that are rejected should be marked so they are not incorporated into the work.

Forms are Set in Position and Pinned to the Base

Forms are to be set true to line and grade on a thoroughly compacted base with uniform bearing throughout their entire length and width. Using loose earth pebbles or other shims to bring forms to the required grade is not permitted. Whenever adequate and uniform form support is not obtained, the forms must be removed, the base corrected and compacted, and the forms reset. At least 3 form pins are to be used in each 10-foot (3-meter) length. These pins must be long enough to hold the form in position during the placing and finishing operations.

Pin keys must be straight and free-moving in the pockets and capable of holding the forms tight against the pins. The joint locks must not be bent or worn and must be capable of holding the ends of the forms in true alignment. The pins and locks are checked when the forms are set but should be rechecked just prior to placing of concrete and tightened if necessary. Make a final visual check at the same time to insure forms are at proper line and grade. Smooth riding pavement with good surface finish is extremely difficult to obtain with poorly aligned and set forms.

The forms are to be cleaned and oiled prior to placing of the concrete. When hook bolts or wiggle bolts are fastened to the forms, the forms must be oiled prior to placing of these units.

Fine Grading of Subgrade or Subbase (451.05 A and B)

After the embankment has been placed and compacted the subgrade is brought to the required grade, cross section, and density in accordance with 204. Base material is provided by plan for all concrete pavements with only a few exceptions. The typical plan section indicates the depth and width of compacted base materials. Generally base material is 304 Aggregate Base and must be placed, shaped, and compacted in accordance with that specification. Fine grading of the base material should be done in advance of the concrete paving operation to allow the Engineer to check the established grade for conformance to the plan elevation. After the grade has been checked and accepted, no further disturbance of the base material is allowed.

Fixed Form Construction and Slip Form Construction

The surface of the base material is left approximately 1 inch (25 mm) above grade after compaction has been completed to the required density. Then, after forms have been set to grade for form paving or the string line is set for slip form construction, the slight excess is removed with a subgrade planer (subgrader). The fine grading operation should result in a slight removal so that the trimmed surface is compacted thoroughly without low areas. Low areas require the addition of material, compacting, and regrading resulting in a delay in progress of fine grading.

When automatic subgraders are used, they will precede the setting of forms. Grade will be maintained from a preset string line that will be parallel to the grade line. After final trimming the surface will be treated the same as for conventionally graded base.

Loose base material windrowed along the inside of the forms cannot be removed by machine so removal of this material by use of a shovel is necessary. This shall be done before re-compacting.

The trimmed surface left by the subgrader should be compacted to restore surface density. This rolling operation also smoothes the surface and reduces the friction between the base and the pavement.

For fine grading between forms the resulting base surface must be checked using a multiple pin template operated on the forms. The template must be operated behind the subgrader and roller. Any high or low spots encountered shall be corrected immediately, then rerolled and rechecked before continuing. Where the subgrader is operated on a string line, the grade will be checked based on the grade stakes for the pavement. The Inspector should record the limiting stations of the area checked and conformance to the specification requirements in project records.

The subgrader is usually one of the heaviest pieces of equipment operating on the forms. Therefore, this is an opportune time for the Inspector to observe the forms for excess movement or displacement. Areas where movement or displacement is noticed should be rechecked for compliance with requirements before placing concrete.

Moisture is controlled by spraying the base prior to fine grading, preferably in the late afternoon of the day before fine grading. This provides the uniform moisture distribution necessary for density. After removal of excess material during fine grading, moisture is present for the final surface compaction.

It is good practice to recheck the alignment and grade of forms, the form locks, and the pin keys after fine grading. Some Contractors assign employees to this job. The Inspector should check these items regardless of the Contractor's operation to assure that any irregularities have been corrected. Since the paving equipment relies on the forms for support, it cannot be expected to produce a quality-riding surface when yielding or improperly set forms are encountered.

Placing Concrete (451.06)

Prior to placing concrete, the subbase must be thoroughly moistened with water. This keeps the subbase material from absorbing water from the plastic concrete affecting its workability and decreasing its set up time. Different moisture levels throughout the depth of concrete can build in stresses that lead to cracking.

The concrete must be placed as close to the paving and finishing operation as possible to limit rehandling. Excessive handling of plastic concrete can reduce the air entrainment and thus long term durability of the pavement.

Even distribution of concrete on the base, or in each course being placed, is the first step toward an acceptable job. The most even distribution in initial placing results in minimum variation in final surface settlement. If concrete is deposited in piles, or windrows, unequal consolidation may take place before finishing operation are begun. This never will be overcome throughout the finishing procedure and can be the cause of unequal settlement and rough surfaces after finishing has been completed. In the case of transmit mixer or dump truck delivery, use discharging methods that spread each batch as evenly as possible. Better results are obtained when a hopper-type spreader is used with either transit mixer or dump truck delivery.

Workers should not walk in the concrete unless they are wearing clean boots that do not have dirt, earth, clumps, or other foreign matter on them.

Concrete must not be allowed to displace dowel bar assemblies or expansion joints.

A separate concrete spreader is required when the width of pavement being placed in one operation is 12 feet (3.6 meters) or more and the area of any given width exceeds 10,000 square yards (8,300 square meters). Spreaders must be adjusted to leave the proper amount of concrete for the required slab thickness. The amount of concrete left is determined by the elevation of a strike-off plate located behind the screw augers, paddle, or hopper that distributes the concrete.

Concrete Spreader

The elevation of the bottom of the strike-off plate in relation to the top of the forms is shown on an indicator that is visible to the operator. The equipment should be checked to make sure that the indicator shows zero when the bottom of the strike-off is exactly even with the top of the forms.

Concrete spreaders are powerful pieces of equipment that will handle heavy accumulations of concrete. However, this is not a reason to permit improper distribution. When a slipform paver is equipped with a dowel bar inserter the separate spreader requirement may be waived provided the slipform paver is capable of spreading, consolidating, screeding, and float finishing the freshly placed concrete. The contractor should provide the Engineer documentation that the slipform paver will meet this specification.

The initial placing of the concrete should be just enough so that a slight excess is carried ahead of the spreader as it levels the concrete to a uniform surface. (If a spreader is not required, the concrete can be spread and leveled easily with shovels.) Unless this is done there will be an irregular surge past the strike-off of the spreader or past the finishing screed. This necessitates excessive manipulation of the surface in order to obtain specified smoothness requirements. Excessive manipulation tends to alter the quality, durability, and wear resistance of the finished pavement.

Concrete should not be mixed, placed or finished after dark without operating an adequate and approved lighting system.

When the air temperature is 35 °F (2 °C) or below, the concrete temperature must be between 50 and 80 °F (10 and 27 °C) at the point of placement.

When the air temperature is greater than 35 °F (2 °C), the concrete temperature cannot exceed 90 °F (32 °C).

Concrete cannot be placed on any surface that is frozen or has frost.

Two test beams are to be made for each 7500 square yards of concrete, or fraction of 7500 square yards that is placed each day.

Concrete Running Yield Check

The running yield of concrete may be determined at any time during concrete paving and can provide an easy, accurate method of checking that the proper thickness is being placed. When a constant width and thickness is placed a running yield factor in cubic yards per foot (cubic meters per meter) can be calculated. This factor is determined by calculating the amount of concrete required for one foot length (one meter) of finished pavement of the width and depth being placed. This factor is computed by using Equations 451.2 and 451.3:

$$\text{Yield Factor} = \frac{\text{Width (ft)} \times \text{Thickness (ft)} \times 1\ \text{ft}}{27\ \text{ft}^3 / \text{yd}^3}$$

Equation 451.2 – Yield Factor

$$\text{Yield Factor} = \frac{\text{Width (m)} \times \text{Thickness (mm)} \times 1\ \text{m}}{1000\ \text{mm} / \text{m}}$$

Equation 451.3 – Yield Factor (metric)

Example:

A contractor is placing a 24-foot wide slab that is 9 inches thick. Determine the yield factor for this cross-section. Using Equation 451.2 the following calculation results:

$$\text{Yield Factor} = \frac{24\ \text{ft} \times (9\ \text{in}/12\ \text{in/ft}) \times 1\ \text{ft}}{27\ \text{ft}^3/\text{yd}^3} = 0.667\ \text{yd}^3 \text{ per foot of length}$$

Once the running yield factor has been calculated, it can be used to determine the concrete volume required for any length of slab of the same dimensions. The running yield is determined by multiplying the running yield factor by the length placed as shown in Equation 451.4.

$$\textit{Running Yield} = (\textit{Yield Factor}) \times \textit{Length Placed}$$

Equation 451.4 - Running Yield

The actual quantity used is easily computed for any length of slab by multiplying the number of batches placed by the number of cubic yards (cubic meters) per batch.

Example:

Using the yield factor determined above calculate the running yield for 4,245 linear feet of concrete pavement when 360, 8-cubic yard truckloads were used. Also determine the volume used and compare the volume used to the volume required and show which is greater. Determine the difference in volume and the percent over-run or under-run.

Running Yield = (0.667 yd^3/linear ft) X (4,245 linear feet)

= 2,830 yd^3 (required volume)

Volume Used = (360 batches) X (8 yd^3 per truck) = 2,880 yd^3

2,880 yd^3 (volume used) > 2,830 yd^3 (volume required)

2,880 yd^3 - 2,830 yd^3 = + 50 yd^3 difference

(50 yd^3 ÷ 2,830 yd^3) x 100 % = 1.77% overrun

The quantity used may be from 1 to 3 percent greater than that required, generally due to wasting over the forms, spillage, etc. An overrun of 3% or more should be investigated to determine the cause. Overruns may be caused by several factors, including inaccurate weighing, low subgrade/base, excessive waste, etc. Similarly, an under run in concrete may be due to inaccurate weighing, high subgrade/base, insufficient width, thickness of slab, settlement of forms, etc.

Hot Weather Construction

When high air temperatures, low humidity, and winds are encountered during concreting operations the rate that concrete hydrates (hardens) increases. High temperatures, especially when accompanied by wind and low humidity, tend to cause a rapid loss of moisture from the surface of the pavement resulting in early setting and a reduction in time allowed for finishing.

Lowering the concrete temperature to 75º F (24º C) or below will help offset the effects of high ambient temperatures. Selection of a cool water supply is the most effective means of lowering the mix temperature. Sprinkling of coarse aggregate stockpiles for moisture control also aids in controlling the mix temperature.

It is a good practice when form paving, to maintain the slump of the concrete near the top limit during hot weather. Increasing the slump will help delay hydration, thereby making more time available for the finishing operations.

During hot weather operations there may be a tendency to add water to the surface of the concrete to aid in finishing. This practice cannot be allowed. Using water on the surface during finishing results in an increase in the water-cement ratio and washes out the entrained air in the concrete at the surface. Both of these changes adversely affect the long term durability of the surface of the pavement. The use of the whitewash brush to sprinkle water has probably been the cause of the majority of scaling occurring in concrete surfaces.

Under extreme drying conditions caused by high temperatures coupled with low humidity and high winds, mixing water may evaporate quickly from the surface of the concrete. This water may be restored by applying a fog spray of water on the surface, provided the surface has been completely finished and will not be screeded or straightedged. This provision should be controlled carefully and should be the exception rather than the rule.

An approved Type B or D (705.12) set retarding admixture is required when the concrete temperature exceeds 75°F. Set retarders help slow down the setting time thereby providing more time for finishing. The use of this admixture will result in less slump loss and result in higher strength concrete.

Protection from Rain

Concrete paving must not be undertaken in rainy conditions, however in the course of paving, rain can occur and the Contractor must take steps to protect the plastic concrete from damage. If the pavement is adequately protected from rain extensive corrective work can be avoided.

A roll of polyethylene sheeting on the finishing machine or the curing machine can be quickly unrolled to protect large areas of pavement. When the concrete has not been protected and has been damaged by rain, increased attention to corrective measures will be necessary to obtain durable concrete.

Concrete that has been exposed to rain will have some mortar or paste washed from the surface resulting in a “sandy” appearance along with a speckled or splattered surface pattern. If the surface has not been machine finished, it should be screeded with the machine. This screeding will eliminate the sandy texture and force grout to the surface. For a surface which has been machine finished, the machine may be used to make a single pass over the area affected, or the surface may be dragged with the burlap to remove the sand and work grout to the surface. A broom drag may have to be used for several passes to restore the surface finish. When correcting damage to newly placed concrete surfaces, the excess surface water must first be removed; NOT worked into the concrete. Cement must not be placed on the surface in an attempt to restore cement paste washed away by the rain. Such a practice is detrimental to the concrete and must not be allowed.

When a rain persists for a lengthy period, it will be necessary to remove any protective covering to finish and texture the concrete before it sets. Membrane curing should not be applied when the surface is wet and may be delayed until paving is resumed. If polyethylene sheeting is used as a covering, curing may be delayed indefinitely provided the sheeting is maintained in accordance with the specifications. However, membrane curing should eventually be applied to provide a surface uniform in appearance.

If rain damages the curing membrane, the surface should be re-sprayed after the excess water has dissipated to restore the impervious covering and retain moisture necessary for curing.

If, for any reason, measures taken by the Contractor to produce a surface that meets specifications are unsuccessful, the affected portions of the pavement must be repaired or replaced to comply with contract requirements.

Cold Weather Construction

During cold weather, provisions must be made to prevent concrete from freezing until it has attained adequate strength. Concrete that has been frozen prior to gaining sufficient strength may be permanently damaged; and may never achieve the design strength. Therefore, it is necessary to protect the concrete from freezing temperatures during the cure period.

The temperature of the concrete and the surrounding air directly control the rate of hardening of the concrete. As the ambient temperature decreases, the rate of hardening decreases. The rate of hardening ceases at the freezing point. If the concrete is maintained just above freezing, it will not be damaged. However, it will require a lengthy curing period before it will harden and gain sufficient strength.

The Contractor is responsible for protecting concrete during cold weather. If damage might possibly occur, the surface shall be protected by any means that prevents the concrete from freezing and retains the heat of hydration.

In order to control the rate of hardening and strength gain, it may be necessary to control the temperature of the concrete being placed and to protect the concrete thereafter to retain the heat of hydration during curing. If the air temperature is 35º F (2º C) or below when concrete is being placed, the concrete must be have a temperature from 50º to 80º F (10º C to 27º C) when placed. The Contractor is responsible for ensuring that the concrete temperature is in the required range.

If the concrete temperature is less than 50° F the mixing water or aggregates may be heated. The heated water and aggregate should be introduced into the mixer before the cement, so that the temperature is reduced before cement is added to avoid the possibility of a flash set. One further precaution is to delay the introduction of the air-entraining agent until the temperature has been reduced, because hot water tends to reduce its effectiveness.

The subgrade or base and forms must be free from frost when concrete is placed. Covering these areas usually prevents frost and avoids delays.

Any request to incorporate an accelerating admixture during cold weather construction must be submitted and approved.

Job Control Testing and Sampling

All material being used in the production of concrete shall be sampled, tested and approved, or accepted by certification before being used. Material that has not been sampled before delivery to the project must be sampled and submitted for testing. Such material must not be used until approval has been given by the Laboratory. Sampling must be done in accordance with the specifications and as outlined in Item 499.

Concrete for use in pavements must meet the specified requirements for air, slump and yield. Tests must be conducted to check for compliance with these requirements. The test results must be within the following limits:

<table>
<tr><th>AIR</th><th>SLUMP</th><th>YIELD</th></tr>
<tr><td>6 ± 2%</td><td>1 – 3 inches</td><td rowspan="2">± 1%</td></tr>
<tr><td>8 ± 2% when using No. 8 Course Aggregate</td><td>4 – inches maximum</td></tr>
</table>

The Contractor must be notified of out of specification test results and make immediate adjustments to the mix. Production should be stopped and check tests made to confirm noncompliance of the original tests. Concrete that does not meet specification requirements must not be used unless adjustments can be made to correct the deficiency prior to incorporating it into the work. The fact that concrete has been produced and transported to the project does not justify its use unless it conforms to requirements.

Insufficient air may be corrected by the addition of an air-entraining agent and remixing the load to generate additional entrained air. Variations in yield should not be cause for rejection; however, immediate adjustments must be made in the batch weights and must be followed by additional yield tests until conformance is obtained. Slump may be increased by the addition of water provided it remains within the limits of the water-cement ratio. If slump is excessive, the concrete should not be used.

Concrete cylinders are not required for pavement concrete. However, if for some reason cylinders are desired, they should be cast from concrete obtained at the paving site and are to be made in accordance with Item 499. Cylinders are to be shipped to the Laboratory on the fourth day after casting where they are tested for compressive strength at 28 days of age.

Results of air, slump, and yield tests must be recorded on the Concrete Inspector's Daily Report. Results of flexural tests on beams are to be recorded in the project records. Results of compression tests on cylinders (if made) will be reported by the Laboratory.

Placing Reinforcement (451.07)

Distributed steel or reinforcement used in reinforced pavement (Item 451) is generally welded wire fabric or mesh. Its principal function is to hold together the fractured faces or slabs after cracks have formed. Adequate load transmission across the crack is thus assured, and the infiltration of incompressible material into the crack is prevented or delayed. It does not increase the flexural strength of an unbroken slab. Like tiebars, steel mesh is designed to withstand tensile stresses and hold the slab together.

Mesh is usually delivered to the job in advance of paving operations and stored. It should be carefully stacked and kept clean. Before it is used, it should be inspected to see that it has not been damaged in shipment or in storage, and that it is free from dirt, oil, and mud, which will hinder the bond with the concrete. Any mesh that has been bent or has broken welds should be rejected. If the mesh is repaired, it should be rechecked before using. Mesh with rust, mill scale, or a combination of both will be considered satisfactory provided the minimum dimensions are not less than specified. Recent research indicates that tight, scaly, and pitted rust does not prevent bond, but actually improves it.

Therefore, mesh should not be rejected for rusting unless the rust is so severe that the wire dimensions are reduced to less than the minimum specified. Reinforcing mesh details for (Item 451) pavement are shown on Standard Construction Drawing BP-1.1. The longitudinal wire is designated as a W8.5 or D8.5 (MW55 or MD55) size and has a nominal diameter of 0.329 inch (8.4 mm). The longitudinal wires are to be spaced at 6 inch (150 mm) centers. A W4 or D4 (MW26 or MD26) wire is used transversely and has a nominal diameter of 0.225 inches (5.7 mm). Transverse wires are to be spaced at 12 inch (300 mm) centers. If it is suspected that the wire dimensions have been reduced, the District laboratory should be requested to check the wire dimensions with a micrometer.

Concrete Spreader with a Mesh Cart

If mesh is placed along the rough grade or the shoulder to be easily accessible during paving, it should not be done so far in advance that mud will accumulate on it. Take care to prevent the mesh from becoming badly bent.

If a mesh cart is used on the forms behind a spreader, the mesh is stacked in cart-sized piles at intervals along the grade. These stacks should be placed on wood blocks or in some manner to keep them from becoming caked with mud or soil.

The specifications allow three methods of installing reinforcing mesh. The allowable methods are:

1. Place one layer of concrete, place the mesh on top of this layer so that it is located at its final location without any further manipulation, and place the second layer of concrete on top of the mesh. If the pavement is being placed in two layers, the concrete for the base layer should be distributed uniformly on the base and then struck off by means of a mechanical spreader to the proper depth. The strike off should leave a plane surface without voids or high or low spots on which to place the mesh
2. The mesh may be supported on chairs at the correct elevation and securely anchored to the base and the concrete placed in one layer.
3. Place and spread one layer of concrete; while the concrete is still plastic, use a mesh depressor that vibrates or mechanically installs the mesh to the proper depth in the slab. This method eliminates the need for placing two courses of concrete and thereby eliminates the possibility of a plane of weakness (a cold joint) between two separately placed courses. Control of the mesh placement within the slab is more accurate than when placed between courses, based on measurements of cores removed

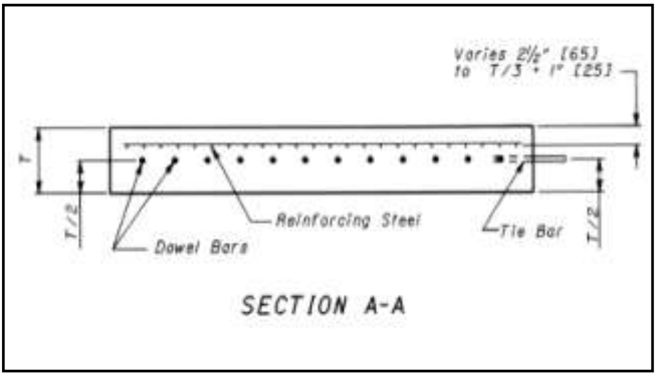
for checking thickness requirements. Another advantage of this method is that a bulkhead can be placed readily and quickly in the event of breakdown since the concrete is placed full depth, and not in two separate courses.

Placing Two layers of Concrete

Mesh Supported on Chairs

Using a Mesh Depressor

Mesh is required to be located in the slab within the range of 2 1/2 inches to T/3 + 1 inch (64 mm to T/3 + 25 mm) below the finished concrete surface (where T is the thickness of the pavement). In its final position, reinforcing mesh must not touch either dowel bars or tie bars. Mesh must also be located such that there is 2 inches (50 mm) clearance from a longitudinal joint or pavement edge to the reinforcing wires and 12 ± 2 inches (300 ± 50 mm) from any transverse joint.



Location of Reinforcing Steel Mesh

If the mesh is bent, it should be straightened before it is placed; if it has a gradual bow, place it so the concave side is down. Workers placing steel must not track mud or dirt into the concrete.

Two types of machines have been approved for use in vibrating the mesh into position. One type consists of a grid of steel plates approximately 15 feet (4.6 m) in length and extending the full width of pavement being placed. The self-propelled machine is positioned over the mesh, stopped, the mesh depressed into the freshly placed concrete, and moved ahead to repeat the operation.

Mesh Depressors

The other type is also self-propelled and consists of long tapered longitudinal runners across the width being placed. This machine gradually depresses the mesh into position in the fresh concrete using an oscillating tamping motion while continuously moving forward.

Since there is forward movement during placing, the latter type of machine may cause movement of the mesh across transverse contraction joints when not properly adjusted. When using a machine of this type, periodic checks must be made by uncovering the mesh at joint assemblies to assure that the specified clearance of 12 ± 2 inches (305 ± 51 mm) is being maintained on each side of the center of the transverse joint. If the mesh position is found to be outside of tolerance, it should be corrected and the machine adjusted at once; or its use immediately discontinued. Production may be continued without the mesh installer by changing to the two-course method.

Both types of machines can be adjusted to control the depth of the mesh. Therefore, depth checks must be made daily to confirm that the machine is placing mesh to the required depth. Standard Construction Drawing BP-1.1 requires the mesh to be placed below the top surface of the pavement a distance of between 2 1/2 inches to T/3 + 1 inch (64 mm and T/3 plus 25 mm) where T is the thickness of the slab. When mesh depth is out of tolerance, immediate adjustments must be made by the Contractor.

The mesh is to be placed between the forms, or between the pavement edges, leaving 2 inches (50 mm) between the ends of the wires and the side forms, pavement edge, or pavement centerline. Reinforcing mesh is normally shipped in lengths of 19 feet (5.9 m) by 11 feet 8 inches (3.6 m) wide which will fit the specified joint spacing of 21 feet (6.5 m) for reinforced concrete pavement with an allowance of 12 ± 2 inches (300 ± 50 mm) from the center of each transverse joint. If shorter lengths are provided, transverse laps must be 12 inches (305 mm) and mesh sheets must be fastened at the edge of the lane and two other locations.

Usually, mesh is not fabricated for lane widths greater than 12 feet (3.6 m). Therefore, when placing pavement lanes in excess of 12 feet (3.6 m) in width it will be necessary to tie additional mesh to the standard width sheet. This is done by tying the outer longitudinal wire of adjacent sheets together. A minimum of four ties should be placed along the overlapped longitudinal wires to hold the two sections of mesh in the same plane until the concrete sets.

If the screeding operation has been done properly and the mesh placed in flat sheets and tied properly, there will be no difficulty with the steel working up into the finishing operations.

Joints (451.08)

Joints are classified as transverse and longitudinal. Transverse joints are further classified as contraction, expansion, and construction joints. Detailed instructions for joints are found in the specifications and in the standard construction drawings. See Standard Construction Drawing BP-2.1 for longitudinal joint details and BP-

2.2 for transverse joint details. The Inspector should know the requirements of the specifications and the drawings before inspecting joint construction. All transverse joints are to be constructed normal to the centerline of the pavement lane unless otherwise noted on the construction plans.

Joint sawing is required to prevent uncontrolled cracking of concrete pavement and is required for all transverse contraction joints and for all longitudinal joints when concrete pavement has been placed between two lanes at the same time.

Joint openings are to be constructed in accordance with the requirements of the applicable standard construction drawings.

The timing of the sawing operation is critical. The use of HIPERPAV software is required to determine the sawing time limits to help protect from early uncontrolled cracking. The software is available as detailed in Supplement 1033 as well as the requirements for analysis. It must be noted that the use of HIPERPAV does not relieve the Contractor of his responsibilities under 451.16 regarding the repair of cracks in the completed pavement.

The HIPERPAV analyses must be run 24-hours prior to placing concrete and for every pour. The HIPERPAV files and printout must be provided to the Engineer. If HIPERPAV predicts early age slab cracking will occur, whether due to standard construction practices, joint sawing methods, mix design or curing, the contractor cannot start construction until modifications have been made to eliminate HIPERPAV's predicted slab cracking.

If HIPERPAV predicts that joint sawing can exceed 24 hours, all joints must be cut by the 24^{th} hour.

Sawing must be done after the concrete hardens sufficiently to support the sawing equipment and to avoid spalling and raveling. This operation cannot be tied to normal working shifts. A standby saw is required at the paving site in the event of breakdown or inability of one machine to maintain necessary progress.

Inspection should include random checking of each day's sawing to assure the width and depth specified is achieved. Saw blades will wear with use so continued checks must be made. Since the timing of sawing is critical, inspectors assigned to this operation must be aware of the importance and document the actual time of sawing.

Sawing may be done wet or dry, and the cut must be cleaned by a jet of water (if sawed wet) or air under pressure (if sawed dry).

Longitudinal Joints (451.08.A)

Joints between adjoining lanes of pavement or shoulders are longitudinal joints. They are necessary to control cracking in the longitudinal direction due to the warping stresses in wide concrete slabs. Joints between <u>separately-placed</u> adjoining lanes are longitudinal joints as well as construction joints. In general, the maximum pavement width used by the Department without a longitudinal joint is 16 feet (4.9 m) (for ramp pavements). Normal mainline pavements are 12 feet.

Epoxy coated tiebars or hook bolts are required at longitudinal joints to tie the lanes and prevent them from moving apart or from settling unevenly. Since they tie the lanes together by bond, tiebars or hook bolts are not to be oiled.

Longitudinal Joint - (in simultaneously placed lanes)

Both tiebars and hook bolts should be placed in accordance with requirements of standard construction drawings called out in the plans. Tiebars are 5/8-inch (16 mm) diameter, deformed reinforcing bars, 30 inches (760 mm) in length. The spacing of tiebars or hook bolts varies with the pavement thickness. The maximum spacing of tiebars is 26 inches for pavement that is 10 inches (250 mm) thick or less, and 20 inches (508 mm) for pavement that is greater than 10 inches (250 mm) in thickness. Tiebars or hook bolts must be approximately at right angles to, and placed at 1/2 the thickness of the pavement. For example if the slab is 10 inches thick the tiebars are to be placed at 5 inches as measured from the surface of the slab.

Tiebars may be set on chairs prior to concrete placement; installed in the concrete after it is placed and spread; or may be inserted in the plastic concrete using a mechanical device on a slip form paver. Chaired tiebars must be adequately anchored to the base material. A mechanical inserter must be able to install the tiebars at mid-depth in the plastic concrete. Tiebars must be inserted after the concrete has been placed to its full depth and after the reinforcing mesh is placed (mesh is not required for 452 pavement). The tiebar inserter must be located in the paving train to assure consolidation of the concrete around the tiebars. Pushing tiebars into the plastic concrete by hand is not acceptable.

Mechanical Devices for Installing Tiebars in Longitudinal Joints between Lanes Placed Simultaneously – Wheel

Mechanical Devices for Installing Tiebars in Longitudinal Joints between Lanes Placed Simultaneously –Guillotine

Tiebars Can be Chaired at Longitudinal Joints Prior to Concrete Placement

When a standard (water-cooled diamond bladed) concrete saw is used to make the longitudinal joint between simultaneously placed lanes the following applies:

- Pavement ≤ 10 inches thick; saw the joint to a minimum depth of one-fourth the specified pavement thickness.
- Pavements > 10 inches (255 mm) thick; saw the joint to a minimum depth of one-third the specified pavement thickness.
- Saw joints 1/4 ± 1/16 inch (6 ± 1.6 mm) wide as measured at the time of sawing.

When using early-entry (dry cut, light weight) saws, only use saw blades and skid plates as recommended by the manufacturer. Perform the early entry sawing after initial set and before final set as follows:

- Saw the joint 2-1/4 to 2-1/2 inches (56 to 63 mm) deep.
- Saw joints approximately 1/8 inch (3 mm) wide as measured at the time of sawing.

Longitudinal Joint - (between separately placed lanes)

Standard 30-inch long tiebars can be installed in the slip formed edge of the pavement using a mechanical inserter at longitudinal joints when lanes are placed separately. This is normally done by a mechanical ram which pushes a tiebar 15 inches into the edge of the slab along the joint and at the center of the slab. Tiebars cannot be placed by hand. Bent tiebars are not permitted in longitudinal construction joints.

Mechanical Ram Inserts Tiebar in a Slip Formed Edge

Hook Bolts Screwed into Coupling at a Butt Joint

The epoxy coated hook bolt or an epoxy coated hook bolt alternate (wiggle bolt) may be used in longitudinal joints when using fixed form paving. An epoxy coated coupling attached to one half of the device is bolted to the side-form for the first lane placed. Before placing concrete in the adjoining lane, the other half is coupled to the embedded part after removal of the forms. The hook bolts are to be securely fastened to the forms so they are positioned properly in the slab. The right-angled hooks on each side of the coupling anchor provide the tie. The position of the hooks is not important, that is, they do not have to be turned down, up, or sideways.

The hook bolt alternate (wiggle bolt) with a coupling may be mechanically inserted into the plastic concrete through a hole in the side-form of a slip form paving machine. When this is done, the contractor normally uses a plastic cap in the threaded end of the coupling to keep concrete out of the threads. This plastic cap is removed once the concrete is set and a hook bolt is installed in the coupling.

The inside and outside edges of the paved lane must be edged to a 1/8-inch (3 mm) radius. The slab should be edged as soon as the concrete becomes stiff enough to remain firm without running back into the groove. The edge should be cut first with a small trowel and then followed by the edger. The edging tool should be held flat with the pavement surface. Tool marks left by the edging tool must be removed. Since the final texturing is to follow edging, this operation must not be permitted to lag.

Tooling with a 1/8 inch Radius Edger

Tool Marks are Removed after Edging

Longitudinal joints between separately placed lanes are to be saw cut to a minimum depth of 1/2 inch (13 mm) and a minimum width of approximately 1/8 to 1/4 inch (6 mm).

Longitudinal joints between separately placed lanes require extra care to assure that a smooth transition from one lane to the other will result. Good workmanship is necessary at these joints to obtain satisfactory results. Hand finishing and straightedging should be performed carefully so that each lane will be at the same elevation. The surface of the pavement in the joint area should not vary more that 1/8 inch (3 mm) from a 10-foot (3.0 meter) straightedge in both longitudinal and transverse directions.

Tooling a Longitudinal Joint at a Butt Joint

Tooling the Edge when Fixed Form Paving Contraction Joints (451.08.D)

Load Transfer Devices (451.08.B)

Contraction joints in concrete pavement are constructed at right angles across a pavement lane and are also called transverse joints. These joints control cracking of concrete pavement that result from stresses from volume changes during curing of the concrete. These joints are designed to transfer the loading from traffic from one slab to the next and require the use of dowel bars to accomplish this function. These dowel bars are called load transfer devices. Dowel bars can be pre-installed using dowel bar assemblies or can be installed using dowel bar inserters during slip form paving.

In contraction joints load transfer is achieved using round, straight, smooth, epoxy-coated steel dowels that are placed across the joint. Dowels must be placed at mid-depth, parallel to the slab and be 18 inches long. The required diameter of the dowel depends on the pavement thickness. The required dowel diameter is shown in Table 451.08-1 in the specifications and below (unless otherwise specified in the plan):

Table 451.08-1 Dowel Size

Thickness of Pavement (T)	Diameter of Steel Dowels
Less than 8 1/2 inches (215 mm)	1 inch (25 mm)
8 1/2 to 10 inches (215 to 255 mm)	1 1/4 inches (32 mm)
Over 10 inches (255 mm)	1 1/2 inches (38 mm) or as in the plans

Dowels must be spaced at 12-inch (300 mm) centers beginning 6 inches (150 mm) from the longitudinal joint. The spacing between the end dowel and the outside edge of the lane may be increased up to 12 inches (300 mm). A dowel must be placed 6 inches (150 mm) from the outer edge of the pavement when the spacing between the end dowel of the basket and the outside edge exceeds 12 inches (300 mm). Contraction joints are required to be spaced in the pavement at intervals not to exceed the maximum spacing indicated in Standard Construction Drawing BP-2.2 or the plan construction drawings. The maximum contraction joint spacing for reinforced concrete pavement (Item 451) is 21 feet (6.5 m). For non-reinforced concrete pavement (Item 452) and concrete base (Item 305) the maximum spacing is 15 feet (4.6 m).

To function properly dowels must be placed parallel to the surface and parallel to the centerline of the pavement since expansion and contraction movements occur in this direction.

Dowel Basket Assemblies

To assure proper alignment of dowels, a cage or basket is often used. This, together with the dowels, is called a dowel basket assembly. Dowel basket assembly wires as well as the dowels are required to be epoxy coated according to 709.13 of the CMS. Dowel basket assembly wires are to conform to Standard Construction Drawing BP-2.2.

Dowel basket assemblies are to be positioned not to exceed the maximum spacing for the type of pavement specified and must be perpendicular to the centerline and edge of proposed pavement or forms. Locating the transverse alignment may be by any method that assures a right angle to the centerline. On curves, the joints should be approximately on radial lines.

Transverse contraction joints must be continuous across the full width of pavement placed. Therefore, the line of a joint in a lane already placed must be continued in all other adjoining lanes.

Dowel Baskets are Pinned to the Base

When properly located and placed, dowel basket assemblies are anchored in place with steel pins. At least eight 1/2-inch (13 mm) diameter steel pins, 18 inches (460 mm) in length, are required to hold each 12-foot (3.6 m) basket assembly. The pins are driven at an angle to brace the assembly from lateral movement and to prevent vertical displacement when concrete is placed. Two of the pins are driven opposite each other at each end of the dowel assembly, and the remaining four are driven in a staggered pattern on each side. The assembly should not be hit when driving the anchor pins. If wires of the basket are bent, the dowels may be thrown out of line and require the entire assembly to be rejected unless it can be removed, straightened, and reset properly. Any badly distorted assembly should be rejected. The epoxy coating must not be damaged during the above operation.

Clips with Power Driven Fasteners, Steel Pins or a Combination of the two are used on a Stabilized Base to Anchor Dowel Basket Assemblies

If concrete pavement is placed on an existing concrete pavement or stabilized base, the dowel baskets must be held firmly in position by use of power-driven fasteners and appropriate clips or pins driven in predrilled holes of a diameter slightly less than the pin diameter. The Contractor may use either of these methods or a combination of the two in sufficient numbers to adequately anchor the basket assembly. The method used must secure the dowel basket from lateral and vertical displacement during concrete placement.

If the dowel basket assembly is placed on a base consisting of sand, a minimum of 6 steel bearing plates approximately 5 inches (127 mm) square must be placed under each 12-foot (3.6 m) dowel assembly unit. Bearing plates also are required when any base material is used which permits distortion or settlement of the dowel assembly due to poor stability. One bearing plate is to be used with each of the four end anchor pins with the others spaced uniformly along the assembly. Shimming with pebbles, stones, etc. is not permitted. If shimming is necessary, it is obvious either that the base is not prepared properly or the dowel basket assembly is bent or misaligned. In either instance, the base or assembly must be rejected until corrective action has been completed.

Dowel Shipping and Spacer Wires

After dowel assemblies have been set and anchored properly, the shipping and spacer wires used to hold both halves of the dowel basket together during shipping and handling must be removed. The shipping wire is normally cut at two locations and removed immediately prior to placing the concrete. The shipping and spacer wires are usually a small diameter wire parallel to the dowels and hooked or tack welded to the basket assembly wire. Shipping wires run the same direction that the dowels. Dowel basket assemblies must be anchored to the base before the shipping and spacer wires are removed.

Shipping Wires are to be Removed after Baskets are Pinned

Checking Assemblies

Specifications require that dowel basket assemblies be preset prior at the beginning of paving unless the Engineer determines that it is impractical to do so. This allows time to spot check the baskets to assure they are parallel to the base and centerline of the pavement. Checking of the assemblies is to be done after the removal of the shipping and spacer wires. Spot measurement checks of the distance between the dowel and the forms (made at each end of the dowel) or the proposed edge of pavement provide a check for being parallel to centerline. The distance to each end of the dowel must be equal for the dowel to be parallel to the forms and the centerline. After some experience, this check can be a visual since dowels out of alignment stand out when observing them in relation to the forms.

An A-Frame Level is used to Check that Dowels are Parallel to the Base

An adjustable A-frame level is used to spot-check several dowels in every assembly unit to assure that all dowels are parallel with the surface of the base. The level is first placed on the base adjacent to a basket assembly and adjusted to read level. Then the level is placed on the dowels. The bubble will indicate level if the dowel assembly is set properly and is parallel to the surface of the base. At least three dowels are to be checked in each 12-foot (3.6 m) section, one at each end and at the middle. If the dowels are not parallel with the surface when checked, the assembly must be adjusted and rechecked. If proper alignment cannot be obtained, the assembly must be removed and replaced.

Dowel Bar Inserter

Specifications allow dowels to be placed in the full thickness of the concrete pavement slab by a mechanical device called a dowel bar inserter (DBI) approved by the Engineer. It is intended to permit this method provided the Contractor is able continuously to install dowels properly.

A DBI is normally part of a finish paving machine and is located behind the vibrators and the initial strike-off of the slab. Immediately before inserting the dowels, they must be coated with a layer of new light form oil that serves as a bond-breaking material. Loose dowels are placed on an installing rack on the self-propelled paving machine directly above the pavement. These racks must be located to provide the correct dowel spacing in the joint. Once all dowels are in position in the rack above the slab, each dowel is pushed downward into the plastic concrete with vibration by two metal fingers which must push the dowel to the proper elevation. The metal fingers must insert each dowel so that it is parallel to the base and the pavement centerline and be at the center of the slab thickness.

After the dowels are placed at mid-depth, the fingers are withdrawn leaving the dowels in position supported by the concrete. The dowels are to be installed after the concrete is placed to its full depth and after the mesh is positioned properly. The only operations permitted after positioning the dowels are machine's final strike-off, mechanical float finishing, and hand finishing of the surface of the concrete.

Concrete Paving Machine with a Dowel Bar Inserter (DBI)

As noted above; if a dowel bar inserter is used the requirement to use a separate concrete spreader may be waived by the Engineer provided the paving machine is capable of uniformly spreading the concrete. Since there are no basket assemblies set out in front of the paving machine with this method, the contractor can back up dump trucks or other hauling units directly in front the paving machine to discharge concrete.

A pachometer should be used to verify the proper alignment of the dowels. Dowels may be 2 inches (50 mm) from the actual mid-depth location and deviate 3/8 inch (10 mm) from parallel alignment in both the horizontal and vertical planes of the concrete slab.

Pachometer

Preventing Bond to Dowel Bars

For dowels to function properly in the concrete slab, they must be oiled with a thin coating of new light form oil for at least one-half their length to prevent the concrete from bonding to them. Most of the dowel assemblies have one end of the dowel welded to the basket wire. The free end, opposite the welded end, must be oiled. Dowels must be oiled within 2 hours of placing the concrete around them. Exercise care to see that the free end of the dowel is oiled. It is always better to oil more than half the length of each dowel to be certain that bond is prevented so that the joint will function properly.

The Free Ends of all Dowels are to be Oiled within 2 Hours of Placing Concrete

Epoxy coated dowels should be inspected to assure the coating is continuous on the lateral surface of the dowel and that the coating is not perforated, cracked, or otherwise damaged, in which case it must be rejected. In addition, the coating must be free from holes, voids, contamination, cracks, and there shall not be more than two holes (pinholes not visually discernable) in any 12-inch (305 mm) length of the coated dowel. The free ends of the dowels must be free of burrs or projections.

Saw Cutting

When a standard (water cooled diamond bladed) concrete saw is used to cut the contraction joint the following applies:

- Pavement ≤ 10 inches thick, saw the joint to a minimum depth of one-fourth the specified pavement thickness.

- Pavements > 10 inches (255 mm) thick, saw the joint to a minimum depth of one-third the specified pavement thickness.
- Saw joints 1/4 ± 1/16 inch (6 ± 1.6 mm) wide as measured at the time of sawing.

When using early-entry (dry cut, light weight) saws, only use saw blades and skid plates as recommended by the manufacturer. Perform the early entry sawing after initial set and before final set as follows:

- Saw the joint 2-1/4 to 2-1/2 inches (56 to 63 mm) deep.
- Saw joints approximately 1/8 inch (3 mm) wide as measured at the time of sawing.

Joints should be spot checked to make sure that the contractor is sawing the pavement to the required depth.

Standard Diamond Saw

Lightweight Dry-cut Saw

If a crack appears ahead of the machine during pavement sawing, it is an indication that sawing is late. When such cracking is noted, stop sawing that joint immediately and move the saw ahead several joints. Saw a joint, move ahead several more joints, and saw another joint. Continue skipping three or four joints and sawing every fourth or fifth joint until sawing is back on schedule. The presence of slight raveling indicates proper timing of sawing. Saw every joint in order when sawing is back on schedule. After sawing has been completed for the day's production the saw can be returned to saw the skipped joints. The standby saw may be put into service to saw the joints skipped if an experienced operator is available.

This procedure of skipping ahead and sawing every fourth or fifth joint relieves the stresses that occur when the concrete hardens and shrinks during curing. Once these stresses are relieved, the sawing of the in-between joints is not as critical but should be done as soon as possible.

The pavement is normally subjected to expansive forces the following day when the temperature rises. When temperatures drop during the evening of the following day, the pavement again experiences shrinkage stresses and all joints originally bypassed must be sawed before these stresses result in random cracking.

The HIPERPAV analysis for each pour should be utilized to predict the time for sawing as detailed in 451. 08. Generally pavement should be sawed the same day, usually six to eight hours after placing. Concrete placed late in the day may not harden to permit sawing until the next day, but sawing should be completed before the following late afternoon temperature change as shrinkage will again occur as temperatures drop. The Contractor is responsible for determining the optimal sawing time to prevent uncontrolled cracking.

Joints in lanes adjacent to previously-placed lanes that are tied together must be sawed as soon as possible to prevent uncontrolled cracking. If a new lane is tied to an existing concrete pavement, which is expanding and contracting with changes in temperature, stresses will be transmitted to the new slab unless joints are sawed as quickly as possible. The following provisions are important to obtain quality sawed joints in these areas:

- All transverse joints, except construction joints in the previously placed lane of pavement, must be in-line with those in the newly placed lane.
- The joint sawing must be done as soon as the saw can be operated on the newly placed pavement lane without damaging or excessive raveling of the joint.
- Full depth joint cracking in the previously placed lane indicate movement. Therefore, joints in the newly placed lane, which are in line with the cracked joints, must be sawed first.
- The cut is to be made from the old slab to the outside or open edge of the new slab being sawed.

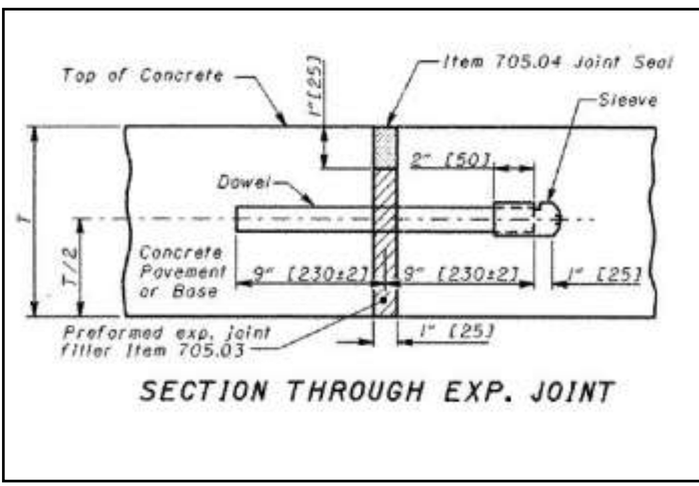
A sudden drop in temperature, a wide range between day and night temperatures, or a cold rain creates additional problems when sawing contraction joints. These thermal changes add stresses and make the timing of sawing especially critical. When these conditions occur or are anticipated, increased attention to the sawing operation to assure control of cracking is needed.

Expansion Joints (451.08.C)

Relief for compressive forces that are caused by movement in the pavement (typically in hot weather) is provided at bridges, structures, and at intersections in the form of expansion joints. Expansion joints permit contraction and expansion movement.

The first two regularly spaced joints in the concrete pavement adjacent to a bridge approach slab must be expansion joints (when a pressure relief joint is not included in the plans). Other expansion joints may also be detailed in the plans at locations at other structures and at intersections. Standard Construction Drawing, BP-2.2 provides additional information on the installation of expansion joints. All expansion joints are dowelled and allow the pavement to expand or grow due to temperature variations. A standard expansion joint allows for 1 inch (25 mm) of expansion.

Typical Expansion Joint Basket Assembly



SCD BP-2.2 Detail of Section Through Expansion Joint

If the pavement consists of two or more separately placed lanes, the expansion joints must be a continuous straight line for the full width of the concrete pavement, including concrete shoulders. All expansion joints are perpendicular to the centerline adjacent to a skewed approach slab.

Preformed compressible material 1 inch (25 mm) thick is installed in a dowel assembly at the location of the expansion joint. It must be set perpendicular to the dowel as well as perpendicular to the line of forms and the pavement centerline. The material must extend down to the base and to the side forms to allow free movement throughout the entire joint. The top of the expansion material is held 1 inch (25 mm) below the pavement surface. It is permissible to place the expansion material closer to the pavement surface to facilitate sawing of this joint, provided all material is removed to a depth of 1 inch (25 mm). This area shall be sealed using a hot applied joint sealer meeting the requirements of 705.04.

Standard 18 inch (460 mm) long epoxy coated dowels are required for load transfer, in all expansion joints.

An expansion cap, also called a sleeve, is placed on the opposite ends of adjacent dowels (each dowel will have one cap but on alternate ends) to create a void in the concrete to permit expansion movement. The cap must be placed after the dowel has been oiled. The cap contains a crimp or stop that provides for the 1 inch (25 mm) void. These caps must not be forced beyond the crimp, otherwise, the space for expansion will be compromised and the joint will not function properly.

Inspectors must assure that the 1 inch (25 mm) thick preformed expansion joint filler is held rigidly in position and extends full width of all lanes. The preformed expansion joint filler must be the required height and must extend to the top of the base (or bottom of the new pavement) so that no concrete is permitted to flow under it. Holes in the expansion joint filler must be neatly punched or drilled, and the dowels must fit tightly through the holes with no gaps in which concrete could flow. The free end of each dowel (the end not welded to the basket wire) must be oiled with a bond breaker and the expansion cap/sleeve attached immediately prior to placing the concrete.

The Contractor must provide adequate consolidation throughout the slab depth adjacent to the preformed expansion joint filler and around dowels by use of hand-held internal vibrators. The top of the joint should be formed to a 1 inch (25 mm) wide and 1 inch (25 mm) deep opening, carefully edged using an edger having a 1/8 inch (3 mm) radius, on top of the preformed expansion joint filler and sealed with 705.04 joint sealers.

Construction Joints (451.08.E)

Construction joints are transverse joints placed at the conclusion of each day’s paving or when production is interrupted for more than 30 minutes. These joints are formed by using an adequate bulkhead that provides a straight joint. Construction joints in all concrete pavements are to be dowelled and perpendicular to the centerline. Construction joints may be located at a contraction joint or between contraction joints. The bulkhead must have openings provided for individual dowels or a dowel basket assembly. The bulkhead must be shaped to conform to the typical section of the pavement.

Locate construction joints at or between contraction joints. If located between contraction joints, construct the construction joint no closer than 10 feet (3 m) to the last contraction joint.

In non-reinforced concrete base (305), construction joints must not be closer than 6 feet (1.8 m) to another transverse joint.

At skewed joints between approach slabs and approach pavement, exercise care to position the dowels parallel to the centerline. Recent experience indicates movement occurs at such joints. Make provisions for this movement by placing dowels the same as for contraction joints.

The joint may be hand-formed or sawed to the same dimensions required for transverse joints in adjoining pavement.

Transverse Construction Joints are Dowelled

Smooth epoxy-coated dowels must be used in construction joints placed parallel to the surface of the base. The dowel size and spacing is the same as required for standard contraction joints. See 451.08 B for those details.

Finishing (451.09)

Finishing behind the concrete paving operation can be done by a variety of methods. In all cases a 10 foot straightedge must be used to continually check the pavement surface for smoothness.

Diagonal pipe floats suspended from self-propelled machines have been used successfully to machine-finish slip formed pavement without damage to the unformed edges. They are equipped with a water spray system that applies a fog spray of water. Such water should always be a fog spray and should be used only at the start of a finishing pass. With pipe floats it may not be necessary to hand straightedge the entire pavement surface. However, a straightedge should be used periodically to check the pavement surface.

The Contractor is required to round the edges of the pavement slab to the radius specified before the concrete sets. For an inside slab edge the radius is to be 1/8 inch (3 mm) and for an outside slab edge the radius is typically 1/2 inch (13 mm). Any tool marks left by the edging tool must be eliminated.

Some slip form paving machines trail several sections of forms while others have no trailing forms. When trailing forms are used, they provide protection to the edges while the surface is straightedged. However, straightedging should not be confined to the area of the trailing forms.

Final finishing is perhaps the most important step in the paving operation, at least from the public viewpoint, because it determines whether the final surface meets the necessary tolerance for a smooth riding surface. Projects using high-strength, quality concrete and the best of modern paving equipment often end up with substandard surfaces, simply because of careless work and lack of attention to details during final finishing.

The work of the hand finishers will be simplified if forms or string lines are set accurately. The finishing machines must also be adjusted and operated properly. If finishing machines are not operated properly, additional work is required for the hand finishers to correct surface irregularities and produce an acceptable surface that complies with the specifications. The preferred method is to keep the machines in proper adjustment and limit the amount of handwork that is required. In any case, it is up to the Inspector to insist that the finishers produce a pavement with the required smoothness and an acceptable uniform final surface texture.

The Inspector should ensure that the finishers check their hand tools before paving operations begin to make sure that they comply with specifications. Straightedges should be tested with a string or a master straightedge to make sure they are straight. Inspection of tools should be done daily to correct for wear. Tools should be restored to the desired accurate form. They must be rigid enough to remain straight with no bending while in use.

After the mechanical finishing, while the concrete is still plastic, minor irregularities and surface marks should be removed with a scraping straightedge. When necessary, remove excess water and laitance from the surface transversely by means of a scraping straightedge. Any such excess should be wasted over the forms or removed from the pavement edge if slip forming.

A number of different types of straightedges have been used satisfactorily. They must be strong enough to maintain a true straightedge and yet light enough to handle. In some cases, they also must be heavy enough to cut or scrape off any high spots left by the machine finishing operations. They must be a minimum of 10 feet (3.0 meters) long to comply with the specifications.

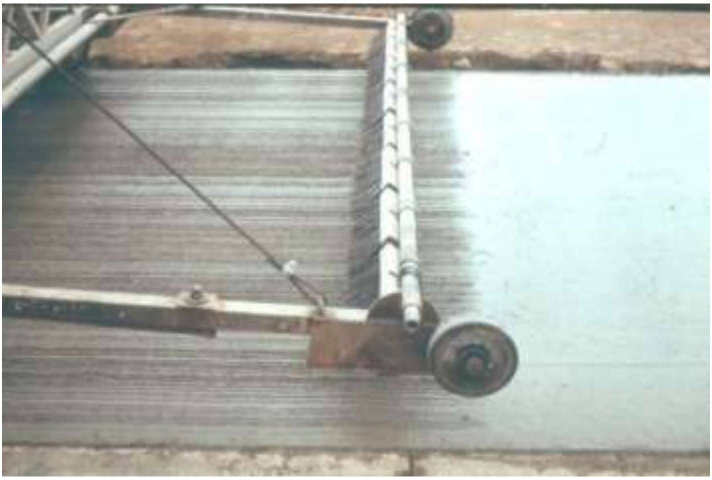
The straightedge is operated from the side of the pavement transversely and should be advanced along the pavement in successive stages. By proper manipulation, it can be used as a float to smooth the surface or as a cutter to remove high spots. Long-handled floats may be used to smooth and fill in open textured areas in the surface, but this must be done before straightedge finishing. The use of such floats should be held to a minimum. If open textured areas persist, the aggregate grading, mix design, and the method of placing the concrete must be evaluated and corrected. A properly proportioned mix along with correct paver operation should not require excessive hand floating.

No water is to be added to the surface during this or any other operation.

Texturing

The final surface texture should be applied when most of the water sheen has disappeared but before concrete becomes non-plastic. Surface textures for concrete pavement vary with the type of construction. Finishing methods used must produce the texture as described in the appropriate specification item.

Unless otherwise specified concrete pavement (451 and 452) must be textured by the use of a broom drag in the longitudinal or transverse direction immediately followed by an approved device which produces a random pattern of grooves. The broom drag must produce a uniform, gritty texture. Brooms suspended from a machine or truss and dragged over the pavement surface have provided satisfactory longitudinal texture. The broom should be lifted clear of the surface when not being used.



Broom Finish in the Longitudinal

Broom Finish in the Transverse Direction

Concrete base pavement (Item 305) must have a final surface finish that is a uniform, gritty texture as obtained with a broom drag in the longitudinal or transverse direction. No grooves are put in base pavement because it is normally covered with asphalt concrete prior to opening it to traffic.

The broom drag is used in the longitudinal or transverse direction to provide a more skid resistant pavement. The Department has found that new concrete pavement would lose skid resistance after one year of service with merely a light burlap drag prior to tine grooving. Broom dragging roughens the area of concrete between grooves that results in a longer lasting skid resistance.

Transverse Grooving by the Cure/Texture Machine (left) and by Hand Methods

Transverse Grooving by the Cure/Texture Machine (left) and by Hand Methods

The Contractor must put randomly spaced transverse grooves in the plastic concrete immediately after the broom finishing application. The grooves must be spaced in a random pattern at 3/8 to 1¾ inches (10 to 45 mm), with 50 percent of the spacings less than 1 inch (25 mm). All grooves must be in the range of 0.05 inch (1.3 mm) to 0.08 (2.0 mm) deep and 0.10 inch (3 mm) wide. The use of a wire tine rake for the transverse texture grooving can impart the desired groove depth.

Longitudinal tining may be used if approved by the Director. If longitudinal tining is authorized for use, the tine spacing must be placed at a uniform spacing of 3/4 wide with tines 1/8 deep by 1/8 inch wide. Longitudinal tining must be applied using a machine specifically made for this application and must be controlled from a stringline that controls the line and grade of the tining operation.

Randomly Spaced Transverse Grooves

Station Numbers

The Contractor is required by specification to stencil complete station numbers into the plastic concrete pavement (Item 451 and 452) each 100 feet (50 meters) before the concrete sets. The dies used to form the station numbers must be 3 to 4 inches (75 to 100 mm) high and 1/4 inch (6 mm) in depth. The numbers are placed parallel to the pavement edge, centered 12 inches (0.30 m) from, and facing the right edge of the pavement. For the purposes of placing station numbers; the right edge is the edge to the right of the normal direction of travel.

The numbers should be impressed into the plastic concrete following the texturing of the surface and before curing is applied. If the impression is made too early, the number will tend to close up and not be as distinct as desired.

For divided highways station numbers must be provided for each pavement direction.

If concrete shoulders are placed with a traveled lane, the station numbers should be placed 12 inches (0.3 m) in from the outside edge of the shoulder and facing the pavement.

Station numbers are not required on concrete base (Item 305).

Concrete Curing (451.10)

Curing is the treatment or protection provided to concrete during the curing period. Proper curing consists of keeping the concrete moist and warm to insure adequate hydration of the cement. Curing protects concrete from early shrinkage due to changes in temperature and, or loss of moisture before it has developed sufficient strength to resist the resulting tensile stresses.

It is extremely important to provide adequate curing during the first few days, with the first few hours being most important to obtain a strong durable pavement. Strength loss due to lack of moisture during this period is difficult to regain even with subsequent curing.

During windy, hot, dry weather, it is very important that finishing is completed rapidly and the curing be placed before the surface dries out to the extent that plastic shrinkage cracks develop. These cracks can never be sealed, and they are an indication that the surface may have been depleted of the necessary water to properly complete the chemical reaction of cement hydration. Water curing may halt this shrinkage cracking, but the addition of more water will not correct the cracking once it occurs.

In cold weather, the concrete may continue to bleed after finishing. Take care in placing any type of curing under these conditions so that the surface will not be marked.

Prior to the application of any curing material, ensure that it meets the requirements of 705.05, 705.06, or 705.07 Type 2. This also applies to any equipment used in the application.

Liquid Membrane Curing

For concrete pavement an approved curing membrane must be sprayed on all exposed surfaces using a self-propelled mechanical sprayer with adequate shielding from wind. The curing membrane must be applied at a minimum rate of 1 gallon per 150 square feet as soon as the free water has dissipated from the surface. Approved liquid membrane curing compounds are white in color so that coverage can be readily observed. They are sprayed over the exposed concrete faces while the concrete is still plastic. Hand spraying can be used on pavement with integral curb, for small irregular areas, sections of variable width, and on pavement edges after form removal.

Project inspection should include a daily check of the Contractor’s curing compound application rate to assure that the correct amount of curing membrane was applied to the pavement. To do this check determine the amount of curing compound required for the days placement and compare it to the amount of curing compound actually used by the contractor.

To calculate the amount of curing compound required, the area in square feet (square meters) of pavement that is to be cured must be determined. This area includes the top surface of the pavement plus the area of any pavement edges that are to be cured if the contractor is slip form paving. Once the area has been calculated it is divided by the specified application rate in gallons per square yard (liters per square meter). The formula below is used to calculate the required amount of curing compound in gallons (liters):

$$\textit{Required Gallons} = \frac{\textit{Area (square feet)}}{\textit{Rate (gallons/ square feet)}}$$

$$\textit{Required Liters} = \frac{\textit{Area (square meters)}}{\textit{Rate (liters/square meter)}}$$

The above equations give the amount of curing compound required in gallons (liters). The amount of gallons (liters) required is compared to the amount that was actually used during the day's work. The amount of gallons (liters) of curing actually used must be equal to or greater than the required amount of gallons (liters).

If properly applied, these membrane-forming compounds prevent evaporation and the retained water provides excellent curing. Therefore, make sure that the specified rate of application is adhered to and that the curing compound is applied evenly. This ensures that a uniform thickness of membrane coating is obtained. If this is not done, the quality of the concrete pavement will be affected. It should be noted that concrete with a grooved (tined) surface may require more curing compound to obtained complete coverage that a base pavement without tining. The specified application rate is a minimum and the Contractor must use more if the visual coverage is lacking.

White pigmented compound is the only membrane curing compound acceptable on paving projects. This has an advantage over clear type compounds in summer construction in that it provides a coating that reflects heat from the surface. This decreases heat absorption in the pavement and the tendency for transverse cracks to develop during warmer afternoon temperatures. In addition, its white color permits visual inspection for uniform coverage.

The white pigment used in the membrane acts as an abrasive that tends to enlarge the apertures of the spray nozzles and to reduce the efficiency of pumping equipment. Equipment used to apply membrane should be cleaned frequently and checked to see that it is providing a uniform protective covering. Streaks, lines, and dribbles indicate malfunctioning sprayers. The Contractor must correct the equipment to provide uniform, consistent coverage over the entire pavement.

Cure /Texture Machine Applies Curing Compound After Transverse Grooving

Water Curing

A water cure using wet burlap, waterproof paper, or polyethylene sheeting may be used however this type of curing must remain in place for 7 days unless test beams have attained a modulus of rupture of 600 psi. This type of curing should be placed as soon as possible without marring the surface.

The contractor may choose to water cure by placing wet burlap on the exposed surfaces followed by waterproof paper or polyethylene sheeting. Make sure that the pavement is kept wet at all times. This type of curing requires constant checking throughout the curing period. This method is not used very frequently and therefore is not discussed in detail.

Waterproof paper or polyethylene meeting specification requirements (705.05 and 705.06 are placed on the concrete as soon as possible after finishing without marring the surface and are left in place for the full curing period.

The combination of wet burlap and waterproof paper or polyethylene sheeting is less labor intensive than a burlap-only cure because it will keep the concrete wet and does not require regular wetting.

Curing blankets, sheeting, and burlap should be placed to cover the full lane width and lapped at least 12 inches (0.3 m). Edges should be completely covered when forms are removed. This may be done by turning down the edge of the blankets or narrow strips pulled out from under them. These narrow strips are placed on the concrete before main sheets are laid.

Curing materials should never be dragged over fresh concrete and should be placed so as not to mar the surface. One of the principal precautions in this curing method is to make sure edges along forms are sealed so that there is no possibility of air getting under the curing material. This is important because air can circulate over the pavement drying out the surface and resulting in inadequate curing. In addition, heavy winds will get under the blankets and rip them off leaving the pavement without any curing at all.

All physical curing blankets, sheeting, etc, must be free of holes and torn areas and it must be securely anchored against blowing. These types of curing methods must be checked daily.

Removing Forms (451.11)

The presence of forms during early curing protects the pavement edges against damage and serves as a curing method (for the pavement edges).

During warm weather, the common procedure is to remove the forms approximately 24 hours after the concrete is placed. During cold weather, it may be advisable to leave forms in place for a longer period. In any event, forms should not be removed until the concrete has attained sufficient strength to prevent damage to the concrete surface or breaking of the edges during removal.

The method used to remove the forms should not damage the concrete pavement. In addition, the Contractor should be encouraged to use a method that will not bend or otherwise damage the forms. The method used to move forms away from concrete should ensure that each form section is pulled horizontally away from the edge before it is lifted.

Pin keys should be loosened first, form joint locks unfastened, and nuts removed from the ends of hook bolts (single lane paving). Then, pins should be removed from their sockets using a direct vertical lift without any pressure toward the concrete. The action necessary to exert the vertical lift should be from the forms or the ground outside forms. If any equipment is used to pull pins that may ride on the concrete, make sure that no pressure is on the concrete other than the weight of the equipment.

After pins are removed and other preliminary work finished, light blows with a hammer or careful prying on base flanges may be used to separate forms from concrete. Prying against the concrete edges with bars to break forms loose should never be permitted.

When forms have been removed, edges should be checked immediately and honeycombed areas filled with mortar. Inspect filled areas to make sure the entire areas are tightly packed and struck off flush with surface of the pavement edge.

Curing must be applied to the edges as soon as forms have been removed and edge patching has been completed. This assures satisfactory curing as well as preventing the loss of water necessary for hydration of the cement.

Surface Smoothness (451.12)

There are two methods that could be used to check the smoothness of a completed concrete pavement. Item 451.12 requires the use of a 10-foot rolling straightedge or Proposal Note (PN) 420 that requires the use of a non-contact profiler to measure smoothness. When PN 420 is required as part of the contract documents, 451.12 does not apply.

When 451.12 apply, the Contractor is required to check the surface smoothness of the completed pavement using a 10-foot rolling straightedge. The rolling straightedge can be a two- or four-wheeled with an indicator wheel in the center that detects high and low areas in the pavement surface. This equipment must alert the operator when encountering any high or low areas of pavement in excess of a preset tolerance. This alert may be by a pointer scale, by audio, or by marking the pavement surface with dye or paint.

Testing is done after the final curing and cleaning of the pavement to detect any surface variations that are in excess of the allowable tolerances. For pavements, the tolerance is 1/8 inch in 10 feet (3 mm in 3.0 m). For ramp pavements and for those pavements that exceed an 8-degree curvature or 6-percent grade, the tolerance is 1/4 inch in 10 feet (6 mm in 3.0 m).

10-foot Rolling Straightedge

The Contractor must tow or walk the equipment over the completed pavement. The Contractor must test two lines, one in each wheel path, in each 12-foot (3.6

meter) lane. The wheel paths are located 3 feet (1 m) measured transversely from the pavement edge on each side.

Proposal Note 420 – Surface Smoothness Requirement for Pavements

Larger concrete paving contracts (those exceeding 1 mile in centerline length) generally include Proposal Note (PN) 420 *Surface Smoothness Requirements for Pavements*. When this proposal note is included, the provisions of 451.12 do not apply and the Contractor is required to use the information included in PN 420 to determine surface smoothness. This proposal note requires testing of the surface of completed pavement with a non-contact profiler and software that will produce an International Roughness Index (IRI).

The non-contact profiler must meet the requirements of Supplement 1058. The equipment and operator must be previously approved by the Department. All equipment and operators that are approved are listed on the Department's web site. The equipment and operator must be checked against the Contractor's approval letter and against the Department's web site. The Contractor must demonstrate the use of the equipment prior to its use on the project.

Low Speed Non-Contact Profiler used to Measure Pavement Smoothness

Low Speed Non-Contact Profiler used to Measure Pavement Smoothness

The Contractor is paid a bonus for exceptionally smooth concrete pavement and there are deductions if the pavement is not constructed smooth enough. The pavement must be of a certain level of smoothness to be accepted otherwise, corrective work is required. The IRI is measured for localized roughness for any 25 feet section and for smoothness of any 0.10 mile section. Where there is localized roughness with an IRI greater than 160 inches per mile in 25 feet corrective work is required. For an IRI greater than 95 inches per mile in any 0.10 mile section, corrective work is also required.

Defective work as described under PN 420 includes removal and replacement , or diamond grinding to restore the surface to within the tolerances required.

Profile Grinding (451.13)

When 451.12 applies and the surface deviations as measured with the 10-foot rolling straightedge must be ground the diamond grinding equipment must conform to Item 257. Bush hammering, carbide tipped grinders, or any method that may damage the bond of the aggregate or shatter the aggregate is not permitted

A 10-foot (3.0 meter) straightedge must be used to check for compliance when corrective work is in progress. The straightedge can also be used to determine the transverse limits of the area to be corrected. Usually variations extend beyond the wheel path and may require diamond grinding and grooving the entire lane width. This determination can only be made by checking with a straightedge.

Low areas should be corrected by grinding on each side until within tolerance. If these areas cannot be corrected by grinding, they must be repaired or replaced to the satisfaction of the Engineer.

Pavement Grooving (451.14)

It may be necessary to restore transverse grooves in concrete pavement after the concrete has hardened when the finishing operation did not conform to 451.09 and, or when the tining operation did not provide the correct pattern or depth. Grinding to restore trueness leaves a corduroy texture in the longitudinal direction. The randomly spaced transverse grooves must be restored as detailed to the dimensions given in 451.09.

The equipment required for transverse grooving must be self-propelled, power driven machines specifically designed to groove hardened concrete pavement with diamond impregnated blades or diamond impregnated cylinder rings. The blades or cylinder rings must be mounted on an arbor head so that the resulting grooves are randomly spaced. The grooving equipment must have a depth control device that detects variations in the surface and adjusts the cutting head to maintain the proper groove depth.

Note that when pavement is ground to meet the requirements of 451.12 Surface Smoothness or PN 420, the restoration of transverse grooving is not required.

Sealing Expansion Joints (451.15)

Only expansion joints are required to be sealed. This should be done as soon as possible after saw cutting and before the pavement is open to construction equipment or any other traffic. Proper sealing prevents intrusion of stones and debris into the joint that would keep it from opening and closing as designed with the movement of the pavement.

The Engineer may allow the use of a temporary seal material to allow opening to traffic. This material must be removed prior to the final sealing of the joint.

All joints must be cleaned prior to filling. Cleaning consists of operating a saw blade backward through the saw groove to remove all pebbles, trash, dirt, etc. Any other operation which satisfactorily cleans the groove is permissible. The final step in cleaning consists of blowing out the joint opening using compressed air or by a jet of clean water.

Hot-applied joint sealer (705.04) is required for sealing expansion joints. Since the hot applied sealer requires heating, frequent checks should be made to avoid overheating to a temperature higher than the manufacturer’s recommendation.

Joint walls must be inspected just ahead of filling to make sure that they are dry and thoroughly clean. It is essential that the walls be in this condition if the sealer is to function properly. If the sealer fails to adhere to the concrete, water and foreign material will enter the joint.

Pour liquid sealing compounds in such a manner that complete filling from the bottom of the joint slot to approximately level with the surface of the pavement is assured. With some compounds it may be necessary to fill the joint in several applications. Workers should not allow the sealing compound to spatter or drip onto the adjacent pavement.

The sealing material will run to the low side if the joint is filled too fast. Hot poured compounds may flow out of the joint at the edge of the pavement if some method of plugging the edge is not used.

As air temperature increases, the pavement will expand or lengthen and the joints will close. Conversely, the slabs contract as the temperature falls, causing the joints to open. Joint filling should be such that the surface of the hot-applied sealing material will be approximately level with the pavement surface when the pavement temperature is about 70 °F (21 °C).

Never over-fill a joint to the extent that a bump will be produced at the joint. Such a practice is a waste of material, creates an unsightly condition, and affects the riding quality of the finished pavement. The bumps created by the excessive material will be readily noticeable to the traveling public from a smoothness standpoint, as vehicles pass over each joint.

Prior to final acceptance of the pavement any unsatisfactory joint seal should be removed and replaced. All low spots in sealing compounds must be brought to the desired level, and any high spots should be cut off and the excess material removed.

Opening to Traffic (451.16)

The completed pavement may be opened to traffic, including construction traffic, after 7 days have elapsed. Or the pavement may be opened to traffic after 5 days provided the modulus of rupture of the test beams is 600 pounds per square inch (4.2 Mpa) or greater.

If it is determined that it will be necessary to open a portion of the pavement in fewer than 5 days, high early strength concrete shall be used, and the pavement may be opened to traffic after 3 days provided the test beams attain a modulus of rupture of 600 pounds per square inch (4.2 Mpa) or greater. In no case should concrete pavement be opened in less than 3 days.

Concrete test beams are required for each 7,500 square yards (6,500 square meters), or fraction thereof, of pavement placed each day. Instruction for making and testing beams are found in Item 499. Beams are tested at the project by the project personnel.

Beams normally are tested at 5 and 7 days. If results are not needed before the end of 7 days, only one beam break is necessary. This break should be made at the age of 7 days.

The maximum capacity of the beam breaker is 1,000 pounds per square inch (6.7 Mpa) and is marked on the beam breaker dial. The capacity must not be exceeded. Beams that do not break when loaded to the capacity of the breaker should be recorded as >1,000 psi (>6.7 Mpa) or whatever the unbroken strength was when the test was stopped, such as 850 psi + (5.9 MPa +) for example.

Slump, air, and yield tests shall be made and recorded each time beams are cast. Concrete for these tests shall be obtained from the same batch of concrete as that was used in casting the beams.

The Contractor is responsible for repairing cracked or deficient pavement at no cost to the Department. These deficiencies include:

- Transverse or diagonally cracked full depth pavement
- Longitudinal cracked full depth pavement
- Spalled pavement surfaces
- Pavement panels which have cement or mud balls

Repair methods are specified in 451.16 and include the following:

1. **Transverse or diagonally cracked full depth pavement**. Repair with a full depth repair according to Item 255 and applicable standard construction drawings. Repair cracks by replacing the pavement the full width and full depth between longitudinal joints, perpendicular to the centerline and at least 6 feet (1.8 m) longitudinally. Install smooth dowel bars at the interface between the original pavement and the replaced pavement section. Locate and size the repairs to ensure that the repair limits are at least 7 feet (2.1 m) away from any transverse joint. Item 255 and Standard Construction Drawing BP-2.5 applies.
2. **Longitudinally cracked full depth pavement**. Repair longitudinal cracks within 15 inches (380 mm) of a tied longitudinal joint by routing and sealing the crack according to Item 423. For longitudinal cracks beyond 15 inches (380 mm), repair the same as for transverse or diagonal cracks stated above.
3. **Spalled pavement surfaces**. Repair spalled pavement with Item 256, Bonded patching of Portland cement concrete pavement.
4. **Pavement panels which have cement or mud balls**. Repair cement balls or mudballs by coring out the area, full depth with a diamond core bit and replacing the removed concrete with the same concrete as in the pavement. Remove and replace any pavement panel with 5 or more cement balls or mudballs. Locate the limits of the repair along the longitudinal joints and at least 1 foot (0.3 m) past the transverse joints to remove any existing dowel bars. Install smooth dowel bars at the transverse limits of the repairs. Install Type D (Drilled Tied Longitudinal) Joint along the longitudinal limits.

Pavement Thickness (451.17)

The Contractor must cut cores from the completed pavement to check the pavement thickness and to determine a price adjustment if necessary. When the constructed pavement thickness is less than plan by more than 0.2 inches a deduction to the contract bid unit price is made.

One random core must be taken for every (Lot) 2,000 square yards (1,650 square meters) of a pavement unit or a major fraction thereof. Not less than 3 cores will be cut for any pavement unit. For the purpose of coring, the Department will consider the entire pavement area of a specified thickness a unit. The Engineer will determine the locations for the random cores according to Supplement 1064.

Core thickness must be measured by the Engineer in accordance with AASHTO T 148. When a core shows a deficiency in thickness of more than 1/2 inch (13 mm) from the specified thickness the Contractor must take additional cores as directed by the Engineer to determine the limits of the deficiency. Follow the procedures below to determine how and when to cut additional cores:

1. Take a core five (5) feet (1.5 m) longitudinally on both sides of the deficient core. If both cores are less than 1/2 inch (13 mm) deficient in thickness; the zone of deficiency has been determined.
2. If either or both cores are more than 1/2 inch (13 mm) deficient in thickness; cut a core 50 feet (15 m) longitudinally from the deficient core(s). If the 50 foot (15 m) core(s) is more than 1/2 inch (13 mm) deficient, cut additional cores in 100 foot (30 m) longitudinal intervals until a core is less than 1/2 inch (13 mm) deficient in thickness; until the pavement ends; or until overlapping an adjacent pavement Lot's core in the same lane.
3. If a pavement Lot has cores more than 1/2 inch (13 mm) deficient in thickness and the Lot's constructed width is greater than 12 feet (3.6 m) obtain cores transverse to the location of the more than 1/2 inch (13 mm) deficient cores. Obtain transverse cores at a location 1/2 the distance from the deficient core to the furthest edge of pavement. Obtain transverse cores for each core more than 1/2 inch (13 mm) deficient in thickness.
4. The Engineer will use the cores that measure less than 1/2 inch (13 mm) deficient in thickness to define the limits of the deficiency. The price adjustment would apply to these limits of deficiency. Note that zone of deficiency is also called zone of deficient thickness.

Price adjustments are based on the pavement average thickness. The pavement is to be constructed such that the thickness is not more than 0.2 inches (5 mm) less than the specified thickness at any location. When this criterion is met the Contractor receives 100% of the contract bid price.

When a core or cores are greater than 1 inch deficient in thickness, the pavement must be removed and replaced. The Zone of Deficiency for the removal is determined as outlined above.

For zones of deficiencies with pavement thickness 1/2 inch to 1 inch deficient the Engineer must calculate the average thickness of concrete pavement to determine price adjustments.

Two averages must be calculated as follows:

1. Calculate a Project Average Thickness (PAT) using all cores from all lots that are ≤ 1/2 inch deficient in thickness.
2. Calculate a Deficient Zone Average (DZA) using all cores with a thickness deficiency of >1 1/2 inch.

Notes: When calculating PAT: Cores > 1/2 inch thicker than the plan thickness are considered to be plan thickness + 1/2 inch for the PAT calculation. For example if plan thickness is 10 inches and the core measured 10.75 inches, use 10 inches + 1/2 = 10.5 inches when calculating the PAT.

The PAT and DZA are used to determine the price adjustment for each section of deficient pavement using the zone of deficiency area previously determined based on the coring operation.

The following table illustrates how the price adjustment is applied:

Table 451.17-1 Concrete Pavement Deficiency

Deficiency in Thickness as Determined by Cores	Proportional Part of Contract Price
0.0 to .2 inch (0.0 to 5 mm)	100 percent
0.3 to 0.5 inch (6 to 13 mm)	$\text{Ratio}\left[\dfrac{PAT}{PST}\right]^6$
0.6 to 1.0 inch (15 to 25 mm)*	$\text{Ratio}\left[\dfrac{DZA}{PST}\right]^6$
Greater than 1.0 inch (25 mm)	Remove and replace

*The District Construction Engineer will determine whether pavement areas from 0.6 inch (15 mm) up to 1 inch (25 mm) deficient in thickness will be allowed to remain in place at the reduced price or must be removed and replaced.

If any deficient core is greater than 1 inch (25 mm) deficient in thickness determine the limits of over 1 inch (25 mm) deficiency by following 451.17, steps 1 thru 4 to determine the limits. Remove and replace those areas greater than 1 inch (25 mm) deficient in thickness.

The Contractor must fill all core holes using the same concrete used in constructing the pavement. When filling the core hole, the surface should be damp and should be painted with a grout consisting of cement and water having the consistency of a thick paint. Stiff concrete should then be rodded into the core hole before the grout dries. The surface should be struck off, and curing membrane applied to provide curing essential for a durable repair.

The pavement areas represented by the PAT of DZA are to be calculated and paid separately.

Deductions are determined and applied to each separately placed width of pavement.

If any pavement area is removed and replaced the replaced pavement must be cored and core values determined are to be included in the average calculations.

Example

A Contractor places 150,000 square yards of 10 inch concrete pavement. The contract price is $38.00 per square yard. If the project average thickness (PAT) is 9.7 inches and the plan specified thickness (PST) is 10 inches, what would the Contractor be paid?

The thickness deficiency is: 10” – 9.7” = 0.3”

From Table 451.17-1 look up the price adjustment for a 0.3” thickness deficiency.

Use that formula to determine the Proportion Part of Contract Price as follows:

$$\text{Proportion Part of the Contract Price} = \left[\frac{PAT}{PST}\right]^6 = \left[\frac{9.7}{10}\right]^6 = 0.8330$$

Then the Contractor’s Payment for 150,000 sq. yd is calculated as follows:

(150,000 sq. yd.) X ($38.00 per sq. yd.) X (0.8330) = $4,748,100

Note that this results in a deduction of $951,900 for this pavement area.

Method of Measurement (451.18)

Concrete pavement is measured by the number of square yards (square meters) completed and accepted in place. The width of pavement used to calculate the area equals the pavement width shown in the typical sections of the plans. The Engineer will measure the length along the centerline of each roadway or ramp.

Irregular areas of pavement should be field measured and the area calculated in square yards (square meters) for payment.

Any plan changes that involve concrete pavement quantities must be shown fully documented. In addition, any areas found to be deficient in thickness must be documented and the adjustment made in the pay quantity.

Basis of Payment (451.19)

Payment is made for accepted quantities of pavement by the square yard (square meter) at the contract bid price. If pavement is found to be deficient in thickness, the Department will pay a reduced price according to 451.17.

There is no additional payment for any pavement constructed and found to have an average thickness in excess of the thickness specified.

Documentation Requirements - 451 Reinforced Portland Cement Concrete Pavement

1. Document subgrade/subbase preparation
2. Document contraction, expansion, and longitudinal joints dowel and tiebar sizes, type; coating; support; placement; spacing
3. Document forms set 100% bearing, correct alignment and grade, rigid, clean and oiled
4. Document length of lap, clearance maintained on steel mesh
5. Document contraction joint spacing; free ends of dowels oiled, dowel assembly tie wires cut; number and size of pins used to hold dowel assembly, alignment of dowels.
6. Document concrete placement including all quality control testing; method of placement, finishing, tining, curing (type and amount), stamping of stationing, weather conditions.
7. Document use of HIPERPAV software, time of sawing, depth and width of sawed joints.
8. Document coring for thickness verification and results.
9. Record results of beam breaks and opening to traffic.
10. Measure length and width for pay.
11. Document on CA-D-3A or CA-D-3B or other approved forms.

452 NON-REINFORCED PORTLAND CEMENT CONCRETE PAVEMENT

Description (452.01)

This item of work involves construction of a non-reinforced Portland cement concrete pavement on a prepared surface. The same methods and practices are utilized in the construction of 452 pavement with some exceptions are listed below. The major difference between 451 and 452 pavement is the elimination of the steel reinforcing mesh in the 452 specification.

Construction (452.02)

Non-reinforced Portland cement concrete pavement is constructed in accordance with 451 with the following exceptions:

1. Reinforcing mesh specified in 451.07 is not required.
2. Dowels are required in transverse contraction joints in mainline pavement, ramps, acceleration/deceleration lanes, and collector/ distributor lanes <u>but not</u> in concrete shoulders adjacent to the above-listed pavements unless the contraction joints are within 500 feet (150 m) of a pressure relief joint.
3. The spacing of contraction joints in 452 is 15 feet (4.6 m) unless the 452 pavement is placed as a shoulder tied to 451 or 305 pavement. In this case the joints in the 452 pavement must match the spacing, alignment, sawing, and sealing requirements of the adjacent pavement.
4. Construction joints in 452 pavement must not be located closer than 6 feet (1.8 m) from another parallel joint.

Method of Measurement (452.03)

Non-reinforced Portland cement concrete pavement is measured by the square yard (square meter) of pavement completed and accepted. All of the provisions of 451 method of measurement apply to 452.

Basis of Payment (452.04)

Payment for 452 pavement is the same as for 451 pavement. Payment is made for accepted quantities of pavement by the square yard (square meter) at the contract bid price. If pavement is found to be deficient in thickness, the Department will pay a reduced price according to 451.17.

There is no additional payment for any pavement constructed and found to have an average thickness in excess of the thickness specified.

Documentation Requirements - 452 Non-Reinforced Portland Cement Concrete Pavement

1. Document subgrade/subbase preparation
2. Document contraction, expansion, and longitudinal joints dowel and tiebar sizes, type; coating; support; placement; spacing
3. Document forms set 100% bearing, correct alignment and grade, rigid, clean and oiled
4. Document length of lap, clearance maintained on steel mesh
5. Document contraction joint spacing; free ends of dowels oiled, dowel assembly tie wires cut; number and size of pins used to hold dowel assembly, alignment of dowels.
6. Document concrete placement including all quality control testing; method of placement, finishing, tining, curing (type and amount), stamping of stationing, weather conditions.
7. Document use of HIPERPAV software, time of sawing, depth and width of sawed joints.
8. Document coring for thickness verification and results.
9. Record results of beam breaks and opening to traffic.
10. Measure length and width for pay.
11. Document on CA-D-3A or CA-D-3B or other approved forms.

499 Concrete - General

Control of concrete is divided into two categories: large quantity-critical usage and small quantity non-critical usage. All pavement and structure concrete, and in general any other concrete usage exceeding 200 cubic yards (150 cubic meters) per day, is considered large quantity critical usage.

When placing small quantity non-critical usage concrete from sources having a record of supplying approved material, the concrete may be accepted by field tests and backed up by random test beams, concrete cylinders, and random plant inspections as deemed necessary by the Engineer. The following list shows examples of small quantity non-critical usage concrete:

1. Sidewalks - Not to exceed approximately 500 square yards (418 square meters) per day.
2. Curbing, combination curb and gutter - Not to exceed approximately 500 linear feet (152 linear meters) per day.
3. Patching and temporary pavements.
4. Building foundations and floors.
5. Slope paving and paved gutter.
6. Guardrail and fence post anchorages.
7. Metal pile castings.
8. Culvert headwalls.
9. Catch basins, manhole bases, and inlets.
10. Sign, signal, and light bases.

Acceptance of concrete under the small quantity non-critical usage procedure does not waive the responsibility for using approved materials. Concrete accepted under these provisions must be reported using an abbreviated TE-45 form along with company tickets indicating quantity, class, slump, and air test results and time of batching.

At least one concrete control inspector must be present whenever small quantity non-critical usage concrete is being placed, and two or more inspectors are required for large quantity critical usage placement.

Introduction

Concrete used in highway construction is a mixture of coarse aggregate, fine aggregate, Portland cement, water, entrained air, and permissible mineral or chemical admixtures. In this mixture, each aggregate particle is completely coated by a paste of cement and water. This paste binds the aggregate particles into a mass called concrete. The cement paste can consist of Portland cement, fly ash, ground granulated blast furnace slag, or microsilica, water, air voids, and any admixtures. The cement paste comprises from 25 to 40 percent of the total concrete volume. To have quality concrete it is necessary that both aggregate and paste be sound and durable.

Aggregate, cement, and admixtures to be used in concrete are sampled and tested by the Laboratory to assure that ingredients meet quality standards. However, the quality of the paste depends on proper construction techniques. These techniques include the minimum use of water, and favorable temperature and humidity during the curing period.

Approximately 30 pounds of water is required to complete the chemical reaction with 100 pounds of cement. Although a small amount of water is needed to complete the chemical reaction with cement, additional water is necessary to make the concrete workable. As the paste is thinned out with water, its quality is lowered: it will have less strength and less durability. For quality concrete, a proper proportion of water and cement is essential. This proportion is called water-cement ratio. The water-cement ratio is determined by dividing the weight in pounds (kilograms) of the total actual mixing water by the weight in pounds (kilograms) of cement used in the mix. A maximum water-cement ratio is specified to avoid excess water and to assure quality paste and, therefore, quality concrete.

To provide a dense mixture of the aggregate, cement, and water, it is necessary to have various sizes of aggregate particles so that the smaller particles fill the voids between the larger particles. Therefore, aggregate is divided into two categories: coarse aggregate and fine aggregate. Coarse aggregate is aggregate with 95 to 100 percent of its particles larger than the 4.75 mm (No. 4) sieve. Fine aggregate is aggregate with 95 to 100 percent of its particles smaller than the 4.75 mm (No. 4) sieve. Coarse and fine aggregate are graded, that is, they contain several sizes of particles combined together. When placed in concrete, these various sizes of particles become coated with the cement paste and form a dense mass with the voids filled.

In addition to requirements that it be strong and dense, concrete must be durable. Durability means resistance to the elements. Concrete that is not exposed to the elements such as water, freezing, and thawing, generally will be durable. When non-durable concrete is subjected to these destructive forces, scaling and deterioration generally follows and progresses with each cycle of freezing and thawing unless preventive measures are taken. In order to provide concrete with additional durability, an air-entraining admixture is added to the concrete to generate billions of air bubbles of microscopic size in the concrete. This air-entraining agent may be interground with the cement, or it may be an admixture, or both. These microscopic air bubbles form in the paste of the concrete as it hardens and create tiny air pockets in the hardened concrete. When moisture is present and freezing takes place in air-entrained concrete, the water expands and moves through capillaries to these very small air pockets and the expansive force is relieved. Without these relief air pockets, the forces created by the expanding ice formation would rupture the concrete at its surface. This rupturing is known as scaling.

Basically, this is the theory of concrete mixes. Quality concrete consists of a mixture of sound, durable, graded fine and coarse aggregate, together with cement, water, and air entrainment. When properly mixed, placed, and cured, the resultant concrete has strength and durability, and provides the service life for which it was designed. Only by vigilant inspection can fulfillment of these requirements be assured.

Duties and Responsibilities

The concrete control inspector is responsible for the fulfillment of all required tests and enforcement of all specification requirements for concrete. The Inspector cannot alter or waive any provision of the proposal, plans, or specifications. Any failure of the work or materials to conform to specifications must be corrected immediately. If necessary, production must be stopped for correction rather than permitting work that does not meet specification requirements to proceed. The Inspector must notify the Contractor and the Engineer of such action. The Inspector's duties include verifying that approved materials are used, performing tests as outlined in this manual, adjusting the mix as required, and enforcing the mixing requirements for the mixes used.

Copies of forms to be filled out or verified by the Inspector are interspersed within the text of this section and the use of the forms is described.

Materials (499.02)

All materials to be used in the production of concrete must be tested and approved or accepted by certification prior to use. A copy of the Laboratory report or e-mail indicating approval of material must be in hand before a material is used. When necessary, material may be used when notification of its approval has been given by phone from the Laboratory, provided the phone approval is recorded in the project records prior to use. When written approval is received, it is filed in the project records. No material is used unless it is determined that it has been approved.

Portland Cement

Cement generally is shipped in bulk quantities by truck from the cement plant or terminal to the concrete plant. The cement normally will be from a plant operating under the "Cement Certification Procedure" outlined in Supplement 1028 and will require a ½ gallon sample which equals to a 10-pound (4.6 kg) sample every 180 days from each ready mixed concrete plant. The Office of Materials Management (Laboratory) or the District Test Lab typically samples Portland cement.

Normally Type I Portland cement (701.04) is used. However, the general specifications permit the use of Type IA air entraining Portland cement (701.01), Type II moderate sulfate resistant Portland cement (701.02), Type III high-early strength Portland cement (701.05), and Type I(SM) Portland blast furnace modified slag cement (701.09).

An approved air-entraining admixture is required to provide the specified air content when non-air entraining cements are used and may be required if air-entraining cement is used to obtain the proper amount of air.

Type I (SM) Portland blast furnace modified slag cement (701.09) may be used only between April 1 and October 15. This type of cement is not permitted with Proportioning Option 1 (the fly ash option) or Proportioning Option 3 (the ground granulated blast furnace slag option). Only Type I (701.04) Portland cement is permitted in High Performance concrete (Class HP1, HP2, HP3, and HP4).

If high-early-strength concrete is specified, Type III must be used. If high-early-strength is not specified but it is desirable to accelerate the strength gain to expedite the work, the Contractor may use, at his own expense, high-early-strength cement (Type III), additional cement, approved chemical admixtures, or a combination of these materials.

If moisture is exposed to cement prior to mixing, it may cause the concrete to have slower setting time and reduced strength. Therefore, cement must be stored in waterproof bins or silos.

Truck transports generally load the cement into the storage bins using compressed air, so it is important that adequate vents are placed at the top of the bins. Unless adequate vents are provided, cement must not be loaded at the same time concrete is being batched. Small or restricted vents may be inadequate and could result in inaccurate weighing of the cement at the time cement was being loaded into the bins.

Aggregate

Fine and course aggregate must be approved prior to use under the Supplement 1069, “Pre-qualified Aggregate Supplier Program” and meet the requirements of 703.01. Pre-qualified aggregate suppliers/producers are listed on ODOT’s website.

Controlling the use of aggregate is the responsibility of project personnel, while the Laboratory is responsible for approving material.

Fine Aggregate

Fine aggregate for concrete includes natural sand and sand manufactured from stone. Natural sand is required to be used in any exposed concrete riding surface including 255, 256, 451, 452, 526, and 511(bridge deck concrete).

Fine aggregate consists of relatively small particles and does not tend to separate as much as coarse aggregate. Therefore, segregation generally is not a problem with the fine aggregate unless extremely careless methods of handling are employed.

Coarse Aggregate

If concrete is used for 305, 451 or 452 pavement it must also comply with 703.13 which is a test for freeze-thaw resistance (D-cracking susceptibility).

Coarse aggregate is a graded material consisting of a combination of various particle sizes that require extreme care when handling to prevent the smaller particles from separating from the larger ones. The separation that may occur during handling is known as segregation. If aggregate is dropped from a bucket or from a belt and allowed to form a cone-shaped stockpile, or if it is pushed over the edge of a stockpile, the larger aggregate particles will roll to the bottom, outside edge, of the pile. The smaller particles have less tendency to roll because of their small size and weight and remain closer to the center. This results in a segregated stockpile. Non-uniformity results when such material is used in the concrete mix and difficulty can be encountered in controlling the water demand, slump, and yield of the resultant concrete.

Coarse aggregate must be maintained with uniform moisture content above saturated surface dry condition. Watering or sprinkling of aggregate may be desirable to provide concrete of uniform slump, to lower the aggregate temperature during hot weather, in addition to overcoming the possibility of a rapid slump loss. When placing concrete during freezing weather, however, it is impractical to water a stockpile to maintain uniformity.

When sprinkling is desirable, it should be done in advance of use so that the water will be distributed uniformly throughout the stockpile. If stockpiles are large or contain aggregate having high absorption, such as slag, it may be necessary to start watering several days in advance. However, the sprinkling should be discontinued to permit excess moisture to drain off overnight.

Microsilica

Microsilica, also known as silica fume or condensed silica fume, is a pozzolanic admixture that must comply with 701.10. In its finely-divided form and in the presence of water, it will chemically react with calcium hydroxide released by the hydration of Portland cement to form compounds with cementitious properties. This light to dark gray powdery product is the result of the reduction of high-purity quartz with coal in an electric arc furnace in the manufacture of silicon or ferrosilicon alloys. Silica fume rises as an oxide vapor from a furnace 3,630° F (2,000° C). It cools, condenses, and is collected in cloth bags. The condensed silica fume is then processed to remove impurities and control particle size.

Condensed silica fume particles are 100 times finer than cement particles. The specific gravity of silica fume varies between 2.10 and 2.25 but can be as high as 2.55. When used in concrete it will fill the void space between cement particles resulting in impermeable concrete.

Microsilica or condensed silica fume is provided in dry densified powder form and must be protected from moisture. The microsilica normally will be from a plant operating under the "Microsilica Certification Procedure" outlined in Supplement 1045 and will require a 10-pound (4.6 kg) sample every 180 days from each ready mixed concrete plant.

Ground Granulated Blast Furnace Slag (GGBFS)

Ground Granulated Blast Furnace Slag (GGBFS) is a material that may be allowed or required by certain specifications. It is used as a cement replacement. The GGBFS material is produced from granulated blast furnace slag granules that are ground to a consistency somewhat finer than cement. The granules are produced by tapping molten slag from an iron blast furnace and using high-pressure water to rapidly quench the material. The granules produced have a consistency and color of sand and are composed primarily of glass. The granules are then ground in a cement mill into a fine white powder.

The material is required to meet the ASTM C 989 Specification. This specification identifies three grades of material: Grade 80, Grade 100, and Grade 120. Only Grades 100 and 120 are permitted under the Department's specifications. GGBFS generally is shipped in bulk quantities by truck from the cement plant or terminal to the concrete plant. The GGBFS normally will be from a plant operating under the "GGBF Slag Certification Procedure" outlined in Supplement 1034 and will require a 10-pound (4.6 kg) sample every 180 days from each ready mixed concrete plant.

Concrete produced using GGBFS will have a slower strength gain in cooler temperatures than normal mixes without it. Because of this, there are certain prohibitions for its use during cooler temperatures; GGBFS must be kept dry as with Portland cement and fly ash. It is handled generally in the same manner as cement and fly ash. It is normally delivered in bulk; however, for a small project it can be provided in bags. In either case, it should be stored in a dry location.

Fly Ash

When coal is used to fire the boilers of modern power stations it is first finely ground or pulverized to the fineness of face powder before being fed into the furnace. The burning powdered coal gives off heat to generate electricity, any coarse particles fall to the bottom of the furnace, and hot gasses given off are swept away to be exhausted up the chimneystack. The fine particles that are in this exhaust and which are trapped before passing into the atmosphere are "fly ash." During the combustion process, the bulk of these particles assume an almost spherical shape, like microscopic ball bearings. One of the properties of fly ash is that, in the presence of hydrating Portland cement, it behaves like cement. Fly ash reacts with calcium hydroxide to form compounds possessing cementitious properties.

Two classes of fly ash are allowed for concrete in 701.13. The two classes are Class F and Class C. Class F fly ash is produced from burning anthracite or bituminous coal. Class C fly ash is produced from burning lignite or sub-bituminous coal. Class F fly ash is the type normally found in Ohio. However, Class C fly ash is also becoming available to concrete producers now. Class C fly ash has some cementitious properties by itself while Class F does not.

Fly ash used in Department work must meet the requirements of ASTM C 618 except the maximum loss on ignition (LOI) must not exceed 3 percent. The LOI is a measurement of the carbon content or unburned coal in the fly ash. In order to maintain air entrainment at a particular level (in concrete containing fly ash), the fly ash must have a low LOI. The ASTM specification allows a higher LOI than our specifications. ODOT specifications require the lower LOI to minimize problems entraining air in the concrete.

Fly ash will normally be shipped in bulk quantities by truck from the power station to the concrete plant. Fly ash, like cement, has a certification process. This process is described in Supplement 1026, "Fly Ash Certification". Certified fly ash requires a half-gallon (2L) sample every 180 days from each ready mixed concrete plant. Non-certified fly ash shall be sampled every 100 tons (91 metric tons) and be approved prior to use.

Concrete containing fly ash is permitted only between April 1 and October 15 due to slow strength gain in cold temperatures.

Bulk fly ash must be stored in waterproof bins prior to use. Normally fly ash is handled in the same manner as cement. Only one source of fly ash is permitted in any one structure unless otherwise approved by the Director.

Air-Entraining Admixture

Air-entraining admixtures are used to entrain the proper amount of air in concrete for freeze thaw durability. These admixtures must comply with 705.10 and conform to Supplement 1001, "Approval and Testing of Air Entraining Agents and Chemical Admixtures for Concrete". The list of approved air entraining admixtures for Department use can be obtained from the Construction Management System (CMS) or from the Qualified Products List (QPL) on the ODOT website.

Air-entraining admixtures are randomly sampled at the concrete plant. The Laboratory generally takes these samples.

Chemical Admixture for Concrete

Approved set-retarding, or water-reducing and set retarding admixtures, are permitted in order to increase the workability of the concrete and to extend the time of discharge from 60 to 90 minutes. These admixtures are permitted and often required for superstructure concrete..

Should the Contractor propose to use calcium chloride as an accelerator in the concrete, it must be determined if such use is permitted by specification, plan or proposal note. If not, the Contractor must request permission of the Director in writing to use such admixtures.

Admixtures used under 499 must meet the requirements of 705.12 that specify that they meet ASTM C 494, except that the relative durability factor shall be 90.

These admixtures must comply with Supplement 1001, “Approval and Testing of Air Entraining Agents and Chemical Admixtures for Concrete”.

The list of approved admixtures for Department use can be obtained from the Construction Management System (CMS) or from the Qualified Products List (QPL) on the ODOT website.

Chemical admixtures as defined by ASTM C 494 include:

- TYPE A - Water reducing
- TYPE B - Retarding
- TYPE C - Accelerating
- TYPE D - Water reducing and retarding
- TYPE E - Water reducing and accelerating
- TYPE F - Water reducing, high range
- TYPE G - Water reducing high range and retarding

Generally liquid admixtures are shipped and stored at the plant in drums or tanks. The admixture material is withdrawn directly from the drum and dispensed into the concrete. Drums or tanks containing liquid admixtures should be agitated before being used. In the absence of a dispenser, the admixture must be introduced accurately into the mix by hand. Drums or tanks for storage of liquid admixtures should be watertight and protected from freezing.

At ready mix plants producing large volumes of concrete, the air entraining and other chemical admixtures are delivered in bulk quantity by tank trucks. These bulk admixtures are pumped into storage tanks at the plant and then dispersed into concrete batches.

Water

Water that is suitable for drinking is satisfactory for use in concrete (potable water). Water must be free of sewage, oil, acid, strong alkalis, vegetable matter, clay, and loam. Water from such sources should be avoided. Whenever there is a reason to suspect that water proposed for use in concrete is not suitable, it must be tested and approved before it may be used. A one-gallon (3.8L) sample in a non-corrosive container (plastic or glass) must be transmitted to the Laboratory with a TE-31 Sample Data form for comparative testing.

Wash water used to clean out ready mixed concrete must be discharged from the mixing drum prior to recharging any truck with new materials.

An adequate supply of water must be available at the concrete plant to provide for mixing and stockpile watering for uninterrupted production. Adequate storage tanks kept filled or a connection to a water supply system usually will provide a sufficient supply.

Proportioning (499.03, 499.04, 499.05)

Concrete is to be proportioned (mixed) and controlled as per the requirements of 499.03, 499.04, and 499.05. Slump, air content, yield, and water-cement ratio is given in Tables 499.03-1, -2, -3, and -4 and also in Tables 499.04-1, -2, and -3. Additionally these tables provide the aggregate weights, and cement content for each class and proportioning option of concrete.

The slump must be maintained within the nominal slump range shown in the table for that mix design. The slump of concrete delivered to a project may be increased by the addition of water only if the maximum water cement ratio (or water to cementitious ratio) is not exceeded.

Do not allow the use of any concrete that exceeds the maximum slump. An occasional load of concrete with a slump in excess of the nominal slump, but below the maximum limit shown in the table, may be incorporated into the work provided that an immediate adjustment is made to reduce the slump.

The maximum slump permitted for all Class HP concrete is 8 inches (200 mm). This slump is to be measured at the point of placement into the forms. In some cases, it will not be practical to use this maximum slump due to a required cross slope or a super-elevation.

Concrete Classes (499.03C)

The Department uses prescription mixes that are found in concrete tables in 499.03 C. Table 499.03–2 shows Class S, Class C, and Class F concrete using No. 57 or No 67 size coarse aggregate. The class of concrete is generally called out in the specification of the item of work in which the concrete is to be used. The proportioning of these classes is based on developing an average compressive strength at 28 days as follows:

Class S = 4,500 psi (31 mPa)

Class C = 4,000 psi (28.0 mPa)

Class F = 3,000 psi (21.0 mPa)

The tables give the quantities of each ingredient for each class necessary for one cubic yard (cubic meter) of concrete. The tables include the saturated surface dry (SSD) weight in pounds (kilograms) of the fine aggregate and the coarse aggregate. The cement content in pounds (kilograms) and the water-cement ratio are also found in these tables. The table also specifies the air content range that is permitted and must be provided.

Proportioning Options for Portland Cement Concrete (499.04)

Under section 499.04 of the Specifications there are three proportioning options permitted to the standard specified Class C, Class F, and Class S mixes given in Table 499.03-2 and Table 499.03-3. The air content of these mixtures must comply with each respective table. The slump of the concrete must also comply with Table 499.03-1.

These options are only permitted if the Contractor submits a request to use them to the Engineer for approval, prior to use. The Contractor must not use any option mix unless the request is made in writing. The submittal must be made timely so that the Laboratory can evaluate each submittal and approve it prior to using it.

The saturated surface dry aggregate weights in the concrete tables were calculated using the same specific gravities used in 499.03 C.

Proportioning Option 1 (499.04 A. Reduced cement and use of fly ash)

Proportioning Option 1 allows the Contractor to reduce the cement content of the standard Class C, F, or S concrete mix as much as 15 percent by weight with the substitution of an equivalent weight of fly ash. Use the combined weight of cement and fly ash when calculating the water-cement ratio or allowable water with Proportioning Option 1 mixes. This option can only be used between April 1 and October 15 unless authorized by the Director.

Particular attention must be paid to the air content of Option 1 mixes. Variations in the quality of fly ash used can influence the air content.

Table 499.04-1 gives the quantities per cubic yard (cubic meter) for Class C, F, and S concrete using Option 1 using No 57 or 67 size coarse aggregate. This table includes No. 8 size gravel and limestone Class C, Option 1 concrete mixes for smaller concrete pavement projects as allowed by 703.13 of the specifications.

TABLE 499.04-1 Option 1 Concrete (Cement and Fly Ash)

Quantities Per Cubic Yard (Cubic Meter)						
Aggregate Type	SSD Aggregate Weight		Cement Content lb (kg)	Fly Ash lb (kg)	Water-CM Ratio Maximum	Design Yield Cubic Feet (m^3)
	Fine Aggregate lb (kg)	Coarse Aggregate lb (kg)				
Class C Option 1 (Using No. 57 or 67 Size)						
Gravel	1140 (676)	1700 (1009)	510 (303)	90 (53)	0.50	27.02 (1.00)
Limestone	1260 (748)	1595 (946)	510 (303)	90 (53)	0.50	27.00 (1.00)
Slag	1320 (783)	1330 (789)	510 (303)	90 (53)	0.50	26.99 (1.00)
Class F Option 1 (Using No. 57 or 67 Size)						
Gravel	1260 (748)	1800 (1068)	400 (237)	70 (42)	0.55	27.00 (1.00)
Limestone	1350 (801)	1730 (1026)	400 (237)	70 (42)	0.55	27.00 (1.00)
Slag	1380 (819)	1475 (875)	400 (237)	70 (42)	0.55	27.00 (1.00)
Class S Option 1 (Using No. 57 or 67 Size)						
Gravel	1060 (629)	1640 (973)	608 (361)	107 (63)	0.44	27.02 (1.00)
Limestone	1230 (730)	1490 (884)	608 (361)	107 (63)	0.44	27.03 (1.00)
Slag	1220 (724)	1300 (771)	608 (361)	107 (63)	0.44	27.02 (1.00)
Class C Option 1 (Using No. 7, 78, or 8 Size) per 703.13 [2]						
Gravel	1310 (777)	1440 (854)	510 (303)	90 (53)	0.50	27.01 (1.00)
Limestone	1350 (801)	1410 (837)	510 (303)	90 (53)	0.50	26.97 (1.00)
[1] CM = cementitious material. [2] 8% +/- 2% entrained air content						

Proportioning Option 2 (499.04 B. Reduced cement and use of Type A or D admixture)

Proportioning Option 2 allows the Contractor to reduce the cement content of the Standard Class C, F, or S concrete mix by 50 pounds per cubic yard (30 kg per cubic meter). This option requires the use of an approved water reducing (Type A) or water reducing and retarding (Type D) admixture. An equivalent volume of aggregate is substituted for the volume of cement removed from the mix.

Table 499.04-2 gives the quantities per cubic yard (cubic meter) for Class C, F, and S concrete with Option 2 (using No 57 or 67 size coarse aggregate). This table includes No. 8 size gravel and limestone Class C, Option 2 concrete mixes for smaller concrete pavement projects as allowed by 703.13 of the specifications.

TABLE 499.04-2 OPTION 2 CONCRETE
(Cement Reduction of 50 lb w/ 705.12, Type A or D)

Quantities Per Cubic Yard (Cubic Meter)					
Aggregate Type	**SSD Aggregate Weight**		**Cement Content lb (kg)**	**Water-Cement Ratio Maximum**	**Design Yield Cubic Feet (m^3)**
	Fine Aggregate lb (kg)	**Coarse Aggregate lb (kg)**			
Class C Option 2 (Using No. 57 or 67 Size)					
Gravel	1190 (706)	1780 (1056)	550 (326)	0.50	26.99 (1.00)
Limestone	1320 (783)	1670 (991)	550 (326)	0.50	27.00 (1.00)
Slag	1385 (822)	1395 (828)	550 (326)	0.50	27.02 (1.00)
Class F Option 2 (Using No. 57 or 67 Size)					
Gravel	1315 (780)	1880 (1115)	420 (249)	0.55	27.00 (1.00)
Limestone	1410 (837)	1810 (1074)	420 (249)	0.55	27.03 (1.00)
Slag	1440 (854)	1540 (914)	420 (249)	0.55	27.00 (1.00)
Class S Option 2 (Using No. 57 or 67 Size)					
Gravel	1120 (664)	1710 (1015)	665 (395)	0.44	27.00 (1.00)
Limestone	1290 (765)	1560 (926)	665 (395)	0.44	27.02 (1.00)
Slag	1270 (753)	1370 (813)	665(395)	0.44	27.01 (1.00)
Class C Option 2 (Using No. 7, 78, or 8 Size) per 703.13 [1]					
Gravel	1370 (813)	1510 (896)	550 (326)	0.50	27.01 (1.00)
Limestone	1420 (842)	1480 (878)	550 (326)	0.50	27.00 (1.00)
[1] 8% +/- 2% entrained air content					

Take care to assure that the water-cement ratio is not exceeded with the No 8 size coarse aggregate mixes. By reducing the cement content 50 lbs per cubic yard (30 kg per cubic meter), the allowable water at a 0.50 water-cement ratio is reduced 25 lbs per cubic yard (15 kg per cubic meter). This results in about 3 gallons of water per cubic yard (15 liters per cubic meter) less allowable water than without the option. It may not be possible to produce concrete at a 3- or 4-inch (75 or 100 mm) slump and stay within the allowable water cement ratio with this smaller aggregate size.

Proportioning Option 3 (499.04 C. Cement reduction and use of GGBFS with Type A or D)

Proportioning Option 3 allows the Contractor to reduce the cement content of the Standard Class C, F, or S concrete mix by 50 pounds per cubic yard (30 kg per cubic meter). This option requires the use of an approved water reducing (Type A) or water reducing and retarding (Type D) admixture. An equivalent volume of aggregate is substituted for the volume of cement removed from the mix. The remaining cement is proportioned, by weight as 70 percent Portland cement meeting 701.01 or 701.04 and a maximum of 30 percent ground granulated blast furnace slag (GGBFS) conforming to 701.11. The water cement ratio is based on cementitious ratio on the combined weight of Portland cement and GGBFS.

Table 499.04-3 gives the quantities per cubic yard (cubic meter) for Class C, F, and S concrete with Option 3 (using No 57 or 67 size coarse aggregate). This table includes No. 8 size gravel and limestone Class C, Option 3 concrete mixes for smaller concrete pavement projects as allowed by 703.13 of the specifications

TABLE 499.04-3 OPTION 3
(CEMENT REDUCTION AND USE OF GGBFS)

Quantities Per Cubic Yard (Cubic Meter)						
Aggregate Type	SSD Aggregate Weight		Cement Content lb (kg)	GGBF Slag lb (kg)	Water-CM Ratio Maximum	Design Yield Cubic Feet (m^3)
	Fine Aggregate lb (kg)	Coarse Aggregate lb (kg)				
Class C Option 3 (Using No. 57 or 67 Size)						
Gravel	1185 (703)	1775 (1053)	385 (228)	165 (98)	0.50	27.00 (1.00)
Limestone	1310 (777)	1670 (991)	385 (228)	165 (98)	0.50	27.01 (1.00)
Slag	1385 (822)	1385 (822)	385 (228)	165 (98)	0.50	27.02 (1.00)
Class F Option 3 (Using No. 57 or 67 Size)						
Gravel	1320 (783)	1870 (1109)	294 (174)	126 (75)	0.55	27.02 (1.00)
Limestone	1400 (831)	1810 (1074)	294 (174)	126 (75)	0.55	27.02 (1.00)
Slag	1440 (854)	1535 (911)	294 (174)	126 (75)	0.55	27.02 (1.00)
Class S Option 3 (Using No. 57 or 67 Size)						
Gravel	1105 (656)	1715 (1017)	465 (276)	200 (119)	0.44	27.00 (1.00)
Limestone	1280 (759)	1555 (923)	465 (276)	200 (119)	0.44	27.02 (1.00)
Slag	1270 (753)	1360 (807)	465 (276)	200 (119)	0.44	27.02 (1.00)
Class C Option 3 (Using No. 7, 78, or 8 Size) per 703.13 [2]						
Gravel	1370 (813)	1500 (890)	385 (228)	165 (98)	0.50	26.99 (1.00)
Limestone	1410 (837)	1480 (878)	385 (228)	165 (98)	0.50	27.01 (1.00)

[1] Use only *701.04* or *701.01* cement with this option.
[2] 8% +/- 2% entrained air content
GGBF = ground granulated blast furnace slag;
CM = cementitious material.

Use of the Option Mixes (499.04)

The use of any of the options previously described does not waive the requirement of any concrete under 499.03 D. 6 of the CMS to use a retarding admixture (Type B) or a water reducing and retarding (Type D) admixture if the plastic concrete temperature exceeds 75° F (24° C) at the point of placement. The concrete temperature must be monitored by the Inspector.

The use of Proportioning Option 1, 2, or 3 is prohibited in concrete mixes designed or intended to obtain high early strength. Thus, the use of either option would not be permitted for Class FS and MS concrete used for pavement repairs as these mixes are intended to obtaining rapid strength development.

The approval of any Option mix design change does not waive the responsibility of the Inspector. The Inspector must assure that the Option mix meets all of the specified parameters in regard to air content, slump, yield, and water-cement ratio or water to cementitious ratio.

Additional Classes of Concrete for Rigid Replacement (499.05)

The Specifications provide for two other classes of concrete (Class FS and Class MS) normally used for full depth rigid pavement removal and rigid replacement (Item 255). These concretes are intended for high-early-strength; therefore, the previously described proportioning options do not apply to these classes of concrete.

The Contractor is permitted to use coarse aggregate sizes No. 57, 6, 67, 7, 78, or 8 in either Class FS or MS concrete. If No. 7, 78, or 8 size is used the concrete is to have 8 ±2 percent air content. If any other size coarse aggregate is used, the air content must be 6 ± 2 percent.

It should be noted that Class FS or MS concrete is for use in full depth rigid pavement removal and rigid replacement (Item 255). It allows No. 57 and No. 67 size coarse aggregate that does not have to be tested in accordance with 703.13 (testing for d-cracking susceptibility). If it is necessary to use either Class FS or MS concrete in 451 or 452 and No. 57 or No. 67 size coarse aggregate is to be used, the aggregate must comply with 703.13.

When either FS or MS concrete is used, it may be necessary to approve the mix design proposed by the Contractor or the ready mixed concrete company. The specific gravity of all aggregates must be known to figure the absolute volumes at all component materials to assure that the concrete yields a cubic meter (cubic yard) of concrete. Just like any concrete the air, slump, and yield must be controlled and the water-cement ratio must not be exceeded.

Class FS Concrete (499.05 A. Fast Setting Concrete)

Class FS concrete must be proportioned with 900 pounds per cubic yard (534 kilograms per cubic meter) and a maximum water-cement ratio of 0.40. This concrete may be opened to traffic after 4 hours if test beams have attained a modulus of rupture of 400 psi (2.76 MPa). This concrete must have either a Type B or a Type D admixture (a set retarder) added at the plant. Immediately prior to placing the concrete, calcium chloride (an accelerator) must be added and mixed at the project site.

Calcium chloride with 94 to 97 percent purity is limited to 1.6 percent by weight of cement, and calcium chloride with 77 to 80 percent purity is limited to 2.0 percent by weight of cement. If calcium chloride is added in liquid form, the water in the solution must be considered to be part of the mixing water and an appropriate adjustment must be made to not exceed the 0.40 water cement ratio.

In lieu of calcium chloride, any other approved accelerating admixture is permitted. The addition rate must be as recommended by the admixture manufacturer to produce concrete of the required strength within the time frame desired.

After curing compound is applied, the concrete is to be covered with polyethylene sheeting and further covered with insulation board that has been wrapped with plastic. The intent is to keep the heat in the concrete so that the concrete can gain strength rapidly. During warm weather, 400 psi (2.76 MPa) is normally attained in 5 1/2 hours.

Class MS Concrete (499.05 B. Moderate Setting Concrete)

This class is a moderate setting Portland cement concrete for accelerated strength development. Class MS concrete is to consist of a minimum of 800 pounds of cement per cubic yard (475 kilograms of cement per cubic meter) and the maximum water cement ratio is limited to 0.43. This mix may be opened to traffic after 24 hours provided test beams have attained a modulus of rupture of 400 psi (2.76 MPa).

Basics Concepts used in Concrete Quality Control

Volume

There are three types of volumes used in concrete quality control:

1. solid (absolute)
2. loose (bulk)
3. liquid volume

Solid and loose volume is normally defined by the number of cubical units of enclosed or occupied space. Normally one speaks of the number of cubic feet or cubic yards (cubic meters) of concrete. Liquid volume is designated by gallons (liters) for measurement of water and ounces (milliliters) for measurement of admixture dosage rates.

Unit Weight

Unit Weight is an important volume relationship used in concrete quality control. Unit weight is defined as the ratio of the weight of a material in pounds (kilograms) to the space or volume that it occupies in cubic feet (cubic meters). The unit weight of any material is calculated by Equation 499.1:

$$Unit\ Weight = \frac{Weight\ of\ Material}{Volume\ of\ the\ Material\ Weighed}$$

Equation 499.1 – Material Unit Weight

Concrete is sold by volume, but is batched by weight. The Inspector determines the unit weight of the concrete and uses it to calculate the yield of the batch. The yield is the actual number of cubic feet (cubic meters) or volume of concrete that a batch or load produces. Equation 499.2 shows how yield is calculated:

$$Yield = \frac{Total\,Batch\,Weight}{Unit\,Weight}$$

Equation 499.2 – Batch Yield

Specific Gravity

Specific gravity values of aggregates are used to calculate aggregate weights used in concrete mix design. Where the actual specific gravity of an aggregate varies by more than ±0.02 from those listed in 499.03, the mix design weights shown in the tables must be adjusted. This section shows how to make those adjustments.

The specific gravity of any material is the ratio of the weight in pounds (kilograms) of the material to the weight of an equal volume of water. Another way to say this is that it tells how much heavier or lighter a given material is than water. Water has a specific gravity of 1.00. The unit weight of water is 62.4 pounds per cubic feet, lb/ft^3 (1,000 kilograms per cubic meter, kg/m^3).

The concrete tables in 499.03 C give the quantities of all materials to be used in each cubic yard (cubic meter) of concrete, depending on what class of concrete and the type of aggregate is used. The aggregate weights given in the tables are the saturated surface dry (SSD) design weights. These prescription mixes were developed using the specific gravities shown in Table 499.A:

Table 499.A – Design Specific Gravities

MATERIAL	SPECIFIC GRAVITY
Natural sand and gravel	2.62
Limestone sand	2.68
Limestone	2.65
Slag coarse aggregate	2.30
Fly ash	2.30
Ground granulated blast furnace slag GGBFS	2.90
Microsilica	2.20
Cement	3.15

If the specific gravities of the proposed materials for use on a project vary by more than 0.02 from the specific gravities shown in Table 499.A, the Engineer must adjust the table weights as specified in 499.03 D.3. This is done by dividing the SSD design table weight by the design specific gravity (from Table 499.A) and multiplying this by the actual specific gravity that is going to be used on the project. Equation 499.3 shows this calculation:

$$Adjusted\,DW_{SSD} = \frac{DW_{SSD}}{DSG} * ASG$$

Equation 499.3 – Adjusted SSD Design Weight

where:

DW_{SSD} = Design Weight (SSD) from the appropriate table in 499.03 or 499.04

DSG = Design Specific Gravity from Table 499.A

ASG = Actual SSD specific gravity to be used on the project

Adjusted DW_{SSD} = Design Weight (SSD) adjusted for the actual aggregate specific gravity

Example

Class S concrete using natural sand and limestone coarse aggregate is to be used on a project. The specific gravity of the fine aggregate is 2.66 and there is the specific gravity of 2.68 for the coarse aggregate. Determine the adjusted SSD design weights of fine and coarse aggregate based on these specific gravities.

The SSD design weights and design specific gravities for Class S concrete in Table 499.03-2 for natural sand and limestone coarse aggregate are:

AGGREGATE TYPE	DESIGN WEIGHT (SSD)	DESIGN SPECIFIC GRAVITY
Fine Aggregate (Nat. Sand)	1240 lbs	2.62
Coarse Aggregate (Limestone)	1510 lbs	2.65

The SSD design weights adjusted for the specific gravities are calculated as follows:

Fine Aggregate Adjusted $DW_{SSD} = \frac{1240}{2.62} \times 2.66 = 1259\,lbs$

Coarse Aggregate Adjusted $DW_{SSD} = \frac{1510}{2.65} \times 2.68 = 1527\,lbs$

These adjusted aggregate weights (DW_{SSD}) would be further adjusted for moisture contained in them at the time of use instead of the table weights.

Absolute Volume

The material proportions for concrete mixtures in 499.03 and 499.04 are given in absolute volumes. Any adjustments to the aggregate proportions must be done using absolute volumes. For example the yield of a batch of concrete is required to be accurate within a tolerance of ± 1 percent at the target (design) air content and slump. If an over- or under-yield is experienced adjustments in the batch weights are made by the Inspector in an effort to comply with this tolerance. Based on the yield calculated by the Inspector it will be necessary to calculate the weight in pounds (kilograms) of aggregate required for a certain amount of yield correction in cubic feet (cubic meters). Adjustments to correct yield are to be based on the absolute volume.

When the specific gravity of any material is known, the absolute volume of any weight of that material can be calculated as shown in Equations 499.4 and 499.5:

$$Absolute\,Volume\,(ft^3) = \frac{Weight\ of\ Material\,(lbs)}{Specific\,Gravity \times 62.4\,(lbs/ft^3)}$$

Equation 499.4 – Absolute Volume

$$\left(Absolute\,Volume\,(m^3) = \frac{Weight\ of\ Material\,(kg)}{Specific\,Gravity \times 1000\,(kg/m^3)} \right)$$

Equation 499.5 – Absolute Volume (metric)

Example

The absolute volume of 94 lbs (42.6 kg) of Type 1 cement that has a specific gravity of 3.15 is:

$$Absolute\ Volume(ft^3) = \frac{94\,lbs}{3.15 \times 62.4\,lbs/ft^3} = 0.48\,ft^3$$

$$\left(Absolute\ Volume(m^3) = \frac{42.6\,kg}{3.15 \times 1000\,kg/m^3} = 0.0135\,m^3 \right)$$

This calculation shows that 94 lbs (42.6 kg) of cement, which represents 1 cubic foot of loose volume, has an absolute volume of 0.48 ft^3 (0.0135 m^3).

Yield Adjustment using Absolute Volume

To make a yield adjustment, a volume of over-yield or under-yield is first determined. This absolute volume must be converted to a weight of material. An absolute volume of any material can be converted to a weight of that material by using Equations 499.6 and 499.7:

$$Weight\ (lbs) = AV \times SG \times 62.4$$

Equation 499.6 – Weight from Absolute Volume

where:

AV = absolute volume of the material (ft^3)

SG = specific gravity of the material

62.4 = lbs/ft^3

$$Weight\ (kg) = AV * SG * 1{,}000$$

Equation 499.7 – Weight from Absolute Volume (metric)

where:

AV = absolute volume (m^3)

SG = specific gravity

$1{,}000 = kg/m^3$

Example

Calculate how many pounds (kg) of a coarse aggregate with a specific gravity of 2.66 would be required to adjust an under-yield of 0.64 ft^3 (0.018 m^3). The calculation is as follows:

Weight (lbs) = (0.64 ft^3) x (2.66) x (62.4 lbs/ft^3) = 106.2 lbs

(Weight (kg) = (0.018 m^3) x (2.66) x (1000 kg/m^3) = 47.88 kg)

Thus, 106 lbs per cubic yard (48 kg per cubic meter) of coarse aggregate with a specific gravity of 2.66 would have to be added to correct the above under-yield volume of 0.64 ft^3 (0.018 m^3).

Moisture Correction

Aggregate can be in one of four moisture conditions:

1. Oven-dry aggregates are heated until they are completely dry. There is no moisture within the aggregate particles or on the surface of the particles.
2. Air-dry aggregate is dry on the surface but still contains some water within the aggregate particles. Air-dry aggregate will absorb a small amount of mixing water if used in concrete. Aggregate in this condition requires adjustments to the design weights and adjustment of the batch water.
3. Saturated surface dry (SSD) aggregate looks damp, but it contains no free water on the surface. The aggregate particles have completely absorbed all the water possible and do not contribute water to the batch. The concrete tables in 499.03 give SSD weights of coarse and fine aggregate, but aggregate in this condition rarely exists in aggregate stockpiles.
4. Wet (damp) aggregate has water on the particle surface and shows a water sheen. The aggregate particles have absorbed all the water they can and will contribute water to the concrete mix. Aggregate in this condition requires adjustments to the design weights and adjustment of the batch water.

In the field, aggregate used in concrete will be in a wet (damp) condition or air-dry condition. Aggregate in the SSD or oven-dry conditions is used by inspectors to determine moisture correction factors for use in adjusting the SSD design weights.

Before concrete can be batched, the concrete mix SSD design weights shown in the concrete tables in 499.03 and 499.04 must be converted to batch weights. This is done by adjusting the design SSD weight of each aggregate and adjusting the amount of batch water to compensate for the moisture in the aggregates. If all aggregates at the concrete plant were in the SSD condition, the weights given in the concrete tables could just be weighed up and incorporated into the concrete batch and no adjustments to the water would be necessary. Seldom, if ever, will aggregate in the field be found in the SSD condition.

It is necessary to determine the amount of total moisture in all aggregate in order to determine the weight of wet (damp) or air-dry aggregate necessary to give the correct weight of SSD aggregate. This total moisture content is used in the determination of the water-cement ratio. For example, if an aggregate is determined to contain 5 percent total moisture, then each 105 pounds (kilograms) of that aggregate actually consists of 100 pounds (kilograms) of aggregate and 5 pounds (kilograms) of water. In order to obtain 100 pounds (kilograms) of aggregate by dry weight, it is necessary to take into account the water that will be weighed along with the aggregate.

Total Moisture Correction Factor

The Total Moisture Correction Factor (TMCF) is a term that is useful in determining the batch weights from SSD design weights (that have been corrected for specific gravity). The TMCF can be determined by a moisture test. To determine the TMCF use Equation 499.8.

$$TMCF = \frac{WW\ (or\ ADW)}{ODW}$$

Equation 499.8 – Total Moisture Correction Factor (TMCF)

Where:

TMCF = Total Moisture Correction Factor

WW= Wet weight of the sample

ADW = Air Dry Weight of the sample

ODW = Oven Dry Weight of the sample

If the total moisture content (in percent) has been determined by an aggregate moisture test, use Equation 499.9 to calculate the TMCF:

$$TMCF = \left(\frac{\%\ Total\ Moisture}{100}\right) + 1.0000$$

Equation 499.9 – Total Moisture Correction Factor (TMCF)

The total moisture percent is changed to a decimal (by dividing it by 100) and then added to 1.0000 to get the TMCF. For example if the total moisture in an aggregate sample, after testing, is determined to be 5.8 % then the TMCF is determined as follows:

$$TMCF = \frac{5.8\,\%}{100} + 1.0000 = 1.0580$$

Absorbed Moisture Correction Factor

Another factor that is useful in determining the batch weights from SSD weights (that have been corrected for specific gravity) is the Absorbed Moisture Correction Factor (AMCF). This factor can be determined by a test. It is defined as follows:

$$AMCF = \frac{SSDW}{ODW}$$

Equation 499.10 – Absorbed Moisture Correction Factor (AMCF)

Where:

AMCF= Absorbed Moisture Correction Factor

SSDW= Saturated Surface Dry Weight of the sample

ODW= Oven Dry Weight of the sample

The percent of absorption of the fine aggregate and coarse aggregate is obtained from the aggregate reports furnished by the Laboratory. The percent of absorption represents the amount of water, expressed as a percentage of its own dry weight, which an aggregate will absorb. The water that is absorbed by aggregate is not available as mixing water in the concrete. Adjustments must be made in the amount of total allowable mixing water to compensate for the free water on the aggregate surface.

The percent absorption of any aggregate can be found on the Office of Materials Management website under Information, Aggregate, and Specific Gravities List.

The percent absorption is on the far right column of this list. The sources are listed in alphabetical order. Once the percent absorption of any aggregate is known, the AMCF can be determined by Equation 499.11:

$$AMCF = \frac{\%\ Absorption}{100} + 1.0000$$

Equation 499.11 – AMCF

The percent absorption of the aggregate is changed to a decimal (by dividing the percentage by 100) and then it is added to 1.0000 to get the AMCF. For example, if the percent absorption for a coarse aggregate is 2.22 % then the AMCF is determined as follows:

$$AMCF = \frac{2.2\,\%}{100} + 1.0000 = 1.0220$$

Free Moisture Correction Factor

The Free Moisture Correction Factor (FMCF) can be calculated once the TMCF and the AMCF are determined by using Equation 499.12:

$$FMCF = \frac{TMCF}{AMCF}$$

Equation 499.12– FMCF

Where:

FMCF= Free Moisture Correction Factor

TMCF= Total Moisture Correction Factor

AMCF=Absorbed Moisture Correction Factor

The FMCF is used to adjust the corrected SSD design weights of the coarse aggregate and the fine aggregate from the concrete tables in 499.03 or 499.04 to batch weights that are used to produce a batch of concrete. The batch weight for any aggregate is determined by either Equation 499.13 or 499.14:

$$BatchWeight = AdjustedDW_{SSD} \times FMCF$$

Equation 499.13 – Batch Weight method 1

$$BatchWeight = Adjusted\ DW_{SSD} \times \frac{TMCF}{AMCF}$$

Equation 499.14 – Batch Weight method 2

Where:

$AdjustedDW_{SSD}$= Design Weight (SSD) from the concrete table, adjusted for the specific gravity

FMCF= Free Moisture Correction Factor

TMCF= Total Moisture Correction Factor

AMCF=Absorbed Moisture Correction Factor

Example

Assume that the following are the design weights SSD adjusted for specific gravity for a cubic yard of Class C concrete:

Cement	600 lbs
SSD Fine Aggregate	1160 lbs
SSD Coarse Aggregate	1735 lbs
Maximum Water	300 lbs
Total Design Weight	3795 lbs

Prior to concrete placement, the total moisture contents of the fine and coarse aggregates are determined. The fine aggregate has total moisture of 4.95 percent and the coarse aggregate has total moisture content of 3.25 percent. The absorption of the fine aggregate is 2.85 percent and the absorption of the coarse aggregate is 2.1 percent. Determine the batch weights using the above moisture data.

First, determine the TMCF and the AMCF for each aggregate type using Equations 499.9 and 499.11:

Fine Aggregate TMCF	$=\frac{4.95\%}{100}+1.0000$ $=1.0495$	(Equation 499.9)
Fine Aggregate AMCF	$=\frac{2.85\%}{100}+1.0000$ $=1.0285$	(Equation 499.11)
Coarse Aggregate TMCF	$=\frac{3.25\%}{100}+1.0000$ $=1.0325$	(Equation 499.9)
Coarse Aggregate AMCF	$=\frac{2.2\%}{100}+1.0000$ $=1.022$	(Equation 499.11)

Next, use Equation 499.14 to determine the fine and coarse aggregate batch weight:

Fine Aggregate Batch Weight	$=1160\times\frac{1.0495}{1.0285}$ $=1184\,lbs$	(Equation 499.14)
Coarse Aggregate Batch Weight	$=1735\times\frac{1.0325}{1.022}$ $=1753\,lbs$	(Equation 499.14)

Next, determine the amount of water added to the mix by each aggregate. To determine this weight subtract the SSD design weight from the batch weight determined above:

Water in Fine aggregate	= 1184 – 1160	= 24 lbs
Water in Coarse aggregate	= 1753 –1735	= 18 lbs

Next, the mix design weight of water must be adjusted to determine the batch weight of water. In this example, the fine aggregate and coarse aggregate would both contribute water (24 lbs and 18 lbs respectively) to the mix. The batch weight of water is calculated by subtracting the amount of water added by the aggregate from the design water weight as follows:

Water Batch weight = 300 lbs - 24 lbs – 18 lbs = 258 lbs

Once the batch weights of all the ingredients have been determined, they should add up to the same as the original design weights. This is a good check to assure that no errors were made in the calculations. The batch weights for a cubic yard of concrete based on the total moistures and the aggregate absorptions given in this example are:

Cement	600 lbs
SSD Fine Aggregate	1184 lbs
SSD Coarse Aggregate	1753 lbs
Maximum Water	258 lbs
Total Batch Weight	3795 lbs

Since the total batch weight equals the original adjusted SSD design weights in this example, the mix has been adjusted properly for the moisture in the aggregates. Even though the maximum water value in the total batch weight (258 lbs) is different than the original design weight of water (300 lbs) the net water was not changed. The free moisture in the aggregates will contribute 42 lbs to the mixing water. In this example, the w/c ratio was kept the same as the original design.

Job Control Tests

The concrete control Inspector must perform various field tests to determine whether a concrete mixture is within specifications for slump, air content, and yield. Additionally moisture testing has to be performed for use in the concrete mix design. Specification 499.03 requires that concrete quality control tests are performed at the point of use. However tests for total air content and slump may also be made at ready mix and central mix plants, for information purposes. These tests are desirable to detect loads that will not conform to specification requirements before they leave the plant. Variances should be pointed out to the Contractor so that necessary adjustments can be made in the following batches. This type of testing determines quality and is the responsibility of the Department, except when concrete is produced in accordance with a QC/QA specification where the quality control is the responsibility of the Contractor.

Item 499.03 specifies the point of testing concrete. Unless otherwise directed by the Engineer, tests on plastic concrete for pavement are made on samples taken from the concrete after it has been placed on the base. In the event excess slump is encountered it may be desirable to visually observe the consistency (slump) of the concrete in the bucket or trucks before deposition to avoid the necessity of costly removal after it is placed.

Tests for structural concrete must be made at the site of the work at the time the concrete is being placed. Normally, concrete may be obtained directly from the hauling units for testing. However, when concrete is being transferred from the hauling units to the point of use by means of conveyors or by pumping, the amount of slump and air may change slightly. Therefore, concrete obtained from the discharge of these conveyances should be tested at least twice daily (for large continuous concrete placements) to compare with tests conducted at the hauling units. Any appreciable change in the properties (slump and air) should be noted and considered in analysis of tests conducted at hauling units.

There may be occasions where it is not practical to test concrete samples at the point of placement since this would interfere with placing operations, such as for a pier cap. Usually there is not adequate space for testing. In this situation, the sample could be taken from the point of placement and tested at a different location. Correlation of test data may be necessary to fulfill the intent of 499.03 (testing at the point of placement). Tests could be conducted on concrete obtained from the hauling units and allowance made for a change in slump and air as determined by the comparative tests at the point of placement.

Slump, yield, and entrained air tests are made by the concrete control Inspector. In addition, it is the Inspector's duty to make required test cylinders and beams. Any adjustment of batch weights that may be necessary because of the routine job control tests must be relayed to the concrete plant for immediate use. The concrete Inspector must be familiar with the tests being conducted and should occasionally review the test procedures to assure that all tests are properly conducted.

Representative Concrete Samples

When obtaining a sample from dump trucks, side dump hauling units, or other types of hauling units that do not discharge by a chute, the contents are first discharged or spread on the base. Samples are then taken from several different locations within the load.

When sampling from truck mixers, truck agitators, end dumps, or other units discharging by a chute, the sample is obtained at three or more regular intervals throughout the discharge of the entire batch. Do not sample at the beginning or end of discharge. Sampling is done by repeatedly passing a receptacle through the entire discharge stream, or by diverting the stream so that it discharges into a container. The rate of discharge must be regulated by the rate of revolution of the drum, and not by the size of the gate opening.

The sample consists of not less than 1 cubic foot (0.03 cubic meters) when it is used for cylinders and not less than 1 cubic foot (0.03 cubic meters) per beam. Smaller samples may be permitted for routine air content and slump test.

The sample is carried to the place where cylinders and beams are to be molded or where the test is to be made. The sample is then remixed with a shovel just enough to ensure uniformity. The sample must be protected from sunlight and wind during the period between sampling and testing. The test must be conducted immediately so that the time between sampling and test completion is held to a minimum.

Moisture Testing

This test is the responsibility of the Department except for work under a QC/QA specification, when the Contractor is responsible. A moisture test is made for each aggregate size to be used. These tests must be made just prior to the start of concrete production and are used to adjust the batch weights and to determine the water-cement ratio. Therefore, moisture tests are required at the start of production, daily for all major concrete placements, and anytime a sizeable change occurs in the moisture content of the stockpiles. Space is provided on Form TE-45 for documenting the moisture content test on each aggregate used.

Any appreciable change in the amount of water added at the mixer must be investigated, additional moisture tests made and, if necessary, the batch weights adjusted accordingly. Following a heavy rainfall, periodic moisture tests are necessary until the moisture content becomes uniform. Slight variations in the mixing water requirements do not require a moisture test and adjustment. However, it may become necessary to alter the methods of watering, stocking, and withdrawing the aggregate to avoid fluctuations in water.

The total percent moisture is determined by using Equation 499.19:

$$Total\ Percent\ Moisture = \left(\frac{NWW - NDW}{NDW}\right) \times 100\,\%$$

Equation 499.19 – Total Percent Moisture

where:

NWW = Net Wet Weight of the aggregate sample

NDW= Net Dry Weight of the aggregate sample

To determine the percentage of moisture or water in fine or coarse aggregate, place a representative sample of 5 to 10 pounds (3 to 5 kg) in a pan that has been weighed empty and determine the wet weight of aggregate and pan. Place pan and aggregate over a fire, or in an oven, and dry to constant weight. Subtract the weight of the empty pan from both the wet and dry weights obtained. The results will be the net wet weight and the net dry weight. Next, subtract the net dry weight from the net wet weight, which results in the moisture content (weight of water) in the wet aggregate sample in pounds (kilograms). Divide the moisture content by the net dry weight and multiply by 100 % to obtain the percent moisture in the sample.

Example

Assume that the following weights are obtained for a sample of aggregate:

Empty Pan Weight	= 1.22 lb (0.553 kg)
Weight of Wet Aggregate + Pan	= 8.68 lb (3.937 kg)
Weight Dry Aggregate + Pan	= 8.44 lb (3.828 kg)

The calculations involved to determine the moisture content in the sample are:

English calculation

A. Tare Weight of Pan = 1.22 lbs.

B. Wet Aggregate + Pan Weight = 8.68 lbs.

C. B - A = Wet Aggregate Weight = 8.68 - 1.22 = 7.46 lbs.

D. Dry Aggregate + Pan Weight = 8.44 lbs.

E. D – A = Dry Aggregate Weight = 8.44 – 1.22 = 7.22 lbs.

F. C – E = Weight of Water = 7.46 – 7.22 = 0.24 lbs.

G. (F ÷ E) x 100% = (0.24 ÷ 7.22) x 100 % = 3.3 % moisture

Metric calculation

A. Tare Weight of Pan = 0.553 kg

B. Wet Aggregate + Pan Weight = 3.937 kg

C. B - A = Wet Aggregate Weight = 3.937 – 0.553 = 3.384 kg

D. Dry Aggregate + Pan Weight = 3.828 kg

E. D – A = Dry Aggregate Weight = 3.828 – 0.553 = 3.275 kg

F. C – E = Weight of Water = 3.384 – 3.275 = 0.109 kg

G. (F ÷ E) x 100% = (0.109 ÷ 3.275) x 100% = 3.3 % moisture

Space is available on the TE-45 form for documenting the moisture content of the aggregate used.

Control of Mixing Water

Moisture testing of the aggregate used in the concrete mix design allows the calculation of the total amount of mixing water that can be used per cubic yard of concrete. This mixing water limit should not be exceeded for the batch of concrete.

The field adjustment of slump to workable limits can be obtained by added water (up to the mixing water limit) only if the maximum water-cement ratio is not exceeded and the air content is within specification. The Contractor and/or the Supplier assume the responsibility and financial loss for concrete that is rejected because it is outside the specification limits. Therefore, the Contractor/Supplier should have the right to adjust the amount of mixing water.

The specifications (concrete tables in 499) limit the amount of water for all classes of concrete by specifying a maximum water-cement (w/c) ratio or maximum water-cementitious (w/cm) ratio:

1. The w/c ratio is a ratio of the weight of water to the weight of cement in a batch of concrete.
2. The w/cm ratio is a ratio of the weight of water to the weight of cementitious materials in a batch of concrete.

For the Department's work cementitious materials include cement, fly ash, ground granulated blast furnace slag (GGBFS), and micro silica. The maximum w/c ratio and maximum w/cm ratio are expressed mathematically by Equations 499.15 and 499.16:

$$Maximum\ w/c\ Ratio = \frac{Max.\ Allowable\ Water\ Weight,\ lbs\ (kg)}{Weight\ of\ Cement\ \ lbs,\ (kg)}$$

Equation 499.15– Maximum w/c Ratio

$$Maximum\ w/cm\ Ratio = \frac{Max.\ Allowable\ Water\ Weight,\ lbs\ (kg)}{Weight\ of\ Cementitious\ Materials,\ lbs\ (kg)}$$

Equation 499.16 – Maximum w/cm Ratio

The maximum w/c and w/cm ratios are used by the inspector to determine the maximum allowable water in a concrete batch. The concrete tables give the weight of cement and cementitious materials and the maximum allowable w/c or w/cm ratio for a cubic yard (cubic meter) of concrete. The maximum allowable weight of water can be determined for any of the concrete mixes by using one of the following versions of Equations 499.17 and 499.18:

$$MAWW, lbs\ (kg) = \left(Max.\ w/c\ Ratio\right) \times CW, lbs\ (kg)$$

Equation 499.17 – Maximum Allowable Water method 1

where:

MAWW = Maximum Allowable Water Weight

Max. w/c Ratio = Maximum water/cement ratio given in the tables of 499.03 and 499.04

CW = Cement Weight specified in the tables of 499.03 and 499.04

$$\mathrm{MAWW, lbs\ (kg)} = \left(Max.\ w/cm\ Ratio\right) \times CMW, lbs(kg)$$

Equation 499.18 – Maximum Allowable Water method 2

where:

MAWW= Maximum Allowable Water Weight

Max. w/cm Ratio = Maximum water/cementitious ratio given in the concrete tables of 499.03 and 499.04

CMW = Cementitious Material Weight specified in the tables of 499.03 and 499.04

Once the maximum allowable water weight per cubic yard (cubic meter) is determined for a certain class of concrete, it is adjusted based on the moisture contained in each aggregate at the time of use and the moisture that each aggregate will absorb. The batch weight of water is determined by multiplying the adjusted water weight per cubic yard (cubic meter) by the number of cubic yards (cubic meters) in the batch.

The Inspector must recognize the Contractor's/Supplier's right to make a change in water to prevent the possibility of having concrete rejected for excessive slump. Inspectors are still required to record all adjustments of mixing water and to control slump and yield. If water is added to the concrete truck at the project site, the amount must be recorded and added to the total batch weight and used in the calculation of the w/c ratio (or w/cm ratio) to assure that they are not exceeded.

The Contractor/Supplier does not have the right to adjust the water requirements without informing the Inspector. The Inspector must know when a change is made and the amount of change in order to control and enforce the specification requirements. Inspectors are encouraged to cooperate with the Contractor to effectively control the mixing water to provide concrete of uniform slump.

The amount of water to be added to the mix to produce concrete of the proper slump cannot be determined accurately. Therefore, it is necessary to rely on past experience with the materials being used to estimate the amount of water to use at the start of concrete placements.

CAUTION: Additional water may be added if the estimated quantity of water produces low slump concrete, but excess water cannot be removed if the slump is in excess of maximum allowed. Estimating water should be on the conservative side unless relying on recent experience. When the Inspector is not familiar with the materials being used, it is good practice to choose an amount of water about 5 gallons per cubic yard (25 liters per cubic meter) less than the estimated net mixing water.

Example

Determine the maximum allowable water content for an 8-yd³ load of Class C, Option 3 concrete with the following one cubic yard design weights:

Cement	385 lbs
GGBFS	165 lbs
Fine Aggregate	1310 lbs
Coarse Aggregate	1670 lbs
Max. w/cm ratio	0.50

First determine the maximum allowable water per cubic yard by use of Equation 499.18:

$$\text{MAWW, lbs (kg)} = \left(\mathit{Max.\ w/cm\ Ratio}\right) \times \mathit{CMW, lbs(kg)}$$

(Equation 499.18)

$$= 0.050 \times (385 + 165)$$

$$= 0.50 \times 550$$

$$= 275\ lbs$$

Since 1 gallon of water weighs 8.32 lbs, the maximum allowable water per cubic yard can be calculated as follows:

$$\text{Gallons of Water} = \frac{275\ lbs}{8.32\ lbs/gallon} = 33 \text{ gallons}$$

Next, to determine the maximum allowable water for the 8-yd^3 batch, multiply the one yd^3 allowable water by the size of the batch:

$$(275 \text{ lbs/yds}^3) \times (8 \text{ yds}^3 \text{ /batch}) = 2{,}200 \text{ lbs}$$

or

$$(33 \text{ gallons /yd}^3) \times (8 \text{ yds}^3 \text{ /batch}) = 264 \text{ gallons}$$

Therefore, the maximum allowable water is 2,200 lbs or 264 gallons for the 8-yd^3 batch. This 2,200 lbs (or 264 gallons) is the maximum allowable water; that is, the amount of water that would be adjusted depending on the moisture contained in the aggregates used in the concrete.

Slump

Slump is a measure of the workability of the concrete and nominal and maximum slump values are given in 499.03. It is measured by a standard test in accordance with ASTM C 143. This test is done at the point of placement.

Slump is controlled by the amount of water that is batched into the concrete. Slump is increased as water is added to a batch of concrete. There are chemical admixtures (Type F and G) that can increase the slump chemically, without the addition of extra water.

The specifications in section 499.03 D.1 require that the saturated surface dry (SSD) aggregate weights in the concrete tables be corrected to compensate for the moisture contained in each aggregate at the time of use. The amount of free water in the aggregate contributes to slump and to the water-cementitious ratio.

Table 499.03-1 Concrete Slump (below) shows the nominal slump and maximum slump allowed for certain items of work. Note that the nominal slump for any of the listed work items can be increased to 6 inch (150 mm) if a high range water reducing (superplasticizing) admixture is used in the concrete. The maximum slump may be increased to 7 inches (180 mm) if high range water reducing (superplasticizing) admixture is used.

TABLE 499.03-1 CONCRETE SLUMP

TYPE OF WORK	NOMINAL SLUMP INCH (MM)[1]	MAXIMUM SLUMP INCH (MM)[2]
Concrete pavement (*305*, *451*, 452 *615*)	1 to 3 (25 to 75)	4 (100)
Structural Concrete (*511*, *610*, *622*)	1 to 4 (25 to 100)	5 (125)
Class S, Superstructure concrete (*511*, *526*)	2 to 4 (50 to 100)	4 (100)
Non-reinforced concrete (*601*, *602 603*, *604*, *608*, *609*, *622*)	1 to 4 (25 to 100)	5 (125)
[1] This nominal slump may be increased to 6 inches (150 mm), provided the increase in slump is achieved by adding a chemical admixture conforming to the requirements of *705.12*, Type F or G.		
[2] This maximum slump may be increased to 7 inches (180 mm), provided the increase in slump is achieved by adding a chemical admixture conforming to the requirements of *705.12*, Type F or G.		

Slump Test Requirements

This test is the responsibility of the Department except for work under a QC/QA specification, when it is that of the Contractor. A slump test using the slump cone will be made each time a set of cylinders is cast for structures or a set of beams is cast for pavements. Further tests are required as needed to maintain control of the slump within the limits specified.

Slump requirements apply at the point of use; therefore, slump must be determined at the work site on concrete being placed in the forms. When concrete has to be conveyed by any means (by a concrete pump, concrete conveyor, or bucket) from the hauling units to the forms where it will be incorporated into the work, the slump should be determined from concrete obtained as it is being placed in the forms. Usually, such tests cannot be conducted properly at the point of use, but the sample can be obtained and removed to a convenient site for immediate slump determination. By correlating such tests with tests on the same concrete being discharged from hauling units several times a day, the difference in slump can be determined and applied to all other tests conducted on concrete from the hauling units. In this manner, there will be less interruption in production and less interference in conducting the tests.

At the ready mix and central mix plants, loads may be checked for slump so that appropriate adjustments may be made to avoid shipment and rejection of concrete at the work site. Loads that only slightly exceed the slump requirements when tested at the plant should not be rejected. However, adjustment should be considered for subsequent loads to avoid the possibility of rejecting succeeding loads.

Conducting tests at the plant does not eliminate the necessity of conducting test at the site. Further tests will be required as the concrete is being placed.

The specification requirements for slump vary depending on the type of work being constructed. Table 499.03-1 lists the required nominal slump and the maximum slump in inches (millimeters). These slumps are achieved using water and any required admixture. If the Contractor wants more slump than specified on Table 499.03-1, a Type F or Type G admixture may be used and the nominal slump may be increased to 6 inches (150 mm) and the maximum slump may be increased to 7 inches (180 mm). The higher slump is allowed regardless of the type of work.

A retarding admixture (Type B or D) is required in all concrete if the plastic concrete temperature exceeds 75° F (24° C). The admixture must be dispensed in accordance with the admixture manufacturer's recommendations and the water cement ratio must not be exceeded.

Slump must be maintained at the specified nominal slump except that an occasional load exceeding the nominal range but within the maximum slump limit may be used. This is allowed provided an immediate adjustment is made to reduce the slump of succeeding loads to within the nominal slump range. Before using concrete exceeding the nominal slump, the Contractor or supplier must take positive action to reduce the slump of following loads. If the high slump was the result of adding too much water at the site, less water should be added to the next load. If high slump results from water added at the plant notify the plant before using the batch and order an immediate reduction in water. Use of concrete having the slump between nominal and maximum should be restricted to an occasional load.

Slump Test (ASTM C 143)

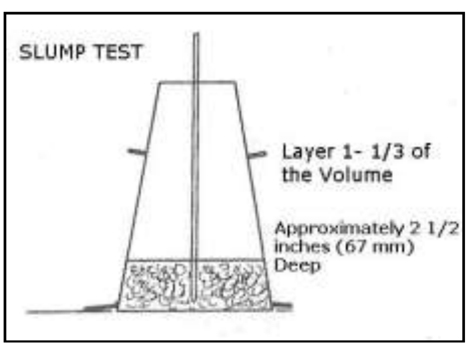
Start the slump test within five minutes of obtaining a composite sample. The inner surface of the slump cone is dampened and placed on a clean, flat, moist, non-absorbent, rigid surface, such as a smooth plank.

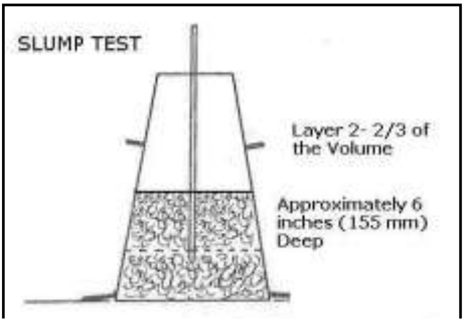
Pulling the Slump Cone Vertically from a Prepared Sample

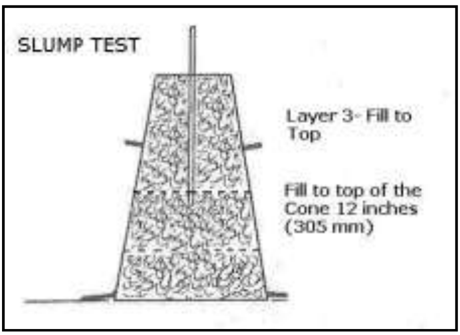
Equipment Necessary for the Slump Test- Slump Cone, Tamping Rod, Scoop and Ruler

<u>Component Parts and Accessories</u>

1. Slump cone – A metal mold in the shape of a cone with an 8-inch ± 1/8 inch (203-mm ±3.2 mm) diameter base, a 4-inch ± 1/8 inch (102-mm ±3.2 mm) diameter top that is 12 inches tall. The mold must be made of metal no thinner than 0.045 inch (1.14 mm). The inside metal surface must be smooth.
2. Accessories
3. Tamping rod- a straight 5/8-inch (16 mm) diameter rod that is approximately 24 inches (600 mm) long with a rounded (hemispherical) tip.
4. Ruler- a ruler or tape to measure the slump of the sample.
5. Scoop- metal scoop is used to place the concrete sample into the slump cone.







Method of Operation

The Inspector holds the cone firmly in place, while it is being filled, by standing on the foot pieces.

The mold is filled in 3 layers, each approximately 1/3 the volume of the mold; the first layer approximately 2 1/2 inches (67 mm) deep, the second layer 6 inches (155 mm) deep, and the third layer 12 inches (305 mm) to the top of the cone.

In placing each scoop of concrete in the slump cone, the scoop is moved around the top edge of the cone as the concrete slides from it in order to insure uniform distribution of concrete within the cone.

Each layer is rodded 25 strokes with the tamping rod. The strokes are distributed in a uniform manner over the cross section of the mold and should penetrate into but not through the underlying layer. The bottom layer is rodded throughout its depth.

In filling and rodding the top layer, the concrete is heaped above the mold and any excess is maintained above the top while rodding. After the top layer has been rodded, the surface of the concrete is struck off with the tamping rod so that the mold is exactly filled.

Next, release the foot pegs while pressing down firmly on the hand holds on the slump cone, while being careful to keep the cone firmly on the base. Remove any excess concrete at the base of the slump cone.

Lift the slump cone straight up in one steady motion. The operation of raising and removing the mold is performed in 3 to 7 seconds by a steady upward lift, with no lateral or twisting motion being imparted to the concrete sample.

The slump is the distance the concrete drops from the original height of the sample, which is 12 inches (305 mm). To measure the distance, place the slump cone beside the slumped concrete and place the tamping bar on top of the cone so that the bar is level and is above the displaced original center of the sample. Measure the distance from the displaced original center of the sample to the bottom of the tamping rod. The distance measured is the slump of the concrete.

Measurement of Slump

The entire operation from start of filling through mold removal must be completed within the elapsed time of 2 1/2 minutes. The slump must be recorded in inches (millimeters) to the nearest 1/4-inch (6 mm). Slump cone test results should be recorded in the column labeled "Slump inches (millimeters)" on the TE-45 Report.

Concrete Yield

The yield of a concrete batch is the volume that it occupies. Concrete is sold by volume but it is batched by the weight of each ingredient. This test is the Department’s responsibility except for work under a QC/QA specification in which it is that of the Contractor. The first yield test for each day's production is made after the slump and entrained air content have been properly adjusted. A yield test is then done to confirm the volume of concrete in the batch.

Yield tests are made whenever the yield is in doubt, after adjustments are made in the mix, or when cylinders or beams are cast. Unless the quantity of concrete to be mixed is small, at least two tests should be made each day.

Yield must be within a tolerance of ± 1 percent at the design air content and at the specified slump. Therefore, 1 cubic yard (27 cubic feet) may vary from 26.73 to 27.27 cubic feet per cubic yard (1 cubic meter may vary from 0.99 to 1.01 cubic meter). An 8 cubic yard load is 216 cubic feet (8 x 27 cu.ft. / cu.yd.). This load may vary from 213.84 to 218.16 cubic feet (a 7-cubic meter load may vary from 6.93 to 7.07 cubic meter). A consistent over or under yield, even within the tolerance, should be corrected in order to maintain the correct cement factor.

Yield Test (ASTM C 138)

The yield is calculated by performing a field test to determine the unit weight of a representative sample of concrete taken from the batch. The Department uses the bottom pot of the pressure meter to determine the unit weight of a concrete sample. The unit weight of the concrete is then used to calculate the yield by the following formula:

$$Yield = \frac{Batch\,Weight}{Unit\,Weight}$$

Equation 499.20– Yield

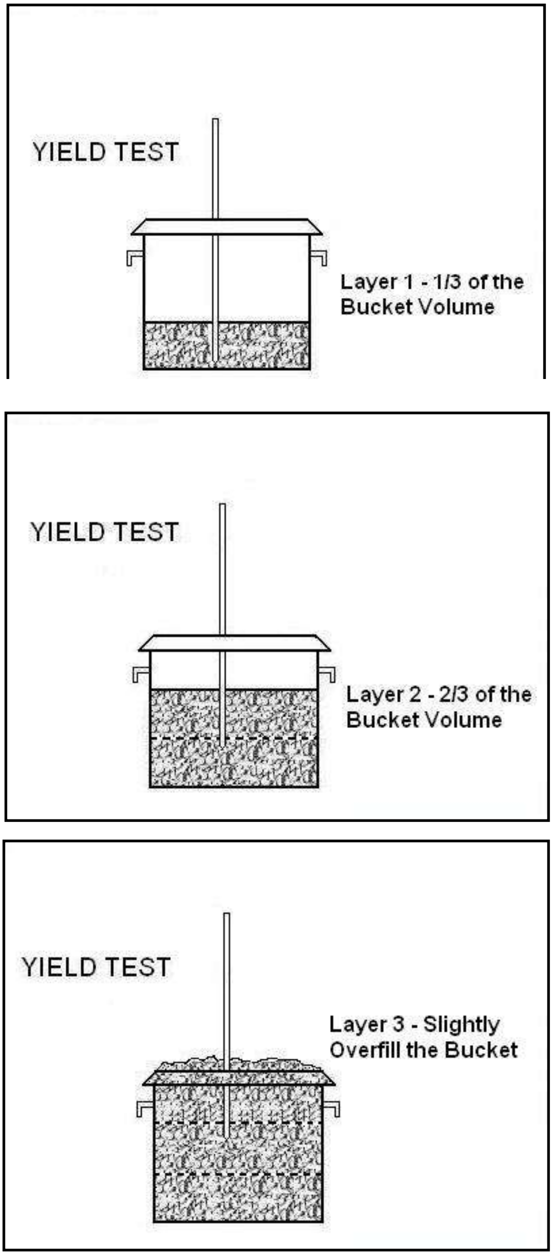
Unit weight is the ratio of the weight of a material to the volume that it occupies. Unit weight is expressed in pounds per cubic foot (kilograms per cubic meter).

Equipment Used for the Yield Test

Scale Used for the Yield Test

Component Parts and Accessories

1. A volume measure, a pressure meter air pot at least 0.20 ft³ (0.006 m³.) capacity. The container volume must be known or an air pot factor must be determined prior to use.
2. Accessories
   a. Strike-off bar
   b. Scoop
   c. Strike-off plate - a flat square plate at least 2 inches wider than the diameter of the measure and at least ¼-inch (50 mm) thick if made of steel and ½-inch thick if made of glass.
   d. Tamping rod – A straight 5/8-inch (16 mm) diameter steel rod which is approximately 24 inches (600 mm) long with a rounded (hemispherical) tip.
   e. Scale- a scale of a capacity to weigh the pot filled with concrete
   f. Rubber mallet, 1.25 ± 0.50 lbs (0.6 kg ± 0.25 kg)



Yield Test – Bucket is Filled in Three Equal Layers

Method of Operation

The concrete yield is determined as follows:

1. To determine the unit weight of a concrete sample, first weigh the bottom of the empty air pot to the nearest 0.01 pound (0.005 kg).
2. Next, fill the measure with concrete, representative of that being placed, in 3 equal layers, rodding each layer with 25 strokes of the tamping rod. After rodding each layer, tap the measure on the sides 10 to 15 times with an appropriate mallet to close any voids left by the tamping rod and to release any large bubbles of air that may have been trapped.
3. After the consolidation is completed, strike off excess concrete and finish even with the top edge of the measure with the metal strike-off plate. After strike-off, clean all excess concrete from the exterior of the measure and determine the gross weight of the measure and the concrete sample.
4. Calculate the net weight of the concrete sample in pounds (kilograms) by subtracting the weight of the measure from the gross weight.
5. The net weight of the concrete sample is then used to determine the unit weight. The unit weight is the product of the net weight of the sample under test and the air pot factor as follows:

$$Unit\ Weight = \left(Net\ Weight\ of\ the\ Sample\right) \times \left(Air\ Pot\ Factor\right)$$

Equation 499.21 – Unit Weight

The air pot factor is the inverse of the volume of the air pot in cubic feet, as shown in Equation 499.22:

$$Air\ Pot\ Factor = \frac{1}{Air\ Pot\ Volume}$$

Equation 499.22 – Air Pot Factor

Therefore, an air pot volume of ¼ cubic feet or 0.25 cubic feet would have a pot factor as follows:

$$Air\ Pot\ Factor = \frac{1}{1/4\ ft^3} = \frac{1}{0.25\ ft^3} = 4.00$$

Note: The air pot factor is determined by a Laboratory test and is written on the side of all air pots. This factor is determined by a calibration process described in the section entitled Determination of the Air Pot Factor.

When the air pot factor is multiplied by the net weight of the concrete sample that is consolidated and struck off into the air pot's volume (per Equation 499.21), mathematically it is the same as dividing the net weight of the sample by the volume of the concrete sample weighed. This gives the Unit Weight of the sample in pounds per cubic foot (kilograms per cubic meter).

The calculated unit weight of the concrete is the number of pounds per cubic foot (kilograms per cubic meter) for the sample under test. The unit weight is used to calculate the yield.

Next calculate the yield using Equation 499.20:

$$Yield = \frac{Total\ Batch\ Weight}{Unit\ Weight}$$

The total batch weight of the concrete is the weight of all the ingredients used in the batch or a cubic yard. This includes cementitious materials; moist coarse and fine aggregate; water added at the plant plus any water added at the job site to adjust slump. This total batch weight is divided by the unit weight of the concrete sample to determine yield. The yield is the number of cubic feet (cubic meters) of concrete in the batch.

Example

The following are the batch weights for an 8 cubic yard (7 cubic meter) load of concrete, delivered to the project:

		English (lbs)	Metric (kg)
1	Cement	4,800	2,492
2	Fine Aggregate	10,698	5,550
3	Coarse Aggregate	13,229	6,868
4	Water	1,664	864
5	Total Batch Weight (1+2+3+4)	30,391 lbs	15,774 kg

An air pot with an air pot factor of 4.022 (141.24) is weighed empty and determined to be 7.98 lbs (3.62 kg). The gross weight of the air pot and the concrete sample is determined to be 43.52 lbs (19.83 kg). Determine the unit weight of the sample and the yield of the batch of concrete.

First determine the net weight of the concrete sample:

Gross wt. of measure + concrete	43.52 lbs (19.83 kg)
Tare weight of measure empty	-7.98 lbs (- 3.62 kg)
Net weight of concrete sample	35.54 lbs (16.21 kg)

Now that the net weight of the sample is known the unit weight is determined by the use of Equation 499.21 as follows:

Unit Weight = $(Net\ Weight\ of\ the\ Sample) \times (Air\ Pot\ Factor)$

= 35.54 x 4.022 (16.21 x 141.24)

= 142.94 lbs/ft³ (2289.5 kg/m³)

Next determine the yield of the 8 cubic yard (7 cubic meter) load of concrete by using Equation 499.20 as follows:

$$\text{Yield} = \frac{Total\ Batch\ Weight}{Unit\ Weight}$$

$$= \frac{30{,}391\, lbs}{142.94\, lbs/ft^3}$$

$$\left(\frac{15{,}774\, kg}{2289.5\, kg/m^3}\right)$$

= 212.61 ft³

$(6.89\, m^3)$

In English units, the intended number of cubic feet per batch is determined by multiplying the number of cubic yards in the batch by 27 cubic feet per cubic yard (27 x 8 = 216 = the intended number of cubic feet per batch). If the number of cubic feet per batch, as determined by the yield test, is within 1 percent of the design, at the specified air and slump, no change is necessary in the batch weights. However, if the volume of concrete is not within 1 percent of the intended volume, or if there is a continued over-yield or under-yield even though within 1 percent, then a yield adjustment must be made. A yield adjustment involves reducing or increasing the batch weights to correct an over-yield or under-yield situation.

In the above example, 8 cubic yards or 216 cubic feet was the intended yield but the calculated yield was 212.61 cubic feet. Therefore, there was an under-yield of 1.6 %, which exceeds the allowable 1%. To correct this under yield the batch weights of the coarse and fine aggregate batch weights must be increased (thus adding more volume of material to the batch). Adjustment to correct an over-yield or under-yield should be based on the absolute volume of dry material.

In Metric units, the yield is compared to the design number of cubic meters batched to determine if the batch is within the one percent yield tolerance. The allowable deviation in yield for a 7 m^3 batch is 6.93 m^3 to 7.07 m^3. In the above example, the yield was found to be 6.89 m^3, which is less than the allowable range. Again, this under yield situation requires an adjustment in the batch weights.

Form C-45, Concrete Control Test Form, is provided for documenting and calculating the tests run in the field. A copy of this form is shown in Figure 499.A

Concrete Control Test Form (C-45)

Project No. __________ Co./Rt./Sec. ________________

Name:______________________________ Date:__________ Truck No.____________

Arrival Time:_______________ Discharge Time:________________

Placement Description: ____

Placement Location: ____

Cylinder Sample Numbers: ________________________________ Class _____ Concrete

Full Pot Weight = (+) _________________ lbs.

Empty Pot Weight = (-) _________________ lbs.

Concrete Weight = _________________ lbs.

Air Pot Factor = × _________________

Weight of One Cubic Foot (Unit Weight) = _________________ lbs / ft^3

Batch Weight

Fine Aggregate :	_______ lbs / _____	yd^3 =	__________	lbs
Coarse Aggregate	_______ lbs / _____	yd^3 =	__________	lbs
Cement	_______ lbs / _____	yd^3 =	__________	lbs
Water Batch Weight	_______ lbs / _____	yd^3 =	__________	lbs
Other _______________	_______ lbs / _____	yd^3 =	__________	lbs

One Cubic Yard Batch Weight = __________ lbs

Yield Test Results

$$Yield = \frac{One\ Cubic\ Yard\ Batch\ Weight}{Unit\ Weight\ of\ the\ Sample} = \_\_\_\_\_\_\_\_\_\_\_\_ \text{ cubic feet}$$

Air = ______ % , Slump = _______ inch , Air Temp. = ______ , Concrete Temp.= ______

Figure 499.A - Concrete Control Test Form C-45

Making a Yield Adjustment

Assume the actual calculated number of cubic feet (cubic meters) per batch is 212.61 cubic feet (6.89 cubic meters), which is more than 1 percent under the 216 cubic foot (7.0 cubic meters) intended volume. Therefore, the batch weights must be increased. Equation 499.21 shows the calculation of the under yield:

$$Percent\ OY\ or\ UY = \left(\frac{Actual\,Yield}{Intended\,Yield} \times 100\% \right) - 100\,\%$$

Equation 499.23 – Under Yield Calculation

Where:

Percent OY or UY= Percent Over-Yield or Percent Under-Yield

If the number obtained by Equation 499.21 is a negative number, there is an under yield and volume must be added to get the yield back to the intended yield. Conversely, if the number is positive, there is an over yield situation and volume must be removed from the batch to reduce the yield back to the intended yield.

Using the example numbers, the % Under or Over Yield can be determined:

Percent OY or UY =

$$\left(\frac{212.61\,ft^3}{216.00\,ft^3} \times 100\,\% \right) - 100\,\% = 98.4\,\% - 100\,\% = -1.6\%$$

$$\left(Percent\,OY\,or\,UY = \left(\frac{6.89\,m^3}{7.00\,m^3} \times 100\% \right) - 100\,\% = 98.4\,\% - 100\% = -1.6\% \right)$$

The total batch weight should be increased to adjust the under-yield. Since the batch of concrete did not produce the intended volume, additional volume of material must be added to adjust the under yield. Adjustments are made in the fine and coarse aggregate based on absolute volume. The cement is the minimum specified, and therefore, is not changed. Water may vary slightly, and must be considered in making the adjustment. The calculations for adjusting the mix are as follows:

Total under yield = 216 ft^3 - 212.61 ft^3 = 3.39 ft^3 (7.00 m^3 - 6.89 m^3 = 0.11 m^3)

Thus, the 8 yd^3 (7 m^3) load must be adjusted by adding 3.39 ft^3 (0.11 m^3) of volume. By adding this much volume to the load, the yield should increase in subsequent loads after the adjustment is made. The volume needed to adjust the under-yield is replaced with sand and stone in the same proportion as in the original concrete sample.

Next, determine the percent of fine and coarse aggregate in relation to the total aggregate weight in the original mix design. For this calculation the corrected SSD design weights are to be used.

Fine aggregate (SSD)	10,160 lb	(5271 kg)
Coarse aggregate (SSD)	12,944 lb	(6720 kg)
Total Aggregate (SSD)	23,104 lb	(11,991 kg)

% Fine Aggregate =

$$\frac{10{,}160\,lbs}{23{,}104\,lbs} \times 100\,\% = 44\,\%$$

$$\left(\frac{5271\,kg}{11{,}991\,kg} \times 100\,\% = 44\,\% \right)$$

% Coarse Aggregate =

$$\frac{12{,}944\,lbs}{23{,}104\,lbs} \times 100\,\% = 56\,\%$$

$$\left(\frac{6720\,kg}{11{,}991\,kg} \times 100\,\% = 56\,\% \right)$$

Next, determine the proportion of the 3.39 cu. ft (0.11 cubic meter) under-yield volume that must be fine and coarse aggregate. These adjustments maintain the same proportion of aggregate in the adjusted mix design as was in the original mix design.

Fine Aggregate	= 3.39 ft^3 x 0.44	= 1.49 ft^3 (= 0.11 m^3 x 0.44 = 0.048 m^3)
Coarse Aggregate	= 3.39 ft^3 x 0.56	= 1.90 ft^3 (= 0.11 m^3 x 0.56 = 0.062 m^3)
Total	= 3.39 cu. ft^3	(= 0.110 m^3)

Now that the absolute volume of fine aggregate and coarse aggregate necessary to correct the under yield are known, the weight of each material can be calculated since the specific gravities of each aggregate are known.

Fine Aggregate Adj	$=1.49\ ft^3 \times 2.59 \times 62.4\ lbs/ft^3$ (Equation 499.6)
	= 241 lbs
	= ($0.048 m^3 \times 2.59 \times 1000\ kg/m^3$) (Equation 499.7)
	= (124 kg)
Coarse Aggregate Adj	$=1.90\ ft^3 \times 2.63 \times 62.4\ lbs/ft^3$ (Equation 499.6)
	= 312 lbs
	= ($0.062\ m^3 \times 2.63 \times 1000\ kg/m^3$) (Equation 499.7)
	= (163 kg)

Thus from the above, it can be seen that 241 lbs (124 kg) of fine aggregate and 312 lbs (163 kg) of coarse aggregate are required to adjust the yield of this 8 cubic yard (7 cubic meter) load.

If the mix appears to be over-sanded, only the coarse aggregate needs to be adjusted. However, if the mix appears under-sanded, or bony, the adjustment should be in the fine aggregate only.

The adjustments in the SSD weight of fine and coarse aggregate for the above example are as follows:

Fine Aggregate	10,160 + 241 = 10,401 lb (5271 + 124 = 5395 kg)
Coarse Aggregate	12,944 + 312 = 13,256 lb (6720 + 163 = 6883 kg)

The new adjusted batch weights must next be determined and the water-cement ratio must be checked to make sure the specified water-cement ratio is not exceeded with the new batch weights.

Determination of the Air Pot Factor

This test is done by the Laboratory or the District Test Lab and is shown here.

The air pot container is filled with water at room temperature and the top covered with a glass plate to eliminate all air bubbles and excess water. Determine the weight of water in the measure to the nearest 0.01-pound (.005 kg). Measure the temperature of the water and determine its density from the table below:

DENSITY OF WATER			
ENGLISH		METRIC	
Temperature (Degrees F)	Density (lbs /cu. ft.)	Temperature (Degrees C)	Density (kg/ m^3)
60	62.366	16	999.10
65	62.337	18	998.64
70	62.301	21	998.06
75	62.261	24	997.42
80	62.216	27	996.70
85	62.166	29	995.90

Calculate the air pot volume factor by dividing the density of water (from the table) by the weight of water required to exactly fill the measure. Measures should be calibrated once each year and the pot factor painted on the measure. This air pot factor should be nearly 4.000 (141.24) indicating that the measure is about 0.25 cubic foot (0.00708 m^3) of volume.

Example

Assume the temperature of the water used to fill the air pot bottom is 70º F and the following is determined in the laboratory:

1. Weight of air pot bottom empty plus the glass plate = 8.98 lbs
2. Weight of air pot bottom plus glass plate plus water = 24.47 lbs
3. Weight of water in air pot bottom = (2) - (1) = 15.49 lbs
4. Density of water at 70º F, from the above table = 62.301 lbs/cu.ft.

$$\text{Air Pot Factor} = \frac{\textit{Density of water}}{\textit{Weight of water in air pot bottom}} = \frac{62.301\, lbs/ft^3}{15.49\, lbs} = 4.022$$

Total Air Tests (ASTM C 231 or ASTM C 173)

The air content of concrete is measured by a standard test in accordance with either ASTM C 231 (Pressure Meter Method) or ASTM C 173 (Volumetric Method).

Pressure Meter Method

Volumetric Method

Air tests must be made for several loads or batches at the start of daily production and after any adjustment in the batch weights. A test is made whenever it is suspected that adequate air entrainment is not being maintained. An air test must also be made when a yield test is made and when cylinders or beams are cast.

The requirements apply at the point of use; therefore, these tests must be made by the concrete control Inspector at the job site. However, it may be desirable to check the air content of the concrete at the plant for the first few batches of the day and also after any adjustment has been made in the concrete mix design. These checks can detect deficiencies in air content at the plant where immediate corrections can be made.

The approximate amount of entrained air may be determined quickly by using a Chace Indicator. Every load of transit mix concrete used in superstructures must be checked for air entrainment. The Chace Indicator permits a quick check of every load. Its use also is desirable for all concrete work to quickly check the requirement for entrained air. Whenever the specification limits are exceeded according to the Chace Indicator, a more accurate determination must be made using an air meter (Pressure Meter or Volumetric Meter).

Make a test from the same batch of concrete at least once a day using the Chace Indicator and an air meter to compare the results. Comparison of these results provides the Inspector with a guide when using the Chace. If the Chace indicates 4.5 percent and the meter test result is only 4.0 percent, the air must not be permitted to drop below 4.5 percent when checked using the Chace.

Use a Pressure Meter or Volumetric Meter to determine the air content to be reported when making yield tests and when casting cylinders. An accurate determination is necessary in each case; therefore, an accurate test is required.

A Chace Indicator and Volumetric air pot can be used for all types of concrete. The Pressure Meter must not be used when slag or light weight coarse aggregate are used in the concrete. The Pressure Meter is limited to concrete consisting of relatively dense coarse aggregate such as gravel or limestone. A Volumetric Meter test must be used when slag or lightweight aggregates are used. Detailed explanation of each method follows.

Air Content of Freshly Mixed Concrete by the Pressure Meter (ASTM C 231)

This test method is used with dense aggregate concretes for which the aggregate correction factor can be determined. This method is not applicable to light weight aggregates, air-cooled blast furnace slag, or aggregates of high porosity. If these aggregates are incorporated, a volumetric air test (ASTM C 173) must be used.

This air test measures the entrapped and entrained air in the concrete sample. The air content from this test is the apparent air content of the sample. A separate test is made on the aggregates used to make the concrete to determine an aggregate correction factor for the concrete aggregates. This percentage value is subtracted from the apparent air content to obtain the amount of entrained air in the concrete. Department specifications specify the amount of entrained air that is required in the concrete at the point of use.


Assembled Pressure Meter


Equipment Necessary for Pressure Meter Test

The Pressure Meter Test is performed as follows:

Parts and Accessories

1. Component Meter
   a. Pot at least 0.20 ft^3 (0.006 m^3.) capacity
   b. Top including gage, pump, and clamps
2. Accessories
   a. Calibration cylinder
   b. Section of straight tubing
   c. Section of curved tubing
   d. Strike-off bar
   e. 16 mm (5/8") Tamping rod
   f. Rubber syringe
   g. Rubber mallet, 0.6 kg ± 0.25 kg (1.25 ± 0.50 lbs.)
   h. Wooden carrying case

Method of Operation

Follow these steps to use a Pressure Meter to determine the percentage of air in a sample of concrete:

1. Place a representative sample of the concrete in the bowl in 3 equal layers, consolidating each layer by 25 strokes of the tamping rod distributed over the entire cross section of the bowl. After each layer is rodded, tap the sides of the measure smartly 10 to 15 times with the rubber mallet to close any voids left by the tamping rod and to release any large bubbles of air that may have been trapped. Rod the bottom layer through its depth but do not forcibly strike the bottom of the bowl. When rodding subsequent layers penetrate the previous layer only about 1 inch (25 mm).
2. Strike off the concrete surface, level full, using the straightedge (or a plate when determining the unit weight) then clean the edge and exterior of the pot thoroughly.
3. At this point, the pot and sample is weighed. This gross weight is documented for later use when determining the yield.
4. Next place the top on the pot and clamp securely. Close the air valve between the air chamber and the bowl and open both petcocks.
5. Using the rubber syringe, inject water through one petcock until all air is expelled through the opposite petcock. Leave petcocks open.
6. With built-in pump, pump up air to the "Initial Pressure" line on gage. This initial pressure line is given on the paper in the carrying case lid.
7. Wait a few seconds for the compressed air to cool to normal temperature, and then stabilize the gage hand at the proper initial pressure line by pumping or bleeding off as needed.
8. Close both petcocks and press down on the "thumb lever" to release air into the base. Hold thumb lever down for a few seconds. Tap the sides of the bowl several times sharply with the mallet. Lightly tap the gage to stabilize the hand on the dial.

9. Read and record the percent of air entrainment as shown on the gage. This is the apparent air content of the concrete in percent.
10. The true percentage of air-entrained in the concrete is the apparent air content, as found is in 9 above, minus the aggregate correction factor as determined is in the following section entitled Determination of Aggregate Correction Factor. Therefore, subtract the aggregate correction factor from the apparent air content found in 9 and record it on the TE-45 Report, as percent of entrained air in concrete.

Determination of Aggregate Correction Factor

Since aggregate particles generally are porous, they contain a small amount of volume of air that is included in the apparent air content, as measured in 9 above. This volume percentage must be deducted from the total air content percentage to obtain the true entrained air content of the concrete. To obtain the aggregate correction factor it is necessary to run an air determination (with the pressure meter) on equivalent amounts of fine aggregate and each size of coarse aggregate that would be contained in the air pot volume of concrete. This factor varies with different aggregate sources and must be determined by actual tests. The aggregate correction factor is determined prior to any concrete placement and is applied as long as there is no change in the source of the aggregate or proportioning used in the concrete under test.

The Aggregate Correction Factor is determined as follows:

1. The amount of each aggregate to be used in the test is determined by dividing the volume of the air pot by the intended volume of the concrete batch. This ratio is multiplied by the actual batch weight of the particular aggregate that was used in the concrete. Use equation 499.24 to determine the weight of each aggregate to be used in the test.

$$\text{Aggregate weight} = \left(\frac{APV}{IBV}\right) \times ABW$$

Equation 499.24 – Weight of each Aggregate

where:

APV = Air Pot Volume in cubic feet (m^3)

IBV= Intended Batch Volume in cubic feet (m^3)

ABW = Aggregate Batch Weight in lbs. (kg) for the intended volume

Example: Given the following information determine the amount of fine and coarse aggregate necessary for an aggregate correction test:

Volume of Air Pot = 0.25 ft^3 (0.00708 yd^3)

Intended Volume of Concrete per Batch = 8 yd^3 or 216 ft^3 (7 m^3)

Aggregate Batch Weight for Fine Aggregate = 10,698 lbs (5550 kg)

Aggregate Batch Weight for Coarse Aggregate = 13,229 lbs (6868 kg)

Fine Aggregate Weight	$= \frac{0.25 ft^3}{216\ ft^3} \times 10{,}698\, lbs$	(Equation 499.24)
	$= 12.38\, lbs$	
	$= \left(\frac{0.00708\, m^3}{7.00\, m^3} \times 5550\, kg \right)$	(Equation 499.24)
	$= 5.6\, kg$	
Coarse Aggregate Weight	$= \frac{0.25 ft^3}{216 ft^3} \times 13{,}299 lbs$	(Equation 499.24)
	$= 15.31\, lbs$	
	$= \left(\frac{0.00708\, m^3}{7.00 m^3} \times 6868\, kg \right)$	(Equation 499.24)
	$= 6.9\, kg$	

Therefore, 12.38 pounds (5.6 kg) of sand and 15.31 pounds (6.9 kg) of stone are used to determining the correction factor.

2. Fill the air pot 1/3 full of water. Carefully add a portion of the coarse aggregate then a portion of the fine aggregate. Jar the pot and rod the aggregate to eliminate any entrapped air. Carefully repeat, adding portions of each aggregate until all the aggregate is inundated into the pot. Each aggregate addition must be added carefully as instructed in order to get the entire quantity into the volume of the pot. Make sure that aggregate in the pot remains submerged at all times. If the sand is not rodded into the voids between the coarse aggregate particles, the aggregate quantities will overflow the pot. Aggregates should be in approximately the same moisture condition as those used in the concrete.
3. Strike off any excess foam and keep the aggregates inundated for a period of time approximately equal to the time between introduction of water into the mixer at the concrete plant and the time of performing the air test in the field.
4. Screw the short piece of straight tubing into the threaded petcock hole on the underside of the top cover. Place the top on the pot and clamp

securely. Close the air valve between the air chamber and the measuring bowl and open both petcocks.

5. Add water with a syringe through the petcock having the pipe extension below until all air is expelled from the second petcock. Leave both petcocks open.
6. Pump up the air pressure in the air chamber to a little beyond the initial pressure line marked in the carrying case lid. Wait a few seconds for the compressed air to cool to normal temperature and then stabilize the gage at the proper initial pressure line by pumping or bleeding off air as needed and tapping the gage slightly.
7. Screw the curved tube into the outer threaded end of the petcock. Close both petcocks and press the thumb lever to release the air into the bowl. Fill the 5 percent calibrating vessel level full of water from the base by controlling the flow of water with the petcock valve on the curved tube.
8. Release the air at the free petcock and let the water in the curved pipe run back into the base. The air meter now has 5 percent of its volume removed.
9. With both petcocks open, pump the air pressure in the air chamber to slightly beyond the initial pressure line. Wait for the compressed air to cool and then stabilize the gage hand at the proper initial pressure line by pumping or bleeding off air as needed and tapping the gage slightly.
10. Close both petcocks and press the thumb lever to release the air into the bowl.
11. Read and record the air content shown on the meter. The aggregate correction factor will be the difference between the air content on the meter minus 5 percent.

Note: Normally the aggregate correction factor will be between 0.1 and 0.8 percent. This factor will ordinarily remain constant (with limestone or gravel coarse aggregate) for the same combination and quantity of aggregate. It is essential, therefore, to determine the aggregate correction factor accurately since any errors made in the factor will be reflected in all air content determinations. BE SURE THAT ALL AIR ENTRAPPED IN THE INUNDATED AGGREGATE IS ELIMINATED WHEN PREFORMING THE TEST.

Checking Calibration of Gage

All Pressure Meters are calibrated and tested for leaks. Any changes found in the manufacturers initial pressure line is marked in red on the paper in the carrying case lid, before the meters are issued by the Laboratory. However, rough handling or worn or damaged parts will affect the calibration. Therefore, the operator should check the meter every 3 months. The method of checking is as follows:

1. Fill the base with water.
2. Screw the short piece of straight tubing in the threaded peacock hole on the underside of the cover. Clamp cover on the base with the tube extending down into the water.

3. With both petcocks open, add water with syringe through the petcock having the pipe extension below, until all air is forced out of the opposite petcock. Leave both petcocks open.
4. Pump up air pressure to a little beyond initial pressure line marked in carrying case lid. Wait a few seconds for the compressed air to cool to normal temperature and then stabilize the gage hand at the proper initial pressure line by pumping or bleeding off as needed.
5. Close both petcocks and immediately press down on the thumb lever exhausting air into the base. Wait a few seconds until the hand is stabilized. If all the air was eliminated and the initial pressure line was correctly selected, the gage should read 0 percent. If two or more tests show a consistent variation from 0 percent then change the initial pressure to compensate for the variation. Use the newly established "initial pressure" line for subsequent tests.
6. Screw the curved tube into the outer end of petcock and, by pressing on the thumb lever and controlling flow with petcock lever, fill the 5 percent calibrating vessel lever full of water from the base.
7. Release the air at the free petcock. Open the other petcock and let the water in the curved pipe run back into the base. There is now 5.0 percent air in the base.
8. With petcocks open, pump air pressure in the exact manner as outlined in step 4 above. Close petcocks and immediately press the thumb lever. Wait a few seconds for the exhaust air to cool to normal temperature and for the needle to stabilize. The dial should now read 5.0 percent.
9. If two or more consistent tests show that the gage reads less than 4.9 percent or more than 5.1 percent then remove the gage glass and reset the dial hand to 5.0 percent by turning the recalibrating screw located just below and to the right of the center dial.

Air Content of Freshly Mixed Concrete by Volumetric Method (ASTM C 173 modified for ODOT use)

This test method can be used on concrete containing any type of coarse aggregate. This method gives the total air content, which includes both entrapped and entrained air. This method must be used if lightweight coarse aggregate, air-cooled blast furnace slag coarse aggregate or aggregate of high porosity is used in the concrete under test.

The method involves taking a known volume of concrete and breaking it down by washing it with water in a sealed container. A fixed amount of water is used to wash the sample of concrete in the container. After the washing, the volume of the sample and wash water decreases by the volume of air washed from the known volume.

Assembled Brass Volumetric Air Meter

Plastic Volumetric Air Meter and Accessories

Parts and Accessories

1. Meter
    a. Bottom Pot, 0.075 cu. ft (2.1 L) capacity
    b. Top cone including gage glass, clamps and top plug
2. Accessories
    a. Water filler and dispersion tube
    b. Strike off bar
    c. 5/8" (16 mm) Diameter tamping rod
    d. Brass cup, capacity 23 milliliter
    e. Small rubber syringe
    f. Can of 70% isopropyl alcohol (poison)
    g. Rubber mallet 1.25 ± 0.50 lbs (0.6 kg ± 0.25 kg)
    h. Carrying case

Method of Operation

The percent of entrained air in a sample of concrete is determined as follows using the volumetric air meter:

1. Place a representative sample of the concrete in the bowl in 2 equal layers, consolidating each layer by 25 strokes of the tamping rod. After each layer is rodded, tap the sides of the measure 10 to 15 times smartly with the rubber mallet to close any voids left by the tamping rod and to release any large bubbles of air that may have been trapped.
2. Strike off the concrete surface, level full, using the straightedge.
3. Place the cone on the pot and clamp securely.
4. Insert the dispersion tube into the neck of the meter. Add at least one pint of water followed by one pint of isopropyl alcohol. Continue adding water until it appears in the graduated neck of the top section of the meter. Remove the dispersion tube. Bring the water level up until the bottom of the meniscus is even with the 0 mark.
5. Attach and tighten the water-tight cap.
6. Repeatedly invert and agitate the unit for a minimum of 45 seconds to free the concrete from the base. Do not invert the meter from more than five seconds at a time.
7. Tilt the meter approximately 45 degrees and vigorously roll and rock the meter for approximately 1 minute keeping the neck elevated at all times.
8. Set the meter upright and allow it to stand while the air rises to the top until the liquid stabilizes. Consider the liquid stabilized when it does not change more than 0.1% within a one-minute period.
9. If the liquid level is obscured by foam, use the rubber syringe to add sufficient alcohol from a calibrated cup equaling 1% of the volume of the base. Record the number of calibrated cups of alcohol required to disperse the foam.
10. Repeat the rolling and rocking procedure until two consecutive readings do not differ by more than 1/4 %.

11. Once the level has stabilized, determine the level of water in the neck of the meter to the nearest 1/4%. Add the number of cups of alcohol used to disperse the foam to the meter reading.
12. Disassemble and empty the contents in the bowl and examine the bowl to make sure that all of the concrete was dislodged during the agitating and rolling and rocking procedures. If there is a significant amount of concrete remaining in the bowl, the test is invalid and must be redone.

Chace Air Indicator for Determination of Entrained Air (AASHTO T-199)

This method of test covers the determination of the air content of freshly mixed concrete by displacing the air with alcohol and observing the change in level of the liquid in a tube. The apparatus is light and small, and the test procedure requires only a few minutes.

This method is satisfactory for determining the approximate air content of freshly mixed concrete. It should not, however, be considered suitable for replacing the pressure method) or volumetric method and in no case should the value obtained through the use of this method be accepted as determining the compliance of the air content of concrete with the requirements of specifications. The method is most useful for determining whether the concrete has a low, medium, or high air content, and whether the air content is reasonably constant from batch to batch of concrete.

Parts and Accessories

1. Air Indicator
    a. 0.22 cubic inches (3.6 ml) capacity cup
    b. rubber stopper
    c. glass top.
2. Accessories
    a. Rubber syringe
    b. Tamping blade
    c. Can of 70% isopropyl alcohol (poison)

Chace Air Indicator Equipment

Method of Operation

The percent of entrained air in a sample of concrete is determined as follows:

1. Fill the metal cup with cement mortar taken from the concrete, from which any particles larger than a No. 10 (2.00 mm) sieve have been removed with the tamping blade. A No. 10 (2.00 mm) sieve has openings of 0.0787 inches (2 mm) wide or a little less than 3/32 inches (2.38 mm). Use the tamping blade to pick up mortar. The mortar should not be wet screened to remove the material larger than a No. 10 (2.00 mm) sieve. Spade material into the cup with tamping blade to compact the mortar. Strike off excess even with top of cup.
2. Hold finger over stem opening of glass top and fill the glass tube with alcohol to the marked line about 1 inch (25 mm) from the large end of the glass.
3. Carefully insert cup filled with mortar into the glass top and turn indicator to a vertical position with the graduated stem up. Be sure stopper is firmly in place. Adjust liquid to top line of stem by adding alcohol with syringe, making sure that all air bubbles are removed. This can be done by slightly tilting the indicator.
4. Place finger over the stem opening to prevent liquid loss. Gently roll the indicator from vertical to horizontal and back several times until the mortar has been washed out of the cup.
5. With the indicator in the vertical position, carefully remove finger from the opening and count the number of spaces from the top line to the new liquid level, estimating to the nearest 0.1. Each space represents 1 percent of entrained air. The air indicator is designed to read directly for a concrete mix having 15 cubic feet of mortar per cubic yard (0.56 cubic meters of mortar per cubic meter) of concrete. Therefore, the air content

as determined by each test must be corrected for mixes with a different mortar content.

6. No conversion factor is used when gravel coarse aggregate is used in the concrete mix. In this case, the percentage of entrained air is read directly from the stem. However, when limestone or slag is used it is necessary to multiply the stem reading by 1.05 to determine the percentage of entrained air. Record the result to nearest 0.1 percent.

Chase Air Indicator

Temperature of Freshly Mixed Portland Cement Concrete (ASTM C -1064)

Parts and Accessories

Container - the container must be large enough to provide at least 3 inches (75 mm) of concrete in all directions around the sensor of the temperature-measuring device.

Temperature Measuring Device - the device used must be capable of measuring freshly mixed concrete to ± 1° F (± 0.5° C) throughout the entire temperature range to be encountered.

Concrete Thermometer

Method of Operation

The temperature of freshly mixed concrete may be measured in the transporting equipment provided the sensor of the temperature measuring device has at least 3 inches (75 mm) of concrete cover in all directions. The temperature is measured as follows:

1. Place the temperature measuring device in the freshly mixed concrete so that the temperature sensing portion is submerged a minimum of 3 inches (75 mm).
2. Gently press the concrete around the temperature-measuring device at the surface of the concrete so that the ambient temperature does not affect the reading.
3. Leave the temperature-measuring device in the freshly-mixed concrete for a minimum of 2 minutes or until the temperature reading stabilizes, then read and record the temperature.
4. Complete the temperature measurement within 5 minutes after obtaining the sample.
5. Report the temperature to the nearest 1° F (0.5° C)

Gradation of Aggregate

If aggregate is from a certified source there is no need for further sampling and testing. However a routine sieve analysis can be made to check compliance with gradation requirements. Gradation can be checked immediately when sieves are available on the project.

The following instructions describe how to make a sieve analysis on the project.

1. The sieve set as received is assembled for transportation.

a. Place the entire assembly in the inverted position, unfasten the hooks, and remove the rocker box, refastening the hooks in the staples.
b. Unpack each piece in the order that it occurs.
c. Place the rocker box on a flat surface and insert the sieve container with the sieve to be used therein
d. Place the sieve retainer inside the container.

After the set has been assembled, it is ready to sieve the sample.

2. Place the sample on the sieve.
3. Grasp the handles of the locker box, place the thumbs on the sieve retainer, then rock and shake the box vigorously until all material that will pass the sieve has gone through into the box (using enough pressure to hold the sieve firmly in place).
4. When this is complete, lift the retainer, sieve, and container out of the box together and rotate 1/8 turn, resting the assembly on top of the box.
5. Place the lid over this assembly and invert, emptying the material retained on the sieve into the lid.
6. Dump this aggregate into a pan and weigh to the nearest 0.01 pound (0.01 kg) subtracting the weight of the pan.
7. Repeat the sieving process for each sieve to be used, each time weighing the material retained on the sieve. The percent passing each sieve is determined by adding the weights of all fractions retained on smaller sieves, dividing that total by the total weight of sample, and multiplying by 100.

For example, assume the following weights of aggregate were retained on each of the sieves.

Sieve Size Inch (mm)	Weight Retained lbs (kg)	Percent Retained %	Total Percent Passing	Spec. Range
1 1/2 (37.5)	0.00 (0.00)	0.0	100	100
1 (25)	0.95 (0.43)	3.1	96.9	95-100
1/2 (12.5)	17.63 (8.00)	57.8	39.1	25-60
No. 4 (4.75)	10.39 (4.71)	34.1	5.0	0-10
No. 8 (2.36)	0.64 (0.29)	2.1	2.9	0-5
Passed				
No. 8 (2.36)	0.87 (0.39)	2.9		
Total	39.48 (13.83)	100.0 %		

The percent retained is obtained by dividing the amount retained by the total amount.

Ret. 1 inch (25 mm) Sieve	0.95 ÷ 30.48 (0.43 ÷ 13.83)	= 3.1 %
Ret. 1/2 inch (12.5 mm) Sieve	17.63 ÷ 30.48 (8.00 ÷ 13.83)	= 57.8%
Ret. No. 4 (4.75 mm) Sieve	10.39 ÷ 30.48 (4.71 ÷13.83)	= 34.1%
Ret. No. 8 (2.36 mm) Sieve	0.64 ÷ 30.48 (0.29 ÷ 13.83)	= 2.1%
Passed No. 8 (2.36 mm) Sieve	0.87 ÷ 30.48 (0.39 ÷13.83)	= 2.9%
Total		100%

The total percent passing is obtained by addition as follows:

2.9 passing No. 8 (2.36 mm)	
2.9%+2.1% retained on No. 8 (2.36mm)	=5.0% passing No. 4 (4.75 mm)
5.0%+34.1% retained on No. 4 (4.75 mm)	=39.1% passing 1/2 inch (12.5 mm)
39.1%+57.8% retained on 1/2 inch (12.5mm)	=96.9% passing 1 inch (25 mm)
96.0%+3.1% retained on 1 inch (25 mm)	=100% passing 1 ½ inch (37.5mm)

The sieve size, total percent passing, and specification range columns are recorded on the back side of the TE-45 form under "Remarks," each time an analysis is made.

Making and Handling Concrete Cylinders (ASTM C 31)

The preparation and handling of concrete test specimens are an important part of the Inspector's duties, since the cylinders furnish an indication of the quality of the concrete being produced as the work progresses. Cylinders must be made and handled strictly in accordance with the following instructions.

On structures over 20-foot (6.1 m) span, two (2) test cylinders 6 inches (152 mm) in diameter and 12 inches (305 mm) high are made from each 200 cubic yards (150 m^3) of each class of concrete, or fraction thereof, incorporated into the work. On structures of 20-foot (6.1 m) span or less and bridge deck overlay projects, at least two cylinders are made for each 50 cubic yards (40 m^3) of each class of concrete.

Parts and Accessories

1. Cylinder molds
2. Scoop
3. 5/8-inch (16 mm) steel tamping rod

The cylinder molds are placed on a firm, level surface, such as a board, so that the bottoms will not become deformed in the process of making the cylinders.

Cylinders are always made in pairs and both from the same batch of concrete.

Equipment for Making Concrete Cylinders

Method of Operation

The molding of the specimens is performed as follows:

1. With the scoop, fill each mold evenly 1/3 full of fresh concrete and rod each mold 25 times with the tamping rod, distributing the strokes evenly over the cross-sectional area of the mold and completely penetrating the layer of concrete. The rod should lightly touch the bottom of the mold. Tap the mold lightly 10-15 times to close any air voids left by the tamping rod.
2. Next, fill the mold 2/3 full of concrete and rod 25 times as before, making sure that the second layer of concrete is completely penetrated by the rod. The rod should penetrate 1 inch into the previous layer. Tap the mold as before.
3. Finally, fill the mold to overflowing and rod 25 times as before. Again, the sides of the mold should be tapped lightly 10 to 15 times to close any voids left by the tamping rod.
4. Using the tamping rod or trowel, strike off the excess concrete flush with the top of the mold. This concludes the operation, and there should be no further manipulation of concrete or mold. Specimens are made in one continuous operation.

When cylinders are made, the following tests should also be made using concrete from the same batch:

1. slump
2. yield
3. concrete temperature
4. air test

Be sure and acquire a sufficient quantity of concrete to provide for all these tests. Record the test values on the TE-45 Report. Reporting these values from the same batch as used for casting cylinders provides valuable data for evaluating compressive strengths of cylinders. Therefore, always determine slump and air from the same batch of concrete used in cylinders.

In all cases, the cylinders shall be cured as nearly as possible in the same manner as the concrete that they represent.

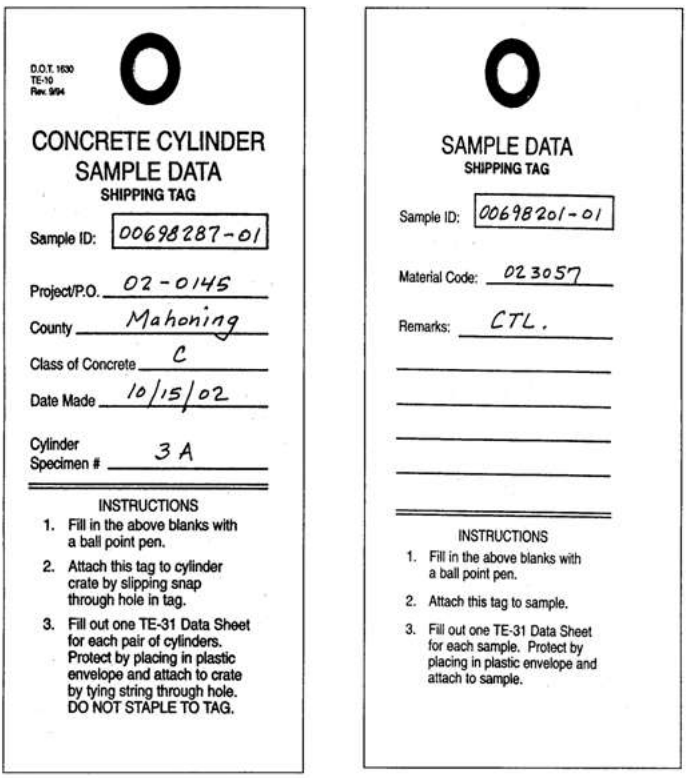
Two TE-10 tags and one TE-31 Form describing detailed information on the concrete to be tested are filled out when the cylinders are molded. When cylinders are prepared for shipment to the Laboratory, the TE-31 Form must be enclosed in a plastic envelope and placed around one of the cylinders as it is placed in the packing case. The case staves hold the TE-31 Form in place.

If the test is the result of a request for Progress Sample, the face of the TE-31 form must be marked "Progress" in the upper left hand corner. Write the name of the person requesting the Progress Samples after the word "Progress" along with the description of the authority which he or she represents.

Concrete cylinders using ordinary Portland cement are prepared for shipment and sent to the Laboratory on the fourth day after molding. If high-early-strength cement is used, cylinders are shipped on the second day after molding. Should the shipment day fall on a non-work day, shipment must be made on the following workday.

After the cylinders are packed in shipping cases, pass the snap on the webbed strap through the hole in the TE-10 tag, before engaging the snap to the ring on the strap on the top of the case. A filled out copy of a TE-10 tag is shown in Figure 499.B and a filled out copy of a TE-31 form is shown in Figure 499.C.

Cylinder test results will be reported in CMS.



D.O.T. 1630
TE-10
Rev. 9/94

CONCRETE CYLINDER
SAMPLE DATA
SHIPPING TAG

Sample ID: 00698287-01

Project/P.O. 02-0145

County Mahoning

Class of Concrete C

Date Made 10/15/02

Cylinder Specimen # 3 A

INSTRUCTIONS

1. Fill in the above blanks with a ball point pen.
2. Attach this tag to cylinder crate by slipping snap through hole in tag.
3. Fill out one TE-31 Data Sheet for each pair of cylinders. Protect by placing in plastic envelope and attach to crate by tying string through hole. DO NOT STAPLE TO TAG.

SAMPLE DATA
SHIPPING TAG

Sample ID: 00698201-01

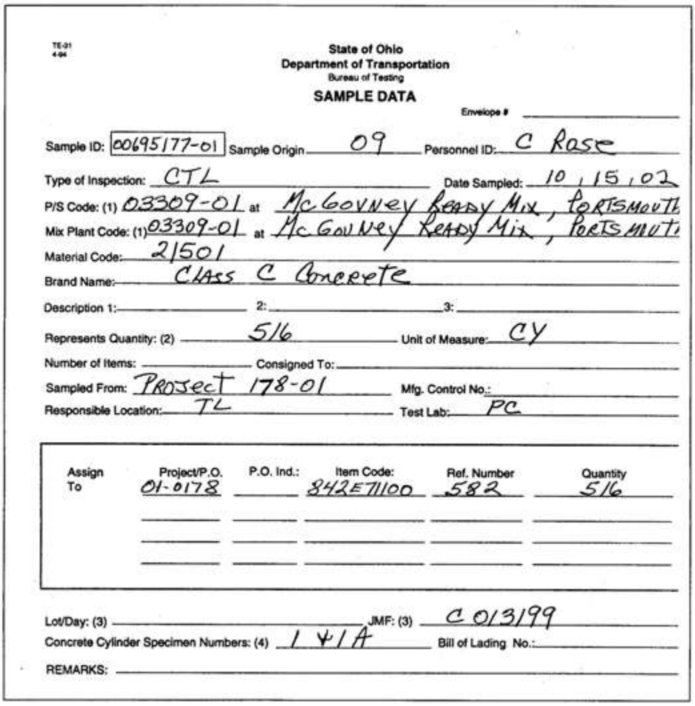
Material Code: 023057

Remarks: CTL.

INSTRUCTIONS

1. Fill in the above blanks with a ball point pen.
2. Attach this tag to sample.
3. Fill out one TE-31 Data Sheet for each sample. Protect by placing in plastic envelope and attach to sample.

Figure 499.B - Filled Out TE-10 Tags



TE-31
4-94

State of Ohio
Department of Transportation
Bureau of Testing
SAMPLE DATA

Envelope #: ____

Sample ID: 00695177-01 Sample Origin: 09 Personnel ID: C Rose

Type of Inspection: CTL Date Sampled: 10 , 15 , 02

P/S Code: (1) 03309-01 at McGovney Ready Mix, Portsmouth

Mix Plant Code: (1) 03309-01 at McGovney Ready Mix, Portsmouth

Material Code: 21501

Brand Name: Class C Concrete

Description 1: ____ 2: ____ 3: ____

Represents Quantity: (2) 516 Unit of Measure: CY

Number of Items: ____ Consigned To: ____

Sampled From: Project 178-01 Mfg. Control No.: ____

Responsible Location: TL Test Lab: PC

Assign To	Project/P.O.	P.O. Ind.:	Item Code:	Ref. Number	Quantity
	01-0178		842E71100	582	516

Lot/Day: (3) ____ JMF: (3) C 013199

Concrete Cylinder Specimen Numbers: (4) 1 + 1A Bill of Lading No.: ____

REMARKS: ____

Figure 499.C - Filled Out TE-31 Form

Making Concrete Test Beams

The concrete control Inspector will make and test concrete beams as described here, and report the results in the ODOT Construction Management System as explained in Supplement 1023.

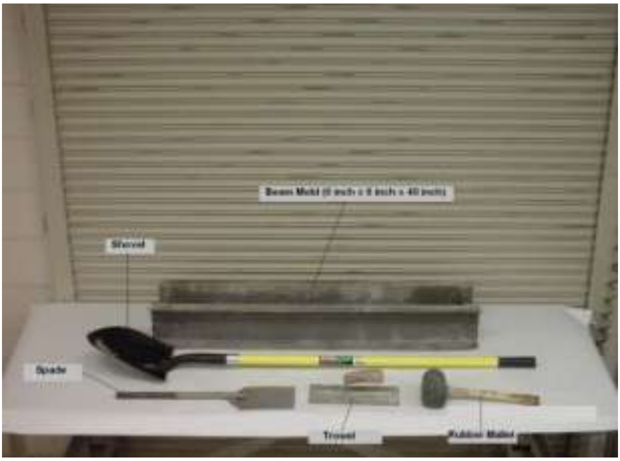
Where beam tests are made to determine when a section of pavement or base may be opened to traffic, two 6-inch x 6-inch x 40-inch (152 mm x 152 mm x 1016 mm) concrete beams are made, using the same concrete being placed in the pavement or base.

Section 511.17 of the specifications requires falsework for structures to remain in place until the concrete has attained adequate strength as determined either by the length of curing time or by the testing of standard concrete beams. When beams are desirable to determine removal of falsework, they must be made from the same concrete as that supported by the falsework.

The Laboratory (through the District Engineer of Tests) will provide the Inspector with the equipment for making and testing of concrete beams.

Parts and Accessories

1. 6" x 6" x 40" (152 mm x 152 mm x 1016 mm) steel molds
2. Spading tool
3. Trowel
4. Rubber mallet
5. Beam testing machine



Equipment for Beam Testing

Method of Operation

The beams must be made as described here. Beams must be made and tested in accordance with Supplement 1023. Steel beam molds must be free of dirt, hardened concrete, or rust. They are placed on a smooth, clean, level, and unyielding surface that has been lightly oiled to prevent the concrete from sticking. The inside of each mold is oiled in the same manner.

1. Using a shovel, fill each mold half full with 3 inches (75 mm) of concrete representative of that in the batch.
2. With the blade of the spading tool held at an angle to the ends of the mold, spade the concrete 20 times at equal intervals from one end of the mold to the other.
3. Then, turning the blade of the spading tool, cross-spade 20 times at equal intervals back in the opposite direction of the end of the mold.
4. Spade entirely around the side and ends of the mold.
5. Tap along each side of the mold 15 times (total of 30 taps per lift) with the rubber mallet.
6. Fill the mold to overflowing with concrete and repeat the spading and taping operations as before.
7. Strike off the excess concrete, and trowel the concrete flush with the top of the beam mold.
8. After concrete is set the beam numbers are scratched into the concrete for future identification.
9. Beams must be cured as nearly as possible in the same manner as the concrete from which they are made.

Beams are normally tested at 3, 5, or 7 days of age. If the results are not needed before the end of the 7-day curing period, only one beam break is necessary and should be made at the age of 7 days.

The beams must be tested with the center loading, hydraulic type-testing machine. The load is applied with a hydraulic jack. The machine scale reading is a direct reading of the modulus of rupture in pounds per square inch (megapascals).

Testing Beams with Center-Loading Hydraulic Type Testing Machine

The hydraulic, center-loading, beam breaker is designed to test 6 inch x 6 inch x 40 inch (152 mm x 152 mm x 1016 mm) concrete beams. Two flexural strength tests can be made with each beam. The breaker shows a direct read out in pounds per square inch (megapascals) directly on the dial. No charts or conversion tables are needed to change total load to flexural strength, as is the case with other types of beam breakers now in use. The standard 6 inch x 6 inch (152 mm x 152 mm) beam is the only size beam on which this breaker can be used.

Hydraulic Beam Tester in Position on Beam

Pressure Gage Dial

Parts and Accessories

1. Beam Breaker
    a. A main frame with two 7-inch (178 mm) channels containing two fixed rollers.

   b. Yoke assembly containing hydraulic ram, pressure gage with 4 1/2-inch (114 mm) dial, choker valve located just below the gage, and center roller.
2. Accessories
   a. Carrying Case

Method of Operation

The flexural strength, in pounds per square inch (megapascals) is obtained is in the following manner:

1. Prepare the beam for testing by rotating it 90 degrees around the long axis from the position in which it was molded. The original top of the beam should now be on the side and the top and bottom of the beam should be the sides of the beam that were originally against the mold. Raise the beam at least 2 inches (50 mm) off the ground by supporting each end. This allows clearance under the beam so that the center pin from the yoke of the beam breaker can be inserted under the beam.
2. Lift the breaker from the carrying case and set it on the beam to be tested with the 2 fixed rollers resting firmly on the surface and one of them about 1 inch (25 mm) from the end.
3. Remove the center roller, a 1-inch (25 mm) round pin from the two U-shaped clevises by sliding it out. The yoke assembly, containing the ram, pressure gage, and choker valve now can be pivoted into the vertical (operating) position with the clevises extending below the bottom surface of the beam. There is a stop on one side of the main frame with which the yoke assembly hinge-bracket must be in contact in order for the yoke assembly to be in the vertical position. Return the pin to the clevises. The yoke pin should now be underneath the beam.
4. Close the choker valve (the valve just below the gage dial) by turning it in a clockwise direction, when facing the dial, and open it approximately 1/4 of a turn. Once this valve is adjusted to the position of 1/4 turn open, this procedure does not need to be repeated with each test but only if the valve has been inadvertently turned to some other position. Do not attempt to operate the beam breaker with the choker value closed.
5. Close the pump valve by turning the pinned extension valve stem in a clockwise direction. This valve is located on the right side of the pump when facing the dial, and is opened and closed by a extending through the flange of the aluminum channel forming the top of the main frame. This valve must be closed firmly so that the pump will operate properly.
6. Adjust the black hand of the gage to the zero point by turning the knurled brass knob on the side of the gage housing.
7. Set the red hand (maximum indicating hand) near zero by turning the knurled brass knob in the middle of the plastic dial cover.
8. Operate the pump by slow steady stokes until the beam breaks or the specified strength plus 100 psi (1.0 mPa) is reached. Read the flexural strength, in pounds per square inch (megapascals), as indicated by the red hand. Unless otherwise required by the specifications, discontinue the test at 100 psi (1.0 mPa) over the specified strength in order to avoid

unnecessary damage to the beam breaker and note on the report that the test was terminated before failure.

9. Open the pump valve and the pump plunger will retract so that the center roller can be withdrawn and the broken portions of the beam can be removed. If additional tests are to be made immediately, repeat the foregoing procedure.
10. If no more tests are to be made immediately, the yoke assembly should be folded down into the horizontal (carrying) position and the center roller again inserted through the clevises in the preparation for storage. Then place the beam breaker in the carrying case.

Recording Results

Record the slump, air content, concrete temperature, and concrete yield on the TE-45 or TE-45 Supplement form. Record all beam tests results on the TE-45 later after they are tested and enter them in CMS as detailed in Supplement 1023.

Care and Maintenance of Concrete Testing Equipment

Testing equipment represents a considerable monetary investment by the Department and therefore, it is essential that the equipment be given proper care to avoid damage. The equipment has been provided for testing purposes and must be used in the appropriately to avoid unnecessary abuse or damage. Periodic review of test procedures is desirable not only to assure accurate and uniform testing but to prevent damage by improper use of equipment.

The equipment is subject to wear and will need repair and replacement of parts at times. When this repair work is needed, the piece of equipment should be sent to the District laboratory at once. Equipment must be in good working condition in order to provide test results that are representative of the material being tested. In addition, with the volume of work in progress, it is vital that testing equipment be repaired quickly and returned to the project in order to provide the equipment necessary for job control. If this cannot be accomplished, the Engineer must make arrangements for temporary use of other equipment rather than omit any required tests.

All equipment must be thoroughly cleaned immediately after use, being especially sure that all concrete and mortar is removed from around gaskets, seals, and moving parts. Thorough cleaning will prevent buildup of hardened concrete that can affect the operation of the equipment as well as the test results.

Pressure Meter

When the top assembly is removed, it should be placed on a clean surface to prevent damaging the gasket and any earth or fresh concrete from clogging the clamping mechanisms. All fresh concrete should be removed from all parts of the meter to facilitate its accuracy and continue its efficient service.

Volumetric Air Meter

The volumetric meter should not be rolled, rocked, or bumped on hardened concrete, stone, or steel. It should be used on a clean board or sack. When the top cone is removed, it should be placed on a clean surface to prevent earth or fresh concrete from clogging the springs around the fasteners. The inside of the glass tube should be kept clean of cement particles so as not to obscure readings. All fresh concrete should be removed from all parts of the meter to facilitate its accuracy and continue its efficient service.

Chace Air Indicator

When emptying the instrument at the completion of a test, flush out particles of sand from between the glass and cup to prevent damage when removing stopper. This can be done by holding the indicator with stem end down, finger over stem, and opening and shaking gently. Carefully remove stopper, and wash and clean the indicator with clean water. Keep the equipment in protective container when not in use. Should the glass be broken, the remainder of the set should be returned to the Laboratory for repair.

Center Loading Hydraulic-Type Beam Testing Machine

This beam breaker is a piece of testing equipment and should be handled and cared for like any other precision instrument. The following precautionary measures will help keep the breaker in proper operating condition:

1. Be sure that the choker is open 1/4 turn before applying load.
2. Do not operate beyond the maximum point indicated on the dial.
3. Store in the carrying case when not in operation.
4. Remove curing membrane, rust, etc., from the center roller so that it will fit in the devices easily.
5. Keep thin film of oil on steel parts to prevent rust.
6. Make frequent checks for worn places or breaks in the rubber hose. Do not operate the breaker with worn or damaged hose. This beam breaker is actuated by a high-pressure hydraulic system and might be unsafe if operated with worn or damaged parts.
7. DO NOT ATTEMPT TO REPAIR THE BEAM BREAKER IN THE FIELD. Return the beam breaker to the Laboratory for any repairs or adjustments that may be necessary.

The coarse aggregate to be used in the concrete in Table 499.03-2 mixtures must include No. 57 or No. 67 size. There is also a Table 499.03-3 which shows Class C concrete (with gravel and limestone) using No. 8 size stone if it is approved for 451 or 452 pavement as allowed by 703.13. It is the intent to use No. 57 or No. 67 size coarse aggregate in all other concrete except the high performance (HP) concrete classes. Table 499.03-4 gives the proportioning for the high performance concrete classes. These are Class HP1, HP2, HP3, and HP4 and they require No. 8 size coarse aggregate. These concrete mixtures are specified for structural concrete items and for approach slabs. These mixes have a target air content of 7 % and a maximum slump of 8 inches. The water cement ratio of these mixes is lower than the normal concrete. The slump is obtained by the use of a high range water reducer (Type F or G).

Only Type I cement (701.04) and Class C fly ash (701.13) may be used in any high performance (HP) concrete classes. The water–cement ratio is based on the total cementitious materials which include Portland cement, fly ash, GGBFS, and microsilica solids.

Concrete Mix Adjustment (499.03 D)

During concrete production and placement, the concrete control inspector is responsible for adjusting the yield of the concrete mix design. The inspector must understand what affects the yield so that the yield can be maintained within a certain tolerance. Section 499.03 has a tolerance of ±1.0 percent for the yield.

Controlling the Yield

As discussed earlier, the yield of a concrete mix is the volume occupied by the mix. The concrete is designed to occupy a given volume. Concrete is batched by weight (not volume) so monitoring the volume (yield) after batching is of extreme importance.

Relative Yield

The term relative yield is used to understand the effects on yield. The relative yield of a concrete mix is defined as the one cubic yard (one cubic meter) batch weight divided by the one cubic yard (one cubic meter) unit weight of a representative sample of the concrete, as shown in Figure 499.25:

$$\text{Relative Yield} = \frac{\text{Batch Weight for } 1\ yd^3\ (1\ m^3)}{\text{Unit Weight for } 1\ yd^3\ (1\ m^3)}$$

Equation 499.25 – Relative Yield method 1

Another way to calculate the relative yield is to divide the actual yield by the intended yield, as shown in Equation 499.26:

$$\text{Relative Yield} = \frac{\text{Actual Yield } yd^3 (m^3)}{\text{Intended Yield } yd^3 (m^3)}$$

Equation 499.26 – Relative Yield method 2

The relative yield is a dimensionless number (it has no units). When working with relative yield, it is less confusing to include [yd^3] or [ft^3] ([m^3]) in brackets so the units are not mixed. A relative yield expressed in [yd^3] is multiplied by 27 ft^3/yd^3 to change it to the number of cubic feet [ft^3] of relative yield.

A relative yield of less than 1.00 is an under-yield and a relative yield of greater than 1.00 is an over-yield.

Example

An 8 cubic yard batch of concrete has the following batch weights:

Coarse Aggregate	13,328 lbs
Fine Aggregate	9,448 lbs
Cement	5,080 lbs
Water	2,400 lbs
Total Batch Weight	30,256 lbs

The result of a unit weight test performed on a concrete sample is 141.35 lbs/ft^3. Determine the yield and relative yield of the batch.

First the yield can be calculated from the data given:

$$\text{Yield} = \frac{30{,}256\, lbs}{141.35\, lbs/ft^3} \quad \text{(Equation 499.2)}$$

$$= 214.03\ ft^3$$

Next, determine the one cubic yard batch weight:

$$\text{Batch Weight for 1 yd} = \frac{30{,}256\, lbs}{8\ yds^3} \quad \text{(Equation 499.2)}$$

$$= 3782\, lbs/yd^3$$

The unit weight for one cubic yard is determined using the unit weight given:

Unit Weight for 1 yd^3 = (141.35 lbs/ft^3) x (27 ft^3/yd^3) = 3816.45 lbs/yd^3

Note that in the above calculation the one cubic yard unit weight is determined by multiplying the one cubic foot unit weight by the conversion factor of 27 ft^3/yd^3. This converts the unit weight to lbs/yd^3 instead of lbs/ft^3.

Now the relative yield can be determined by the use of Equation 499.25 as follows:

$$\text{Relative Yield} = \frac{3782\, lbs/yd^3}{3816.45\, lbs/yd^3} \qquad \text{(Equation 499.25)}$$

$$= 0.991\, yd^3$$

Another way to calculate the relative yield is to divide the actual yield by the intended yield (Equation 499.27):

$$\text{Relative Yield} = \frac{(214.05\, ft^3 \div 27\, ft^3/yd^3)}{8.00\, yd^3} \qquad \text{(Equation 499.26)}$$

$$= 0.991\, yd^3$$

In the above calculation, the actual yield (in cubic feet) is divided by a conversion factor of 27 ft^3/yd^3 to convert the actual yield in cubic feet to cubic yards.

The relative yield expressed in cubic feet is:

Relative Yield = 0.991 [yd^3] x 27 ft^3/yd^3

= 26.76 [ft^3]

In the above example the relative yield is less than 1.000 [yd^3] or 27.00 [ft^3], therefore, there is an under yield. The amount of the under yield can be determined as follows:

Under Yield = 0.991 – 1.00

= -0.009 [yd^3]

or

Under Yield = 26.76 – 27.00

= - 0.24 [ft^3]

The negative sign indicated that there is an under yield. A positive number would have indicated an over yield.

The under yield expressed as a percent is determined by multiplying the amount of the under yield in decimal form by 100% as follows:

Under Yield (%) = -0.009 x 100 %

= -0.9 %

Cement Factor

The cement factor is defined as the weight of cement in a cubic yard (cubic meter) of concrete, based on the concrete's yield. Cement factor is expressed as the number of pounds of cement per cubic yard (kilograms of cement per cubic meter).

If the concrete is over yielding, the cement that was batched into the load is spread over a greater volume of concrete than intended by the mix design. If this happens, the cement factor is less per cubic yard (cubic meter) than intended. The opposite is true if there is an under yield. In the case of an under-yield situation, the cement that was batched into the load is concentrated into less volume than for which it was designed. In this situation the cement factor is greater per cubic yard (cubic meter) than was intended by the design.

The relative yield is used to determine the cement factor as shown in Equations 499.27 and 499.28:

$$\text{Cement Factor}\,(lbs/yd^3) = \frac{\text{Cement Weight}\,(lbs/yd^3)}{\text{Relative Yield}}$$

Equation 499.27 – Cement Factor

$$\left(\text{Cement Factor}\,(kg/m^3) = \frac{\text{Cement Weight}\,(kg/m^3)}{\text{Relative Yield}}\right)$$

Equation 499.28 – Cement Factor (metric)

The cement weight in the above equations is the amount of cement intended to be in a cubic yard (cubic meter) of concrete.

In the above example, the relative yield was 0.991 and the cement content was 635 lbs per cubic yard (5080 lbs / 8 cubic yards = 635 lbs/yd^3), therefore, the cement factor is:

$$\text{Cement Factor} = \frac{635\,lbs/yd^3}{0.991} = 641\,lbs/yd^3$$

(Equation 499.27)

As shown by the above calculation, the under yield resulted in a cement factor of 641 lbs per cubic yard instead of 635 lbs per cubic yard.

The cement factor can influence the strength of the concrete. An excessive over yield results in less cement per cubic yard (cubic meter), as the cement factor will be less than intended. This could result in less strength than expected from the batch. An excessive under yield results in a higher cement factor and therefore higher strength than anticipated. There should not be a noticeable effect on strength if the yield is maintained within 1 percent of the design as required by 499.03 of the specifications.

Air Content Effects on Yield

Air content in concrete has a significant effect on the yield. Air content in a concrete mix has no weight but does contribute volume. The air content used in the design is the target air content. At the target air content, the yield should be within the tolerance of ±1.0 percent as specified in 499.03 of the specifications.

The inspector should determine if a yield problem is the result of an air content that is higher or lower than the target air content before a mix adjustment is made. There is a way to compute what the relative yield of a concrete batch would be at an air content that is different from the tested air content.

First, determine the relative yield and the tested air content of a concrete sample. Next, compute the non-air portion of the mix. The non-air portion of the mix is the volume of all of the component materials except air. This value is determined by multiplying the actual relative yield by the actual non-air decimal. Once the non-air volume is determined, the relative yield at any other air content can be calculated. Equation 499.28 is used to determine the relative yield at a different "target air" content:

$$\text{Relative Yield at a Target Air} = RY\,actual \times \left(\frac{NAD\,actual}{NAD\,target} \right)$$

Equation 499.28 – Relative Yield at Target Air

Where:

RY actual = actual relative yield (yd^3)

NAD actual = actual non-air decimal

NAD target = target non-air decimal

Example:

As an example, the relative yield of a concrete mix is found to be 0.974 [yd^3] and there is 4.2% air content. What is the relative yield at 6% air content?

The actual non-air portion of the mix at 4.2% air content is 95.8 percent (100% - 4.2% = 95.8%) of the total volume. The actual non-air decimal then is 0.958 (95.8%). To calculate the relative yield at 6% air, the target non-air portion of the mix would be 94 percent (100% - 6 % = 94 %) of the total volume. The target non-air decimal is 0.94 in decimal form. Now the relative yield at 6% air can be calculated as follows:

$$\text{RelativeYield} = \frac{0.974\,yd^3 \times 0.958}{0.94} = 0.993\,yd^3$$

(Equation 499.28)

The calculations show that by increasing the air content of the concrete from 4.2% air to 6% air, the relative yield changes from 0.974 [yd^3] to 0.993 [yd^3]. The inspector should not adjust the batch weights to correct the yield to within ±1.0 % but should direct the contractor to increase the air content percentage in subsequent concrete loads to bring the concrete to the proper yield.

The air content affects the unit weight of the concrete. When the air content percentage in the concrete is increased, the unit weight of the concrete is decreased. This is due to the increased volume of air bubbles within the mortal fraction of the concrete volume. This lower unit weight results in raising the yield higher than it was at the lower air content, assuming the batch weights are identical. When the yield is calculated the same batch weight is divided by a lower unit weight, so the yield increases.

Adjusting Yield

The concrete control inspector should not make adjustments in the mix design unless it is necessary. Mix design adjustments should not be made every time high or low air content affects the yield, because when the air content is at the target air the yield will be off. The specifications typically allow air content to deviate ±2 % from the target air content. For all Department mix designs, the desired yield should be established at the target air content. Once the mix design is adjusted to yield properly at the target air content, future mix design adjustments are rarely needed.

To adjust the mix design to correct the yield, the adjustment is always made in the aggregate weight by adding or subtracting material. The adjustment is made by volume and the volume of the adjustment is converted to a weight of either coarse or fine aggregate or both proportionately.

Modifying Mix Designs

It may be necessary to modify an existing concrete mix design while under production by changing the component materials in the concrete. The mix designs in 499 are designed to produce one cubic yard or 27 cubic feet per cubic yard (one cubic meter) of concrete. During production, it may be necessary to change the quantity of a material in the mix: it may be necessary to add or to remove a material for the mix design, or use an aggregate that has a different specific gravity than in the mix design.

The yield must be maintained if a component material is changed in the mix design. If the volume of one material is changed, then the volume of another material must be adjusted to compensate for the volume change made. If any volume is added or removed from the design volume an equivalent volume must be removed or added respectively to maintain the yield.

Modifying Aggregate Proportions

Section 499.03 D permits the Engineer to modify the SSD weights of coarse and fine aggregate that are shown in the concrete tables. This may be necessary to improve the finishing characteristics of the concrete, to ensure a workable mix within the slump range, or to control the yield. These modifications made in the aggregate proportions are not to change the total weight of aggregate specified per cubic yard (cubic meter) except for the following reasons.

1. To correct the SSD aggregate weights to compensate for the moisture contained in the aggregates at the time they are used.
2. If it is not possible to make concrete of the proper consistency without exceeding the specified water-cement ratio, the contractor must either use a water-reducing admixture or increase the cement content. If cement is added to the concrete, the absolute volume of aggregate must be adjusted by the amount of cement absolute volume added. There is no compensation to the Contractor for the use of an admixture or additional cement.
3. If at any time the specific gravity of the aggregate being used changes by more than 0.02 from the specific gravity specified in 499.03 C, the SSD design weights in the concrete tables must be adjusted to conform to the new specific gravity.
4. To adjust the batch weights based on the yield determined from field tests at the work site. Maintain the cement content within ±1 percent and do not exceed the water-cement ratio specified.

It may be necessary or required by specifications to add an intermediate-size coarse aggregate. If it is necessary to add a quantity of aggregate, the yield will change unless an adjustment is made to offset the volume added to the concrete. The same thing is true if it is necessary to remove a component material from the original mix design. If any volume of material is removed, the same volume must be added to the concrete mix to adjust the yield for the volume removed. The following example illustrates how a volume change is made.

Example

To improve the finishing characteristics of a Class S concrete using limestone coarse aggregate, it is decided to remove 100 lbs of coarse aggregate from the following original SSD mix design:

Cement	700 lbs
Coarse Aggregate	1530 lbs, (Specific Gravity = 2.65)
Fine Aggregate	1260 lbs, (Specific Gravity = 2.62)
Water	350 lbs

What is the new SSD mix design if 100 lbs of coarse aggregate is removed? Make the volume adjustment by adding fine aggregate without affecting the yield of the mix.

The new amount of coarse aggregate is 1430 lbs (1530 – 100 = 1430). The absolute volume of 100 lbs of this coarse aggregate removed from the concrete is:

$$\text{Absolute Volume} = \frac{100}{(2.65)\times(62.4)} \qquad \text{(Equation 499.4)}$$

$$= 0.60\ ft^3$$

Since 100 lbs of coarse aggregate is removed, the volume is decreased by 0.60 ft³. In order to maintain the yield 0.60 ft³ of fine aggregate must be added. This volume is used to calculate the weight of fine aggregate necessary to be added to maintain the original yield as follows:

$$\text{Addition of Fine Aggregate} = (0.60)\times(2.62)\times(62.4) \qquad \text{(Equation 499.6)}$$

= 98 lbs

This calculation shows that 98 lbs of fine aggregate (of specific gravity 2.62) must be added to offset the 100 lbs of coarse aggregate (of specific gravity 2.65) removed from the mix design. The new fine aggregate SSD design weight becomes 1358 lbs (1260 + 98 = 1358).

Therefore, the following is the new SSD mix design:

Cement	700 lbs
Coarse Aggregate	1430 lbs, Specific Gravity = 2.65
Fine Aggregate	1358 lbs, Specific Gravity = 2.62
Water	350 lbs

Note that the specific gravities of the coarse and fine aggregates are similar, therefore, the difference in the weight between the coarse aggregate removed and the fine aggregate added is only 2 lbs.

Modifying the Slump

It may be necessary to increase the slump of the concrete by adding water to the mix design, or reduce the slump by removing water from the mix design. With the addition or removal of water from a mix design, both the water-cement ratio and the yield will change.

If the concrete in use is being batched at the maximum water-cement ratio, no additional water is permitted or the water-cement ratio would be exceeded. It may be necessary to add cement, as required by 499.03 D.2 to maintain the water-cement ratio.

Example:

A concrete mix has a water-cement ratio of 0.50 and the slump is 2 inches at the maximum allowable water. It is decided to add 10 lbs of water to the mix design to increase the slump. Determine the amount of cement necessary to maintain the 0.50 water-cement ratio. Determine the amount of volume added due to the addition of the 10 lbs of water and this necessary amount of cement.

Since the water-cement ratio is defined as follows (Equation 499.13):

$$\text{Max. w/cRatio} = \frac{Weight\ of\ Water}{Weight\ of\ Cement}$$

The following form of Equation 499.13 calculates the weight of cement from the w/c ratio:

$$\frac{Weight\ of\ Water}{Max.\ w/c\ Ratio}$$

Equation 499.29 – Cement Weight from w/c Ratio

Therefore, the amount of cement necessary is:

$$\text{Weight of Cement} = \frac{10\ lbs}{0.50} \qquad \text{(Equation 499.29)}$$

$$= 20\ lbs$$

To maintain the yield, a volume adjustment must be made for both the 10 lbs of water and the 20 lbs of cement as follows:

Volume of Water Added $= \dfrac{10}{1.00 \times 62.4}$ (Equation 499.4)

$$= 0.16\ ft^3$$

Volume of Cement Added $= \dfrac{20}{3.15 \times 62.4}$ (Equation 499.4)

$$= 0.10\ ft^3$$

The total added volume due to the water and cement is 0.26 ft ^{3} (0.16 + 0.10 = 0.26) in this example. In order to maintain the yield, 0.26 ft ^{3} of aggregate must be removed from the design.

Modification of Aggregate Specific Gravity

If there is specific gravity changes in the aggregates used, the yield of the concrete mix will change. If there is a specific gravity increase then the volume occupied by the same weight of aggregate will decrease and there will be an under yield. If there is a specific gravity decrease, the volume of the same weight of aggregate increases and the mix will over yield.

Example:

A concrete mix contains 1,735 lbs of a crushed limestone with specific gravity of 2.65. The aggregate stockpile is depleted and the contractor changes to natural gravel coarse aggregate with a 2.57 specific gravity. Adjust the 1,735 lbs to the new specific gravity and show how this would affect the yield.

Determine the original volume in the mix design:

Original Mix Design Volume $= \dfrac{1{,}735\ lbs}{2.65 \times 62.4\ lbs/ft^3}$ (Equation 499.4)

$$= 10.492\, ft^3$$

If the specific gravity changes to 2.57 this same weight of aggregate would have the following absolute volume:

New Mix Volume $= \dfrac{1{,}735\ lbs}{2.57 \times 62.4\ lbs/ft^3}$ (Equation 499.4)

$$= 10.819\ ft^3$$

These calculations show that same weight of a lower specific gravity aggregate has a greater volume and would result in an over yield. To correct the over yield the original volume is used to determine how much weight of the new, lower specific gravity aggregate to use:

New Aggregate Weight $= 10.492\ ft^3 \times 2.57 \times 62.4\ lbs/ft^3$ (Equation 499.6)

$$= 1{,}683\ lbs$$

In summary with the lower specific gravity the weight decreased from 1,735 lbs to 1,683 lbs per cubic yard.

Use Equation 499.30 to calculate a weight adjustment due to a specific gravity change:

$$Weight\ at\ a\ New\ Specfic\ Gravity = \frac{W_{Original} \times SG_{New}}{SG_{Original}}$$

Equation 499.30 – Weight Adjustment due to Specific Gravity Change

where:

$W_{Original}$ = Original weight of aggregate (at the original specific gravity)

$SG_{Original}$ = Original specific gravity of the aggregate

SG_{New} = New specific gravity of the aggregate to be used

For the above example, the calculation is as follows:

New Weight = $\frac{1{,}735 \times 2.57}{2.65} = 1{,}683\ lbs$	(Equation 499.30)

Equipment for Batching and Mixing Concrete (499.06)

Batching Plants (499.06 A.)

The various materials for each batch of concrete are proportioned at a batch plant. Batch plants may be classified as:

1. Portable or stationary
2. Manual, semi-automatic, or automatic
3. One or two stop
4. Separate or accumulative weighing

These classifications are dependent on the mobility and the method of weighing and discharging. Batch plants used on the project site usually are portable and may be moved from job to job. They may be manual, semi-automatic, or automatic with the latter two categories most common. If all materials for a batch are discharged at the same point, it is a one-stop plant. A two-stop plant is a plant where two stops of the truck mixer is required.

Portable plants are moved from site to site to reduce the length of haul to the placing site. Stationary plants usually are used at commercial ready-mix or central-mix plants. Central-mix plants used for concrete paving are set up at the job site and, therefore, are portable.

Plants may employ accumulative weighing for the coarse and fine aggregate; however, separate weighing devices must be used for weighing cement. Accumulative weighing permits the weighing of coarse aggregate and then the fine aggregate, using the same hopper and scale. The predetermined weights for the two materials are set on the scale for the cutoff. Cement must be weighed separately on a separate scale and hopper, regardless of how the aggregate is weighed.

For manual plants, each material is weighed and discharged by manually pulling levels to open and close gates. In semi-automatic plants, these gates are operated through electronic controls to open and close at the touch of a button. If the electric controls are interlocked and the completion of one weighing signals the start of next weighing, etc. and the whole cycle if weighing and discharging is interlocked completely, the plant is classed as automatic.

Automatic plants are coming into widespread use with many being computerized. Some plants use punched cards which have the weights of the materials represented by holes punched in the card. The size of the batch is dialed by a selector knob, the punched card is placed into the control panel, and a button is pressed to start the cycle. Materials for the batch size selected are automatically weighed and discharged.

A system of interlocks prevents a batch from being discharged that does not contain the correct amount of each material. All automatic plants have this feature. This prevents incorrect batches in the event that an aggregate bin becomes empty or other trouble develops which would tend to result in incorrect batch weights. Most automatic plants may be operated manually or semi-automatically, which permits production in case of an electronic failure.

The accuracy of the weighing mechanisms used to weigh each component in the concrete is specified in 499.06 A. These weighing tolerances are shown below:

WEIGHING TOLERANCES

Item	Weighing Tolerance* (Percent)
Cement	± 0.5
Fly ash	± 0.5
GGBFS	± 0.5
Micro silica	± 0.5
Coarse aggregate	± 0.5
Fine aggregate	± 0.5
Water	± 1.0
Admixtures	± 3.0

* Weighing tolerances apply throughout the range of use.

Prior to use of a concrete plant, make an inspection to assure that all requirements of the specifications are fulfilled and that scales meet the batching tolerances specified. This inspection includes checking:

1. Plant bins for adequate partitions to prevent intermingling of materials.
2. All weighing and metering devices to assure that their accuracy has been attested to within a 12-month period immediately prior to use by one of the following methods:
    a. By a Sealer of Weights and Measures
    b. By a Scale Servicing Company
    c. By a Certificate of Performance issued by the National Ready Mixed Concrete Association
3. The plant must maintain ten 50-pound (23 kg) standard test weights or the services of a scale servicing company for testing weighing devices for accuracy. The ten 50-pound (23 kg) test weights must be sealed within a 3-year period by the Ohio Department of Agriculture. If the service of a scale servicing company is used, these weights will not be required; however, all weights used in testing by the Scale Servicing Company must conform.
4. Water meters for accuracy.
5. That a separate weighing device is used for weighing cement.
6. Admixture dispensers to assure proper dosage will be used.

If a Certificate of Performance has been issued by the National Ready Mixed Concrete Association, the weighing and metering devices will not require checking for accuracy and the concrete batch facilities may be approved. The certification from the National Ready Mixed Concrete Association must be within a 6-month period prior to use and must certify that the plant's weighing and metering devices do meet 499 batching tolerances.

Plant bins are checked for holes in partitions and to see that separator plates are extended high enough to prevent spillage of materials when the bins are charged. Accumulation of aggregate in the corners must be avoided. Any evidence of this should be called to the attention of the plant operator and corrected immediately.

The test weights must have a seal indicating that they have been checked by the Ohio Department of Agriculture. These seals must be renewed every 3 years. Each scale must be checked with test weights through the range in which it is to be used. Should a scale be used to weigh the aggregate accumulatively, say totaling 13,356 pounds (6058 kg), it must be checked through 13,400 pounds (6078 kg). This will require the weights being attached and the scale checked for 500 pounds (227 kg), the weights removed, 500 pounds (227 kg) of aggregate added and the scale checked again with the weights, this time to 1,000 pounds (454 kg). This process is repeated until 13,400 pounds (6078 kg), or the total range actually being used, is reached. All scales shall be checked within the 12-month period immediately prior to use.

If a scales servicing company is employed by the producer to check and adjust the scales, the test weights used may range up to 1,000 pounds (454 kg). When these test weights are used, the scales should be checked by adding the weights to the scale and checking the scale as outlined in the previous paragraph. All weights used by the Scale Servicing Company must be sealed every 3 years by the Ohio Department of Agriculture.

A weight increment greater than 500 pounds (227 kg) may be used to check the batch plant scales in the lower range of use when large batches of concrete will be produced. However, smaller increments will be necessary when nearing the limit of use. This situation occurs for a paving operation with a central mix plant consistently producing larger batches. On the other hand, when the batch plant will be producing small or varied size batches of concrete, a maximum of 500-pound (227 kg) increments should be maintained. The testing must be for the range of use for the scale, and tolerances mentioned previously should be maintained. Adjustments should be made when necessary.

Water meters also must be checked and calibrated prior to use. Whether the water is metered by weight or by volume, the amount of water required for one cubic yard (cubic meter) of central mix, or transit mix concrete, or one batch of site mix concrete, should be metered and carefully collected for immediate weighing. The weight of the collected water must be within 1.0 percent of the weight indicated on the meter if the water is weighed. If the water is metered by volume, the water should be collected and weighed, then divided by 8.32 pounds per gallon (1 kg per liter). The volume in gallons (liters) thus obtained must be within 1.0 percent of the volume metered. Variations outside the tolerance must be corrected and the water meter rechecked until it is within the required accuracy.

Admixture dispensers are checked by actually discharging a given amount of admixture to verify the accuracy of the unit. Admixture dispensers must be accurate to within 3.0 percent of the indicated amount.

All checks made prior to starting production for each construction season must be documented. Checks made during concrete production must be noted on the TE-45 Report. Weighing and dispensing devices must be tested as often as the Engineer deems necessary to assure their continued accuracy.

During the batching operation, the Inspector should occasionally observe the amounts of the materials being weighed to assure that proportioning complies with the mix design. Therefore, the Inspector must know the various weights for the volumes being used as well as be familiar with plant components. Checks must be made to determine that the indicator dials return to zero when the batch is discharged. This is especially important for the cement scale. If the scale does not return to zero, it is an indication that material is building up or hanging up in the hopper. This material must be removed and the dial adjusted to read zero. Any scales not zeroing properly must be repaired.

Concrete Mixers (499.06 B.)

Transit mix trucks are used to haul plastic concrete batches to the concreting site. The concrete may be mixed at the plant and agitated during hauling, agitated during hauling and mixed at the point of use, or mixed in transit if it can be shown that mixing is accomplished during transit. Transit mixers also may be used to haul mixed or partially-mixed central mix concrete. When used for hauling concrete that has been mixed completely in a central mixer, the mixer is operated at agitation speed. If the concrete is only partially mixed, all materials must be mixed for at least 30 seconds in a stationary mixer and then mixed in the transit mixer for not less than 50 revolutions at mixing speed. This latter mixing is known as shrink mixing.

Central mix concrete may be hauled in truck agitators, commonly known as dumpcrete trucks, or trucks having bodies without agitation. Non-agitating equipment must have smooth, mortar-tight bodies capable of discharging concrete at a satisfactorily controlled rate. If dump trucks are used for non-agitation hauling, they must have smooth bodies with rounded corners and be free of internal ribs.

Mixers and agitators must meet certain sections of AASHTO M 157. Section 499.06 B. requires conformance with AASHTO M 157 Sections 10, 11.2, 11.5, and 11.6 except that the Department will allow mechanical counters. These sections are reprinted at the end of this section in a section entitled AASHTO M 157.

Handling, Measuring and Batching Materials (499.07)

Stockpile foundation areas must be cleared of all wooded brush or other debris, and shaped to provide drainage. The area may be compacted, stabilized, or paved to prevent the existing ground from infiltrating into the bottom of the pile. If the aggregate is placed directly on the ground, the bottom foot of aggregate must not be removed until final cleanup, and any material that has become contaminated must be reprocessed to meet specifications before use.

Where one stockpile adjoins another of a different size material, a substantial bulkhead or divider of sufficient length and height must be placed between the two to prevent intermingling of the different sizes. Intermingling of stockpiles must not be tolerated.

Aggregate must be dumped directly on the prepared stockpile as near to its final location as possible without additional handling. After the first layer is placed directly on the foundation, trucks must unload at the outside edge of the pile and the material moved into position on the succeeding layers. A crane with a bucket is ideal for picking up the aggregate and placing it on top of the material in place. Exercise care to deposit each bucket in a manner that prevents the aggregate from rolling and segregating. Therefore, the bucket should not be high in the air when the aggregate is released.

Front-end loaders are satisfactory to build a stockpile provided they stay off the stockpile (unless they are equipped with rubber tires) and if care is exercised to place each scoop load in a manner to avoid segregation. Equipment having steel treads must not be used on coarse aggregate stockpiles, nor should any equipment be permitted to push, shove, or roll coarse aggregate as segregation may result. If the Contractor uses equipment that appears to be causing segregation, additional tests must be run and, if there is a variance from specification gradation requirements, the use of the equipment must be discontinued.

Sand may be dumped directly on the prepared foundation for the bottom layer and succeeding layers placed by crane with bucket, by front-end loader, or by dozer.

Equipment that operates on stockpiles must not be permitted to move on and off the stockpile unless the foundation is stabilized or paved to prevent tracking of foundation material onto the stockpile. The tracking of foreign material onto stockpiles (while stockpiling aggregate or removing aggregate from stock piles to charge the concrete plant) can result in mud balls in the concrete.

Coarse aggregate is absorptive and will attract and absorb mixing water when used in a dry condition in concrete. This absorption of water needed for workability can result in a rapid slump loss when the aggregate is dry. Such a slump loss usually results in finishing and texturing problems. Coarse aggregate is required by 499.05 to be maintained with a uniform moisture content.

A moisture test must be made to determine the moisture content for use in adjusting the batch weights and the mixing water. When the actual moisture content of the fine and coarse aggregate is compared with the absorption of the aggregate, the Inspector will know if the aggregate is in a damp or saturated condition. Moisture contents greater than absorption indicate saturation, while those less indicate a damp condition.

Batching Coarse Aggregate

Segregation is possible when withdrawing coarse aggregate from stockpiles for charging into the plant bins, unless care is exercised. Cranes with buckets, and front-end loaders, are satisfactory for this operation provided the aggregate is handled in such a manner to avoid segregation. Any operation that results in excessive segregation, such as sliding or rolling, must not be permitted.

Batching Fine Aggregate

The use of a dozer is satisfactory for moving fine aggregate from large stockpiles to a conveyor for the transfer to the plant bins. With a dozer, material from the same level in the stockpile is pushed into a hopper feeding the conveyor. Being from the same level, the sand has the same moisture content and uniformity is maintained.

Fine aggregate will be handled in such a manner that the moisture content will be reasonably uniform for each day's production. Whenever the moisture content is suspect for a given stockpile, the stockpile should be rotated or mixed prior to charging the hopper feeding the conveyor. This will assure uniformity of the moisture content.

Batching Cement

Cement is usually fed by gravity from storage silos to weigh hoppers. Cement may also be pumped or blown from an auxiliary storage silo to a cement bin in the plant.

Batching Water

Water may be pumped into a measured storage tank, having the capacity required for the batch, where it flows by gravity into the central mixer or transit mixer. Water meters are in common use and can measure the water accurately per batch by volume or by weight. Water measuring devices should be checked and adjusted to an accuracy of 1 percent.

Batching Tolerances (499.07)

The batching tolerances are specified in 499.07 and are shown on the following table:

Batching Tolerances	
Item	Batching Tolerance (Percent)
Cement	± 1.0
Fly ash	± 1.0
GGBFS	± 1.0
Micro silica	± 1.0
Coarse aggregate	± 2.0
Fine aggregate	± 2.0
Water	± 1.0
Admixtures	± 3.0

Batching tolerances are different from the weighing tolerances. Weighing tolerances apply to the scales that are used to weigh the individual components of the concrete mix. Batching tolerances apply to the batching process. For instance, a 10 cubic yard load of Class C concrete requires 6,000 lbs of cement. During the process of weighing this amount of cement into the cement weigh hopper, it sometimes is not possible to stop the cement flow exactly at 6,000 lbs. The plant operator should be shooting for 6,000 lbs but is permitted a tolerance of 1.0 from this amount. Therefore, for this amount of cement the variance can be anywhere from 5,940 lbs to 6,060 lbs.

Batch Plant Tickets (499.08)

A concrete batch ticket must be furnished with each load of concrete delivered to the project. This ticket can be hand written, computer generated, or a combination of computer generated and hand written. The following information must be on each ticket of delivered concrete that certifies the ingredients in the load as well as other required data:

INFORMATION REQUIRED ON BATCH TICKET OF EVERY CONCRETE LOAD	
Name of ready-mix batch plant	Actual weights of aggregates:
Batch Plant Number	Coarse lbs (kg)
Batch Plant Location	Fine lbs (kg)
Serial number of ticket	Other lbs (kg)
Date	Actual weight of water lbs (kg)
Truck Number	Actual volume of admixtures:
Class of Concrete	Air entraining fl. oz. (mL)
Job Mix formula (JMF) Number	Superplasticizer fl. oz. (mL)
Time the load was batched	Water reducer fl. oz. (mL)
Size of Batch cubic yards (cubic meters)	Retarder fl. oz. (mL)
	Other fl. oz. (mL)
Actual weights of cementitious material:	Aggregate moisture contents:
	Coarse Aggregate %
Cement lbs (kg)	Fine Aggregate %
Fly ash lbs (kg)	Water Cement Ratio, leaving the plant
GGBFS lbs (kg)	
Micro-silica lbs (kg)	
Other lbs (kg)	

The contractor must provide additional information with the first load of concrete delivered to each project for each JMF. The following information must be provided either on the batch ticket or as a separate computer generated (or hand written) form and attached to the batch ticket:

INFORMATION REQUIRED FIRST LOAD OF CONCRETE DAILY	
Cementitious Materials (Source and Grade or Type):	Admixtures (Brand and Type):
Cement Fly ash Ground Granulated Blast furnace Slag Microsilica Other	Air entraining Retarding Superplasticizer Water reducing Other

It is a contract requirement that the above information be provided by the Contractor. If a Contractor is purchasing concrete from a ready-mix concrete supplier, it is the Contractor's responsibility to assure compliance even if it means putting a person at the plant to provide the required information. If the information is not provided as specified, the concrete is not to be accepted.

Mixing Concrete (499.09)

Concrete is to be mixed in either a central mixing plant or by a truck mixer.

Classifications of Concrete Mixers

Concrete mixers are classed as central mixers or transit mixers. Central mixers are stationary and are located at the batch plant where they are charged directly from the plant. Mixed batches from central mix plant may be transported to the placing site in dumpcrete trucks, dump trucks, or transit mix trucks. Transit mixers are charged directly from the batch plant and mixed in truck-mounted mixers at the plant or at the job site.

Central and Transit Mixing

For central mixing and transit mixing the proportioned materials are charged directly into the mixer from the weigh hoppers. Caution must be observed, especially with transit mixers having narrow openings, that materials are not spilled during the charging of the mixers. Usually it will be necessary to feed the batch gradually from the weigh hoppers into the transit mixers to avoid spillage. The common practice is to revolve the mixer at high speed during charging to aid material entry into the mixer and avoid clogging of the intake opening.

Pre-blending of materials, prior to or during charging of the mixer, plays an important role in obtaining proper mixing. This pre-blending or pre-mixing may be accomplished by depositing materials onto the charging belt in such a manner that all materials enter the drum at the same time, or by discharging all materials directly into the mixer simultaneously rather than separately. If the plant capacity is limited and the entire batch cannot be weighed into the weigh hopper in one operation, smaller complete batches should be required rather than weighing and discharging each ingredient independently. Proper mixing will not be obtained in the minimum mixing time if materials are charged separately; therefore this method must not be tolerated.

Most central mix plants are equipped with a "slump meter" which provides the operator a control of concrete consistency. These meters indicate concrete consistency indirectly by measuring the current or amperage being drawn by the motor that drives the mixer. The mixer operator maintains a predetermined amperage by adjusting the amount of mixing water. The result is uniform consistency between batches.

Mixers and agitators shall conform to paragraphs 10, 11.2, 11.5 and 11.6 of AASHTO M 157, except that mechanical counters are permitted. A copy of these paragraphs of AASHTO M 157 is contained in this manual.

Generally, water is started into mixers first and is charged at such a rate that it will not cease until all other ingredients are in the mixer. In this manner, water is present initially for mixing material during the charging period, and provides a washing action around the drum opening after all the dry materials have entered.

Air-entraining agents and water-reducing set retarders are the most common admixtures for concrete. It is very important that these admixtures do not become blended or mixed in any manner prior to the actual mixing of the concrete. Any mixing of the two could cause plugging of the supply lines. Also, the effectiveness of either or both of the additives may be reduced. To avoid any problem, they should be introduced into the batch separately.

Mixing Concrete (499.09)

The minimum mixing time for central mixers is 60 seconds, beginning when all the materials are in the drum and ending when discharge begins. Transit mixers must operate at the rate of rotation stated by the manufacturer as mixing speed, for not less than 70 revolutions. Checks must be made for compliance with these mixing requirements and the results recorded on the appropriate project documents.

Checks made of mixing time for central mixers are the responsibility of the concrete control Inspector. At least once a day (more often if possible) a check must be made and recorded on the concrete Inspector's daily report. The counter reading on transit mixers before and after mixing must be noted and recorded. The rate of rotation must also be checked. The initial counter reading and number of revolutions at mixing speed are recorded. The contractor is responsible for assuring proper mixing of all batches. Any deficiencies must be called to the contractor’s attention.

If possible, for large quantity-critical usage concrete, the Engineer should periodically check the mixing operation at the plant to assure compliance with specified mixing requirements. Counter readings and rate of rotation are noted and recorded as described above. Excessive speed of rotation may cause inadequate mixing. Centrifugal force causes the materials to cling to the drum rather than be mixed by being picked up and dropped repeatedly by the mixer blades. The Department's interpretation of mixing speed is the speed (called “mixing speed”) that is noted on the metal plate required on every truck mixer. When there is an overlap of agitating speed and mixing speed, only the rate of rotation in excess of agitation is considered as mixing speed. Therefore, the Inspector should examine the metal plate on each truck for the capacity and the rate of mixing. Trucks that have no metal plate are not permitted for State work.

If for some reason it is not practical to mix with transit mixers at the plant, the mixing may be done at the site in the presence of an Inspector who will document this on the TE-45 form. Whether mixing is accomplished at the plant or the site, transit mixers shall rotate at agitation speed while in transit.

If mixing in transit is requested by the ready mix producer, the producer must show that the mixers can and do revolve at a rate in excess of the range for agitation, indicated on the metal rating plate attached to the mixer. Use of counters listing the number of revolutions at agitation speed and the number of revolutions in excess of the agitation range separately will be adequate proof. The Inspector must record both counter readings when counters of this type are used.

The metal rating plate indicates a range for agitation speed and a range for mixing speed. Normally there is an overlap of the two. For example, agitation speed may be listed from 2 to 6 revolutions per minute while mixing speed may be from 4 to 12 rpm. To qualify as mixing speed in such instance, the mixer shall rotate at 7 rpm (next higher over agitation speed). At this rate, 10 minutes of mixing would be required for the required 70 revolutions.

The contractor must assure that the temperature of the plastic concrete does not exceed 90º F (32º C) until it is placed in the work. During hot weather, it may be necessary to use ice in the mixing water or to put sprinklers on aggregate piles to lower the concrete temperature.

Transporting Concrete

The time lapse, from the time water is added to the mix until the concrete is discharged into the work, must not exceed 60 minutes except as modified below. The Inspector in the field must document the time when the concrete is unloaded and assure that 60 minutes have not been exceeded. The Contractor may use, at his own expense, an approved water-reducing set retarding admixture or a retarding admixture for any concrete, and the time may be extended an additional 30 minutes (from 60 to 90 minutes).

Use of completed subgrade or base as roadway for transporting materials should be discouraged except in case of crossovers, or in case of unusual circumstances when it is impractical to operate outside the pavement area. When these unusual conditions exist and equipment is operated on the subgrade or base, increased inspection must focus on these areas to assure compliance with specification requirements before concrete is placed. Increased inspection is necessary to avoid displacement of forms, rutting of surface, and variation from crown tolerances.

When hauling units operate on completed pavement that is opened to construction traffic, they must observe the legal load limits. Generally, dual rear axle units hauling 7 cubic yards (5.4 cubic meters) of concrete are in excess of the legal limit and will not be permitted to operate on the completed pavement when loaded. If the Contractor desires to haul loads containing more than 7 cubic yards (5.4 cubic meters) of concrete and intends to use portions of the completed pavement for the loaded trucks, the Contractor must submit the necessary data to show that the loaded trucks are within legal limits. This data must be submitted to the District office for review.

Periodic inspection must be made of all hauling units. Items to be checked include:

1. Do not permit build up of hardened concrete or cement.
2. Mixing blades of transit mix trucks should be in working order.
3. Revolution counters on transit mix trucks must be in working order.
4. Wash water in the drum of transit mix trucks should be discharged from the mixers before recharging unless the water is metered accurately by a water meter on the transit mixer and results in uniformly consistent concrete.

Daily Report

The Concrete Inspector's Daily Report, Form TE-45, must be filled out completely for each class of concrete used each day, unless less than 50 cubic yards (38 cubic meters) of concrete is used. A filled out TE-45 report is shown in Figures 499.D and 499.E. A supplemental TE-45 form (TE-45 SUPPL.) is to be used on larger concrete placements to document numerous field tests. A blank TE-45 SUPPL. form is shown in Figure 499.F.

Daily placement of concrete less than 50 cubic yards (38 cubic meters) may be reported as described in this manual. A minimum of one group of tests and a completely filled out TE-45 required for every 50 cubic yards (38 cubic meters) placed. One copy of the report must be mailed to the District Laboratory and another copy filed in the project records.

The TE-45 is filled out for each class of concrete used each day. Reports are numbered consecutively for each day when concrete is used, but numbered reports are kept separate for each class of concrete. This form is a two-sided form that is divided into sections that are number from 1 to 9. The sections of the form are filled out in order from 1 to 9.

TE-45
❶

OHIO DEPARTMENT OF TRANSPORTATION
CONCRETE INSPECTORS DAILY REPORT

REVISED 10/02

SAMPLE ID	TYPE OF INSPECTION	JMF	MATERIAL CODE	CLASS OF CONCRETE	DATE MADE
666774-01	CTL	C273076	21527	HP4	05/29/02
P/S CODE	CONCRETE PRODUCER		REPRESENTS QUANTITY	PERSONNEL ID	DATE SHIPPED
03517-03	Tri-Son Concrete #2 Plant-Bellaire		240 C.Y.	XXX-YY-ZZZZ	06/03/02

ASSIGN TO: PROJECT NO.	533-01	PROJECT INDICATOR: PROJECT ✓ P.O. ☐		WEATHER	
	ITEM CODE	REF. NUMBER	QUANTITY	AMBIENT TEMP.	78-84
Compete form in order of numbers ❶ thru ❹ indicated on the tables.	511	41	240	CONCRETE TEMP.	80
				HUMIDITY	44%
Use TE-45 SUPP if there are not enough spaces in step ❸				WIND SPEED	2mph
				EVAPORATION RATE	0.04-0.06

PLACEMENT LOCATION: Bridge No. BEL-7-2.15 Deck, Phase lot 2, SB Side. Starting North side moving South w/Pump.

YIELD - CONSISTENCY - TEST SPECIMENS

❸ TIME	CONCRETE TEMP (°F)	STATION	UNIT WT (lbs/ft³)	BATCH SIZE (yd³)	TOTAL BATCH WEIGHT (lbs)	YIELD (ft³)	SLUMP (in)	AIR (%)	BEAMS AGE	BEAMS STRENGTH	CYLINDERS SPECIMEN NUMBERS	
5:45	80	BEL-7-2.15	140.50	8	30,100	26.78	5.0	8.4				
6:02	80	"	140.37	8	30,050	26.76	6.25	7.7			9	9A
6:26	81	"	140.22	8	30,040	26.78	6.75	7.2				
6:45	80	"	139.78	8	30,070	26.89	6.5	7.2				
7:05	79	"	139.67	8	30,070	26.91	6.5	7.1			10	10A
7:20	78	"	139.52	8	30,070	26.94	7.0	7.0	√5	760		

AGGREGATE MOISTURES

❷	MATERIAL	F.A.	C.A.#1	C.A.#2
A	TARE WEIGHT OF PAN	309gm	322gm	297gm
B	WET AGGREGATE + PAN WT	1877	1946	1932
C	B - A = WET AGGREGATE WT	1568	1624	1635
D	DRY AGGREGATE + PAN WT	1807	1912	1901
E	D - A = DRY AGGREGATE WT	1498	1590	1604
F	C - E = WEIGHT OF WATER	70	34	31
G	(F ÷ E) x 100 = % MOISTURE	4.67%	2.14%	1.93%

ADMIXTURES

TYPE	BRAND Master Builders	DOSE /yd³
AIR ENTRAINING	MB AE 90	9oz
WATER REDUCING (A)		
SET RETARDING (B)	Pozzolith 80	12oz
ACCEL. (C or E)		
WR / SR (D)		
HR WR (F or G)	Rheobuild 1000	55oz
OTHER		

The aggregate design weights in the Construction and Materials Specification manual have changed from DRY to SSD. The actual weights have not changed, therefore it is necessary to use the Bulk Specific SSD specific gravities when adjusting the weights from the ones specified in the design.

When adjusting aggregate weights for moisture, the calculation consists of first taking the aggregate back to dry condition then up to the actual moisture condition. This is done by dividing the SSD design weight by the absorption factor and multiplying by the moisture factor as shown in the AGGREGATE QUANTITIES FOR 1 yd³ BATCH WITH CORRECTION FOR MOISTURE table.

Figure 499.D - Form TE-45, Concrete Inspector's Daily Report (Front Side)

SSD DESIGN DATA

5 MATERIAL	MATERIAL CODE	PROD / SUPPL CODE	PRODUCER / SUPPLIER & LOCATION	SPECIFIC GRAVITY	ABSORPTION	SPECIFIED SSD WEIGHT (1 yd³)	4 CORRECTED SSDWEIGHT (for Sp. Gr)	8 BATCH WEIGHT PER YD	8 YDS
FINE AGG. TYPE Nat. Sand	021502	05029-01	Midvale @ Midvale	act. 2.64 dsgn 2.62	0.74	1320	1330	1382	11,056
COARSE AGG. #1 TYPE Gr. SIZE No. 8	0230080	"	"	act. 2.58 dsgn 2.62	1.95	500	492	493	3944
COARSE AGG. #2 TYPE Gr. SIZE No. 57	0230570	"	"	act. 2.59 dsgn 2.62	1.84	1025	1013	1014	8112
CEMENT TYPE I	37504	06588-01	Cemex-Wampam	3.15		440	440	440	3520
FLY ASH CLASS	NA			2.65					
GGBF SLAG GRADE 100	76303	05015-01	Holcim-Weirton, W.Va	2.90		190	190	190	1520
MICRO SILICA POWDER ☑ SLURRY ☐	37601	06643-01	Elkem Materials-Pa	2.20		30	30	30	240
OTHER									
9 WATER W / Cm RATIO 0.40	TOTAL WATER (Cm x W / Cm) (400+190+30)x0.40=264		± AGG. MOISTURE ADJUSTMENT (- ΣD) -(+54)	- WATER IN ADDITIVES 0		WATER ADDED AT MIXER 210		210	1680

AGGREGATE QUANTITIES FOR 1 yd³ BATCH WITH CORRECTIONS FOR MOISTURE

7 TIME	FINE AGGREGATE				[33%] COARSE AGGREGATE # 1				[67%] COARSE AGGREGATE #2				6 ΣD
	CORRECTED SSD DESIGN WEIGHT (A)	1 + (% MOIST / 100) / 1 + (% ABS / 100) (B)	BATCH WEIGHT [(A) X (B)] (C)	CHANGE TO WATER (C) - (A) (D)	CORRECTED SSD DESIGN WEIGHT (A)	1 + (% MOIST / 100) / 1 + (% ABS / 100) (B)	BATCH WEIGHT [(A) X (B)] (C)	CHANGE TO WATER (C) - (A) (D)	CORRECTED SSD DESIGN WEIGHT (A)	1 + (% MOIST / 100) / 1 + (% ABS / 100) (B)	BATCH WEIGHT [(A) X (B)] (C)	CHANGE TO WATER (C) - (A) (D)	TOTAL CHANGE TO WATER BY AGG.
5:30 pm	1330	MOIST = 4.67 ABS = 0.74	1382	+52	492	MOIST = 2.14 ABS = 1.95	493	+1	1013	MOIST = 1.93 ABS = 1.84	1014	+1	+54
		MOIST = ABS =				MOIST = ABS =				MOIST = ABS =			
		MOIST = ABS =				MOIST = ABS =				MOIST = ABS =			

TESTED BY: ______ TEST RESULTS: ______

REMARKS: ______

Figure 499.E - Form TE-45, Concrete Inspector's Daily Report (Back Side)

TE-45 SUPPL.

REVISED 9/02

OHIO DEPARTMENT OF TRANSPORTATION
CONCRETE INSPECTORS DAILY REPORT
SUPPLEMENT

PROJECT NO.	SAMPLE ID	DATE MADE	PLACEMENT LOCATION	PERSONNEL ID

⊕ TIME	CONCRETE TEMP (°F)	STATION	UNIT WT (lbs/ft³)	BATCH SIZE (yd³)	TOTAL BATCH WEIGHT (lbs)	YIELD (ft³)	SLUMP (in)	AIR (%)	BEAMS		CYLINDERS	
									AGE	STRENGTH	SPECIMEN NUMBERS	

REMARKS:

Figure 499.F - TE-45 Supplemental Form, Concrete Inspector's Daily Report Supplement

The following are instructions for filling out the TE-45 form:

Section 1.

1. SAMPLE ID – The "Sample ID" number is a computer-generated number. This number is generated by CMS when data is being entered onto the "Sample" screen. The number is used to refer to the TE-45 and any cylinder and/or beam specimens made that day.
2. TYPE OF INSPECTION - Typically this will be a Control Sample [CTL]; Independent Assurance Sample [IAS]; or Information [INF] sample. Other options for type of sample can be found in CMS. The following are the abbreviations and names of all types of material samples:

Abbreviation	Type of Sample
BRN	Brand Name
CHK	Check Sample
CRT	Manufacturer's Certification
CTL	Job Control
DUP	Duplicate
IAS	Independent Assurance
INF	Information
OTH	Other Sample
PME	Preliminary
PRE	Pre-Qualified/Approved Source
QAL	Quality Control Sample
SMQ	Small Quantity
SUB	Approved/Sub Catalog Cut
SUP	Supplemental
TMP	Temporary Application
VIS	Visual
Visual	Preliminary

3. JMF – The "JMF" space on the form is for the Job Mix Formula Number assigned to the concrete being produced and tested. The JMF is a listing of the materials that are in the mix, and should be provided by the Ready Mix producer supplying the concrete. The JMF can be verified by going to the list of Concrete JMF's on the web site. This site can be accessed by clicking on Construction, Materials Management, Information List, and

Concrete JMFs. Select the type of concrete. The list is sorted first by fine aggregate and then by the coarse aggregate.

4. MATERIAL CODE - The "Material Code" section of the TE-45 form is a number assigned to the type of concrete represented by the sample. These codes are available from the "Material" Screen in the Construction Management System. The material code can be determined from the same list as No. 3 above for the class of concrete being used.
5. CLASS OF CONCRETE - The class of concrete to be used on any given item should be determined from the plans. Just place the name of the class in this box.
6. DATE MADE - This is the date that the concrete is made.
7. P/S CODE – This is the Producer / Supplier code. In this case, it is the code for the Ready Mixed Concrete Company. This number can be found in CMS by going to the PRD screen. When prompted to enter the Producer/Supplier Code, press the <F4> button on the keyboard. In the BEGIN ABBR NAME section, enter the first 3 to 4 letters of the company name and push <tab>. In the END NAME section, enter the first 3 or 4 letters again, but this time press a higher letter in the alphabet for the last letter. <Tab> down the list to the company that you are looking for. The material code is listed here or you can press <Enter> for more information on the plant. There is also an indicator on the right side of the screen to let you know if a plant is active (A) or inactive (I).
8. CONCRETE PRODUCER - Enter the name and location of the Ready Mixed Concrete Company.
9. REPRESENTS QUANTITY - The "Represents Quantity" space is provided to show how many cubic yards (cubic meters) of concrete the TE-45 represents. The space shows how much concrete was produced during the day the report represents. This value can be found in the contract documents such as the plans or the proposal.
10. PERSONNEL ID - An identification number (Social Security No.) of the inspector performing the test.
11. DATE SHIPPED - The day that cylinders are taken from the project to be shipped to the central or district lab for testing.
12. PROJECT NO. - The project number for the project.
13. PROJECT INDICATOR - Indicate if the concrete is for a project or a Purchase Order.
14. ITEM CODE / REF. NUMBER / QUANTITY - Information from the contract documents.
15. PLACEMENT LOCATION - Indicate where the concrete is being placed. Be specific about which lane, etc.
16. WEATHER - Can be completed as the concrete placement is taking place. Should be used as a reminder to check the conditions before the placement, and throughout the placement in order to determine the evaporation rate.

Section 2

1. AGGREGATE MOISTURE - Use this section to calculate the % moisture of the aggregates being used in the concrete mix. Space is provided for one fine aggregate and two coarse aggregates.
2. ADMIXTURES - Indicate the brand, type, and dosage rate of the admixtures being used. This can be found on the JMF screen.

Section 3

1. MATERIAL - Indicate what type, size, class, or grade of material being used.
2. MATERIAL CODE - One place to get this information is on the PCJMF screen in CMS. Material Codes are given in the first column of the list. Make sure that the materials being used are the same as the materials in the JMF.
3. PROD. / SUPPL. CODE - The producer supplier code is also on the JMF screen. Caution: The P/S code on the JMF for the cementitious material is 04302-01 - State General Materials, DO NOT USE THESE MATERIAL CODES. Determine the names and P/S Codes of the actual materials being used. Make sure that the materials being used are certified or approved for use with ODOT.
    a. CEMENT - Look on the approved list on the Materials Management web site under S 1028 - Cement Certified List. Make sure to use the code for a MFG PLANT and not a TERMINAL Location. The MFG PLANT location should be on the Bill of Lading for the cement.
    b. FLY ASH - Look on the approved list on the Materials Management web site under S 1026 - Fly Ash Certification List.
    c. GGBF SLAG - Acceptable sources of this material can be found in the ISRC screen of CMS. Use material code 37603 for GRADE 100 material and 37604 for GRADE 120 material.
    d. MICRO SILICA - Acceptable sources of this material can be found in the ISRC screen of CMS. Use material code 37601 for POWDER material and 37601S for SLURRY material
4. PRODUCER/SUPPLIER & LOCATION - Enter the name and location of the producer or supplier of each material.
5. SPECIFIC GRAVITY - The information for the actual (act.) specific gravities can be found on the Office of Materials Management website under Information, Aggregate, and Specific Gravities List. The sources are listed in alphabetical order. The desired source name can be quickly found by using the <Find> button (binoculars). Use the SSD values. The Design (dsgn) specific gravity can be found in the Construction and Materials Specification book, Supplemental Specification, Proposal Note, or Plan Note for the project.
6. ABSORPTION - This information is also on the Specific Gravity list mentioned in 23 (above).

7. SPECIFIED SSD WEIGHT (1 yd3) - these weights are taken from 499.03 in the Construction and Materials Specification Book, Supplemental Specifications, Proposal Notes or Plan Note for the project. They are also on the JMF. If a contractor-designed mix (QC/QA) is used, these values, along with the design Specific Gravities and Absorptions, can only be found on the JMF.

Section 4

1. CORRECTED SSD WEIGHT (for Sp. Gr) - This is the SSD design weight of the aggregates adjusted for specific gravity. This is calculated by multiplying the SPECIFIED SSD WEIGHT by the actual SSD specific gravity and dividing by the design specific gravity.

$$Adjusted\,DW_{SSD} = \frac{DW_{SSD}}{DSG} * ASG \qquad \text{(Equation 499.3)}$$

where:

DW_{SSD} = Design Weight (SSD) from the appropriate table in 499.03 or 499.04

DSG = Design Specific Gravity from Table 499.A

ASG = Actual SSD Specific Gravity to be used on the project

Adjusted DW_{SSD} = Design Weight (SSD) adjusted for the actual aggregate specific gravity

Section 5

2. AGGREGATE QUANTITIES FOR 1 yd3 BATCH WITH CORRECTIONS FOR MOISTURE - This form is set up so that the batch weights can be determined 3 times during a placement. Each aggregate used should be adjusted for moisture in the following manner:
   a. CORRECTED SSD DESIGN WEIGHT - Enter the CORRECTED SSD WEIGHT from section 4 in column (A).
   b. MOIST = Enter the total aggregate moisture % that was determined in section 2 row G.
   c. ABS = Enter the aggregate absorption % from section 3 under ABSORPTION.
   d. The free moisture correction factor is calculated from Equation 499.12:

$$\text{FMCF} = \frac{TMCF}{AMCF} = \frac{(\%\,Total\ Moisture/100) + 1.0000}{(\%\,Absorbed\ Moisture/100) + 1.0000}$$

Use the % total moisture in the aggregate at the time of its use (the number after "MOIST = ") to determine the total moisture correction factor, the numerator in the above equation (see Equation 499.9). Use the % absorption of that particular aggregate (the number next to "ABS = ") to determine the absorbed moisture correction factor, the denominator in the above equation (see Equation 499.11).

The formula involves changing the two %'s to a decimal form (by moving the decimal place 2 places to the left) and adding 1.

$$\text{FMCF} = \frac{(4.67\%/100)+1.0000}{(0.74\%/100)+1.0000} = \frac{(0.0467)+1.0000}{(0.0074)+1.0000} = \frac{1.0467}{1.0074}$$

e. BATCH WEIGHT - The batch weight is determined by multiplying the corrected SSD weight by the free moisture correction factor. It is easiest to think of the correction factor in terms of separate values for the moisture and absorption. The form is set up so that corrected SSD weight is multiplied by the value calculated by the top number and divided by the value calculated from the bottom number. For example:

CORRECTED SSD DESIGN WEIGHT (A)	FMCF (B)	BATCH WEIGHT [(A) X (B)] (C)	CHANGE TO WATER (C) - (A) (D)
1330	MOIST = 4.67 ABS = 0.74	$1330\text{x} \frac{1.0467}{1.0074} = 1382$	$1382 - 1330 = +52$

f. CHANGE TO WATER – Subtract the Corrected SSD Design Weight from the Batch Weight to determine the need to change the water. A positive number indicates that there is excess (free) moisture on the aggregate and will contribute to the mix water. If the number is negative, the aggregates are dry and will absorb water from the mix water.

g. Repeat the process for the different aggregates in the mix. Indicate what percent of the total coarse aggregate an aggregate is if two coarse aggregates are blended.

Section 6

1. TOTAL CHANGE TO WATER BY AGG. - Sum the CHANGE TO WATER's for all of the aggregates in the batch.

Section 7

1. WATER - This section determines how much water needs to be added to the mixer after adjusting for water (either provided to or taken from the mix from other sources).
2. W / Cm - Determine the required Water/Cementitious Ratio (W/Cm) from the contract documents or JMF.
3. TOTAL WATER - Sum the weights of all of the cementitious materials and multiply by the Water/Cementitious ratio to determine the total allowable water.
4. AGG. MOISTURE ADJUSTMENT - Enter the negative of the number in 6 If the aggregates are wet, the number should be negative. If they are dry, the resulting number should be positive.
5. WATER IN ADDITIVES - Water in additives needs to be accounted for in the mix water. This is generally used when the micro silica used is in slurry form. You would then determine the amount of solid, determine how much is used, and how much of the slurry was water.

   Example: A slurry mix is used in a Class HP4 mix. There is to be 30 lbs of micro silica in each yd3 of concrete. Determine how much slurry is needed per yd3 and how much water is contributed to the mix if the slurry contains 42% micro silica solids.

   30 lbs micro ÷ 0.42 = 71.4 lbs of slurry required

   71.4 lbs slurry - 30 lbs micro = 41.4 lbs of water added to the mix
6. WATER ADDED AT MIXER - Is equal to the TOTAL WATER minus any free moisture or plus any absorbed moisture in the AGG. MOISTURE ADJUSTMENT minus any appreciable WATER IN THE ADDITIVES.

Section 8

1. BATCH WEIGHT- fill in the amount of aggregates indicated in section 5; carry over the amount of cementitious material in section 3; and enter the amount in section 7. Multiply those amounts by the size of the loads to determine the specified batch weights.

Section 9

1. YIELD - CONSISTENCY - TEST SPECIMENS - This section is completed as the concrete is being placed and tested as follows:

a. TIME - Indicate the time that the trucks are being discharged. This should fall within the 60 or 90 minute limit allowed by the specification.
b. CONCRETE TEMP - The concrete temperature should be taken and entered in this section.
c. STATION - Specify where the concrete that is being sampled and tested is being placed.
d. UNIT WT. - The unit weight is determined by testing the concrete according to ASTM C 29.
e. BATCH SIZE - This amount should be established prior to the placement with the Ready Mixed Concrete producer.
f. TOTAL BATCH WEIGHT - This information should be available from the batch ticket received on every load of concrete.
g. YIELD - The yield is calculated by dividing the Total Batch Weight by the Unit Weight to get the total number of cubic feet in the truck and divided again by the batch size to determine the number of cubic feet in a cubic yard.
h. SLUMP - Determined from test results.
i. AIR - Determined from test results.
j. BEAMS - If a beam is made, indicate the strength result and age in the row of the truck from which it was taken. A mark may need to be made during the concrete placement as a reminder of which load the sample represents.
k. CYLINDERS - If cylinders are taken, indicate the specimen numbers in this area.

2. TE-45 SUPP - If more lines are needed than are provided in section 9, a TE-45 Supplement form is available on the web. This is a continuation of section 9 without the need for the other information that is already completed. The information on this form should be used when entering the required data into CMS.

Check List for Inspection

1. Check foundations of stockpiles for proper preparation and adequate drainage.
2. Check bins for adequate partitions to prevent intermingling of aggregate.
3. Check scales with test weights throughout range of use and determine percent of error. If error is greater than ± 0.5 percent, scales must be adjusted and rechecked. Record checks made on TE-45.
4. Check scales for seal by the Sealer of Weights and Measures or of a scale servicing company. Record on TE-45.
5. Check water meter for accuracy. Record on TE-45.
6. Check admixture dispensers for accuracy. Record on TE-45.
7. Check mixers to assure that hardened concrete is not built up around blades.

8. Inspect hauling units for cleanliness, condition of blades, and operation of counters.
9. Check to assure that all materials have been sampled, tested, and approved or certified prior to start of concrete production.
10. Observe stockpiling of aggregate to assure that handling does not cause segregation, contamination, or intermingling.
11. Adjust quantities obtained from the Concrete Table for specific gravity, moisture, and absorption. Set these adjusted batch weights on appropriate scales.
12. Observe charging of plant bins to assure that materials are not being intermingled.
13. Observe batching operations at start of production and periodically thereafter.
14. Check scales for "zeroing." Have adjustments made when needed.
15. Make adjustments as needed to maintain air, slump, and yield within specified tolerance.
16. When adjustments are made in the mix design, check to assure that proper batch weights are set on the scales.
17. Periodically check transit and central mixers to assure compliance with manufacturer's recommended mixing speeds.
18. Complete TE-45 Report and submit to the District laboratory.

Conversion Factors

	MULTIPLY	BY	TO GET
Area	1 square foot 1 square inch	0.0929034* 645.16*	square meter (m^2) square millimeter (mm^2)
Length	1 inch 1 foot 1 mile	25.4* 0.3048* 1.609344	millimeter(mm) meter (m) kilometer (km)
Mass	1 pound	0.453592 4	kilogram (kg)
Mass per volume	1 pound/cubic foot 1 pound/cubic yard 1 pound/gallon	16.018846 0.5932764 0.1198264	kilogram/cubicmeter (kg/m^3) kilogram/cubic meter (kg/m^3) kilogram/liter (kg/L)
Pressure (stress)	1 pound/square inch 1 pound/square foot	0.0068944 47.88026	megapascals (Mpa) pascal (Pa)
Temp	Fahrenheit (^oF)	(^oF-32)/1.8)	Celsius (^oC)
Volume	1 fluid ounce 1 cubic yard 1 cubic foot 1 cubic foot 1 gallon	29.57353 0.7645549 0.02831685 28.31685 3.785412	milliliter (mL) cubic meter (m^3) cubic meter (m^3) liter (L) liter (L)
Volume per mass	1 fluid ounce / cubic yard 1 fluid ounce / 100 pounds 1 gallon / cubic yard	38.68071 65.19847 4.951132	milliliter/cubic meter (mL/m^3) milliliter/100 kilogram (mL/100 kg) liter/cubic meter (L/m^3)

*exact conversion

AASHTO M 157

The following is a direct reprint from AASHTO M 157 Standard Specification for Ready-Mixed Concrete. The reprint is only the paragraphs referenced in 499.05 B. of the specifications (Sections 10, 11.2, 11.5, 11.6).

AASHTO M 157 Sections 10, 11.2, 11.5, 11.6

10. Mixers and Agitators

10.1 Mixers may be stationary mixers or truck mixers. Agitators may be truck mixers or truck agitators.

10.1.1 Stationary mixers shall be equipped with a metal plate or plates on which are plainly marked the mixing speed of the drum or paddles, and the maximum capacity in terms of the volume of mixed concrete. When used for the complete mixing of concrete, stationary mixers shall be equipped with an acceptable timing device that will not permit that batch to be discharged until the specified mixing time has elapsed.

10.1.2 Each truck mixer or agitator shall have attached thereto in a prominent place a metal plate or plates on which are plainly marked the gross volume of the drum, the capacity of the drum of container in terms of the volume of mixed concrete, and the minimum and maximum mixing speeds of rotation of the drum, blades, or paddles. When the concrete is truck-mixed as described in 11.1.3, or shrink mixed as described in 11.1.2, the volume of mixed concrete shall not exceed 63 percent of the total volume of the drum or container. When the concrete is central mixed as described in 11.1.1, the volume of concrete in the truck mixer or agitator shall not exceed 80 percent of the total volume of the drum or container. Truck mixers and agitators shall be equipped with means by which the number of revolutions of the drum blades, or paddles may be readily verified.

10.2 All stationary and truck mixers shall be capable of combining the ingredients of the concrete within the specified time or number of revolutions specified in Section 10.5, into a thoroughly mixed and uniform mass and of discharging the concrete so that no less than 5 of the 6 requirements shown in Table 5 shall have been met.

TABLE 5- Requirements for Uniformity of Concrete

Test Requirement Expressed as Maximum Permissible Difference in Results of Tests of Samples Taken from Two Locations in the Concrete Batch	
Weight per cubic foot (weight per cubic meter) calculated to an air-free basis, lb/ft3 (kg/m³)	16 (1.0)
Air content, volume percent of concrete	1.0
Slump:	
If average slump is 102 mm (4 in.) or less, mm (in.)	25 (1.0)
If average slump is 102 mm to 152 mm (4 to 6 in.), mm (in)	38 (1.5)
Coarse aggregate content, portion by weight of each sample retained on No. 4 (475-mm) sieve, percent	6.0
Unit weight of air-free mortar [a] based on average for all comparative samples tested, percent	1.6
Average compressive strength at 7 days for each sample,[b] based on average strength of all comparative test specimens, percent	7.5 [c]
a - "Test for Variability of Constituents in Concrete." Designation 26, Bureau of Reclamation Concrete Manual, 7th Edition. Available from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. b - Not less than 3 cylinders will be molded and tested from each of the samples. c - Tentative approval of the mixer may be granted pending results of the 7-day compressive strength tests.	

Note 5 - The sequence or method of charging the mixer will have an important effect on the uniformity of the concrete.

10.3 The agitator shall be capable of maintaining the mixed concrete in a thoroughly mixed and uniform mass and of discharging the concrete with a satisfactory degree of uniformity as defined by Appendix A.

10.4 Slump tests of individual samples taken after discharge of approximately 15% and 85% of the load may be made for a quick check of the probable degree of uniformity (Note 6). These two samples shall be obtained within an elapsed time of not more than 15 min. If these slumps differ more than that specified in Annex A1, the mixer or agitator shall not be used unless the condition is corrected, except as provided in 10.5.

Note 6 - No samples should be taken before 10 percent or after 90 percent of the batch has been discharged. Due to the difficulty of determining the actual quantity of concrete discharged, the intent is to provide samples that are representative of widely separated portions, but not the beginning and end of the load.

10.5 Use of the equipment may be permitted when operation with a longer mixing time, a smaller load, or a more efficient charging sequence will permit the requirements of Appendix A to be met.

10.6 Mixers and agitators shall be examined or weighed routinely as frequently as necessary to detect changes in condition due to accumulations of hardened concrete or mortar and examined to detect wear of blades. When such changes are extensive enough to affect the mixer performance, the proof-tests described in Appendix A shall be performed to show whether the correction of deficiencies is required.

11. Mixing and Delivery

11.2 Mixers and agitators shall be operated within the limits of capacity and speed of rotation designated by the manufacturer of the equipment.

11.5 Truck-Mixed Concrete- Concrete that is completely mixed in a truck mixer, 70 to 100 revolutions at the mixing speed designated by the manufacturer to produce the uniformity of concrete indicated in Appendix A. Concrete uniformity tests may be made in accordance with 11.5.1. and if requirements for uniformity of concrete indicated in Appendix A are not met with 100 revolutions of mixing, after all ingredients, including water, are in the drum, that mixer shall not be used until the condition is corrected, except as provided in Section 10.5. When satisfactory performance is found in one truck mixer, the performance of mixers of substantially the same design and condition of blades may be regarded as satisfactory. Additional revolutions of the mixer beyond the number found to produce the required uniformity of concrete shall be a designated agitating speed.

11.5.1 Sampling for Uniformity of Concrete Produced in Truck Mixers- The concrete shall be discharged at the normal operating rate for the mixer being tested, with care being exercised not to obstruct or retard the discharge of approximately 0.1 m 3 (2 ft 3 approximately) shall be taken after discharge of approximately 15 percent and 85 percent of the load (Note 6). These samples shall be obtained within an elapsed time of not more than 15 min. The samples shall be secured and shall be kept separate to represent specific points in the batch rather than combined to form a composite sample. Between samples, where necessary to maintain slump, the mixer may be turned in mixing direction at agitating speed. During sampling, the receptacle shall receive the full discharge of the chute. Sufficient personnel must be available to perform the required tests promptly. Segregation during sampling and handling must be avoided. Each sample shall be remixed the minimum amount to ensure uniformity before specimens are molded for a particular test.

11.6 When a truck mixer or truck agitator is used for transporting concrete that has been completely mixed in a stationary mixer, any turning during transportation shall be at the speed designated by the manufacturer of the equipment as agitating speed.

AASHTO M 157 Appendix A

(Mandatory Information)

A1. CONCRETE UNIFORMITY REQUIREMENTS

A1.1 The variation within a batch as provided in Table 5 shall be determined for each property listed as the difference between the highest value and the lowest value obtained from the different portions of the same batch. For this specification the comparison will be between two samples, representing the first and the last portions of the batch being tested. Test results conforming to the limits of five of the six tests listed in Table 5 shall indicate uniform concrete within the limits of this specification.

A1.2 Coarse Aggregate Content, using the washout test, shall be computed from the following relations:

P = (c/b) x 100

where:

P = weight % of coarse aggregate in concrete;

c = saturated surface-dry-weight in kg (lb) of aggregate retained on the No. 4 (4.75-mm) sieve, resulting from washing all material finer than this sieve from the fresh concrete, and

b = weight of sample of fresh concrete in unit weight container, kg (lb).

A1.3 Unit Weight of Air Free Mortar shall be calculated as follows:

A1.3.1. Inch-pound units:

$$M = \left(\frac{b - c}{V - \left(\frac{VxA}{100} + \frac{c}{Gx62.4} \right)} \right)$$

A1.3.2. Metric units:

$$M = \left(\frac{b - c}{V - \left(\frac{V \times A}{100} + \frac{c}{1000\,G} \right)} \right)$$

where:

M = unit weight of air-free mortar, kg/m³ (lb/ft³);

b = weight of concrete sample in unit weight container, kg (lb);

c = saturated surface-dry-weight of aggregate retained on No. 4 (4.75-mm) sieve, lb (kg),

V = volume of unit weight container, ft³ (m³),

A = air content of concrete, percent, measured in accordance with Section 18.1.4 on the sample being tested; and

G = specific gravity of coarse aggregate (SSD).

Documentation Requirements - 499 Concrete

1. Fill out form CA-C-1 and TE-45
2. If water is added at project site, 30 additional mixing revolutions are required
3. Insure that specified w/c ratio is not exceeded
4. Time loaded is the first time that water and cement meet
5. Record temperature of mix
6. Record mix design adjustments on form TE-45
7. Check moistures of aggregates at plant; make sure that correct aggregates are used for given JMF
8. Insure that batch tickets are provided as specified in 499.08

500 Structures

501 Structures General

Engineering

When the Contractor performs survey work, the Engineer shall verify the Contractor's accuracy by observation of the work and review of notes. A state survey crew should be available for checking any part where this accuracy is not obtained. The Contractor's surveyor should cooperate with the Engineer by providing the notes on critical work such as bridge seat elevations, profiles of beams or girders, and grade for finishing the deck for review and concurrence. Information that indicates the elevation of bridge seats and deck grades have been properly set must be recorded in the project file.

Relations between the Engineer and surveyor should be in the spirit of cooperation toward achieving the common goal of bridges constructed of specified quality, in plan location, and on proper grade that will benefit both the state and the Contractor.

Construction Plans (501.05)

When railroad involvement is required as specified in 501.05.A., it is the Contractor's responsibility to submit plans to the involved railroads for acceptance at least 50 days before construction begins. The Contractor shall supply the Engineer with documentation proving railroad acceptance. Department acceptance is not required.

The following plans should be submitted to the Engineer at least 7 days before construction begins. These plans shall be prepared by an Ohio Registered Professional Engineer (PE) and checked by a second PE. No Department acceptance is required.

1. Sheeting and bracing adjacent to traffic when required by contract
2. Demolition of structures over or adjacent to active traffic
3. Falsework for cast-in-place concrete bridges over 20 feet (6.1 m)
4. Erection of steel or precast concrete structural members
5. Jacking and support of existing structures
6. Construction stresses from equipment in excess of 60,000 pounds (27,000 kg)
7. Structures for maintaining traffic

Although no Department acceptance is required, these plans should be utilized in the field as the standard to judge whether the contractor is performing the work correctly.

Stop all operations that do not follow the prepared plans. The Contractor must submit to the Engineer, any revised plans, prepared by an Ohio Registered Professional Engineer, 24 hours before construction on the deviated work begins.

If the Contractor requests to weld to a main structural member, that are not shown on the contract drawings, he must submit a plan to the Office of Structural Engineering for acceptance at least 20 days before construction begins.

If a Contractor has to perform corrective work on structures items, the Contractor must submit three copies of a corrective work plan(CWP), to the Engineer, including supporting calculations, prepared by an Ohio Registered Professional Engineer. The Engineer will submit the CWP to the Office of Structural Engineering for review and acceptance prior to performing corrective work.

When traffic is maintained while an overhead structure is being removed, platforms, nets, or other devices must be provided to safeguard the traveling public from falling objects that might fall directly onto the roadway below, be deflected toward the traffic, or bounce into the traveled lanes. Removal of superstructure concrete and structural steel shall, in no case, take place directly over traffic due to the possibility of large pieces falling through the protective devices.

Documentation Requirements - 501 Structures

This section outlines the contractor's requirements for fabrication, shop drawings, material certification, and erection procedures.

1. Use Erection Checklist Form CA-S-20.

502 Structures For Maintaining Traffic

Description (502.01)

This item consists of the construction, maintenance, and subsequent removal of a temporary bridge or culvert for maintaining traffic.

Design and Construction (502.02)

The waterway opening generally should be not less than 75 percent of the effective waterway of the proposed structure based on the 5-year water level. The deck of a bridge must have at least a 23-foot (7.0 m) clear roadway and, if pedestrian facilities existed, at least a 4-foot (1.2 m) wide sidewalk must be provided.

The proposed plan should be reviewed in the District for accuracy of existing features not shown on the project plans. If the proposed waterway is less than 75 percent, comments regarding local knowledge of stream fluctuations will be helpful. In lieu of a bridge, a pipe culvert or multiple pipe culverts with required waterway may meet the requirements for a bridge and will be considered when submitted.

Submit construction plans in accordance with 501.05

All stress-carrying materials to be used in any temporary structure must be carefully examined, since used materials generally are employed and may not possess the physical properties considered in the design. Timber elements must be examined for specified size and soundness. Steel members must be examined for holes and alterations that would reduce their section modules. Welded splices in members are not cause for rejection providing the welds have been made properly and are proven to be free from defects. Existing welded butt splices must be subject to radiographic inspection. Approved welders using approved welding consumables should perform welding. Hardware and miscellaneous materials must be as specified on the submitted plan.

Piles must be driven in accordance with 507. The bearing capacity of each pile must be as specified on the submitted plan but in no case less than 12 tons (107 kn). If piles are not driven to bedrock, the Contractor is responsible for performing the dynamic load necessary to determine the required blow count.

Construction of the temporary structure must be according to details and notes shown on the submitted plan. Proposed substitution of elements of equal or greater strength may be made. All other proposed substitutions or changes in design must be submitted in an amended plan meeting the requirements of 501.05.

When the plans permit the use of an existing superstructure as part of a temporary run-around, the bridge shall be relocated so that there will be no reduction in load carrying capacity. The plans for temporary substructure units must be submitted in accordance with 501.05.

Maintenance (502.03)

The Contractor is required to maintain the temporary structure in good condition with respect to safety, ride quality, and waterway opening for the duration of the run-around. Periodic inspection of the structure must be made and any questionable members or connections that are damaged or over-stressed must be corrected immediately.

Documentation Requirements - 502 Structures for Maintaining Traffic

1. Document structure and its conformance to the plans
2. Document date installation starts and when the structure is removed

503 Excavation for Structures

Cofferdams, Cribs, and Sheeting (503.03)

The Contractor may elect to use whatever materials or methods he considers necessary to accomplish this item unless specific details are required by the plans. Many times when sheeting is installed into streambeds, the streambeds consist of sand or gravel. Sand and gravel are pervious materials and will allow water to flow through them. If this condition exists, water can flow under the sheets and come up through the bottom of the cofferdam. This can loosen the soil in the bottom of the cofferdam and cause it to be very soft and unstable. It can also result in water coming up through any freshly-placed concrete. If this situation exists, the Contractor should take measures to prevent the flow of water up through the bottom of the cofferdam. These measures can consist of driving the sheet piling deep enough to cut off the flow of water, or placing a concrete seal in the bottom of the cofferdam prior to pumping out the water. If additional measures are required, they are considered to be part of the cofferdams, cribs, and sheeting item and no additional compensation should be allowed for these items.

In order to qualify as Cofferdams, Cribs, and Sheeting for a particular substructure unit, the Contractor must perform work to protect and maintain the excavation at that particular substructure unit. This work can include pumping out water, installing cribs or sheeting, or building an earthen cofferdam.

Unclassified Excavation

This item may include bedrock and requires the removal of all materials necessary for construction of structures according to plan. It also includes subsequent backfill and disposal of excavated material.

Protection

Sides of excavation should be protected from caving. If side failure occurs, the disturbed soil should be removed and replaced with properly compacted soil. The sides must not be laid back to the extent where the slope will endanger the stability of adjacent foundations. The stability of the slopes needs to be determined by a “competent person” on the Contractor’s staff.

Undercut for Spread Footings

When footings are not on piling, any material undercut or disturbed below plan or authorized elevation must be replaced with concrete at the Contractor’s expense. If the excavation is allowed to remain exposed for a considerable period of time and the material becomes unsuitable, it must be removed and replaced with concrete at the Contractor’s expense. The additional concrete may be placed with the footing concrete; however, the footing reinforcing steel must be located at the elevation indicated on the plans.

Many Contractors will place gravel in the bottom of the excavation to assist in dewatering and to provide a better work surface for the workers. This is unacceptable as any over excavation of spread footing subgrades must be replaced with concrete, not gravel.

Undercut for Pile Foundations

When footings are supported on piling, any material undercut or disturbed must be replaced with properly compacted material. If the bottom of the excavation becomes muddy, the Contractor may remove the muddy soil and replace it with suitable granular material.

Drainage

When the Cofferdam, Cribs, and Sheeting item is not provided, drainage outside the forms and pumping necessary to keep the surface suitable for placement of concrete are included in the excavation item.

Rock Excavation

This item includes removal and disposal of material that, in the opinion of the Engineer, is rock or hard shale. Shale that is removed by the same methods and comparative effort as soil should be classified as soft shale.

Methods

Rock or hard shale may be removed by whatever methods the Contractor elects. These usually are blasting, jack hammering, or ripping. Note the option to excavate by blasting may be excluded due to the close proximity of existing facilities. It is desirable to have rock excavation below the tops of footings as near to the sides of the footings as practical.

Qualifications for Payment

To qualify for payment as rock excavation, the Engineer must determine that the excavated material is indeed rock or hard shale. In addition, all of the rock excavation below the footing top must be filled with concrete. Rock excavation performed above the top of footing may be to any width; however, payment above as well as below the top of footing is to the plan dimensions of the footing only.

Elevation Changes

In the event bedrock is encountered over 1 foot (0.3 m) higher than indicated by the borings, or bedrock is not encountered at plan elevation, report the findings to the District Construction Engineer for consideration of a change in elevation of the footing. A plan note will usually be provided indicating when raising the footing can begin. When bedrock is not encountered at footing elevation, an investigation of the soil should be made as deep as practical. Hand augers or probes are recommended for initial investigation.

Generally, when bedrock is found less than 1 foot (0.3 m) lower than plan elevation, the additional height of pier or abutment can be provided by additional footing concrete; however, reinforcement should be placed at plan elevation.

When bedrock is found 1 foot (0.3 m) or more below plan elevation, consideration should be given to lengthening the pier or abutment above the footing.

Relative costs should be investigated in either case and, if the cost difference is significant, should be reported to the District Construction Engineer for review.

Approval of Foundations

When the foundations for a bridge are spread footings, they are designed to be supported on soil or bedrock as indicated by the soil borings and drive rods. The Engineer must examine the soil or bedrock encountered at plan elevation for agreement with soil boring data and to assure that it will provide the intended bearing capacity. This bearing capacity will be listed in tons per square foot (tonnes per sq. meter) in the plan notes.

Bearing Capacities

Listed below are bearing capacities that various materials generally will provide, and may be used as a guide in evaluating materials encountered.

NORMAL BEARING CAPACITY	
MATERIAL	**TONS PER SQ. FT. (TONNES PER SQ. METER)**
Clay, Silt, or Clay and Silt	½ to 4 (5 to 39)
Sand or Gravel	1 to 4 (0 to 39)
Cemented Sand and Gravel	5 to 10 (0 to 98)
Soft Shale	3 to 5 (9 to 49)
Hard Shale	5 to 12 (9 to 117)
Solid Rock	5 to 30 (9 to 293)

Questionable Support

The District Construction Engineer should be consulted whenever there is doubt that the material encountered at plan elevation will provide the necessary bearing capacity. Whenever the material encountered is different and of lesser quality than indicated by the borings, an investigation similar to that described in the section titled “Elevation Changes” should be made, and the findings reported to the District Construction Engineer for review.

Cold Weather Excavation

Footings placed on pile foundations that were exposed to temperatures below freezing sometimes settle during the setting of the concrete and result in unsatisfactory footings. It is therefore imperative that the soil in such cases be free from frost and, if disturbed by freezing, compacted to proper density.

Protection

When excavation for footings is performed and freezing temperatures are expected during the time it is exposed, insulation such as an adequate thickness of straw is recommended for protection from frost.

Examination

When the excavated area has become frozen and the area is heated in an enclosure, the effect of the supplied heat on the frozen soil is slight, and a thorough examination for complete removal of frost is required. Satisfactory temperatures found in spot checks of soil over the entire area to as deep as frost may have penetrated is an indication of frost removal.

When frozen soil is thawed out, it requires re-compaction since frost heaving has lessened the density. If reinforcing steel has been placed in a footing area at the time the soil was frozen, it will be necessary for the Contractor to first remove the reinforcing prior to re-compacting the soil.

Backfill at Abutments (503.08)

The backfill material behind the abutments and beneath the approach slabs shall conform to Item 203 Granular Material Type B. The use of this material should facilitate compaction and help alleviate the settlement of the approach slab.

Measurement of Excavation Prior to Altering the Original Ground Line

When the plans do not require the original ground line to be altered by removal of the embankment, and when structural excavation is performed prior to building an embankment, elevations or measurements that establish the elevation of the original ground must be made. Measurements made and recorded from the Contractor's footing grade stakes can be used to establish the elevation of the original ground.

Measurement of Excavation Made After Altering the Original Ground Line

When the original ground will be altered by removal or construction of an embankment prior to excavation, use the plan line of the excavation or embankment items for top boundary of excavation.

Verification of Footing Elevation

The bottom elevation of the footing is to be as shown in the plans. This elevation is to be verified by subtracting the total verified height of the substructure unit below the beam seat, from the beam seat elevation.

Documentation Requirements - 503 Excavation for Structures

1. Verify existing ground elevations
2. Verify that contractor excavated to plan dimensions
3. Make sure that the volume of the existing structure is deducted from the pay quantity for unclassified excavation

Dispose of excavated material not needed or suitable according to 105.16 and 105.17. Note: In recent years this item has been bid as a lump sum. Numbers 1 & 2 above still apply.

504 Sheet Piling Left in Place

Materials (504.02)

Material for sheet piling must conform 711.03 which refers to ASTM A328. Sheet piling that conforms to ASTM A328 is acceptable. Used sheet piling may also be used if it meets the project requirements and is approved by the Engineer.

Driving (504.03)

Steel sheet piling is not driven based on any driving criteria, but is driven a specified tip elevation.

Steel sheet piling will normally be driven with a vibratory hammer suspended by a crane or an excavator mounted sheet driver. In difficult driving conditions diesel impact hammers can be used, but it is more likely that the top of the sheets will crush.

Sheet piling is always interlocked with the adjacent sheets. The manufacturer will fabricate a special shape if sharp corners are required in the wall.

Documentation Requirements - 504 Sheet Piling Left in Place

1. Document sheet piling section modulus
2. Measure area for payment

505 Pile Driving Equipment Mobilization

Basis of Payment (505.02)

Payment is not to be made when the equipment arrives on site, but once the first service pile is installed and accepted.

Documentation Requirements - 505 Pile Driving Equipment Mobilization

1. Document equipment arrival and add to diary for payment.

506 Static Load Test

Description (506.01)

Static load tests are performed on piles to determine the accuracy of dynamic load test results, and to determine if the capacity of the pile being tested has increased or decreased after it has set in the ground for some period of time. The intent of performing the static load test is to potentially reduce the driven length of pile by fine-tuning the pile capacity determination. However, there must be a substantial amount of piling at a structure to justify the expense of a static load test. Generally, 10,000 feet of piling (all of the same size and ultimate bearing value) is the amount required before specifying a static load test.

Static load tests are not performed very often, can be complex and must be performed properly for the results to be useful. Therefore, always contact the Office of Construction Administration or the Office of Structural Engineering for assistance before performing a static load test.

The duration of the static load test is generally 36 to 48 hours.

Determination of Need

The Office of Construction Administration or the Office of Structural Engineering must be consulted before non-performing the static load test. Also consult either of these two offices to determine if a subsequent static load test should be performed.

Static load tests are not performed on piles driven to refusal on bedrock.

General (506.02)

Pile Wall Thickness

Most static load tests are performed on cast-in-place piles (also called pipe piles or tube piles). Because the static load test will place a load on the test pile that is twice the Ultimate Bearing Value (UBV), the test pile may need a thicker wall than that required by 507.06, or the contractor will have to fill the pile with concrete and allow the concrete to cure for five days.

For test piles, if the wall thickness is less than the required wall thickness given by the equation below, then the contractor must fill the pile with concrete and allow the concrete to cure for five days before performing the static load test.

$$t = \frac{2\,R}{113000\,D}$$

where:

t = shell wall thickness (inches)

R = Ultimate Bearing Value, UBV (pounds)

D = diameter of pile (inches)

If the test pile wall thickness is equal to or greater than the wall thickness given by the above equation, the contractor can perform the static load test 72 hours (3 days) after he has finished driving the test piles and anchor piles. Generally, piles with a diameter of 16 inches or greater will meet the minimum wall thickness requirement for the test pile. Also, depending on the UBV, 12-inch and 14-inch piles may not be available with the minimum wall thickness for test piles. These piles will have to be filled with concrete before the static load test.

Driving Test Piles

The test pile can be (and usually is) a production pile. The test pile must be vertical.

The standard plan note for a static load test requires the contractor to drive four piles not including the anchor piles. The first two driven piles are test piles. Each one is driven to the required UBV, as determined by the dynamic load test. This means both of these piles are dynamic load tested (that is one dynamic load test item). **Do not overdrive these first two piles.** Perform the static load test on one of these two piles. If the first pile is not suitable to use for the static load test for some reason, the second pile is driven as a backup. The dynamic load test on the second pile also gives additional data that can be used to interpret the static load test results. The third and fourth piles are driven to reduced blow counts, 75 and 85 percent of the driving criteria. For example, if the driving criteria from the dynamic load testing is 40 blows per foot (bpf), then the third pile is driven to 30 bpf (0.75 × 40) and the fourth pile is driven to 34 bpf (0.85 × 40). The third and fourth piles are also dynamic load tested (one more dynamic load test item).

In some soil, piles will gain capacity with time. This is called “pile set-up” or sometimes “pile freeze.” The reduced capacity piles are driven to see if the pile will gain enough capacity with time to meet the Ultimate Bearing Value requirement. If there is some increase in capacity, but not enough to meet the UBV, then we can still estimate the appropriate driving criteria if we know the amount of pile set-up. However, to do this we need to know the capacity at the end of the initial pile driving, which we can determine from the dynamic load test. This is why we dynamic load test the reduced capacity piles.

Anchor Piles

Production piles can be used as anchor piles. Vertical piles are preferred for the anchor piles, but the contractor may use battered piles for the anchor piles, so long as the battered piles are symmetric around the test pile. The Contractor determines the number of piles to use as anchor piles and the required length of penetration. Anchor piles must be at least 7 feet (2.1 m) from the test pile, measured from center to center. If the anchor piles are also production piles, they may need to be re-driven to the required driving criteria after the static load test, depending on the test results.

Generally, the test pile should be driven before the anchor piles, but this is not required. If the anchor piles were driven first and there was a problem with the first test pile so that the backup test pile had to be tested, then the contractor would have to drive additional anchor piles around the backup test pile.

No other production piles are to be driven until after the results of the static load test have been interpreted.

Application of Load (506.03)

The contractor must wait at least 72 hours (3 days) after driving the test pile and anchor piles before applying the test load. If the contractor has filled the test pile with concrete because it does not meet the minimum wall thickness requirement, then the contractor must wait 5 days before applying the test load. The plan notes may require a longer waiting period.

The test pile should be cut off as near to the ground as practical and the jack placed along the axis of the pile with full bearing on the required load cell and bearing plate.

Instruments

The Contractor must furnish a set of gages or devices capable of accurately determining settlement of the pile to 0.001 inch (0.03 mm) and a calibrated load cell for determining the load applied.

The gages used to measure the settlement of the pile should be placed opposite each other and should be placed at the sides of the pile. They should be supported from posts or fixed objects. The post or fixed objects are to be independent of the test load set up and at least 4 feet (1.25 m) away from the test pile. However, the gages should be placed as close to the test pile as possible. Dial gages generally are furnished and they should have sufficient travel to measure up to 2 inches (50 mm). A backup system is required in case of problems with the gages. The backup system usually consists of a ruler applied to the test pile, with a mirror and string line for measuring settlement.

The primary means of determining the applied load is a calibrated load cell. The pressure gage on the hydraulic jack can be used as a backup load measuring system. The pressure gage alone is not accurate enough for the static load test. Also, if the jack should bind up, the hydraulic pressure would increase while the load transmitted to the pile would not necessarily increase.

Loading

The load is to be applied in increments consisting of a first increment of 1/5 the UBV of the pile (R) and 1/10 R for each increment thereafter. Record the dial gage readings for each gage immediately after each load increment is applied; then every 20 minutes. Calculate the average pile settlement from the gage readings. Apply the next load increment after one hour, so long as the most recent settlement reading indicates a settlement less than 0.01 inch (0.3 mm) within the past 20 minutes. If the settlement is 0.01 inch (0.3 mm) or more within a 20 minute period, continue to take readings every 20 minutes until the settlement is less than 0.01 inch (0.3 mm) per 20 minutes, and then apply the next load increment.

Maintain the test load during each load increment. Due to settlement of the pile, the load and pressure in the jack may decrease with time. The contractor should run the hydraulic pump as necessary to maintain the load on the pile.

Continue to increase the test load until the load is twice the UBV or the pile reaches plunging failure. Plunging failure is defined as when the settlement exceeds 0.03 inch per ton (0.8 mm / 9000 N) for the increment applied. Whenever plunging failure is reached before the total load exceeds 1.5 times the UBV, attempt to apply an additional increment to determine if the pile experiences plunging failure again. If plunging failure is not repeated, apply additional load increments.

If the last load increment has been applied and the pile has not experienced plunging failure, maintain the load for one hour after all measureable settlement has stopped. Continue to make settlement readings every 20 minutes.

Unloading

After loading is complete, unload the pile in 25 percent decrements in 5 minute intervals. Record the settlement readings at the end of every 5 minute interval, just before removing the next decrement of load. After the entire test load has been removed from the test pile, wait 3 hours and then record the final net settlement reading.

If it is necessary to remove and reapply the load (such as a problem with the jack or load cell), reapply the test load using the same procedure used to apply the initial loads, except apply the next load increment 15 minutes after measurable settlement has stopped (instead of one hour).

Load Test Results

The test load Ultimate Bearing Value (Q) is the maximum capacity of the test pile. To determine Q, it is necessary to plot the settlement of the top of the pile versus the load on the pile. Then, draw a straight line through the zero point and the settlement reading for a test load of 0.2R. This line represents the elastic compression of the pile (the distance that the pile compresses under the test load). Draw another line parallel to the first but offset by the distance given in Equation 506.1. The second line is called the Q criterion line.

$$0.15 \text{ inch} + 0.008\text{ D} \qquad (3.8 \text{ mm} + 0.008\text{D})$$

Equation 506.1 – Settlement Offset

where:

D = diameter of pile (inches or millimeters)

The point where the load-settlement curve from the static load test intersects the criterion line is the test load Ultimate Bearing Value (Q). An example from an actual static load test is shown in Figure 506.A.

In some cases the slope of the unloading portion of the curve can be used to determine the elastic compression of the pile.

If the load-settlement curve does not intersect the Q criterion line, then Q is equal to the greatest test load applied (2R).

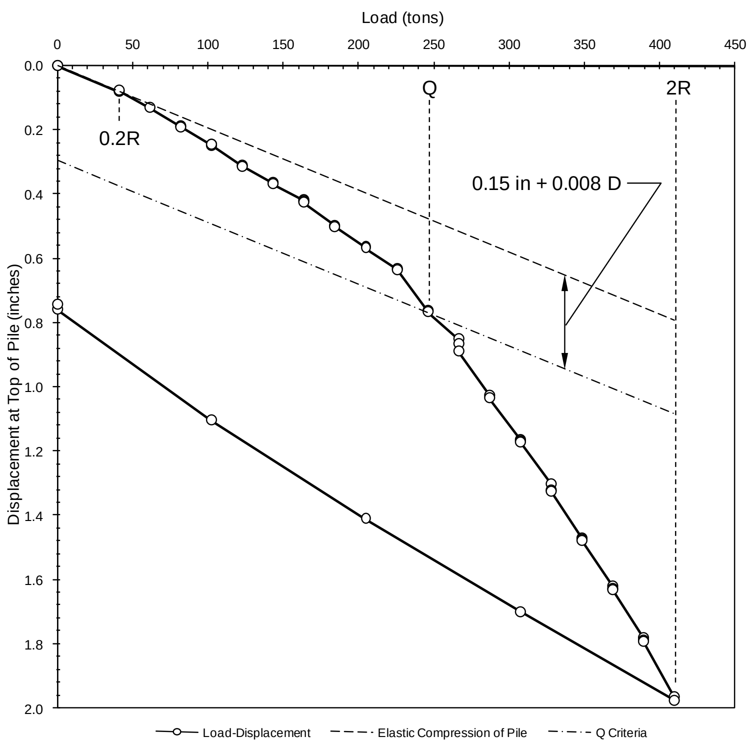


Figure 506.A - Load-Settlement Curve

Restrikes

The standard plan note for a static load test requires the contractor to restrike the test pile and the two reduced capacity piles. The note may also require restriking the backup test pile. The restrikes are performed at least 7 days after the piles were driven. Each restrike test consists of dynamically testing two piles and determining the capacity of the piles. Pile set-up is the increase in capacity for a pile from the time it was initially driven to the time it was restruck. Ideally, the capacity from the restrike test on the test pile should be close to the results of the static load test.

Application of Results

Either the Office of Construction Administration or the Office of Structural Engineering will review the pile driving logs, the static load test results, the dynamic load test results, and the restrike test results, and then recommend the driving criteria for the production piles. Wait for the recommended driving criteria before letting the contractor drive the rest of the production piles.

The static load test results will apply to the same type and size of piling driven with the same type of hammer to approximately the same depth with similar driving characteristics as the test pile.

The pile hammer used for driving the test pile shall be used for driving all piles represented by the static load test. If the Contractor subsequently finds it necessary to use a different size and type of hammer, the Office of Structural Engineering or the Office of Construction Administration will determine if an additional static load test is required; any such additional static load test shall be completed at no additional cost to the Department.

Documentation Requirements - 506 Static Load Test

Documentation for the static load test consists of the driving logs of the test piles and reduced capacity piles, the dynamic load test report, the restrike test report, and the load-settlement readings from the static load test. Identify the piles using the pile numbering system on the plans if the piles tested are production piles.

507 Bearing Piles

Description (507.01)

A pile is a structural column of steel, concrete, timber, etc. that is installed in the ground to support a structure above it. Piles are required when the soil near the surface is not strong enough to support the structure or when the soil may be scoured away. Piles transfer the loads from the structure to deep layers of soil or rock that are capable of supporting the load.

The term "bearing pile" refers to a pile that is used to support a structure. A bearing pile is also called a service pile or a production pile.

The plans include a foundation layout which identifies each pile with a unique number and indicates the pile type, size, and direction of batter (if any). Use the unique number to identify the pile in the construction documentation.

General (507.02)

There are many types of piles, however the Department generally uses either cast-in-place reinforced concrete piles or steel H-piles that are driven into the soil using an impact hammer. The cast-in-place piles are constructed by driving a hollow steel tube, capped at the bottom with a steel plate, into the ground and then filling the tube with concrete.

The plans give the estimated length for each pile. However, the Contractor decides whether to drive a single pile segment for the entire estimated length, or to drive shorter segments and splice them together as he drives the pile into the ground.

Materials (507.03)

The steel for H-piles must conform to ASTM 572, Grade 50 (F_y=50 ksi). This is the industry standard for H-piles. The steel pipe for cast-in-place piles is not specified, however steel conforming to ASTM 252 Grade 2 (F_y=35 ksi) is commonly provided.

Driving Piles (507.04)

Piles are typically either driven to a specified capacity (Ultimate Bearing Value) or to refusal on bedrock. The Ultimate Bearing Value, or UBV, is equivalent to the ultimate pile capacity (in Allowable Stress Design) and the nominal pile resistance (in LRFD). The UBV is the required capacity of the pile. Sometimes, the plans list either the design bearing, the design load, or the factored load in addition to, or in place of, the UBV. Do not mistake the design load for the capacity to which the piles are to be driven.

Typically, H-piles are used when piles are driven to refusal on bedrock and cast-in-place piles are used when piles are driven to a specified capacity. However, H-piles are sometimes used when driving to a specified capacity.

In some cases, such as bridges over water where scour may be a concern, the plans may indicate a minimum pile tip elevation in addition to the UBV. If both a UBV and a minimum pile tip elevation are specified for the piles, both criteria must be met. If the pile is driven to the required tip elevation before reaching the UBV, continue driving until the pile has the required capacity. If the pile is driven to the UBV before reaching the minimum pile tip elevation, continue driving until the pile tip is at the required elevation.

If during the driving operation the pile begins to crush, the driving operation must immediately cease and the crushed section of the pile removed. This is due to the fact that the crushed section will behave similar to a sponge and the energy from the pile hammer will no longer be properly transmitted to the tip of the pile. This results in higher blow counts with minimal penetration of the pile into the ground.

Piles Driving Longer or Shorter than Estimated

In the event a pile reaches 150 percent or more of the estimated depth without achieving capacity, or the event of a pile reaching capacity in less than 80 percent of the estimated depth, about two more piles should be driven in scattered locations to verify this trend. If these piles also exceed the above limits, contact the Office of Construction Administration or the Office of Structural Engineering for advice. You may also contact the District Geotechnical Engineer for advice. Complete information regarding equipment, the driving logs, along with any unusual driving experiences should be provided for review. During this review, the Contractor may be permitted to continue his driving operation. However, the Contractor should not be required to attempt to drive the piles to 80 percent of the estimated penetration. He should also not cut the piling off until after the review.

Occasionally when bearing is achieved before the pile has been driven 80 percent of the estimated penetration, project personnel require the Contractor to continue driving the pile to achieve a penetration of 80 percent of the estimated depth. This is **not** recommended. The value of 80 percent of the estimated penetration is only a guide to aid project personnel. Overdriving the pile may result in damage to the pile or the pile hammer. Do not require the Contractor to overdrive the pile to obtain the 80 percent length without first consulting with the Office of Construction Administration, the Office of Structural Engineering, or the District Geotechnical Engineer.

Pile Driving Equipment

A driving cap that centers the pile under the hammer and uniformly transmits the blow must be used.

Driving leads guide the travel of the hammer and cap during driving and must be capable of keeping the hammer in line with the axis of the pile. The leads should be equipped with a yoke at the base to center the pile and project beyond for anchorage.

Pile Hammers

Pile hammers are powered by compressed air, hydraulic oil pressure, or igniting diesel fuel. These hammers are classified as either single-acting hammers or double-acting hammers.

In addition to power driven hammers, a drop hammer may be used having a ram weight of at least 3,000 pounds (1,360.8 kg) and a distance of fall not exceeding 7 feet (2.1 m).

Single-acting hammers are those that have their rams lifted by either compressed air, hydraulic oil pressure, or igniting diesel fuel. When the ram reaches the top of its stroke, it falls back to its original position by gravity. Hammers that are powered by igniting diesel fuel and open on the top are considered open-end diesel hammers. These hammers allow the ram to become exposed during driving.

Double-acting hammers are those that not only have the ram lifted by compressed air, hydraulic oil pressure, or igniting diesel fuel, but in addition to gravity, compressed air, or hydraulic oil pressure also impart a downward force on the ram.

Double-acting hammers that are diesel powered and are closed at the top, are considered closed-end diesel hammers. The space between the top of the ram and the top of the hammer casing is called the bounce chamber. As the ram rises in the hammer, the volume of the bounce chamber decreases and increases the pressure of the air inside the bounce chamber. This increased air pressure imparts a downward force on the ram.

Hammer Size

The Contractor chooses the size of the hammer to use.

The required blow count, determined by dynamic load testing as required by Item 523, must not be less than 30 blows per foot (100 blows per meter). Increasing the size of the hammer results in lower blow counts. As a result, it is possible for the Contractor to use a hammer that will be too large and the blow count will be less than 30 blows per foot (100 blows per meter). Using oversized hammers may result in pile damage and increase the risk of alignment difficulties.

The hammer must also be large enough to drive the pile to the required UBV and successfully perform dynamic load testing. The use of a hammer that is too small will result in a hammer that will not be large enough to impact the piles with enough energy to successfully perform a dynamic load test. Dynamic load testing cannot determine the total capacity of the pile being driven if the energy applied to the pile by the pile hammer is too low. An example of this situation is the case where a cast-in-place pile has been driven to the top of a hard layer of sand and gravel that may be capable of supporting a load of over 300 tons. If the maximum load that the pile hammer is able to place on the pile is only 120 tons, then the dynamic pile test will only register 120 tons and not 300 tons. If the required UBV is 120 tons or less, then the hammer is large enough. However, if the required UBV is greater than 120 tons, then the pile hammer is not large enough to successfully perform a dynamic load test. (Note: This is a simple example to demonstrate the concept. The actual relationship between hammer energy and pile capacity is much more complex.)

Performance of the Pile Hammer

The driving criteria or blow count that a pile must be driven to depends on the performance of the pile hammer. If the performance of the hammer changes, then the appropriate driving criteria will also change. Therefore, the performance of the hammer should be constantly observed. The performance of the hammer should be compared with the results of the dynamic load testing to determine the required blow count. The Contractor is required to provide the inspector with a means to monitor this operation.

Open-end diesel hammers are the most common type of pile hammer for highway contractors in Ohio. A relatively easy way to monitor the performance of an open-end diesel hammer is to watch the stroke of the ram. During the dynamic load testing, watch how far the rings on the ram come out of the hammer. Then during pile driving, make sure that the rings are coming out of the hammer about the same distance. Because the ram of an open-end diesel hammer falls by gravity, the stroke of an open-end diesel hammer can be estimated from the blow rate (blows per minute) using the following equation.

$$h = 4.01\left(\frac{60}{\text{bpm}}\right)^2 - 0.3 \text{ ft}$$

where:

h = stroke of pile hammer (feet)

bpm = blows per minute

(from Design and Construction of Driven Pile Foundations, FHWA NHI-05-043, page 21-28)

For convenience, the following table gives the results of the above equation for a typical range of values. Additionally, the relationship between stroke and blows per minute for a particular pile hammer can be determined from the dynamic load test.

Blows per Minute	Stroke (ft)	Blows per Minute	Stroke (ft)
37	10.2	42	7.9
38	9.7	44	7.2
39	9.2	46	6.5
40	8.7	48	6.0
41	8.3	50	5.5

Trying to count the blows per minute while also keeping track of the blows per foot is difficult. An easier way to determine the blows per minute while counting the blows per foot during pile driving is to measure the number of seconds required to drive one foot of piling. Then use the following equation to calculate the blows per minute.

$$\text{bpm} = \frac{\text{blows per foot}}{\text{time (seconds)per foot}} \times 60$$

Closed-end diesel hammers must be equipped with a gage placed on the ground and connected to the bounce chamber by a hose. The gage shows the pressure developed for each stroke of the ram. A graph, included with the gage, can be used to convert the pressure to the energy developed by the hammer for each blow. The hose connecting the gage to the bounce chamber comes in different lengths that can affect the reading on the gauge. Therefore, it is important to check that the graph corresponds with the length of hose used.

The Contractor can control the hammer's operating energy by the use of a throttle or fuel setting. The hammer must be operated during pile driving at the same setting used when the dynamic load test was performed.

Alignment in Leads

If the hammer is not properly aligned with the pile, the energy from the hammer will not be properly transmitted to the pile. For the full effect of the hammer energy to be transmitted to penetration of the pile, the axis of the hammer must be in line with the axis of the pile.

Determination of Required Blow Count (507.05)

The driving criteria or required blow count is determined from the dynamic load test results. See Section 523. The first two piles are driven with the dynamic load test equipment attached. The testing company should provide a preliminary recommendation for the driving criteria immediately after driving these two piles. The driving criteria will be a minimum blows per foot for the pile driving. For open-end diesel hammers, the driving criteria will also include a minimum hammer stroke.

Drive the rest of the piles to the recommended driving criteria. It is generally not necessary to ensure the pile has a blow count greater than the required blow count for three or more consecutive feet. For example, if the required blow count is 43 blows per foot, it is not generally necessary to drive the pile until the blow count is greater than 43 for three consecutive feet. See the following table for examples. The exceptions to this are if there is a minimum pile tip elevation, the depth of penetration is less than 80 percent of the estimate, or the pile has to be struck with 150 blows to inspect a splice.

Pile Driving Examples
Required Blow Count is 43 blows/ft

Penetration	Blows/Ft		Penetration	Blows/Ft
37-38	28		41-42	21
38-39	33		42-43	40
39-40	42		43-44	40
40-41	45	Should stop	44-45	43
41-42	43	driving here.	45-46	44
42-43	41		46-47	48
43-44	43		47-48	41
44-45	44		48-49	46
45-46	46		49-50	50

Cast-In-Place Piles (507.06)

A cast-in-place reinforced concrete pile consists of a steel shell that is filled with concrete. To minimize the possibility of the piles being damaged during the pile driving operation, it is important to maintain the minimum wall thickness specified in 507.06 of the Construction and Material Specifications.

Piles may be tapered or of uniform section. The tapered piles generally used are cylinder shells with vertical fluting or corrugations commonly referred to as monotube piles. Monotube piles can be either tapered or of a uniform diameter. All other piles of uniform section are called pipe piles. Tapered monotube point sections come equipped with a bullet-nosed tip. Pipe piles usually have a plate welded on the point that must not extend more than 1/4 inch (6 mm) beyond the surface of the pile at any point. Since cast-in-place metal shells have no specific material requirements, the Engineer should only assure that the metal is of domestic origin. A producing mill certification is often the simplest way to verify this.

The piles must be inspected and necessary measurements made. Due to the possibility of lateral earth pressure causing adjacent piles to collapse prior to filling with concrete, this inspection and measurement should be made after all the adjacent piles are driven. After the piles are driven, cover the tops until they are filled with concrete. Before filing with concrete, remove water and debris. Concrete required for filling the piles is Class C containing a superplasticizer admixture. After the superplasticizer has been added, the slump should range from 6 to 8 inches (150 mm to 200 mm). The concrete should be deposited in a steady small stream to ensure complete filling and consolidation. If there is reinforcing steel in piles, the concrete could become segregated from coming into contact with the reinforcing steel while it is dropping in place. Use drop chutes to eliminate this problem. No driving shall be performed within 15 feet (4.6 m) of filled piles until the concrete has cured at least seven days.

H-piles (507.07)

When H-piles are specified, the plans usually require that they be driven to refusal on bedrock. The standard plan note gives a driving criteria of 20 blows per inch.

However, the note may allow the Contractor to perform a dynamic load test, at his own expense, to determine the driving criteria instead of using the 20 blows per inch criteria.

When the bedrock is hard and unweathered, refusal is obtained after the piles contact bedrock and have been struck at least 20 more times, with a penetration less than or equal to 1 inch (25 mm), to ensure that firm contact has been established. Use care to avoid damaging the piles.

When the bedrock is soft or weathered, driving refusal is obtained at a resistance of 20 blows per 1 inch (25 mm).

Many times pile points or pile shoes are specified to be welded to the tip of the piles. These points or shoes are made of cast steel as opposed to plates welded together and are used to protect the end of the pile from damage during the driving operation.

Mill test reports are required for steel H-piles and should be reviewed by the Engineer for conformance to 711.03 of the Construction and Material Specifications. If pile points or shoes are specified, mill tests should be reviewed for conformance to 711.01 or 711.07

Timber Piles (507.08)

Although still included in the specifications, timber piles are no longer used by the Department.

Splices (507.09)

Splicing may be necessary to provide the required length to achieve bearing. Numerous splices using small lengths in the same pile should be avoided, particularly in an area exposed to view. Splices should be made at least three feet above the ground in order that the weld may be observed while it is subjected to the impacts from the pile hammer. If bearing is obtained prior to observing the weld during three feet of driving, the pile should still be driven a minimum of 150 blows after the splice is made in order to observe the weld. When splicing structural shapes (H-piles), welding must be performed in accordance with 513.21 of the Construction and Material Specifications, which, among other things, requires the use of a prequalified welder. See Figure 507.A - Joint Preparation for Groove-Welded H Pile, for the method of making the required welded butt splice. For H-piles, the plans may include a note that allows the use of a manufactured splicer in place of the full penetration butt weld.

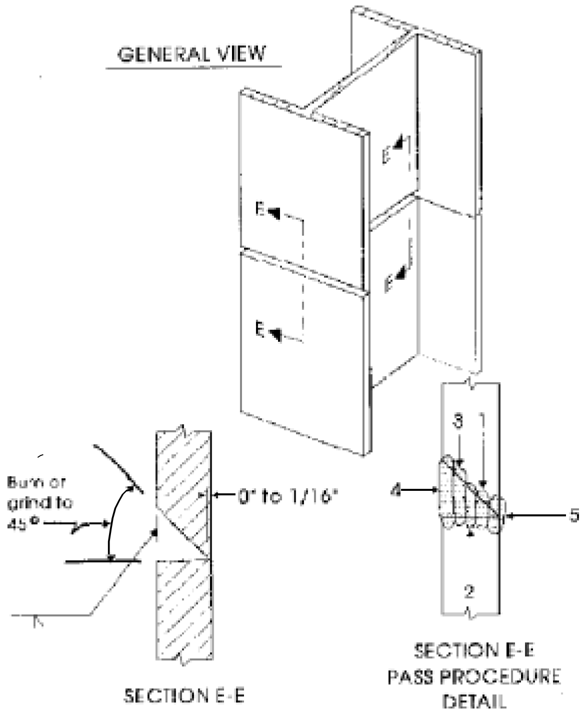


Figure 507.A - Joint Preparation for Groove-Welded H-Pile

NOTES: In case a different number of passes is required than shown in Figure 507.A, a similar sequence must be followed with the finishing pass on the reverse side. Back gouge root pass prior to making the finishing pass.

Defective Piles (507.10)

A pile is considered defective if damaged to the extent that the strength of its section is reduced over 20 percent. This can occur as a collapse of the shell where less than 80 percent of the cross-sectional area remains open or where the shell is ruptured to the extent that the pile will have over 20 percent less strength.

A pile is also considered to be defective if the location of the pile at the ground surface differs from the specified location by more than 1 foot (0.3 m) for piles that are entirely underground, or by more than 3 inches (75 mm) for piles that project above the ground (such as in a capped-pile pier). No attempt should be made to draw these piles to their specified location.

Replacement Piles

If it is practical to withdraw a pile, the replacement can be driven in the specified location. If the defective pile is not withdrawn, it must be filled completely with concrete. If it is under a footing, it must be cut off slightly above the bottom of the footing where it will provide some support, but will not be paid for. A replacement pile will need to be driven beside it. The replacement should be located on the same line parallel to the side of the footing and battered slightly if necessary to avoid contacting the defective pile or adjacent piles.

When a replacement pile is driven alongside, rearrangement of reinforcing steel will be necessary. If sufficient space is not available to avoid crowding of bars, it may be necessary to cut the bars at the pile and provide bars on either side lengthened for bond. In lieu of this, the pile may be cut off below the reinforcement and the footing deepened approximately 1 foot (0.3 m) around the pile and below cutoff.

Only the replacement pile will be included for payment. Any additional material or work required to make it a satisfactory pile will be at the Contractor's expense.

Prebored Holes (507.11)

Abutment piling must be driven through embankments to bearing in the existing soil. Sometimes pre-bored holes are provided in the plans to ensure this. The prebored holes do not need to remain open before the pile is driven.

Method of Measurement (507.12)

The two main pay items associated with the pile driving operation are piles furnished and piles driven.

The quantity of piles accepted for payment as piles furnished will be based on the total order length specified in the plans and required by the Engineer. The order length is the pile length that the designer estimates as necessary to achieve bearing. The Contractor may elect to use piles longer or shorter than the order length as he determines necessary to meet his needs. However, the Contractor is responsible for the cost of the splice if he elects to use piles shorter than the order length which then results in the need to splice the piles to achieve the required order length.

During the driving, the Engineer must monitor the length of piling necessary to obtain bearing. If the order length given in the plans is not sufficient to achieve bearing, the Engineer should inform the Contractor of the necessary additional order length. The Engineer should inform the Contractor as soon as possible to allow him to order the piles in a timely fashion and avoid additional costs due to down time expenses. It will be necessary to negotiate with the Contractor and reimburse him for any additional splices necessary to provide additional length beyond the order length.

The pay quantity for piles driven shall be the sum of non-defective pile lengths measured along each pile's axis from the bottom to the elevation of cutoff. This quantity will be paid in addition to the quantity of piles furnished, and may not necessarily correspond with the quantity of piles furnished.

Documentation Requirements - 507 Bearing Piles

1. Use piling forms CA-S-3 and CA-S-8
2. State difference between piling delivered and piling driven. Excess piling furnished can be kept by project owner (ODOT or Local Public Agency).
3. Measurements should be made to the nearest 0.1 feet (0.05 m)
4. Make layout sheet showing pile location, pile number, test boring, structure number; north arrow, project number, whether pile is battered or straight, required bearing skew if applicable, offset of pile, hammer that is being used
5. Height of drop hammer before release (if used)

The following data should be included in the project records:

1. A driving log, CA-S-3 (Form BR-2-75) showing the blows per foot, stroke of the ram, or operating pressure for each foot of penetration
2. A record of measurements that establish the pay length of each pile. This may be determined by adding the penetration length to the amount protruding out of the ground after the pile has been cut off to the proper elevation, or the total pile length driven minus cutoff, whatever is sufficiently accurate and most practical. For cast-in-place piles a statement that the inside measurement checked the pay length determined as above is to be made.
3. A layout drawing that shows the location of all piles in a structure and assigns a numbering system to the piles that matches the pile number shown in the pile log, CA-S-3 (Form BR-2-75)
4. CA-S-3 (Form BR-2-75) and a copy of the pile layout should be submitted to the Office of Structural Engineering.

508 Falsework and Forms

Location

Prior to the erection of the forms for each substructure unit, the inspector should satisfy himself that the Contractor is placing the forms in the correct location. This should be accomplished by available methods that do not require the use of instruments.

Types and Use

Footing concrete may be placed against rock, hard shale, or sheeting. All other concrete must be placed in substantial forms that are designed and constructed so that finished concrete will conform to plan lines and dimensions and will have a satisfactory surface. Forms for exposed surfaces are to be made of acceptable materials that will produce a smooth surface with a minimum number of joints. Acceptable materials include sheet plywood, fabricated metal forms, fabricated metal frames with plywood inserts, or dressed lumber of uniform thickness with a form liner of plywood, hardboard, or sheet metal.

Form lumber that has had many uses, and bent metal forms that will not produce an acceptable surface on concrete when stripped, regardless of finish specified, are to be rejected. Exercise care to obtain as flush a fit as possible at panel joints. When rustication grooves are required, panel joints should, if possible, be made to coincide.

The underside of a deck that cantilevers out from the fascia beam is considered an exposed surface and requires forms with smooth surfaces. The underside of pier caps is considered an exposed surface and forms with smooth surfaces should be used and cut to fit neatly around columns or piles.

The inside of all forms are to be coated with a bond-breaker. If the forms are not so coated and oiling is necessary, it should be done before placing the reinforcing steel or preferably before assembly of the forms.

Design

Forms must be adequately braced and provided with walers and form ties that are properly designed to maintain the proper dimension and alignment for the proposed height and rate of concrete placement. Some suppliers of form ties specify the height of concrete in feet (meters) per hour that can be placed for their design. All form ties and anchor bolts used for form support must be designed for removal of 2 inches (50 mm) in from the exposed surfaces of concrete.

Incidental Work

Moldings for the 3/4-inch (19 mm) beveled edges and rustification grooves must be surfaced on all sides and be of uniform section. The bevel strip should be nailed at sufficient intervals to completely fill a corner or contact the form for the full length.

Rustification strips are fastened to the forms in such a manner that the molding will remain in contact with the concrete when the forms are stripped, and will not be removed until the concrete has set sufficiently to avoid damage.

Weep holes through abutments and retaining walls are formed in such a manner as to obtain a smooth circular opening. To form the hole, metal such as downspouts or sonotube may be used and later removed, or noncorrodible rigid plastic pipe may be used and left in place, provided the gradient and inside diameter are in accordance with 508.03.

All scrap wood, dirt, and other foreign material, including ponded water, must be removed from within the forms prior to placing concrete. If the forms are too deep or narrow to permit easy removal of foreign material from the top, a temporary opening should be left at the bottom for removal of foreign material. An opening must also be provided when necessary for inspection. Temporary openings must be made mortar tight after the forms have been cleaned and inspected.

An inspection should be made of the forms for proper fit and holes where leakage of cement paste may occur. Openings must be corrected in such a manner as to close the hole and provide a smooth form surface. Filler strips, plugs, and tin commonly are used to plug such openings. Forms should be watched closely during the placing of the concrete and any leaks must be corrected immediately.

Verification of Dimensions

Before any concrete is placed, form dimensions should be measured for compliance with the plan requirements and approved change orders. Measurements that will result in concrete equal to or greater than plan dimensions are considered verified plan dimensions. The measurements must be checked for compliance with the plan dimensions and then recorded and filed in the project records. A statement that the dimensions have been checked and are in compliance with plan requirements is not acceptable verification. The recording may consist of any of the three following methods:

1. A tabulation of all the verified plan dimensions for simple shapes
2. A sketch on an appropriate form showing all of the verified plan dimensions
3. The plan sheet for the structure unit with the verified dimensions checked thereon

Whatever method is used, the Inspector should date and sign the sheet. If checks are made on different days, dates should indicate the day each check was made. If different inspectors check parts of the measurements, each should initial those checks that he has made.

If measurements are not in compliance, make correction and recheck the dimensions before the concrete may be placed.

Description of Falsework (508.02)

Falsework is the system of temporary support of formwork for concrete members. The falsework is to remain in place until the concrete members have attained required strength and are self-supporting. This includes the system of supporting formwork for deck slabs and pier caps.

Falsework Plans

For cast-in-place concrete slab bridges, the Contractor must submit a falsework plan per 501.05.B.3. No superstructure concrete can be placed until the plan is received and the falsework conforms to the submitted plans. The Contractor may substitute elements of equal or greater strength if it does not involve a change in depth that effects elevations. Any other deviations from the accepted plan that the Contractor desires or become necessary due to unforeseen conditions must be covered by submission of a revised plan.

District Review of Falsework Plans

Although ODOT of acceptance of falsework plans in not required, a review should be made at the project to ascertain that the existing conditions shown in the plan are representative of those found in the field.

Falsework Camber

The maximum deflection that is permitted in the falsework of a slab bridge is specified in 508.02. Camber equal to this deflection must be built into the falsework to compensate for falsework deflection. In addition, camber equal to 1/800th of the span must be built into the falsework to compensate for deflection of the slab after falsework is released. Also camber to conform to the vertical curvature of the profile grade must be provided.

If unusual requirements for span of an existing road or channel or restrictions due to vertical clearance exist, contact the Office of Structural Engineering to evaluate acceptable site specific camber requirements.

Falsework Materials

Falsework members must be of the section and length shown on the submitted plans. Members having a greater section modulus may be used; but, if this involved a change in depth and affects elevations, details of modifications should be included on a resubmission of the effected plan.

Steel members such as stringers must be in good condition. They must not show loss of section through rusting, excessive weldments, or holes that would affect their strength.

Timber shall be sound and of the required size. Used timber that shows deterioration and stress cracks may not perform its function and must not be used.

Piling and Posts

Piling must be driven to the bearing called for on the submitted plans. In order to determine the required blow count, it will be necessary for the Contractor to perform dynamic load testing.

Consolidation of Wood

Allowance for consolidation of wood wedges and blocking must be provided. Using rough-cut timber, an allowance of 1/16 inch (2 mm) for each contact surface generally will be necessary.

Independent Support

Where phased construction or adjacent concrete decks are separated by an open joint or closure pour, forms for the cantilevered edges of each slab must be supported independently from the adjacent structure. This is necessary to avoid movement of the forms due to differential deflections during placing of the concrete.

The finishing machine must also be supported by the structure on which the concrete is being placed and independent of any adjacent structure or support. If it is not , the finishing machine will not move with the deck as the concrete is placed and can result in areas where the superstructure concrete is either too thick or too thin.

Closure Pour

Closure pours are normally specified during phased construction when the cross bracing or diaphragms between the phases are not in place prior to the placement of the superstructure concrete. A closure pour is not to eliminate traffic vibration, but to allow differential deflection to take place between the phases when the superstructure concrete is placed. In order to properly place the superstructure concrete, the closure pour should not be waived unless the deadload deflection that occurs when the superstructure concrete is placed is less than ¼ inch.

Superimposed Concrete

Prior to placing sidewalks, safety curbs, or other superimposed concrete on the deck of a slab bridge, the falsework must be removed or released, and allowed to deflect.

Removal of Falsework

Falsework may be removed when the conditions tabulated in the table of section 511.17-1 of the Construction And Material Specifications have been met, unless QC/QA is being used. If QC/QA concrete is being used follow SS898. Any piling not removed must be cut off at least to the slope line or rip rap line of the bed of stream.

Documentation Requirements - 508 Falsework and Forms

1. Received falsework plan submitted per 501.05.B.3 for slab deck bridges
2. Falsework constructed to approved drawings
3. Document bearing obtained and number of falsework piling
4. Number and size of bracing on falsework
5. Protection during cold weather
6. Forms oiled prior to steel placement

509 Reinforcing Steel

Storage

All reinforcing steel received on the project must be stored off the ground and kept free from dirt, oil, and grease. Many times the Contractor will store the reinforcing steel on wood blocks or similar devices. If this is the method chosen by the Contractor to store the reinforcing steel off the ground, it is important that he use enough blocks to prevent the reinforcing steel from sagging and coming into contact with the ground. The reinforcing steel must not be stored in a place where it will be damaged or bent by equipment or be located in the path of drainage. If epoxy coated reinforcing steel is to be exposed to sunlight for more than 2 months, it needs be covered to protect the epoxy from UV breakdown. This requirement can be found in ASTM A775 which is incorporated by reference in section 709.00 of the C&MS.

Cleaning

The reinforcing steel must be cleaned of all dirt, oil, and grease. Oil or grease on the steel will seriously affect bond and must be removed with a solvent. Many times dirt cannot be removed with water alone but must be loosened with the use of a rag or brush before rinsing it off the reinforcing steel. If steel requires cleaning, and this condition exists before placing, it should be cleaned outside the forms where it will not cause an accumulation in the forms that will have to be removed before placing concrete. Once reinforcing steel is placed in the forms, it is difficult to see the dirt, oil, or grease on the bottom side of the reinforcing steel.

Placing (509.04)

Approval from the Office of Material Management must be received before any reinforcing steel is encased in concrete. Conformance of the bars to plan length must be checked. This can be done during placing by comparison of fit in measured forms. All steel required in any structure unit must be included in that unit. Advance separation of the steel by structure units from prepared lists can preclude omissions. Make an accurate check of the total number of bars of each bar mark placed and spot-check spacing. An example is the bars that make up the mats in a deck. The total number of bars is more important than extreme accuracy in the space between adjacent bars.

Clearances

Reinforcing steel must be located at the specified distance from the surface in order for reinforced concrete members to have the proper clearance.

Reinforcement shall be placed in the position shown on the plans and kept in that position while the concrete is being placed. To attempt to position a reinforcing bar cage during or after depositing of the concrete is not permitted due to the fact that the consolidation of the concrete around the perimeter of the reinforcing steel will be compromised.

Bolsters or chairs should be used, or the cage should be assembled and wired so that the proper clearances are obtained before encasement. The bolsters or chairs used to support reinforcing steel in slabs, beams, or girders must be spaced not more than 4 feet (1.2 m) apart both transversely and longitudinally. This spacing is a maximum. The Contractor needs to install enough supports to keep the reinforcing steel from experiencing substantial deflections induced from construction loads.

When placing reinforcing dowels extending out of a footing, they must be located accurately so that they will lap properly with the reinforcement in adjoining concrete. This applies particularly to dowels for pier columns where the location of vertical column bars is specified.

Prior to placing concrete, it is important to check the clearance or cover over the surface of the reinforcing steel. The clearance between the reinforcing steel and the surface of the concrete shall not be less than:

1. 2 1/4 to 2 1/2 inches (57 to 64 mm) between the top mat of the reinforcing steel and the deck surface
2. 1 1/2 inch (38 mm) between the bottom steel and the bottom of a cast-in place deck. The bottom steel must be spaced from the forms, never from the beams. The bolsters have a tendency to indent the forms and cause less than the 1 1/2 inch (38 mm) clearance. A tolerance of 1/8 inch (3 mm) plus or minus in bottom steel clearance is permitted.
3. 3 inches (75 mm) at the face of footings placed against rock or earth.
4. 2 ½ inches (65 mm) to the top of sidewalks.
5. 2 inches (50 mm) at all other surfaces.

A piece of wood approximately 2 inches (51 mm) long with accurate side dimensions of 1 3/8 inch (35 mm) and 1 5/8 inch (41 mm) is recommended for use in checking clearances from the forms for the bottom reinforcing steel.

Transverse reinforcing bars fabricated slightly longer than plan can result in less than the plan clearance to the fascia form. Where the transverse line of steel is made up of more than one bar, any overrun can be taken up in the lapped splices. For narrower decks where the line is a single bar, removal of any extra length that will not provide a 1-inch (25 mm) minimum clearance is required.

Tying Reinforcing Steel

Reinforcing steel must be tied together sufficiently so that each bar will retain its proper position after encasement. When workers will be on the steel, additional tying is necessary to meet this requirement. Bars in the superstructure must be tied at all intersections except where spacing is less than 1 foot (0.3 m) in each direction. In that case alternate intersections shall be tied. This is an area where additional inspection may be required since many times the Contractor fails to adequately tie these bars. When the Contractor utilizes a tie wire gun to tie bridge deck reinforcing, it has been observed that the ties loosen up or break under the repetitive loads invoked by the construction activities.

Supports

Reinforcement may be spaced by metal supports, plastic supports, or precast mortar blocks. Supports should be checked as soon as possible to determine that they will provide the proper clearance. The bolsters or chairs used to support reinforcing steel in slabs, beams, or girders must be spaced not more than 4 feet (1.2 m) apart both transversely and longitudinally. This spacing is a maximum. The Contractor needs to install enough supports to keep the reinforcing steel from experiencing substantial deflections induced from construction loads.

Welding and Splicing

Welding on reinforcing steel is prohibited. This is due to the fact that not only will the welding damage the epoxy coating, but also will result in the diameter of the reinforcing steel being reduced at the point where it has been welded.

In lieu of lap splicing, many times reinforcing steel will be spliced with the use of mechanical connectors. There are various types of mechanical connectors that include:

1. Steel castings that have grout injected
2. Crimp type that are pressure clamped onto the reinforcing with hydraulic jaws
3. Coupling type splices that have threads cut into the end of the rebar
4. Coupling type splices where the rebar ends have been offset pressed and the threads rolled into the end of the rebar
5. Cadweld where the ends of the rebar are butted together and a sleeve is placed over the ends. The sleeve is then filled with molten metal and the molten metal is allowed to cool. This kind of coupler are not normally acceptable for epoxy coated steel.

The most common type of mechanical connectors are the coupling type as described in #3 and #4 above. The mechanical connectors described in #3 above should normally come with two shorter pieces of reinforcing steel that are lapped to the reinforcing steel that is to be spliced. These two pieces of reinforcing steel will normally be a larger diameter (if a splice for a #6 bar is required, the lap section sent with the coupling will be a #7 bar) because the thread cutting process reduces the cross section area of the bar.

Number 14 and 18 (45 M and 55 M) bars are required to be spliced with accepted mechanical connectors.

The mechanical connectors must provide 125 percent of the yield strength of the bar and be installed according to the manufacturer’s instructions. Completed mechanical splices including at least 18 inches of rebar on either side of the splice should be sampled and submitted to the Office of Materials Management for testing.

Bar shall be lapped for a length equal to one and one-half turns when splices in spiral reinforcement are made.

Epoxy Coated Reinforcing Steel (509.09)

When epoxy-coated reinforcing steel is specified, plastic-coated or epoxy-coated bar supports and tie wires are required.

Bars shall be carefully handled and installed so that patching at the job site will be kept to a minimum. It is not expected that the coated bars, when in final position ready for concrete placement, will be completely free of damaged areas. However, numerous nicks and scrapes that expose the steel will not be allowed, regardless of the stage when they occur subsequent to coating in the plant. All damage defined as significant damage must be patched.

Significant damage is defined as any opening in the coating that exposes the steel and that exceeds the following sizes:

1. An area of 1/4 inch (6 mm) square or 1/4 inch (6 mm) diameter.
2. An area approximately 1/8 inch (3 mm) square or 1/8 inch (3 mm) diameter if the opening is within 1/4 inch (6 mm) of another opening of the same or larger size, or a length of 6 inches (152 mm) in length, regardless of area.

All areas to be patched must first be cleaned to a near white metal, i.e. absolutely free of all rust and foreign material.

No concrete is to be placed against the patch until it has adequately cured. Prior to placing concrete the patches should be checked to insure that the patch has cured and is hard.

Verification

Reinforcing steel and any specified mechanical connectors are to be in place and accepted by the Engineer before any concrete is placed. Record this approval in the daily diary. The reinforcing steel and mechanical connectors in each structure unit are verified by a check-off inspection. This verification may consist of a separately-prepared list of all bars and mechanical connectors in each unit, listing the number of bars by bar mark or checked off the record plan sheets with the checks identified and validated. With the exception of the mechanical connectors, all the lists and record plan sheets are summarized on the plan steel list that is verified by reference to them.

Pay Quantity for Reinforcing Steel

It is intended that the Contractor be paid for the weight of reinforcing steel shown in the plans and that no additional calculations are necessary.

If the Contractor believes the pay weight, as shown on the plans, is in error, he is responsible to prove this discrepancy by recalculating the total weight for the entire reference number involved. He must submit his figures to the Engineer for review and approval. The number of pounds (kilograms) of reinforcing steel must be the actual number of pounds (kilograms) of the various sizes incorporated in the concrete as shown on the plans, completed and accepted.

In checking the calculations for the length of bent bars, the centerline length of the bar is the pay length. This involves a deduction from the out-to-out dimension for bends that amounts to the following listed inches (mm) for the number bar shown in the table below.

The most commonly used spiral reinforcement consists of #4 (13M) bars on 30-inch (765) diameter with 1 ½ additional turns of the spiral steel at each end. The weight of the spiral steel is calculated by adding 15.5 lb (7.0kg), which is the weight of the additional turns for both ends, to the sum arrived at by multiplying the length of the spiral cage times 13.9 lb/ft (20.7 kg/m). To determine the weight of spiral steel with diameters other then 30 inch, use Equation 509.1:

$$0.148 \times H \sqrt{\left(\frac{4.5}{2}\right)^2 + \left(\pi\left(D - 0.5\right)\right)^2} + 0.167 \times \pi\left(D - 0.5\right)$$

Equation 509.1 – Spiral Steel Weight

where:

H = Length or Height of Spiral (ft)

D = Outside Diameter of Spiral (in)

When bars with standard hook ends are specified, the pay length allowed for hooked ends beyond the out-to-out dimension is not shown in the plans but is shown in the specifications. When checking the calculations for the length of bars with standard hook ends, a deduction also must be made from the out-to-out dimension for bends that amounts to the following listed inches (mm) for the number bar shown in the table below. The fabricator may add additional length to the bars to facilitate bending. This additional length is not to be included in the pay length.

STD. BAR LENGTH DEDUCTIONS FOR COMMON BENDS – INCHES (MM)				
BAR. NO.	STANDARD BENDS (DEGREES)			
	45	90	135	180
#3 (10M)	¼ (6)	1 (25)	1 (25)	1 7/8 (48)
#4 (13M)	¼ (6)	1 (25)	1 ¼ (32)	2 ½ (64)
#5 (16M)	3/8 (10)	1 1/2 (38)	1 5/8 (41)	3 3/8 (79)
#6 (19M)	3/8 (10)	2 (50)	2 (51)	3 ¾ (95)
#7 (22M)	½ (13)	2 (50)	2 ¼ (57)	4 3/8 (111)
#8 (25M)	½ (13)	2 ½ (65)	2 ½ (64)	5 (127)
#9 (29M)	5/8 (16)	3 1/2 (90)	3 3/8 (86)	6 7/8 (175)
#10 (32M)	¾ (19)	4 (100)	3 ¾ (95)	7 ¾ (197)
#11 (36M)	¾ (19)	4 (100)	4 ¼ (108)	8 5/8 (219)
#14 (43M)	1 (25)	6 (150)	5 5/8 (143)	12 (305)
#18 (57M)	1 3/8 (35)	8 (200)	7 ½ (191)	15 ¾ (400)

Documentation Requirements - 509 Reinforcing Steel

1. The bar markings, the number of, and the clearance maintained on all bars in a specific pour (CMS book and plans)
2. In deck
3. The bar markings
4. The number used
5. Side, end, and bottom clearance being maintained
6. Document top clearance on dry run (deck pour)
7. Document top clearance after final screed strike-off on day of pour (deck pour)
8. Tie reinforcing bars as per 509.04
9. Calculate total weight of bars for payment, if required
10. Make sure Mill Certifications are received to document that reinforcing steel is of domestic origin.

510 Dowel Holes

Materials (510.02)

Nonshrink, nonmetallic grouts include polyester, vinyl ester and epoxy grouts.

Placing (510.04)

Note that when using cement grout the hole's interior surface needs to be damp, while use of nonshrink, nonmetallic grout requires a dry hole.

It is necessary to use surface thermometers to determine the temperature of the concrete into which the dowels are to be inserted. The specification require this temperature to be at least 40°F.

Documentation Requirements - 510 Dowel Holes

1. Number, diameter, and depth of holes drilled
2. Type of grout used
3. Amount of cure time required prior to loading. This is dependent on ambient temperature.

511 Concrete for Structures

General

Concrete mix design, mixing equipment, and control is as set forth in Item 499. Inspectors whose assignments involve concrete as applied to structures are to follow the procedures described here and should familiarize themselves with these instructions.

Mix Design

Concrete for structures will be Class C, S, HP, or as specified in the contract documents. The mix design and control are as outlined in Item 499 except as modified for specific uses as hereinafter described. If the concrete for structures is to be QC/QA, refer to SS 896.

Materials (511.02)

511.02 requires all concrete above the ground line in a given substructure unit or all concrete for any given superstructure to be made of aggregate of the same kind and color, except upon permission of the Engineer.

All superstructure concrete (deck concrete including safety curbs, sidewalks, and parapets) is to be made with natural sand, crushed stone, crushed air-cooled blast-furnace slag, or gravel. The kind and color of aggregate are considered to be the same from any one source.

When a Contractor desires high-early-strength concrete he may use high-early-strength cement, additional cement, accepted water reducing, set-retarding admixture or a combination of these as specified in 511.07. If the Contractor desires high early strength using additional cement and/or admixtures as a continuing practice, his method should be submitted to the Engineer for review.

Control

All concrete used in structures must contain the amount of entrained air specified in 499 unless otherwise specified. An air determination should be made for each part of the structure. This determination should be made as early as possible on the first load of concrete. For substructure concrete, as many additional air tests as necessary should be made to assure required air content. For superstructure concrete, an air test should be made for each load of concrete used. Concrete containing less than the specified amount of air may have the air content increased by addition of an air entrained agent then, providing additional minimum of 30 revolutions, at mixing speed, as long as the time limitation for discharge is not exceeded.

Concrete that is pumped can lose air as the concrete passes through the pump. Therefore, it is important that air tests be made at the point of placement, after the concrete passes through the pump.

The slump of concrete for Class C and S concrete shall be maintained within the range specified in 499.03. An occasional load exceeding the nominal slump (but within the maximum) may be used provided immediate steps are taken to adjust the slump of succeeding loads. Before concrete exceeding the nominal slump range may be used, the Contractor or supplier must take positive action to reduce the slump of following loads.

Accepted chemical admixtures may be incorporated into concrete to improve workability and extend the setting time. Chemical admixtures must meet the requirement of 705.12 that specifies they meet the requirements of ASTM C 494 chemical admixtures. These admixtures are as follows:

- TYPE A - Water reducing
- TYPE B - Retarding
- TYPE C - Accelerating
- TYPE D - Water reducing and retarding
- TYPE E - Water reducing and accelerating
- TYPE F - Water reducing, high range
- TYPE G - Water reducing, high range, and retarding

The type of admixture is optional with the Contractor. However, when the air temperature is 60°F (16° C) or higher at the time of placement of superstructure concrete, and the span is over 20 feet (6.1 m), a Type B or D admixture is required for Class S concrete and Type A or D is required for Class HP concrete.

Records

The results of the air tests together with yield tests are shown on the back of Form TE-45. The Ready Mixed Concrete Plant Ticket must show the number of revolutions at mixing speed. A mixer's rated RPM for mixing speed and agitation speed will be listed with the operating data on the mixer. The mixers must be checked to see that they are operating at the rated speeds. The structure unit in which that load of concrete is placed should be noted on the ticket. A full list of the required data to appear on a batch ticket is listed in Table 499.08.

Advance Notice of Placing Concrete

The Contractor must notify the Engineer at least 24 hours in advance of placing concrete. Review this provision with the Contractor near the start of work on a structure to ensure a clear understanding regarding the stage of completion of work necessary to permit inspection before approval to proceed. The need for all or part of the 24 hours will depend on the amount of additional inspection required to insure that the reinforcing steel has been properly placed, and the forms are in the correct location.

Placing Concrete for Substructures (511.10)

Several methods may be used to convey the concrete to the forms. Any method that assures placement of concrete of the proper consistency without segregation is satisfactory. Usually ready-mix trucks with open chutes, buckets, drop chutes, and concrete pumps are used in placing substructure concrete. Open chutes must be sloped sufficiently to allow concrete of the proper consistency to flow readily. Drop chutes may be maneuvered to distribute the concrete but the delivery end must be kept vertical. Concrete is deposited as near as possible to its final position with as short of a vertical drops as practical, but not over 5 feet (1.5 m).

Consolidation of concrete by the vibration method is required for structures. Spud vibrators generally are used and should have a workman assigned exclusively to each vibrator. The vibrator should be pushed into and pulled out of the freshly deposited concrete slowly and as nearly vertical as possible. For narrow sections, the vibrator may be applied to the sides of the forms or a form vibrator may be used. Establish a pattern of placing and vibrating that provides practically horizontal surfaces and uniform vibrator coverage. Generally a vibrator can consolidate concrete in approximately a 4-inch to 8-inch radius depending on the type of concrete. Class HP concrete and concrete with pozzolans often require more vibration than straight type 1 cement, even when there are high slumps. Visual inspection of consolidation is a two-step process of one, seeing the surface of the concrete flatten out, and two, seeing air bubbles come to the surface within the vibration radius. Therefore, a uniform coverage pattern must be used to assure uniform consolidation.

Footings

Where concrete will be placed to bedrock, the rock should be free of mud and cleared of all loose rock or other accumulations. Soil serving as the footing bottom should be sufficiently dry and stable so that it will not be interspersed in the concrete.

Concrete may occasionally be placed in water. However, with the exception of drilled shafts, concrete is not to be placed under water. When concrete is placed in water, placement should begin in one corner of the forms and continue into that previously deposited until full height of footing is attained. Full height should be carried forward, displacing the water ahead and out a small opening in the opposite corner of the forms. Vibration of the concrete should be kept well back of the water. Concrete must never be deposited in running water since it will cause separation of cement from the mixture. If pumping is controlling the water level, the pumping may be halted or reduced immediately after the concreting is complete, so that the water level rises slowly and inundates the footing to provide the cure.

When the plans require a concrete seal, or it becomes necessary for the Contractor to use a seal to stop the upward flow of water, the concrete must be deposited under water in a manner that minimizes separation of the cement. This type of seal is sometimes referred to as a mud mat. A concrete seal is deposited in a compact mass with a minimum of disturbance from the water it displaces. When a tremie or concrete pump is used the end of the pump or tremie hose or tube must be plugged prior to lowering into the water and kept filled during placement. Failure to keep the tremie or pump filled with concrete during placement could result in water entering into the tremie tube or pump hose. This will result in the cement being washed from the aggregate. The Contractor's plans for the mix and placement should be reviewed prior to the pour. Where the Contractor elects to use a seal, it is his responsibility to choose a thickness and methods that produce satisfactory results.

Piers and Abutments

Concrete for backwalls above the approach slab seat shall not be placed until the abutments have been backfilled to within 2 foot (610 mm) of the bridge seat elevation.

When expansion joints are involved, the backwall should not be placed until after the superstructure concrete is placed. As the superstructure concrete is placed, the beams will grow in length as the camber decreases. If the backwall is placed prior to placing the superstructure concrete, the required opening in the end dam will be lost as the beams grow in length.

The tops of backwalls that become roadway surface require special methods for setting the grade. Although the recommended methods have been used to set the end dams, the elevations can be slightly off grade. Therefore, the tops of the end dams should not be used alone to project the grade for the backwall. The preferred method of obtaining the correct grade is to place a 10-foot (3.05 m) straightedge as a screed supported on the superstructure concrete and the end dam. The backwall can be struck to the proper grade. Grade strips tacked to the backwall form that have their elevations established in a manner described above may be used to establish the grade. In the event that the grade for the surface of concrete is not flush with the end dam edge bar, it should be finished to the grade established above and edged to a radius equal to the offset where it abuts the edge bar.

After the forms have been stripped from backwalls and before the approach slabs are placed, the top surface of concrete is subject to damage by spalling of the sharp edge on the approach slab side. Covering the surface with a plank or any other method that will afford equal protection should be provided.

Concrete should never be deposited through closely-spaced reinforcing steel where it may accumulate and take set prior to encasement or cause segregation of aggregate. The bars, such as the top main bars in a pier cap, should be moved out of the path of the concrete or hopper temporarily until the concrete level has reached the vicinity of the bars, and then reset. If the plans require bearings for which anchor bolt holes will be drilled later, the bars must be reset accurately and checked with a template.

Bearing Seats

Bearing areas on abutments and piers must be finished accurately to the plan elevations in order that the deck may be placed on profile grade. The elevations should be checked accurately at the time of finishing to correct for possible errors and settlement of the forms containing the original marks. Take elevations as soon as possible after completion of the substructure units and record them for future reference.

Bearing seats that are high or uneven must be leveled to the proper elevation by bush hammering or grinding, and then smoothed with a thin film of Portland cement paste to fill the pitted surface. Bearing seats that are over 1/8 inch (3 mm) low are leveled as described above, if necessary, and raised to the proper elevation by steel shims placed under the masonry plates. If elastomeric bearings are specified, steel shims should not be placed under the bearing. In this case, consult the Office of Structural Engineering pertaining to the acceptability of the Contractor's proposed method of correcting the bearing seat.

Where it is necessary to cut down the bearing area, the lowering is extended approximately 1 inch (25 mm) around the area of the masonry plate and carried full width to the face of the abutment or pier cap for drainage.

Construction Joints (511.12)

The surface of construction joints should be even and have coarse texture such as produced by a wood float on fresh concrete. Vibrated concrete with a closed level surface is satisfactory. Where the construction joint terminates at an offset in the concrete surface, such as between the fascias of the deck slab and the sidewalk, the joint should be finished neatly at the corner with a wood float.

Transverse joints as permitted in 511.12, or longitudinal construction joints placed in deck slabs of steel beam or girder bridges, are constructed with keys located between the reinforcing mats and having a depth of 3/4 inch (19 mm). If the Contractor desires a longitudinal construction joint due to an excessive slab width and not provided by the plans or specifications, the request must be submitted to the Office of Structural Engineering for review.

Pre-Pour Conference for Placing Concrete for Superstructures

Prior to the scheduled day for deck placement, preferably the day before, a conference should be held on the project to review the plans and preparations for the pour (Forms CA-S-4 and CA-S-6). The Contractor's superintendent and key personnel, together with the Engineer and available inspectors who will be involved, should attend. At this time the superintendent should state fully his plan of operation and agreement should be reached with the Engineer on all of the following:

1. Provision for adequate concrete delivery to insure continuous placing and to provide sufficient length of workable concrete for proper straight edging. This includes the number of trucks assigned and an access route where ingress and egress will be maintained at all times.

2. Spacing of the trucks, especially at the start and end, so that no load will be delayed unduly in discharging or will placing be delayed for lack of concrete.
3. A system of communicating with the concrete plant to permit ready adjustments in the mix or delivery
4. Proper tools and equipment on hand have been checked and are in good working order. A finishing bridge must be used when the deck cannot be reached for proper finishing.
5. A competent and experienced bridge superintendent who will be in charge, and at least two experienced finishers
6. Factors that might determine the need for chemical admixtures are explained
7. Protection on hand in case of rain or low temperatures
8. For decks with hinges, and where it is planned to terminate a pour at the expansion joint over the hinge, concrete placement should proceed in the direction that will load the longer part of the hinged span first. This will minimize the effects of unequal span loading, unless otherwise specified in the plans.
9. Properly curing the concrete and placing the wet burlap in a timely manner

Closure Pour

Many times a bridge deck will be constructed part width at a time to maintain traffic on a portion of the existing or completed structure. Also, at times, an existing structure will be widened by adding at least two beam lines. A closure pour will be used to account for the differential deflection that will occur between the portion of the deck that has already been placed and has yet to be placed. This closure pour is important and should be performed. A closure pour involves a strip of concrete several feet (a meter) or more wide that is not placed until after the deck concrete is placed in both phases. It is placed the entire length of the deck between the two portions of deck.

When a closure pour is specified, the forms on the second phase of the deck yet to be placed must not be supported by the first phase that has been previously placed. Also, the reinforcing steel must not be spliced, and cross bracing shall not be placed between phases until the concrete in the second phase has been placed.

Immediately prior to placing the concrete in the closure pour it is important that the cross bracing between the first two phases be completely installed. At this time it is also acceptable to support the forms for the closure pour from the two completed adjacent phases.

Setting the Grade for Finishing the Deck

When finishing a deck, setting the grade correctly is paramount for placing a deck on profile grade. A table of screed rail elevations is shown on the plans for composite box beam bridges, rolled beam, girder, and concrete I beam bridges.

The grade must be set by instrument using the elevations in the table. Assuming that expansion joints and camber of beams, girders, or falsework are correct, and setting the grade the plan distance over the beams or plan thickness is not permitted. Elevations must be taken on the end dams and at every point on the beams required for setting the grade of the screed rail, including points over the piers. This is done so that deviations in the camber of the beams or girders can be adjusted when setting the forms, and not later when it would be more difficult.

Deviations in the camber of the beams or girder are corrected by varying the size of the haunch or fill over the beams. The height of the haunch or fill is determined by subtracting the elevation of the top of the beams from the theoretical elevation of the bottom of the deck. The theoretical elevation of the bottom of the deck is determined by subtracting the deck thickness from the screed rail elevations given in Table 511.A - Determining Haunch Height. This is an acceptable method of recording this information.

BEAM ROW	ELEV.	REAR ABUT	¼ PT	½ PT	¾ PT	PIER 1
	Deck Bot	966.64	966.48	966.32	966.16	966.00
A	Beam Top	956.97	965.82	965.68	965.5	965.33
	Haunch Ht	0.67	0.66	0.64	0.66	0.67
	Deck Bot			966.42		
B	Beam Top			965.77		
	Haunch Ht			0.65		
	Deck Bot			966.52		
C	Beam Top			965.87		
	Haunch Ht			0.65		
	Deck Bot			966.42		
D	Beam Top			965.76		
	Haunch Ht			.66		
	Deck Bot	966.64	966.48	966.32	966.16	966.00
E	Beam Top	965.97	965.82	965.66	965.50	965.33
	Haunch Ht	0.67	0.66	.66	0.66	0.67

Table 511.A - Determining Haunch Height

In the case where the beams or girders have excessive camber and it would cause the beam or girder to interfere with the deck thickness, the profile grade should be raised. The new grade should parallel the plan profile as nearly as possible and provide the required deck thickness at points of maximum camber. This will result in increasing the haunch height over the piers and abutments to an acceptable level.

Whenever the profile grade of the deck is adjusted, this must be considered when setting the grade for the approach slabs and pavement in order that a smooth transition will be provided. Even though it has not been necessary to adjust the grade, the as-built grade of the deck should be used to establish the grade of the approach slabs, since the actual dead load deflections may vary from the calculated deflections shown on the plans.

When a closure pour is specified, the designer assumes that the finished elevation of the existing deck is correct. However, due to either conditions beyond his control or conditions he has overlooked, the finished elevation of the deck may not be as he assumed. If this condition exists, it should be detected prior to placing the widened or second portion of the deck. Therefore, prior to placing the widened or second portion of the deck, the Contractor should check the finished elevation of the existing portion of the deck to assure that it is correct. If it is determined that it is not correct, the Office of Structural Engineering should be contacted for additional instructions.

Evaporation Rate

In an effort to reduce or eliminate drying shrinkage cracks in the superstructure concrete, the concrete should not be placed when the evaporation rate of water from the freshly placed concrete is too high. Use the graph in section 511.10 of the CMS to check the evaporation rate.

The Contractor should check the evaporation rate immediately before the placement of superstructure concrete begins. The evaporation rate should also be checked if there is a change in temperature, humidity, or wind speed during the placement of superstructure concrete. The wind speed can have the greatest effect on the evaporation rate; therefore, changes in the wind speed should be more closely monitored. Many times, during the summer months, it will be necessary to place superstructure concrete at night in order to comply with the evaporation rate.

In addition to the evaporation rate, superstructure concrete is also not allowed to be placed when the ambient air temperature is 85° F (30° C) or higher or is predicted to go above 85° F (30° C) during placement. The temperature of the concrete is also not allowed to exceed 90° F (32° C) during the mixing and placement. Many times it is necessary for the Contractor to reduce the temperature of the mixing water and/or aggregates in order to control the temperature of the concrete.

Evaporation retardant is mostly water and its use is not permitted. Be aware that evaporation retardants is also marketed as a finishing agents, but under either name their use is prohibited.

Machine Finishing

A machine finish is required except for small bridges, where the Engineer may waive the requirement. Details of the method of supporting the machine on the deck and the complete procedure for placing the slab should be submitted to the Engineer for review. Supports for the riding rails must be adequate for the weight of the machine to avoid failure or any vertical deflection. The concrete handling, placing, and finishing procedure should be planned so that the concrete will be placed and struck off with a minimum of manipulation and at a sufficient rate to provide workable concrete in an area adequate for proper final hand finishing. Success of the Contractor’s procedure on previous decks should be considered.

For transverse machines, the screed should be assembled or adjusted to the required crown established from a taut line while suspended in the same manner as it will be in operation.

Prior to ordering concrete and after the finishing machine has been made ready, make a dry run over the entire deck. Check slab thickness and reinforcing steel cover along with crown conformance to both end dams and expansion joints. If the rate of crown varies and the machine can be adjusted during operation, the required crown should be determined at regular intervals not exceeding 25 feet (7.62 m), the required increment of adjustment established and the location referenced on the side of the bridge.

Plan dimensions for deck thickness and reinforcing steel cover verified during the dry run and witnessing screed adjustments to the required crown must be recorded in the project records. A last-minute check that form dimensions and reinforcement have been verified and documented should be made at this time on the inspectors Daily Report.

Although proper measurements made during the dry run should assure plan dimensions, check measurements after the concrete is struck to grade to verify that the machine is still in adjustment and reinforcing steel remains in place. Slab thickness measurements can readily be obtained by probing with a 1/4 inch (6 mm) straight wire and the cover over re-steel with a 90° bent wire of the same size. These measurements should be made soon after the start of the finishing operation and periodically thereafter or when an area appears questionable. Wide flat sections such as super elevated slopes are questionable and must be checking. The probing should be performed in plastic concrete where the void will be more easily closed.

Some cover checks are required. However, they need not be as numerous as the depth checks that also reflect cover. It is recommended that as many depth checks be made as available time permits. A statement that check measurements have been made and conform to plan dimensions should be entered in the project records. If localized areas do not conform to plan dimensions these should be noted and any corrective action documented.

During operation, a uniform head of concrete should be maintained along the full length of the screed. Screeds should be lifted from the surface when not in use. During operation, only the operator is permitted on the machine. The machine should be in operation as continually as practical, and the concrete placing procedure should not exceed the speed of the machine.

Tracking or walking in the screeded surface is not to be tolerated.

Final Finishing

It is imperative that final finishing follow immediately behind the finishing machine. If this final finishing should fall behind, the rate of concrete placement should be reduced.

The construction joint surface under the sidewalk or the safety curb should not be used as a place for finishers to stand or as a passageway for workers. Planks may be placed on the sidewalk reinforcement providing sufficient additional ties and braces are used if necessary to obtain a rigid framework that will not disturb the bond of the stirrups.

Minor surface irregularities left after screeding can be corrected with long handled floats. This operation should be held to a minimum and any major irregularities encountered should be corrected by the use of a straightedge. Use of water, evaporation retardants, or finishing agents on the surface of the concrete to facilitate finishing is not permitted. If a Contractor is adding water by continuously "washing" his tools, require that they us a towel to dry the tools prior to reuse.

Texturing

The deck surface must be textured (using a broom) to provide a surface satisfactory to the Engineer. The broom must produce a uniform gritty texture in either the longitudinal or transverse direction. The texturing should take place as the pour progresses after other finishing operations have been completed. Note that if the concrete tears, or "mud balls" are produced on the surface, the Contractor needs to apply less pressure to the broom or wait a few minutes until the concrete has began to set.

After the water curing of the concrete is complete, transverse groves must be sawed into the surface of the deck. The grooves must be spaced at 3/8 to 1 3/4 inch (10 to 45 mm) with 50 percent of spacing being less than 1 inch (25 mm), and must be approximately 0.15 inch (4 mm) deep and 0.10 inch (3 mm) wide. Groves must be within 9 to 12 inches from devices such as scuppers or expansion joints. On skewed bridges, in order to accommodate the equipment used to saw the groves, the grooves must be sawed from 2 inches to 2 feet from the expansion joint. This results in grooves with a staggered or stepped appearance.

Opening a structure to traffic prior to sawing rain grooves exposes the traveling public to a hazardous situation. Therefore, traffic must not be allowed on bridge decks until after the grooves have been sawed.

Emergencies

During the placing of a deck, unexpected difficulties may occur that halt further placing. These may be a sudden shower, a breakdown in the concrete plant or the finishing machine, or other unforeseen interruptions.

When a shower occurs, no manipulation of concrete should be performed other than channeling the concrete that was last deposited so that water will not pond on the concrete and run back on the finished or partially finished surface. The textured surface should be covered with the curing material as rapidly as possible. Untextured surfaces should be covered with polyethylene sheeting. After the shower, all ponded water should be removed from the concrete and out through the forms before resuming placing and finishing operations. The last surface covered with the curing material should be inspected; if it has been marred, the texture should be restored.

Investigate breakdowns immediately. If indications are that it will not allow resumption of concrete placing in sufficient time, a bulkhead must be placed immediately. If practical, the location should not be over a pier. The emergency bulkhead may consist of a wood strip laid across the top of the longitudinal reinforcing bars. This strip should be as deep as the plan cover; usually 2 1/2 inches (64 mm). Kickers can be used to secure the strip or shims inserted between the bars to obtain proper crown and grade. The concrete below the wood strip should be compacted to about a 45-degree slope, and all excess removed as far from the joint as possible and disposed of before it hardens. After the concrete has set but still fractures easily, the bottom edge should be broken to provide a vertical face below the bottom reinforcing steel. This may be accomplished with a pry bar prying up from the forms, but exercise care to see that the surface of the forms is not damaged. See Figure 511.A - Emergency Bulkhead.

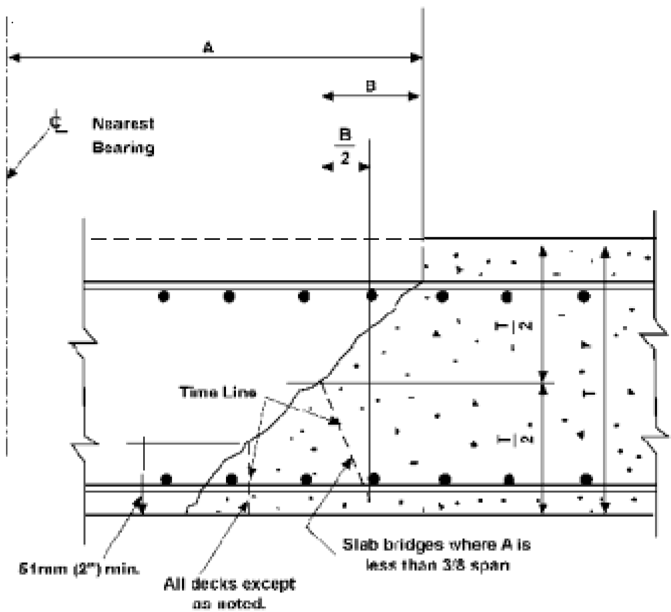


Figure 511.A - Emergency Bulkhead

Curbs and Parapets

Forms for curbs and parapets should be observed carefully for condition of surface, flush fit of panel joints, proper installation of bevel strips, and visual and measured alignment and elevation. Adequate form supports should be provided that insures proper position of concrete during and after placement. Surface rubbing does not justify use of inferior forms or lack of adequate supports.

When expansion devices are used to allow for bridge deck expansion, slightly more open space for expansion must be provided in the curb and parapet than is required for expansion devices. Where conduits cross this opening, give special attention to clearance for expansion fittings to assure free movement of the deck.

Transverse joints may be placed in the sidewalk or curb section near the center of any span.

Slipforming Parapets

In lieu of conventional forming, the Contractor may be permitted to slipform the parapets. This operation is accomplished with concrete that has a slump of around 1± inch.

Prior to placing the concrete, the Contractor must take additional measures to tie the reinforcing steel to prevent it from being dislocated during the slipforming operation. If these additional measures are not taken, the slipforming operation will cause the reinforcing move out of its proper location.

Due to the low slump, many times the Contractor will attempt to add water to the mix as it comes down the chute from the concrete truck and enters into the hopper of the slipforming machine. This is not allowed since it will result in concrete of inferior quality.

During the slipforming operation, small amounts of concrete will drop from the edge of the deck and onto the surface below the bridge. If the slipforming operation takes place directly over a traveled roadway, the Contractor should furnish all necessary platforms to protect the traffic from falling concrete. These platforms will also allow access to complete the finishing operation and facilitate inspector access.

The Contractor should take steps to insure that the finished concrete meets the specified tolerances. These steps should include items such as adequately tying the reinforcing steel, determining the proper slump, and properly setting up the slipforming machine. Failure to meet the specified tolerances could result in the rejection of the parapet.

Any defects such as cracking, tearing, or honeycombing should be repaired immediately. Occasionally, when repairing defects, the Contractor will not completely fill the defect with concrete but will only bridge over the defect by placing the concrete on the surface of the parapet. This is not acceptable. The Contractor should take steps to insure that the defect is completely filled with concrete.

Normally, a small amount of hand finishing is required after the concrete has been formed. Hand finishing can be difficult due to the low slump of the concrete. To facilitate finishing the concrete, many times the Contractor will sprinkle water or evaporation retardant onto the surface of the concrete. The use of these substances to aid in hand finishing is not allowed since it will only result in a surface that is subject to scaling in the future.

After the concrete has taken its initial set, it is important to saw the control joints to the plan depth into the parapet as soon as possible. Any delay in performing this operation will result in additional shrinkage cracks in the parapet.

Curing (511.17)

Curing is governed by 511.17 that requires either Method (a) Water Curing or Method (b) Membrane Curing. Curing time is seven days. No curing is required for surfaces covered by forms for the duration of the curing period. Concrete that will be overlaid with concrete or sealed, and all superstructure concrete, must be cured in accordance with Method (a) Water Curing. Concrete decks placed with Class HP concrete must be cured for 7 days in accordance to Method (a) and then cured within 12 hours in accordance with Method (B).

The curing material must be applied as soon as possible to avoid cracking of the concrete. Application of the curing material should be applied immediately after the finishing operation has been completed.

When it is necessary to work on concrete during the curing period, such as placing deck concrete adjacent to a construction joint, only that area immediately adjacent to the joint should be exposed and the remaining area protected from damage by the workers. Plywood sheets may be used for protection. The exposed area should be kept moistened until adjacent work is completed, after that the cover should be restored and normal cure resumed.

Floor forms provide the cure for the underside of the slab and are not to be removed before the end of the curing period.

Method (a) Water Curing

When two thicknesses of burlap are used to water cure the concrete, they should be kept wet by the continuous application of water from soaker hoses or other sprinkling devices during the required period. In lieu of continual sprinkling devices, white polyethylene sheeting or wet plastic coated blankets may be used to cover the concrete.

On bridge decks, a single layer of wet burlap is kept wet by a continuous application of water and covered by white polyethylene. The polyethylene should be placed transversely. The edges should be lapped and held securely to maintain a moisture seal. The curb area may be covered with a longitudinal strip that is held securely to the fascia form and laps the transverse strips. A continuous batten may be used to seal the blanket to the form and reinforcing bars laid on the laps to make the seal. Check areas suspected of having the seal broken during subsequent work or weather disturbances. Then if it is found to be drying out, soak the burlap and reseal the white polyethylene.

Plastic-coated blankets must be inspected prior to use to assure that they are sound and will retain the moisture required to cure the concrete. All holes and tears must be repaired so that they are watertight. The material should be rejected if defects are numerous and repairs are questionable, or if the plastic coating has cracked from aging.

Burlap and plastic-coated blankets must be thoroughly soaked with water prior to placing on the surface of the concrete. Dry material placed on the surface of the concrete will draw moisture out of the surface of the concrete; this will increase the chances of drying shrinkage cracks. If new burlap is used, extra measures may be needed to insure that it is properly soaked since it doesn't soak up water as well as used burlap. If burlap to be soaked is delivered to the project in a tightly wrapped condition, it should be loosened to allow the penetration of water.

Method (b) Membrane Curing

The concrete curing membrane is white-pigmented material meeting specifications 705.07. The material may be either Type 1 (clear or translucent without dye) or Type-D (clear or translucent with fugitive dye).

The membrane should be applied in one or more separate coats by spraying as a fine mist, at a uniform application rate of one gallon per 200 square feet (70.3 square meters) of surface. The rate of application is controlled by laying out in advance, on the surface to be cured, an area that will be properly covered by the number of gallons of compound in the spray container. The procedure helps insures that the membrane is applied at not less than the required rate.

Cold Weather Concreting

Heated concrete and protection must be provided whenever concrete is placed at an atmospheric temperature of 32° F (0° C) or lower, or whenever weather forecasts predict temperature below 32° F (0° C) within the curing period. Concrete must not be placed in contact with material having a temperature of less than 32° F (0° C).

The official U.S. Weather Bureau forecast for any curing period generally can be obtained from the District Office. This information also can be obtained from some local airports and radio stations.

When the five-day weather forecast does not predict 32° F (0° C) or lower temperatures at any time during the period, the Contractor should not be required to erect enclosures or use insulated forms. However, during the fall, winter, and spring, adequate material and equipment should be on hand to provide for unpredicted temperatures below 32° F (0° C).

To assure freedom from freezing until protection can be established, the temperature of concrete as placed should not be less than the minimum of 50° F (10° C) specified, but should not exceed 90° F (32° C) maximum. Concrete placed at low temperatures above freezing develops higher ultimate strength and greater durability than concrete placed at higher temperatures. Higher temperatures require more mixing water, cause slump loss, possible quick setting, and increase thermal shrinkage. Rapid moisture loss from hot exposed concrete surfaces may cause plastic shrinkage cracks. It is recommended, therefore, that the temperatures of fresh concrete, as placed, be kept as close to the 50° F (10° C) minimum temperatures as practicable. When the air temperature is 32° F (0° C) or lower, it is necessary to raise the temperature of the concrete by heating the mixing water or aggregate, or both. The concrete must be protected from freezing and specified curing temperatures must be maintained by a heated enclosure, by insulated forms, or by either of these in combination with flooding.

Decks slabs less than 10 inches (254 mm) thick must be protected from freezing, and specified temperature maintained for the curing period, by a heated enclosure.

Arrangements for covering and insulating newly-placed concrete must be made in advance of placement and should be adequate to maintain the specification temperature in all parts of the concrete.

During the first few days requiring protection, most of the heat of hydration of the hardening cement is developed. As a result, if heat generated in the concrete is adequately conserved, outside heat generally is not required to maintain concrete at the correct temperature. This heat may be conserved by using insulating blankets and by insulated forms where repeated reuse of forms makes this practical. Outside temperatures, at that concrete walls, piers, abutments, or slabs above ground may be protected with insulation under various conditions, are shown in the charts that follow. On work where protection by insulation is permitted, project personnel should check the protection proposed by the Contractor and be reasonably sure that the proposed insulation is adequate for the expected exposure before concrete placement is permitted to begin.

The application of insulation should be as follows:

1. Blanket insulation is applied tightly against wood forms with nailing flanges extending out from the blankets so they can be stapled or battened to the sides of the framing. Seal the ends of the blankets by removing a portion of the mat and stapling or battening the blanket to headers so as to exclude air and moisture. Corners and angles are most vulnerable. Take extreme care to insure they are well insulated and the insulation held firmly in place.
2. In case of steel forms, the insulation should be applied tightly against the form and held securely with the ends sealed to exclude air and moisture.
3. Where practicable, the insulation or insulated form should overlay any cold concrete previously placed by at least one foot.
4. Any tears in the liner are to be repaired immediately with accepted waterproof material.
5. Where tie rods extend through an insulated form, a plywood washer, approximately 3/4 × 6 × 6 inches (19 x 150 x 150 mm), should be placed on top of the insulation blanket and secured in a satisfactory manner.
6. The tops of all pours must be covered with insulating blankets, except for areas around protruding reinforcing bars that may be insulated with straw or wrapped with insulation blankets. Waterproof covers should be used to cover the top of such pours as required by specifications.

7. Protective enclosures may be constructed of canvas, plywood, polyethylene, plastic, etc. in such a manner that will maintain uniform temperatures and allow free circulation to the warmed air.
8. For the underside of deck slabs, ¾ inch (19 mm) plywood forms have an equivalent thickness of 0.6 inch (16 mm) and will provide protection of 32° F (0° C) minimum air temperature.
9. Close packed straw under canvas may be considered a loose fill type if wind is kept out of the straw. The insulating value of a dead air space greater than about one-half inch (13 mm) thick, does not change greatly with increasing thickness.

Heated Enclosures

When salamanders or other heaters supply heat, local drying and burning of the forms may result and necessitate moving or adjustment of the setup. Regular observance of the forms and burlap should be made to insure that the concrete is kept wet for the duration of the curing period, as required in 511.17. Combustion type heating units shall be vented from the enclosure to preclude damaging fresh concrete. The enclosure should surround the top; sides, and bottom of the concrete to be placed during cold weather.

Temperature Control

Thermometers for use in enclosures should be the high-low recording type and be furnished by the Contractor. If the enclosure is long or high, more than one thermometer may be required. The readings in the morning and the afternoon normally represent the low and high temperature respectively; make careful selection of the time when the high-low recording thermometers are checked.

When insulated forms are used the thermometer must be furnished and installed by the Contractor. They must be of such a type and so located that they will indicate surface temperature of the concrete. In case of a tall section such as pier shafts or retaining walls, more than one thermometer will be required because of the temperature gradient. Temperatures should be read twice daily for high and low readings. When insulated forms are used, temperature of concrete will cause a lag in the change of temperature of the surrounding air. Time of observance need not be as selective for representing the high and low, but is used to indicate a trend that may require venting of the forms or erecting an enclosure. When venting of a vertical form is necessary it should be raised slightly at the bottom to create a chimney effect.

The temperature record must include the required temperature readings for the entire curing period. Outside air temperatures may be local reported temperatures.

Temperature and control methods used as well as temperature readings must be recorded on the Inspector’s Daily Report.

Cold Weather Curing Time

To fulfill the curing requirements for concrete placed in cold weather, the surface temperature must be maintained as specified in 511.15 or be exposed to ambient air temperatures not less than 50° F (10° C) for 5 days.

In case any day's temperature readings fall below the minimum specified, the duration of heating must be extended to provide the required number of days. In case of loss or breakage of thermometers, replacements or other provisions must be made to provide a complete record.

Falsework and Form Removal

Falsework must not be removed until after the time-temperature requirements of 511.17 have been met or satisfactory beam tests have been attained. During cold weather, forms are to be removed after the curing period in such a manner that the temperature of the concrete does not drop more than 20° F (7° C) in any 24-hour period.

Note 1 in Table 511.17-1 states that span is defined as the horizontal distance between faces of the supporting elements when measured parallel to the primary reinforcements. For slab deck bridges the primary steel runs longitudinally down the deck. For beam supported structures the primary steel runs transversely across the deck.

Patching

As soon as possible after the removal of forms, all cavities produced by form ties and all other holes, honeycomb spots, broken corners or edges, and other defects (except air bubble holes that may be filled by grout cleaning) must be cleaned and after having been saturated with water shall be completely filled, pointed, and trued with a mortar of the same proportions as used in the concrete being finished.

On all exposed surfaces, all fins and irregular projections must be removed with a stone or power grinder, taking care to avoid contrasting surface textures. Sufficient white cement must be substituted for the regular cement in the filling of holes and other corrective work to produce a finished surface of the same color as the surrounding concrete.

If shown on the plans, exposed surfaces having an appearance that is not satisfactory to the Engineer shall be grout cleaned in a manner satisfactory to the Engineer.

The Contractor should be advised that it will be necessary to use good formwork to obtain satisfactory surfaces.

Rubbed Finish (511.18)

When specified on the plans, rubbing shall be performed as outlined in 511.18.

Forms should be removed within 2 days after the concrete is placed. Exceptions are the slab fascia form on which other fascia forms are set and wall forms that overlap a joint. If parapets are placed in cold weather, make provisions to remove forms and begin surface finishing on the day following placing, while maintaining a minimum temperature of 50° F (10° C), or postpone the placing of parapets until weather conditions are suitable for proper performance.

Grout Cleaning

Grout cleaning shall be performed as outlined in 511.18.

Float Finish

Concrete for sidewalks, safety curbs, and tops of substructure units are struck off with a template and finished with a float to produce a sandy texture.

Loading General

No traffic is to be permitted on a structure until the concrete has attained the age specified in 511.17. For all spans this is 14 days without a beam test or 7 days with satisfactory beam test.

Loading of Completed Structure Units

No load is to be applied or work conducted that will damage new concrete. This applies to loading or work on any part of the structure that will, in the opinion of the Engineer, cause damage. Usually this criterion will permit work on a footing after 36 hours or sooner with a successful beam test, of normal curing where bending stresses will not occur.

Pay Quantity for Structure Concrete

The quantity of concrete for every reference number will be as determined from the plan dimensions, in place, complete and accepted with adjustments made for necessary changes or errors. Plan dimensions shall be verified and recorded.

The final quantity for structure concrete is rounded off to the unit for the item that is listed in the proposal. Where plan dimensions are in inches (mm), these should be converted to feet (m) and carried to a decimal place that will not affect the accuracy of the final unit.

Calculations made for necessary changes or plan errors are to be identified properly with the structure unit and reference number, and be validated by the signature or initials of the person who made the calculations and the date they were made.

Documentation Requirements - 511 Concrete for Structures

1. Form dimensions and elevations field verified

2. Forms clean and oiled
3. Re-steel placed according to 509.04
4. Concrete vibrated
5. Record surface temperature inside of cold weather protection
6. Forms and reinforcing steel heated to minimum 32° F (0° C) prior to placing concrete
7. Amount of curing compound used and/or method of curing
8. Placement and testing requirements documented on forms CA-C-1 and TE-45
    a. Place superstructure concrete when air temperature is 85° F (29° C) or less and not predicted to be above 85° F (29° C) during placement
    b. Evaporation rate as per 511.10
    c. On deck
    d. Document depth obtained on dry run
    e. Document depth obtained after final screed strike-off on day of pour
    f. Finish deck as per 511.19
    g. Smoothness requirements are outlined in 451.12. A profilometer will be required to check smoothness
    h. Document saw grooves on surface as per 511.20.
9. Loading as per 511.17
10. Prepour meeting forms CA-S-4 and CA-S-6
11. HP test slab acceptance
12. If included results for HP Concrete Testing
    a. Rapid Chloride Permeability Test
    b. Drying Shrinkage Test
    c. Heat of Hydration Test

512 Treating Concrete

This item deals with a variety of concrete treatments including concrete surface sealing, horizontal crack sealing, vertical crack sealing and waterproofing.

Sealing of Concrete Surfaces (512.03)

Improper surface preparation is one of the main reason we see sealer failures. When the sealer is applied to a damp, dusty or laitance laden surface the sealer cannot gain the proper adhesion and peels off, normally in sheets.

Make sure the Contractor is standing a reasonable distance away from the surface being blasted. This should normally be within 18 inches. Using a 7000 psi water blast from 6 feet away does not gain the level of cleanliness they need to apply the sealer correctly.

There is a Qualified Product List (QPL) for these materials maintained by the Office of Materials Management (OMM) located under 705.23

Non-epoxy sealers (512.03.F.2)

These sealers are clear by nature, but are to be tinted with a vanishing dye. Due to this fact it will be difficult to see where progress ended on the preceding day. Establish a method to mark the stop point that will not permanently be visible in the completed work.

Test Site/Application (512.03.G)

Ensure that test sites include a variety of surfaces: Horizontal, vertical, inverted, steel formed finish, troweled, floated, rubbed, etc.

Sealing Concrete Bridge Decks with HMWM Resin (512.04)

HMWM stands for High Molecular Weight Methacrylate.

If the Contractor supplies 3 part HWWM meaning the promoter, resin and initiator are supplied separately be aware the promoter and initiator will react violently with each other. This chemical reaction is so violent that these are components normally arrive to the jobsite on different trucks.

Poor surface cleanliness is the major problem encountered in the field. Dust and debris clog up the cracks and do not allow the HMWM to penetrate effectively.

Be sure to insist that the Contractor coordinate his initial application on the project with the presence of Manufacturer's Representative. This Representative should be a technical representative in lieu of a sales representative.

The application of sand is required to give the sealed surface a rough texture to assist with traction. If the sand is applied after the resin begins to harden it will not become embedded and will merely brush off with the first wave of traffic leaving a potentially slick surface.

There is a Qualified Product List (QPL) for this material maintained by the Office of Materials Management (OMM) located under 705.15

Soluble Reactive Silicate (SRS) Concrete Treatment (512.05)

Proper surface preparation is essential for SRS to perform properly. The manufacturer's representative must be on-site and sign off that the surface preparation is adequate.

The Contractor is required to perform a test section(s). This section(s) should incorporate all of the surface types to be treated. This is due to the fact that the test sections are to confirm application rates and appearance which will depend on the orientation and porosity of the concrete.

After the treatment has cured and prior to opening to traffic, the treated surfaces that experience vehicular or pedestrian traffic should be washed down with water. In some instances the SRS treated surfaces have become very slick when first being exposed to water. It is better to have this initial exposure in a controlled scenario versus allowing it to be the first rain with traffic running on it.

There is a Qualified Product List (QPL) for this material maintained by the Office of Materials Management (OMM) located under 705.24

Treating Concrete Bridges with Gravity-Fed Resin (512.06)

There is a Qualified Product List (QPL) for this material maintained by the Office of Materials Management (OMM) located under 705.25

Sealing Cracks by Epoxy Injection (512.07)

Make sure the requirement for the presence of the manufacturer's representative is enforced even if the Contractor has vast experience with this feature of work.

Note the Contractor may refer to the injection ports and "straws".

Take core samples as soon as the epoxy has cured. This is more critical on larges jobs as the method of epoxy injection may have to be altered if it is not achieving adequate penetration. On small one day type job this will not be possible.

There is a Qualified Product List (QPL) for this material maintained by the Office of Materials Management (OMM) located under 705.26

Waterproofing (512.08)

Care should be taken while placing backfill against areas that have received waterproofing. The waterproofing can be damaged either by direct contact of the equipment or by using backfill materials which contain large sharp edged rocks.

There are Qualified Product Lists (QPL) for the membrane and fabric materials maintained by the Office of Materials Management (OMM) located under 711.24, 711.25 and 711.29.

Documentation Requirements – 512 Treating Concrete

1. General
    a. Document type of material used (make and model)
    b. Quantity of material used and application rate
    c. Area treated or sealed in square yards and/or lineal feet of crack repaired
    d. Contact information for Manufacturer's Representative that is on-site (where required)
    e. Atmospheric conditions and substrate temperatures
2. Waterproofing (512.08)
    a. All surfaces clean and dry prior to placing waterproofing
        i. Type A, B, and D
            1. Amount of primer used
            2. Temperature of bituminous material
            3. Document amount of bituminous required and amount used.
            4. Document lap of fabric
        ii. Type 2 and 3 membrane
            1. Temperature at time of application
            2. Document lap of membrane
            3. Type 3 surface joints sealed

513 Structural Steel

Field Inspection

When the steel arrives on the site and prior to erection it should be inspected for damage and quality of fabrication as thoroughly as time and conditions permit. Fabricated steel should have a TE-24 with the shipment. If fabricated steel does arrive without a TE-24 either the District Engineer of Tests or the Office of Material Management's structural steel section should be notified.

Damage

The nature and extent of any damage that may have occurred because of loading, transit, or unloading should be noted along with the identifying piece mark or member. If corrective work is obvious, advise the Contractor immediately so that the responsible party can be notified and correction can be performed in the most advantageous location.

Storage

Structural steel stored on the site shall be supported off the ground on blocking and stored in an upright position where it will not be affected by drainage. Many times the Contractor will secure angle iron across the top flanges of adjacent beams to prevent them from tipping over. If angle iron or other metal is secured across the top of the beams, it is important to insure that the Contractor has not secured the angles or other metal by welding it to the beam.

Sweep

The specified tolerance for sweep or horizontal curvature of a beam or girder is 1/8 inch (3 mm) in 10 feet (3.05 m). This can be applied to any 10 feet (3.05 m) length of the member or multiple of 10 feet (3.05 m) lengths up to the total length of the fabricated section. Thus, a beam 100 feet (30.5 m) long, checked for its entire length, must not deviate more than ten one-eighth inches (3 mm) for a total of 1-1/4 inches (32 mm) from a taut line stretched between its ends.

Shop Coatings

Any members where thickness appears questionable from a visual examination shall be checked in the field, preferably prior to erection.

General (513.04)

The Contractor is required to furnish the necessary access and area for inspection of all operations. The inspector should not occupy the same float or suspended platform used by the workmen for safety reasons.

Required Documents (513.05)

A TE-24 in the project file provides verification that the structural steel is accepted material and fabrication has been properly performed.

Check of Bearing Seats

A final check shall be made of the elevation of bearing seats on the piers and abutments before erection of structural steel is scheduled to begin. If bearing seats are found that need to be corrected, it must be performed in the manner and to the tolerances described in 511 Bearing Seats of this manual.

The findings of this final check should be filed in the project records.

Erection Methods

Methods and equipment accepted for erection of members must be used in handling during transportation to the bridge site and unloading.

The erection drawings, usually the “E” sheets of the accepted shop drawings, must be used to locate the members on the bridge and may give special instructions for the erector to follow.

Deviations from the accepted erection procedure are not permitted. If the erector proposes deviations in procedure that appear to have merit, they must be referred to the Office of Structural Engineering for review prior to use.

Required Erection Procedures

The specifications require that the Contractor submit an erection procedure for structural steel members. If there is railroad involvement, the PE stamped plan needs to be reviewed and approved by the appropriate railroad. Otherwise the plan must have two PE stamps. For additional requirements refer to CMS 501.05.

Typical Erection Procedures Items

Typical items that should be included in the proposed erection procedure are:

1. A drawing of the complete framing plan showing each girder or beam section by “piece mark” and numbered in the order of proposed erection.
2. A print of the erection sheet of the shop drawings may be used.
3. The number of pieces and load capacity of erection equipment to be used and method of lifting members
4. Field splices to be made on the ground.
5. The number of field splice holes to be filled before erected members are released and allowed to deflect (50 percent required - preferably one-half with pins and one-half with bolts)
6. Methods and details for supporting the first beams or girders at the abutments and piers in each unit - Where some sort of attachment to the pier is used, it should be fully described as to size of members and method of attaching to the pier and steel. In addition to supporting the

beams at the abutment and piers, there may also be additional bracing of the top flange at mid-span to prevent the beam from twisting or buckling under its own weight.

Use Erection Checklist Form CA-S-20.

High Strength Bolting (513.20)

The following described operations are intended to clarify some of the important requirements of the specifications.

Joint Assembly

The beams or girders to be spliced must have their ends brought together at the correct relative elevation with respect to support points, and held at the elevation (and in correct alignment) so that heavy drifting is not necessary to align the holes.

Sufficient pins must be installed to obtain accurate alignment of parts and sufficient bolts to compact the joint. Before the beams or girders are released and allowed to deflect, at least 50 percent of the holes must be filled with pins and snug-tightened bolts. A minimum of 25 percent pins is desired, however, if less than 25 percent will carry the stress. If additional pins cannot improve matching of holes, a lesser number will be satisfactory. If less than 25 percent pins are used, the remaining holes should be filled with snug-tightened bolts. Some joints that will be highly stressed probably will require more than 50 percent of the holes filled with drift pins and snug-tightened bolts; note such cases on the accepted erection procedure. Due to the possibility of damaging the threads on the bolts, any bolts installed prior to installing the drift pins shall be replaced.

On some beams and girders it is possible for the initial bolts used to compact the joints to become loose when the remaining bolts are installed. After all the remaining holes have been filled with bolts and tightened to at least a snug tight condition, the initial bolts should be checked to assure that they are still snug tight.

When the splice is made on the ground all operations to complete the splice shall be performed.

Pins shall be cylindrical and not more than 1/32 inch (1 mm) smaller than the diameter of the hole.

All holes not filled with pins shall be filled with bolts and bolt tightening operations completed on them before removal of any pins.

Bolt Tightening

Tighten bolts by the turn-of-the-nut-method:

1. tighten the bolt to a snug-tight condition
2. match mark the protruding end of the bolt and adjacent surface of the nut
3. tighten the nut the additional specified rotation

Greater variation in tension is usually obtained when the snug-tight condition is performed with power wrenches. More consistent tension is obtained with spud wrenches. When the steel surfaces are flat and compact, the snug-tight condition is obtained when bolt tension is between 5,000 and 10,000 pounds (22,222 and 44,444 newtons).

Snug tight is accomplished by either an impact wrench or an ordinary spud wrench. If an impact wrench is used, snug tight is achieved when the impact wrench begins to impact or hammer on the bolt. This will happen almost immediately after tightening with the impact wrench begins. When a spud wrench is used, snug-tight is achieved when the full effort of a man is applied to the spud wrench and the nut cannot be tightened any further.

Bolts must be match marked after the bolts have been tightened to a snug-tight condition. The purpose of the match mark is to measure the amount of rotation of the nut relative to the bolt. The match marks must be placed properly in order to measure this rotation. The match marks must be placed on the end of the bolt and the adjacent surface of the nut. Contractors have placed match marks in several other locations; however, none of these locations allow the relative rotation of the nut to the bolt to be measured

(See Figures 513.A and 513.B - Match Marked Bolts).

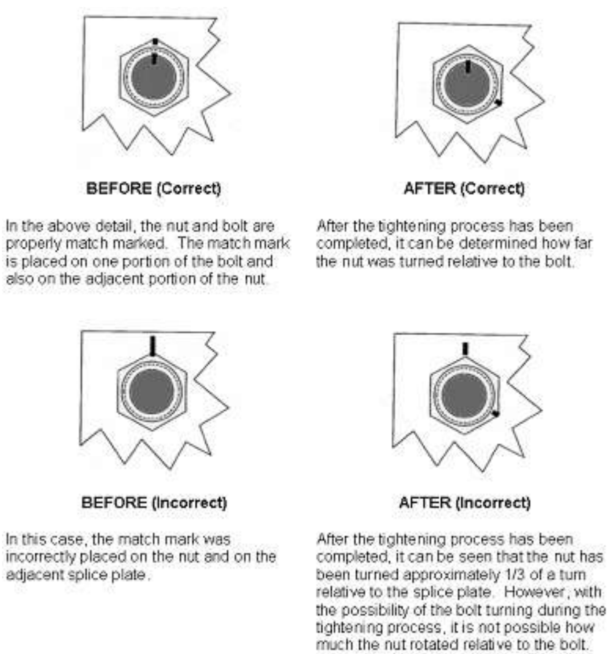


Figure 513.A - Match Marked Bolts

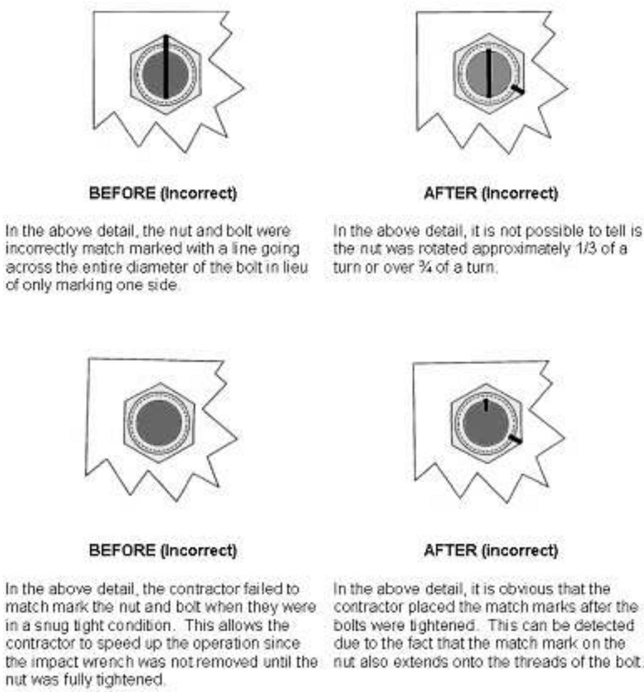


Figure 513.B - Match Marked Bolts

During final tightening, all of the specified rotation must be performed. Although the bolts may be over-tightened in the snug-tight condition by power wrenches, the full specified rotation is still required. A maximum tension is not specified and excessive tension is not cause for rejection.

The first complete joint on a project must be tested. If certain conditions are met, inspection of subsequently-completed joints by testing may be waived by the Engineer. These conditions are:

1. The Engineer has accepted the compactness of the joint.
2. The snug-tight operations have been witnessed and accepted by the Engineer.
3. Match-marking of the protruding end of the bolt and nut have been performed and indicates the required rotation. The Engineer must be satisfied that these conditions have been met completely before the joint will be considered accepted and testing waived.
4. Galvanized A 325 (A 325 M) bolts, and bolts that were installed prior to inserting drift pins and subsequently replaced, shall not be reused. All other A 325 (A 325 M) black (un-galvanized) bolts may be reused if

accepted by the Engineer. Re-tightening previously tightened bolts that may have been loosened by the tightening of adjacent bolts is not considered reuse.

Inspection of Bolted Joints

Even though a joint may appear to have all the bolts in the joint properly match marked and tightened, there is still the possibility that these bolts were not properly tightened. Therefore, it is necessary for the Contractor to provide a torque wrench and a recently calibrated tension testing devise.

The minimum torque required must be determined prior to inspecting the bolts with the torque wrench. This is accomplished with the aid of the tension testing devise. A bolt is first placed in the tension testing devise and tightened to the required tension as given by Table 513.20-2 in the CMS. The torque wrench is then used to determine how much torque is required to turn the nut on the bolt after the minimum tension has been achieved. When calibrating the torque wrench, the Engineer should hold his hand on the nut being tightened in order to detect movement or rotation of the nut on the bolt. The required torque is based on the average torque of three bolts.

The torque wrench should be calibrated at the beginning of each day it is used and for each diameter or length of bolt being tested. Also if the coating varies (i.e. galvanized bolts as opposed to un-coated bolts), the torque wrench should also be calibrated.

Torque wrenches must have the capacity of the maximum job inspection torque required for any bridge.

The Contractor applying the torque should perform the inspection only up to the job inspection torque.

The erector must furnish the Engineer with evidence that the manufacturer or a laboratory has checked the tension-testing device within one year.

Welding (513.21)

Welding requirements must be according to the current ANSI/AASHSTO/AWS "Bridge Welding Code" except as modified by Supplement 1011 and the Construction and Material Specifications.

No attachments, other than specified by the plans, shall be made by welding to any main structural members such as beams, girders, cross bracing, truss members, etc., unless accepted by the Office of Structural Engineering.

Approval of Welders

All welds must be performed by welders qualified for the specific welding method to be used, according to Supplement 1011. The Office of Material Management must approve all welders prior to any welding. A list of qualified welders is maintained by the Office of Materials Management. Welders must have been tested in the last five years.

Electrodes and Welding Procedures

Electrodes used to make all permanent welds to steel must be of the low hydrogen type and must be on the list of accepted electrodes maintained by the Office of Material Management.

In order to prevent moisture in the atmosphere from being absorbed by the electrodes (which can cause potential cracking of the weld), all stick electrodes must be purchased in a hermetically-sealed container or must be dried in an oven at 450 to 500° F (232 to 260° C) for two hours and stored in a suitable container that will maintain a temperature of not less than 250° F (121° C). After removal for use, stick electrodes exposed to the atmosphere for more than four hours for E70XX electrodes and two hours for E80XX electrodes must be re-dried at a temperature of 450 to 500° F (232 to 260° C) before use.

When electrodes have become wet, the coating on the electrode is altered. Drying the electrodes does not restore the electrode coating to the original manufactured condition. Therefore, electrodes that become wet shall not be used.

The welding procedure using shielded metal arc electrodes (stick welding) is the only pre-accepted procedure. If the Contractor proposes to use flux core arc welding (FCAW), submerged arc welding (SAW), or gas metal arc welding (GMAW), he must first have a welding procedure qualification test accepted and then submit a welding procedure specification for approval. Questions on welding procedure qualification tests and welding procedure specifications can be answered by the Office of Material Management's structural steel section.

Weather Restrictions

When the base metal is below the temperature listed in Table 513.A for the thickness of the material being welded, it must be preheated in such a manner that surfaces being welded are at or above the specified minimum temperature for a distance equal to the thickness of the part being welded but not less than 3 inches (76 mm), both laterally and in advance of the welding.

Thickness of Thickest Part at Point of Welding – Inches (mm)	Minimum Temperature	
	A709 70W	All Other Steel
To ¾ (19), incl.	50° F (10° C)	50° F (10° C)
Over ¾ to 1 ½ (19 to 38), incl.	125° F (50° C)	70° F (20° C)
Over 1 ½ to 2 ½ (38 63.5), incl.	175° F (80° C)	150° F (65° C)
Over 2 ½ (63.5)	225° F (110° C)	225° F (110° C)

Table 513.A – Minimum Preheat Interpass Temperatures

When the base metal temperature is below 32° F (0° C), the above specified should be preheated to minimum temperature of at least 70° F (20° C). Preheating is only necessary where the welding begins. Continued welding will make further preheating unnecessary. Welding shall not be done when the ambient temperature is below 0° F (-18° C).

Welding Inspection

The welding operations should be observed and complete welds inspected for conformance to the plans and shop drawings. Fillet welds must be measured with the use of a weld gage or other method that will show the length of the sides in contact with the steel. Deficient welds must be built up to the required size. Badly-shaped welds or welds containing defects such as cracks, pits, craters, and undercutting must be corrected to the satisfaction of the Engineer.

When radiographic examination of welds is required, the report and film must be submitted to the Office of Materials Management, Structural Steel Section, for review and approval. This must be done before any work is performed that would interfere with any necessary corrective work.

Arc Strikes

Occasionally during the welding operation, the electrode will come in contact with an area of steel that is not to be welded. This contact will result in a small burnt spot (or arc strike) in the steel. If not properly removed, an arc strike has the potential of propagating fatigue cracks.

Arc strikes located must be removed by grinding. They can result in unacceptable hard spots or small cracks. Therefore, after the arc strikes are removed, the Contractor must check every location where they occur where the steel is in tension. The Contractor must perform a magnetic-particle test on all arc strike in these locations to assure that no cracks are present. Hardness tests must also be run on all locations to assure that no unacceptable hard areas are present. Hardness values shall not exceed the higher of Rockwell C30 or the hardness value measured in the steel outside the location of the arc strike. If the above testing reveals unacceptable results, the flaw can be removed by grinding and the steel be retested to assure that the flaw has been completely removed.

Normally the Contractor is not equipped nor has the knowledge to perform the above test. Therefore, he will normally make arrangements for a private testing laboratory to perform the required testing.

Cleaning Of Welds

The finished weld must have all slag removed and be neutralized by vigorous wire brushing to remove any film that will affect the proper adherence of paint.

Stud Welding

Shear studs are short rods that have been welded to a piece of steel for the purpose of anchoring that steel to concrete. There are additional requirements to inspect the weld joining the shear stud to a piece of steel.

Qualified Stud Welder Operator

Prior to allowing any production welding, it is first necessary to assure that the stud welder operator is qualified. This is accomplished at the project site since there is no list of qualified stud weld operators.

To be qualified, it is necessary to successfully weld two studs of the same type and size that will be used during the production welding. The studs must be welded to a piece of steel that is similar to the production member in thickness and property or they may be welded to the production member.

The studs should be visually examined after they have been welded. If they were welded properly there should be weld metal completely around the base of the stud (360 degree flash).

In addition to a visual examination, the studs must be bent to an angle of approximately 30 degrees from their original axis. Bend the studs by either striking them with a hammer or bending the stud by use of a pipe.

If the visual examination does not reveal a 360-degree flash or if the weld fails when the studs are bent over, the Contractor must make corrections to his procedure and two more studs must be welded and tested. This should continue until two consecutive studs are tested and found to be satisfactory.

Qualifying the Stud Welding Procedure

Prior to production welding, it is necessary to qualify the stud welding procedure. This should be performed at the beginning of each day's shift, when welding has been interrupted for an hour or more, when attaching the welding cable to a different ground, when changing weld settings, when changing loops in the cable, or when 500 studs have been welded after testing.

The actual testing shall be the same as required for qualifying the stud welding operator.

Post Testing of Stud Welds

After the studs have been welded, it is necessary to test the studs to insure that they have been installed correctly. Test the studs by giving each one a light blow with a hammer. When the studs are tapped, they should emit a ringing sound. Any stud that does not emit a ringing sound should be bent approximately 15° from its original axis.

Perform a visual inspection in addition to tapping the studs with a hammer. Any stud that does not show a 360° flash may be repaired by the Contractor by fillet welding the missing flash. Any stud that the Contractor elects not to repair, or any stud that the Contractor has not repaired properly, must be bent to an angle of approximately 15° from its original axis.

Any stud that does not pass the bend test must be replaced. All studs that have been bent and have not failed should not be straightened.

Bearing Adjustment

When steel beams or girders are first landed, and before sole plates are fastened, bearings may be set approximately plumb. After all beams or girders between expansion joints are in place and the overall length has been checked, make temperature corrections in the plumbness of the bearings. The length of bridge from the fixed bearing and the deviation in temperature of the steel from 60° F(16° C) must be used in calculating the tilt to the bearings when rockers are used.

The coefficient of expansion to multiply with the length and temperature difference is 0.000006 (0.0000117). For example, for a two-span length of 160 feet (49 m) and at 40° F (4° C) for a difference of 20° F degrees (-7° C), the calculation is 160 x 20 x 0.000006 = .0192 feet, or 1/4 inch (49 x 11 x .0000117 = .0060 m or 6 mm) that the rocker should be inclined from the vertical toward the fixed bearing to compensate for the existing temperature.

The same factors must be used to determine the offset in sliding plate bearings.

Adjustments should be made on a cloudy day when a temperature differential in the steel is not caused by the sun's rays.

A final check of correct bearing adjustment must be made after the deck has been completed.

Elastomeric bearings cannot be adjusted for temperature as there is no way to keep them in a deformed shape. Due to this, if it is necessary to correct for temperature due to excessive deformation or racking of the bearings, the beams will have to be jacked up and the bearings reset when the temperature is close to 60° F.

Documentation Requirements - 513 Structural Steel Members

1. Check fabrication for compliance
    a. Pay in accordance with pay weight on IOC from the Office of Material Management
    b. TE-24 on file for Structural Members
2. Bolted Splices
    a. Insure contractor's compliance with approved erection procedure
    b. 50% of holes filled with drift pins and snug tight bolts (25% for each)
    c. Furnish calibration of torque wrenches and skidmore device
    d. Document that engineer inspected first completed joint and others as necessary
    e. Check no fewer than 10% of tightened bolts
3. Welding

a. Welding rods stored in a warm, dry area
b. Inspected for size
c. Document type of welding. (stick welding is pre-qualified all others require Central Office approval)
d. Verify and document welder's qualifications with approved welders list maintained by the Office of Materials Management

514 Field Painting of Structural Steel

Description (514.01)

In order to protect structural steel from corroding, it is necessary to apply a protective coating system. The coating system consists of three coats. On existing steel all three coats are applied in the field. On new steel, normally inorganic zinc primer is applied in the fabrication shop and the remaining two coats are applied in the field.

Quality Control (514.04)

Quality Control Specialist

When applying coating systems it is very important for the Contractor to constantly monitor the quality of the work. Due to his many duties and responsibilities, the foreman is not able to properly monitor the quality of the work. Therefore, the Contractor is required to assign one person the duties of a Quality Control Specialist (QCS). If there is no QCS on the project, the Contractor is not allowed to proceed with any production work.

This person must be formally trained as a QCS. Prior to allowing the QCS to begin working, the Engineer should confirm that the QCS appears on the approved list maintained by the Office of Construction Administration (OCA). This list can be viewed on their website.

The QCS is only to be involved in quality control work while production work is going on. He is not to be a foreman or a member of the Contractor's production staff. He is not allowed to abrasive blast, apply coating, recover spent abrasive, mix paint, run errands, set up or maintain the traffic control, run or work on the equipment, etc. It is also imperative that the QCS does not perform supervisory duties on the production staff. If the QCS is not performing his duties or is involved in any work other than quality control while production work is proceeding, the violation should be documented and remedied. It should then be determined based on the disqualification guidelines in the specification if the violation(s) warrants disqualification of the QCS. If the project staff feels that the criteria for disqualification have been met, all documentation of the violation(s) is then sent to the Office of Construction Administration for review. The QCS should be allowed to continue to work during this review process. If the Office of Construction Administration determines violations are substantiated, the QCS will be permanently disqualified. The Office of Construction Administration will inform the project staff of the disqualification and QCS should then be relieved of his duties.

The quality control specialist must be properly equipped with all the necessary testing equipment, and able to climb to all parts of the structural steel. He is to have the authority to stop the Contractor's work if necessary, and to inform the foreman of all work that does not meet the requirement of the specifications.

Quality Control Points

The purpose for the quality control points is to mandate points in the process where the product being produced can be inspected to help insure compliance with the specifications. It is important that the QCS signs off at all QCPs that the work being inspected has been checked and is in complete compliance with the specifications. This sign-off puts the accountability for quality on the QCS. Only after receiving the QCS sign off should the formal joint inspection begin.

Testing Equipment (514.05)

The testing equipment listed in the specification must always be available for use by the Inspector. If the equipment is not available or in good working order, all production work should be halted. For electric equipment to be in good working order they must have batteries and bulbs. The tables and visual standards must be legible. There must also be film or printing consumables available.

The list in the specification indicates the testing equipment that must be supplied by the contractor, but it in no way limits the means by which the inspector may inspect the work. This may include, but is not limited to, mirrors and larger lights. Note that magnification is not allowed to be used for the determination of SSPC-SP10 blast condition.

Work Limitations (514.06)

Abrasive blasting and painting is to be done between April 1, and October 31. The Contractor should plan his work to ensure that he is an acceptable stopping point on October 31. This date is not to be waived without concurrence from the Office of Construction Administration.

Temperature

Paint, except for inorganic zinc, must be applied when the temperature of the air within the enclosure, steel surface, or paint is 50° F (10° C) or higher and is expected to remain above 50° F (10° C) for the times noted in the table shown in 514.06.A. It should be noted that the times shown in the table are NOT recoat times. They simply dictate the required time a particular temperature must be maintained after the coating is applied. At lower temperatures the paint will not cure and in some cases the paint may not resume curing when the temperatures warm up. It becomes important to pay closer attention to the temperature in the early spring and the late fall. During the early spring and the late fall, the temperatures will be above 50° F (10° C) during the day, but the temperature will drop during the early evening hours before the paint has had enough time to properly cure.

The surface temperature of the steel should be taken in the area that is the coldest. This is not always the same on every structure (i.e. the fascia beam bottom flange). If you cannot tell where the coldest area is by running your hand over the steel, then it may be necessary to take readings in multiple areas.

For inorganic zinc, apply when the air, steel surface and paint is 40° F (4° C) or higher.

Paint must be applied when the temperature of the steel is at least 5° F (3° C) above the dew point. Applying paint to steel at temperatures below 5° F (3° C) above the dew point could result in condensation on the surface of the steel. The dew point is to be determined by using the psychrometer and the psychrometric tables. The psychrometer should be used in the area to be painted or blasted (i.e. in containment up near the beams). Note, if the barometric pressure is unknown when using the psychrometric tables, it is acceptable to assume a barometric pressure equal to 30 inches.

Abrasive blasting must be performed when the steel is at least 5° F (3°) above the dew point. This is due to the possibility of condensation. The Contractor will be required to reblast the steel if this requirement is not met.

Heated enclosures may be used to maintain the temperatures above the minimum specified temperatures. If combustion type heating units are used, the exhaust fumes must not be permitted in the enclosure, but should be vented away from the enclosure. If exhaust fumes are not properly vented, they can leave a deposit on the surface that could affect the ability of remaining coats of paint to properly bond to the steel or the previous coats of paint. These exhaust deposits could also contaminate the freshly applied paint.

A recording thermometer should be used to insure that the minimum temperature is maintained until the coating has cured. The thermometer should be placed close to the perimeter of the enclosure since this is the area subject to cooler temperatures. The paper graph generated by the recording thermometer should be copied and filed as part of the QCP documentation.

Pollution Control (514.08)

Special note should be made to address the handling storage and disposal of hazardous materials used during construction. Handling, storage and disposal of any volatile product is of particular concern. These would normally include thinners, reducers and solvents. Common types of volatile used in a painting operation may include methyl ethyl ketone (MEK), xylene and toluene based materials.

When these types of items are onsite it is important that the Contractor 1) submit MSDS sheets for each product 2) maintain a current inventory sheet as to the quantity of each product 3) properly label usable product and hazardous waste created by the use of these products 4) properly containerize and store these products and wastes so as to not create a health and safety hazard or exposure to the environment 5) waste containers must be managed in such a way that hazardous waste and non-hazardous waste are properly stored and kept separate.

Inspection Access (514.10)

Proper inspection cannot be accomplished unless the inspector has access to every surface to be painted.

To accomplish this, the Contractor is required to provide, erect, and move scaffolding and all other equipment necessary to provide the inspector access to closely inspect the work. On bridges with tall girders, placing scaffolding only under the girders is not adequate to provide proper access to the work. The inspector should not climb around on the structural steel to inspect the work. If the Contractor fails to provide proper access to inspect the work, he should not be allowed to continue since proper inspection cannot be performed.

All scaffolding of any width, whether it is supported by a wire rope, mounted on the back of a truck, or supported by any other means, that is at least 21 inches (533 mm) or more below the surface to be painted must have guard rail placed on all sides. It is not necessary for scaffolding that is less than 21 inches (533 mm) below the surface to be painted to have guardrail on the two sides bounded by the structural steel, but in this case the scaffolding must be at least 28 inches (711 mm) wide.

One row of guardrail is required to be placed around the scaffolding when it is at least 21 inches (533 mm) but less than 43 inches (1092 mm) below the surface to be painted. Two rows of guardrail are required when the scaffolding is placed 43 inches (1092 mm) or more below the surface to be painted.

Remember you should never utilize a means of inspection access that you do not foresee as being safe.

Job Site Visual Standards (514.11)

Prior to production blasting it is imperative that a test section be blasted and the job site visual standards be agreed upon and documented. A comparison to these standards will be utilized for the rest of the project to accept the surface preparation of the steel. The test section also allows the Contractor to adjust his grit size / blast pressure combination to maximize his production, while producing work that is within the specifications.

Note in the event of a dispute SSPC-VIS 1 will govern.

Surface Preparation (514.13)

One of the most important items of work is surface preparation. It is also the most labor intensive and expensive phase of the work.

Solvent Cleaning

Prior to abrasive blasting, areas that contain asphalt cement, oil, grease, or diesel fuel deposits must be solvent cleaned. It is not necessary for the Contractor to solvent clean the entire surface of the steel to be coated, but only those areas that contain asphalt cement, oil, grease, or diesel fuel deposits.

Solvent cleaning per SSPC-SP1 requires the removal of foreign material (other grease and oil) prior to solvent cleaning. This can be done by one or a combination of the following: wire brushes, abrade, scrape, or clean with solutions of appropriate cleaners followed by a fresh water rinse.

Make sure that all solvent brought on site are accompanied by a current MSDS for that product.

All solvent cleaning should be completed prior to the start of the abrasive blasting operation. If this is not accomplished, the abrasive blasting operation will not remove the asphalt cement, oil, grease, or diesel fuel deposits but drive them into the steel.

In order to remove all residual solvent, asphalt cement, oil, grease, or diesel fuel deposits after the solvent cleaning, all solvent-cleaned areas are to be washed with water at a pressure of at least 1,000 PSI (7 Mpa). In order to be effective, the nozzle must be held no further than 12 inches (300 mm) from the surface being washed.

Grinding Flange Edges

The specification require that bottom flange edges of all beams are to be rounded to a radius of 1/8 ± 1/16 inch. This includes both rolled beams and girders. It is impossible for an edge to be given a radius with one straight pass of a grinder. It requires multiple straight passes or the use rounding motion.

The radius is necessary to allow the application of the proper coating thickness. The sharp edge splits the spray of paint which results in only a thin coating of paint being deposited along that edge.

Abrasive Blasting

The prime coat contains zinc that protects the steel by reacting chemically with the surface of the steel. Therefore, it is important to remove all foreign material from the surface of the steel to allow the zinc particles to come in contact with the bare steel. It is also important to roughen up or produce a profile on the surface of the steel. The profile aids the coating in adhering to the surface of the steel.

Steel surfaces to be painted are to be abrasively blasted to a near white metal, SSPC-SP10. SSPC-SP10 is generically defined as white metal with an allowable 5% staining. This allowable staining is a discoloration. It does not have any noticeable thickness. It should be noted that SSPC-SP10 does not allow magnification for this determination. During inspection, pay special attention to areas that are more difficult to blast or areas that might be difficult to inspect.

These areas include under cross frames, around bolt heads and nuts, end dams, cross frames next to or close to back walls, and any other areas of limited access. After the steel is blasted, it must be maintained in that condition until it is painted. The backside of cross frame assemblies that are 3 inches (75 mm) or closer to backwalls may be commercial blast cleaned according to SSPC-SP6. SSPC-SP6 in generically defined as white metal with an allowable 33% staining. Again this staining does not have any noticeable thickness. It is not a residue or film.

The abrasive used in the field must be steel grit. The abrasive must be recycled to minimize the volume of waste material placed into landfills. The size or gradation of the grit is not specified, but must provide a profile of between 1.5 mils to 3.5 mils. G40 and G50 size grit are commonly used by Contractors for abrasive blasting in the field. The profile should be continuously monitored during the blasting operation since the size of the abrasive can be reduced due to being recycled, which can in turn reduce the size of the profile. The size of the profile can also be reduced if the air pressure at the blasting nozzle is reduced. The profile should be monitored by the use of extra-course replica tape and a spring micrometer. Make sure the replica tape is extra-course as this is the appropriate tape to measure our specified profile range of 1.5 mils to 3.5 mils. It is also necessary to account for the 2.0 mil adjustment required for the thickness of the replica tape. This adjustment can be subtracted from every reading or the micrometer can be zeroed to -2.0 mils which results in a direct reading being taken from the micrometer.

Some abrasives, when received by the Contractor, can be contaminated with oil. Therefore the abrasives should be checked to insure that they are free of oil. This check should be made by placing a small amount of abrasives in a jar with tap water. The abrasives and water should then be stirred or shook up. The top of the water should then be checked for signs of oil. If oil is detected, the abrasives should not be used.

Apply a prime coat to the steel that is blast cleaned in the field within 12 hours of the beginning of abrasive blasting. This requires that the time and location the blasting was started is accurately documented. This requirement is extended to 24 hours for shop blasted steel as it is a more controlled environment.

After abrasive blasting is completed, all abrasive and dust must be removed from the surface to be painted. Dust and abrasive must also to be removed from any adjacent painted surface that also includes any adjacent structure. Dust and abrasive should be removed as soon as possible to prevent rust staining of adjacent surfaces. Rust stains can be very difficult to remove.

Occasionally the compressed air used to propel the abrasive can become contaminated with oil or water from the compressor. This oil or water, if deposited on the surface of the steel to be painted, can be detrimental to the coating system. To prevent this problem, the quality control specialist must blow air from a nozzle for 30 seconds onto a white cloth or blotter held in a rigid frame. This testing must be done at the start of each shift, and at 4-hour intervals. If any oil, water, or other contaminates are present on the cloth or blotter, the blasting operation must be suspended until the problem is corrected. After the operation is corrected, and before the blasting operation is permitted to proceed, another test should be made to insure that the problem has been corrected.

Containment and Waste Disposal

The Contractor MUST comply with all Federal, State, and Local laws, rules, regulations and ordinances.

Due to the possibility of the existing coating containing lead or chromium, which are considered hazardous substances, the Contractor is required to erect an enclosure to completely surround the area where the existing coating will be removed. Not only should the enclosure be placed vertically around the sides of the blasting operation, it should also be placed on the ground under the blasting operation. In addition to containing potentially hazardous debris, the enclosure also prevents fugitive dust from escaping into the environment.

The enclosure must be constructed of materials that are free of tears, cuts, or holes to prevent dust and lead from escaping into the environment. Holes, cuts, or tears that do occur should be repaired immediately. The perimeter of the enclosure should also extend up between the beams to the bottom of the concrete deck. All seams should be fastened or lapped in a manner that insures a seal and does not allow any openings between the screens or materials of the enclosure. The area where workers enter and exit the enclosure should also be sealed.

In addition to placing an enclosure around the blasting operations, the Contractor must also place ground covers under all equipment. This ground cover must be placed under the equipment for its entire length, not just a portion of its length. If the ground is not properly covered, there is the possibility that it could become contaminated. These ground covers are also intended to reduce the impact of equipment leaking oil, fuel or hydraulic fluid.

All abrasive blasting debris is to be picked up at the end of the day and must be stored in steel containers that have the lids locked. Normally the Contractor will store the debris in 55-gallon drums with lids. The lids have a ring around them that are capable of being locked. Normally, the Contractor will lock the lids by means of a bolt. This method is acceptable as long as there is a nut placed on the bolt and tightened by the use of a wrench. Many times all of the lids are not properly locked at the end of the day. They should be checked at the end of the day or the first thing in the morning to insure that the Contractor is locking the lids at the end of the day. The use of tie wire, zip ties or duct tape are not acceptable as a means for locking the lids. If the Contractor chooses to use a large roll-off container to store abrasive blasting debris, the requirement for providing a means for locking the lid of the containers must still be enforced.

Within the first week of production blasting the Contractor must sample the abrasive blasting debris and have it sent out for testing. If the samples come back with lead, chromium, cadmium or arsenic contents higher than the limits shown in the table in Section 514.13.D.1 of the Construction and Materials Specifications, the abrasive blasting debris is considered hazardous. Note that parts per million for these items is equivalent to mg/L. The Contractor must dispose of the abrasive blasting debris within 60 days after it is generated. The 60 days starts as soon as the Contractor generates the debris, not after the completion of the abrasive blasting operation. If the debris remains on the project site over 90 days, the State and the Contractor could be cited by the Environmental Protection Agency. On smaller structures the debris can be removed in one operation. However, on larger structures where the abrasive blasting operation extends over a period of several months, it will be necessary to make several trips in order to comply with the 60-day limit. If after the 60 days, the Contractor has not properly disposed of the debris, all abrasive blasting and painting of the structural steel on the project must immediately cease until the waste is properly disposed of. At this time, the Department must cease processing all pay estimates and send notification to the Contractor’s surety that he has breached the contract.

Handling (514.15)

Note that the date of manufacture does not show up on all container labels. Some manufacturers show a code number in lieu of a date of manufacture. You will need to call the manufacturer and give them this code number and they will in turn give you the date of manufacture.

Mixing and Thinning (514.16)

Prior to applying paint it is necessary to thoroughly mix all the ingredients together. This is to be accomplished with a high shear mixer. Paddle mixers are not allowed due to the fact that they will not do an adequate job of mixing the different ingredients together. Using compressed air to cause a stream of bubbles in the paint and paint shakers also is not allowed since it will not properly mix the ingredients.

During the application of the primer, it is important that it be continuously mixed. If it is not continuously mixed, the zinc particles in the primer will settle to the bottom of the container and will not be applied to the structural steel. To insure that the mixing process is not interrupted, it is also important that the mixer be an automated mixer, and not a hand held mixer.

Normally thinning of the paint is not required. However if the Contractor elects to thin the paint, it is important that it be thinned with the correct type and volume of thinner. In order to insure that the Contractor is using the proper type of thinner, only use thinner recommended and supplied by the paint manufacturer. The maximum rate of thinner is to be as per the manufacture’s printed instructions. If the paint manufacturer’s printed instructions do not list a maximum proportion of thinner, the manufacturer should be contacted to obtain their recommendation. Note that the manufacturer may recommend different thinners based on humidity or temperature. All thinning should be done in the presence of the Engineer or Inspector.

In an effort to insure that the thinner the Contractor is using is the thinner recommended and supplied by the manufacture, only use thinner that has been supplied to the project in unopened containers with the labels intact. The amount of thinner used from each container should be monitored to prevent refilling of the container with other types of thinner.

The above restrictions do not apply to the thinners that the Contractor uses to clean his equipment. Be aware that methyl ethyl ketone (MEK) is sometimes used as both a reducer and a cleaner.

Coating Application (514.17)

Paint is only to be applied by the use of brush or spray equipment. Rollers can cause bubbling and other irregularities in the coating and are only permitted where cross frame angles are located within 2 inches (50 mm) of the bottom flanges, where end cross frames are within 6 inches (150 mm) of the backwall, the bottom of the bottom flanges around bearings that are less than 6 inches (150 mm) in height and other areas as determined by the Engineer.

Application Approval

The specification states that each spray operator shall demonstrate to the Engineer or Inspector the ability to apply the paint as specified. This allows the project staff to remove a painter that is unable or unwilling to produce work within the specification requirements.

Surface Cleanliness

All surfaces to be painted shall be free of dust, dirt and moisture. If these or other contaminants are left on the surface they can cause multiple types of defects including adhesion failures and accelerated rusting. Simply blowing down with compressed air is not always sufficient. It is sometimes necessary to wipe the surface down, use a vacuum system, or some other means to adequately prepare the surface to receive paint. This cleanliness requirement includes both the blasted steel surface as well as previously applied coats of paint.

Time Limitations

Apply a prime coat to steel that is blast cleaned in the field within 12 hours of the beginning of abrasive blasting. This requires that the time and location the blasting was started is accurately documented. This requirement is extended to 24 hours for shop blasted steel as it is a more controlled environment.

The maximum elapsed time allowed between the application of any portion of the prime coat and the application of the intermediate coat is 30 days. The maximum elapsed time allowed between the application of any portion of the intermediate coat and the application of the finish coat is 13 days. The maximum recoat times shall also not exceed the maximum recommended by the manufacture. Extending the time beyond that mentioned above could adversely affect the bond of the coating. No additional time is allowed due to weather related delays. Any coat that has been allowed to cure more than the above allotted time is to be removed and the steel reblasted to SP10.

Enclosure

During spray application of the paint the operation is to be totally enclosed. The enclosure must be identical to the enclosure used during the abrasive blasting operation. Failure to properly utilize the enclosure could result in overspray damage to private property including automobiles, the ground, public property, vegetation, streams, lakes, etc. The enclosure is not required if the paint is being applied by brush or roller.

Quality of the Coating

Each coat of paint is to be applied as a continuous film of uniform thickness. It is to be free of all defects such as holidays, runs, sags, etc.

Many time holidays in the form of pinholes are difficult to detect. The best way to view pinholes is with the aid of a flashlight. The flashlight should be placed to shine a beam of light parallel to the painted surface. If pinholes are present in the top coat, they will appear as small white specs about the size of the end of a needle. If they are present in the intermediate coat they will appear as small dark specs.

Note that if you are painting over an inorganic zinc primer you should play close attention to pinholes appearing in the intermediate coat. The inorganic zinc has an inherent characteristic of “outgassing” due to its porous nature. The released gas pushes up through the intermediate coat and causes the pinholes. To avoid the majority of pinholes in this situation the Contractor should properly apply one, or multiple, mist coats of intermediate paint prior to the remaining full application.

Repairing pinholes can be very difficult. Applying another coat of paint over the pinholes will only result in the pinhole reflecting through the additional coat of paint. It is the Contractor’s responsibility to repair the pinholes. The best way to correct pinholes is by removing the coating at least down to the prime coat of paint. If the prime coat is not removed, measurements should be taken to insure that the required minimum thickness of prime paint is still present. If the Contractor elects to attempt to leave the prime coat, he will probably remove the topcoats with sand paper. If a large area needs to be repaired, it will probably be more prudent for the Contractor to abrasively blast the coating down to bare metal and reapply it.

Runs and sags are normally prevalent around bolts and areas of limited access. This is sometimes due to the fact the Contractor tries to paint these areas using a spray gun only (i.e. without the use of a brush). These defects should be corrected after each coat is applied. If not the defect will just translate into the next coat and the repair will be more extensive.

Removing Fins, Tears, or Slivers (514.18)

This item is paid for by the man hour. The quantity of man hours eligible for payment are not to include the superintendent or the QCS, but only the personnel actually performing the work.

Caulking (514.19)

All gaps greater than 1/8 inch need to be caulked. Normally caulking is used to seal gaps around the perimeter of adjacent steel plates and angles. This void is normally caused by rust forming between the plates or angles and forcing them apart to the extent that it is not possible to seal the void with paint.

Caulking materials appear the qualified product list (QPL) maintained by the Office of Material Management (OMM).

Dry Film Thickness (514.20)

Prior to measuring coating thickness it is necessary to determine the effect of the blasted surface of the steel on the paint gage. Due to the fact that the steel has received a profile of between 1.5 to 3.5 mils (40 to 90 µm), this profile will cause the paint gage to read high. To compensate for this additional height it will first be necessary to take a reading on the blasted surface immediately prior to applying the prime coat. Preferably three or more readings should be taken and averaged out. This average reading should then be subtracted from all paint film thickness readings. As an alternate to subtracting the thickness attributed to the surface profile from the paint film thickness, recalibrating the paint gage to read 0 mils on the blasted steel is also acceptable.

It is very important to determine the coating thickness by taking the average thickness in the manner specified in the specifications. This involves taking 5 spot readings for each type of member (i.e. webs, bottom of top flange, top of bottom flange, bottom of bottom flange, crossframes, stiffeners, etc.) over an area of one hundred square feet. A spot reading is comprised of the average of three closely-spaced individual readings. The average reading for this one hundred square feet area may be used to represent up to one thousand square feet of painted steel surface. The number of one hundred square feet areas to be measured is determined by the area of steel painted. Form CA-S1 should be used to tabulate the results.

The spot averages are to be within 80% to 150% of specified minimum and maximum thicknesses, respectively. The area averages must fall within the actual specified minimum and maximum values.

There are provisions in the specification for addressing areas with a film thickness greater than the maximum specified. If a Contractor chooses to have the certified testing done as described in the specification make sure the preparation of the panels mirrors the actual field installation of the paint in question. This includes paint thickness, multiple or mist coats as well as type and quantity of thinner used.

Final Inspection (514.21)

The purpose of the final inspection is to ensure the quality of the surface preparation and coating thickness are witnessed by a third party. This third party could be the project engineer, area engineer or other District personnel.

The Engineer will select the locations and take the dry film thickness (DFT) readings. The Contractor will then perform the removals. The 9 square inches required by the specification is the minimum "clean" area of steel. It normally takes about a 6 inch by 6 inch square to get 9 square inches of "clean" steel. The contractor will normally use Methylene Chloride and MEK as a chemical stripper/solvent. These chemicals are both corrosive and the safety precautions found on the MSDS sheets and manufacturer's literature need to be followed.

A common stripping procedure is as follows:

1. Spray surface with stripper
2. Wait 5-10 minutes to allow the stripper to work
3. Use a scraper or putty knife to remove top coat and intermediate coat. It may take multiple applications of the stripper to accomplish this.
4. Spray the exposed primer with stripper and allow time to work
5. Scrape off majority of primer with being careful not to damage the substrate.
6. Repeatedly apply solvent or stripper and rub with a rag until steel substrate is clean.

This process takes about 15 minutes for each stripped area, if you are working on other areas while the stripper is allowed to sit. It is imperative that the Engineer observe the removal process as the stripper and a scraper can remove lead paint as well as the new paint.

The engineer will evaluate the stripped area and document his findings on Form CA-S-18.

If the surface in the stripped area is not found to be in complete conformance with the contract documents additional locations may be tested. Note the Contractor is only paid for stripped areas that are found to be in conformance with the contract documents.

Once all the required tests have been performed and the progressive project data has been reviewed the Engineer should complete Form CA-S-19,

Destructive test locations shall be repaired per 514.22

Repair Procedures (514.22)

If it is necessary to make repairs, the intent of the specifications is that the repair be made in a manner that the repaired areas will blend in with the surrounding area so that it is not evident that a repair was made.

If the area to be repaired does not cover a large area, abrasively blasting the surface may not be advisable due to the fact that it will damage the surrounding coating that does not need to be removed. In lieu of using abrasives, the engineer may allow alternate methods of preparing the surface. This might include the use of power tools with abrasive bits or hand tools. However, whatever method is used, it is still necessary to prepare the surface in a manner that will give a surface profile of between 1.5 to 3.5 mils (40 to 90 μm).

In order to produce a smooth transition, it is necessary to feather the adjacent coatings. This cannot be accomplished through the use of abrasives. The new coat of paint should only applied to the same coat as was feathered, i.e. the prime coat should only be applied to the feathered prime coat, the intermediate coat should only be applied to the feathered intermediate coat, and the finish coat should only be applied to the feathered finish coat. Applying the finish coat to existing finish coat that has not been feathered or in any other way abraded will result in finish with a dull, frosty appearance in lieu of a bright glossy finish.

Since surface preparation is being performed and paint is being applied, all work limitation and documentation requirements are in effect.

Documentation Requirements - 514 Painting of Structural Steel

1. Document Dry Film Paint Thicknesses on Form CA-S-2
2. The Quality Control Specialist must fill out and sign form CA-S-7 prior to all Quality Control Point inspections
3. Document the Quality Control Specialist's information and the Job Site Visual Standards on Form CA-S-11
4. Document Solvent Cleaning (QCP#1) and Grinding of Flange Edges (QCP#2) on Form CA-S-12
5. Document Abrasive Blasting (QCP#3) on Form CA-S-13
6. Document Waste Disposal (QCP#4) on Form CA-S-14
7. Document Prime Coat Application (QCP#5) on Form CA-S-15
8. Document Grinding Fins and Slivers (QCP#6) and Caulking (QCP#9) on Form CA-S-16
9. Document Intermediate Coat Application (QCP#8) or Finish Coat Application (QCP#10) on Form CA-S-17
10. Document the Final Destructive Tests on Form CA-S-18
11. Document the Final Acceptance (QCP#11) on Form CA-S-19

515 Prestressed Concrete Members

Field Inspection

When prestressed members arrive on the site they should be inspected for damage and quality of fabrication as thoroughly as time and conditions permit. Inspection should include areas that look like they were patched and cracking. Fine cracking at the ends of the beams, whether box beams or I beams, is not unusual and will tighten under erection and dead loading of the members. Cracking in other locations is not usual or acceptable. Any prestressed members should have a certification document (TE-24) with the shipment. Do not accept un-documented members. Notify the District Engineer of Tests or the Office of Materials Management cement and concrete inspection section.

Erection components for prestressed box beam members (i.e. tie rods, splices, nuts, etc) will be considered included under and covered by the fabricator's certification document. For I-beams the embedded components will be covered under the fabricator's certification document. If galvanized crossframes are used for prestressed I-beams, the prestressed fabricator will probably not supply a certification document; they will be provided by a steel fabricator with separate certification documentation (TE-24).

Damage

The nature and extent of any damage which may have occurred because of loading, transit, or unloading should be noted and reported to the Director along with the identifying piece mark or member. If corrective work is obvious, the Contractor should be advised immediately so that the responsible party will be notified and correction can be performed in the most advantageous location. For help on possible corrections, patching repairs, etc. contact the Cement and Concrete section of the Office of Material Management.

Special care should be taken when cutting shipping tendons which are sometimes necessary to allow transport of AASHTO Type 4 modified beams. The location of these tendons as well as the sequence and means of removal are determined by the fabricator. The relaxation in the beam that occurs when the tendons are "released" can induce stress cracking in the beam.

Storage

Prestressed members, if stored on the site, will be supported off the ground on blocking at their design bearing points. Assure that members are stored in a true vertical position.

Sweep

Specified tolerances for sweep or horizontal curvature of a prestressed box beam or I -beam are listed in the Office of Structural Engineering's standard drawing for I beams. I-beams are 1/8 inch every 10 feet with a maximum of 1 inch.

Box beam tolerances are 3/8 inch maximum for box beams 40 feet or less; ½ inch maximum for box beams 40 to 60 feet; and 5/8 inch maximum for box beams greater than 60 feet.

Camber

Camber is based on the design plan requirements and are generally within a tolerance of 1-inch maximum. Box beams also have a maximum side-by-side differential camber of 1/2 inch. The side-by-side differential may override the 1-inch maximum camber tolerance for an individual member. The side by side differential camber is not checked by Laboratory prestressed inspectors as the beams are not installed in their final position.

Phased construction can cause unique problems with camber. Camber is time dependent: as the members get older they will gain camber. If all beams are manufactured for a bridge at the same time but only half are shipped for an initial phase of construction there is a good probability that the second phase beams will have a higher camber than the first-phase beams. For box and I beam structures this additional camber may be able to be absorbed by thinning the haunch or variable depth deck. Field loading of the field-installed beams to reduce the camber is a method some Contractor’s have used to deal with the camber growth. The best methods are for the Contractor to one, order the beams early enough so none of the beams are erected and loaded before they are six months or older, or two, coordinate their and the fabricator’s schedules so that the fabricated age of the beams at time of erection is within 30 days of each other for all phases.

Box Beam Grout Installation

Keyways should be grouted after erection of box beams. Generally, plastic rope or jute is installed into the bottom of the keyway to block the grout from flowing out. Assure that the installation is done properly. Box beam keys have failed because of improper jute installation. Grout should meet the material requirements of the Office of Structural Engineering's standard box beam drawings. OMM has an approved list of grout materials. The manufacturer’s mixing instructions are required and it should be assured that the grout is properly mixed; vibrated into the joints; cured; and sampled for testing. Grouting should not be allowed if there is construction traffic or erection still going on. The grout can be cracked by the vibration and deflection movements and make the keyways worthless. The design of the structure counts on the grout in the shear keys.

Do not allow traffic on the deck before the grout has obtained the required strength. This includes construction traffic.

Galvanized Cross Frame Installation

Galvanized cross frame for prestressed I-beams should not be tightened down until the adjacent beams are set. While bolts are high-strength the connections are not friction type. The bolts should be well tightened but the turn of the nut method of installation is not required. If there are crossframe alignment problems do not allow I-beam field drilling until the Contractor has a method approved by the Engineer to determine where the reinforcing and the prestressing strands are and how to avoid drilling into it.

Do not allow the Contractor to elongate or enlarge slots in the steel cross frames.

Shop Coatings

Box beams should have had a silane treatment on the exterior beams or they also may be delivered with a colored coating (generally epoxy urethane) on the exterior members. I-beams do not require a silane sealer and will generally not be coated at the fabricator's yard

Required Documents

Records must be on file for the following items:

1. Shop-inspected prestressed members will be documented by a TE-24
2. Approval of each kind of paint/sealer field applied when specified
3. Bearing seat inspection
4. Elastomeric bearings accepted
5. An approved erection procedure when required by the specifications
6. The fabricator's approved or Contractor certified shop drawings

Check of Bearing Seats

A final check must be made of the elevation of bearing seats on the piers and abutments before erection of prestressed members is scheduled to begin. If bearing seats are found that need correction, it must be performed in the manner and to the tolerances described in the section entitled "Bearing Seats" in the 511 section of this manual.

Erection

The erection plan submitted by the Contractor should be reviewed with his representative in charge. The purpose of this review is to ensure that ODOT's interpretation of the plan is concurrent with the Contractor's intended course of action. Methods and equipment approved for erection of members must be used in handling during transportation to the bridge site and unloading.

The erection drawings, usually the “E” sheets of the approved shop drawings, will typically be used to locate the members on the bridge and may give special instructions for the erector to follow.

Deviations from the submitted erection procedure will not be permitted. If the erector proposes deviations in procedure that appear to have merit, they must be referred to the Engineer(s) who stamp is on the submitted plan for review and sign off prior to use.

Required Erection Procedures

The specifications require that the Contractor submit an erection procedure for structural concrete members. If there is railroad involvement, the PE stamped plan needs to be reviewed and approved by the appropriate railroad. Otherwise the plan must have two PE stamps. For additional requirements refer to CMS 501.05.

Typical Erection Procedures Items

Typical items that should be included in the submitted erection procedure are:

1. A drawing of the complete framing plan showing each girder or beam section by “piece mark” and numbered in the order of proposed erection. A print of the erection sheet of the shop drawings may be used.
2. The number of pieces and load capacity of erection equipment to be used and method of lifting members.
3. Methods and details for supporting the first beams or girders at the abutments and piers in each unit.
4. Crossframe installation

Use Erection Checklist Form CA-S-20

Documentation Requirements - 515 Prestressed Concrete Bridge Members

1. Document condition of beams on delivery
2. Beams set according to approved erection procedure.
3. Grout mixed per manufacturer directions.
4. Make samples for testing
5. Document vertical offset in adjacent beams, per standard drawing PSBD-1-93

516 Expansion & Contraction Joints, Joint Sealers and Bearing Devices

The allowable procedures for the repair of metalized and galvanized surfaces are described in CMS 711.02, which refers you to ASTM-A-780. The use of a galvanizing spray with zinc dust is not allowed. These unacceptable products go by the name of Spray Galv or Cold Galv. The main problem with these products is that they don't provide the galvanic protection that we require. Most of them are made out of tin and lead in lieu of zinc. When zinc and carbon steel are in contact the zinc sacrifices itself to protect the steel. Conversely when tin or lead are in contact with the steel the steel actually sacrifices itself for the tin and lead.

Expansion and Contraction Joints (516.05)

It is important that the gap that is set between the armor plates of the joint is consistent along the entire length of the joint. The gap determined for the joint must also be adjusted for temperature. The joint manufacturer will normally supply a table to help calculate this adjustment. This is especially true for the more complex joints.

The characteristics of the structure (skew, crown, super elevation, sidewalk) can lead to a complicated installation of the joints. The Contractor should not be allowed to weld anything to the joint or the reinforcing steel.

Joints like strip seal, compression and modular which incorporate a rubber seal into their design need to have the seals installed per the manufacturer's written instructions. They should utilize tools that will not cut or puncture the seals. It is not acceptable to elongate or stretch the seal in order to make it narrow enough to fit in the joint gap.

There are listings on the Qualified Product List (QPL) for items covered in CMS 705.11 and 705.03. This list is maintained by the Office of Materials Management.

Joint Sealers (516.06)

In addition to the protection required in the specification, the Contractor must ensure that the sawcut is not exposed to traffic prior to receiving the sealer without protecting the sawcut. If the sawcuts are not protected rocks, or other hard debris, can get lodged in the top of the sawcut and when this is driven over the rock will spall the edges of the sawcut.

Bearing Devices (516.07)

Note that if the beam seats are low and you are utilizing elastomeric bearings it is not acceptable to use steel shims under the bearing to make up the elevation difference. Contact the Office of Structural Engineering for guidance.

Many of the bearings we use have beveled load plates. This is done to account for the grade in the in the structure. Make sure the beveled bearings are oriented correctly. Sometime it is difficult to tell just by looking at the bearing as the difference may only be a ¼”. If the short side of the bearing is not already marked by the fabricator, measure the bearing and marked it in the field.

When galvanized bearings are welded to the embedded load plates on prestressed beams the weld area must be repaired according to CMS 516.03

There is a listing on the Qualified Product List (QPL) for items covered in CMS 711.21. This list is maintained by the Office of Materials Management.

Documentation Requirements - 516 Expansion & Contraction Joints, Joint Sealers, and Bearing Devices

1. Expansion material placed and measured in appropriate unit
2. Joint Sealer
    a. Area to be sealed clean and dry
    b. Document depth of poured joints
    c. Note types of bond breakers and bonding agents used
    d. Sealers applied per manufacturer’s directions
    e. Measure and pay in appropriate unit
3. Bearing devices
    a. Sliding plates lubricated with flake graphite
    b. Lead sheets and bearing pads set to line and level
    c. Rockers and rollers set vertical at 60° F (16° C) or adjusted for temperature
    d. Anchor bolts placed to proper depth and alignment and set in mortar
    e. Record quantity(s) and pay in appropriate unit(s)

517 Railings

The anchor bolts should be cast into the structure versus drilled and grouted into place after concrete placement. This will alleviate drilling into the epoxy coated reinforcing steel. Hold anchor bolts in place with the use of a template. When the anchors are cast into the concrete the threads should be protected from getting filled with concrete paste.

Failure to release falsework prior to installing railings could cause the railings to deform as the structure experiences the additional dead load deflections associated with the falsework release.

Any preformed PVC fillers or paint coatings used should be listed on the Qualified Product Lists (QPL) for items 711.28 and 708 respectively.

Steel and Iron Railings (517.05)

If field welding is required on galvanized members, repairs should be made similar to CMS 516.03. Cold Galv or Spray Galv should not be used.

Documentation Requirements - 517 Railings

1. Railing
    a. Shop Drawings per CMS 501.04
    b. Test Reports per CMS 501.06
    c. Measure and record length of railing per CMS 517.07
    d. Ensure the fabricator has the required SF prequalification
2. Deep Beam railing
    a. When forming for deck, check bolt layout
    b. Check height
    c. Measure per 517.07

518 Drainage of Structures

Unless otherwise shown in the contract drawings, the Contractor is to provide a minimum of 18” of porous backfill behind the abutments, wing walls, and retaining walls. The placement width is normally erratic due to construction means and methods. You need to make sure that the minimum width is maintained. If the underdrain is at the footing elevation the 18” dimension is measured from the edge of the footing, not the back face of the wall.

Porous backfill is No. 57 size gradation. It must be compacted. Even rounded No. 57 gravel is not self compacting.

It is imperative that the filter fabric used to encapsulate the porous backfill is continuous and properly overlapped. This fabric gets flipped back and forth as the Contractor alternates from porous backfill to Type B granular. This working of the fabric can cause misplacement or tearing. A non-continuous or misplaced layer of filter fabric allows the fine material to “pipe” into the porous backfill which can lead to settlement and lack of drainage.

All drains should be free flowing. They need to have a positive fall. Special care needs to be taken when the drainage hangers, anchors or pipes are attached to a structure prior to final dead load deflection. As the bridge deflects the grade of the pipes may be affected and cause stagnant or pooling sections of pipe.

Documentation Requirements - 518 Drainage of Structures

1. Porous Backfill
    a. Type of stone used
    b. Pay in appropriate unit
2. Pipe
    a. Metal pipe per 707
    b. Plastic pipe per 707.33, 707.45
    c. Laid to grade, outletted per plan
    d. Measure each type per linear foot
3. Scuppers, structural steel, cast steel
    a. Verify prequalification of fabricator to level SF
    b. Shop Drawings per 501.04
    c. Test Reports per 501.06

519 Patching of Concrete Structures

Removal of Disintegrated Concrete (519.03)

It is essential that all of the unsound concrete be removed. The use of a hammer will be necessary to sound tight areas and the use of a sounding chain will speed up deck sounding. The practice of removing additional sound concrete after the deteriorated material is removed helps us ensure that we have a stable surface to pour against.

Special attention should be paid to the locations at the edges of the patch where the reinforcing steel enters the sound concrete. In many cases during the removal process the reinforcing steel is vibrated or impacted which causes cracking around the reinforcing steel penetration point. If this occurs, the Contractor will have to "chase" the cracks to make sure all fractured concrete is removed.

Placing, Finishing, and Curing of Concrete (519.06)

It is very difficult to get proper consolidation of a vertical patch. It may be necessary for the Contractor to utilize a "pencil" vibrator and/or externally vibrate the forms to assist in consolidation. In all cases the Contractor is responsible to provide a well consolidated patch.

Make sure that all form ties and form attachment points in both the new concrete as well as the existing sound concrete are repaired after formwork removal.

Documentation Requirements - 519 Patching Concrete Structures

1. Document that patch a depth of 4 inches (10 cm) in achieved for horizontal patches, and a depth of 3 inches (8 cm) for vertical patches as per 519.03
2. Patch area thoroughly cleaned with water, compressed air, etc.
3. Concrete testing data and batch tickets for Class S concrete
4. Exposed area of patch given a rubbed finish and cured as per 511.17
5. Sound patches before final acceptance
6. Measure length and width for pay

520 Pneumatically Placed Mortar

Description (520.01)

This item of work consists of repairing concrete structures by spraying the area to be repaired with dry premixed sand and cement that is blended with water in a mixing nozzle. The pneumatically placed mortar is then finished and cured. This type of procedure is often referred to generically as "shotcrete" by the industry.

Surface Preparation

Prior to placement of pneumatically placed concrete, the area to be repaired is to be properly prepared. All soft, loose, and disintegrated concrete plus an additional depth of 1/4 inch (6 mm) of sound concrete must be removed. Failure to remove soft, loose, and disintegrated concrete will adversely affect the bond of the mortar and shorten the life of the repair.

The edges or shoulders of the repair areas must be square or slightly undercut. If this is not accomplished, the mortar placed at the edges of the repaired area will be feathered. These feathered areas will not have adequate strength and will scale off.

After all concrete has been removed from the repair area, all dowels and expansion hooks placed, all steel areas restored, and not more than 24 hours prior to placement of mortar, the area to be repaired must be abrasive blast cleaned. The abrasive blast cleaning must be done to remove spalls, latence, and any other foreign material that might be detrimental to achieving a bond with the pneumatically placed mortar. The Contractor should select an abrasive blast method that will control or minimize the amount of fugitive escaping into the atmosphere. Suitable blast methods may include high-pressure water blasting with abrasives in the water, abrasive blasting with containment, or vacuum abrasive blasting.

Unless otherwise specified, the Contractor shall wet the area to be repaired with water for at least 2 hours prior to placing the mortar. The area must be kept wet until the mortar is placed. At the time of placement of the mortar, all free water must be removed.

Reinforcing (520.04)

All existing reinforcing steel bars must have a minimum cover of 1 inch (25 mm). If the existing location of the reinforcing bars would result in less than 1 inch (25 mm) of cover, they are to be driven back into recesses cut into the existing concrete to achieve that coverage. If this is not practical due to the large number of reinforcing bars, the coverage must be obtained by modifying the finished surface. Not that if the reinforcing steel is epoxy coated care should be taken to minimize the damage to the existing coating.

Where the depth of the patch exceeds 1 ½ inch (38 mm) in addition to any existing reinforcing steel, wire fabric is also required. Where the depth of the patch exceeds 4 inches (100 mm) a layer of fabric is to be placed for each 4 inches (100 mm) thickness of patch or fraction thereof.

Preconstruction Testing (520.09)

Due to past experiences with pneumatically placed mortar that was improperly placed and prematurely failed, each operator must demonstrate their ability to construct a sound, durable repair prior to being allowing to place mortar on the structure. This is accomplished by gunning the mortar onto a test panel. The mortar on this test panel is then tested for strength and examined for hollow areas, sand pockets, and bond to the reinforcement. The cores taken for compressive strength samples can not contain any reinforcing steel. If the reinforcing steel spacing is too tight to retrieve a non-reinforced core, it may be necessary to construct a portion of the test panel without reinforcing. The easiest means to examine the test panel for mixing and consolidation issues is to pull a core at the intersection of the reinforcing steel or to simply saw the test panel in half. It is important to look at the cross section of the reinforcing steel, as the backside of the reinforcing steel is usually the most suspect area. The test panel should be water cured for 7 days and handled in the same manner as a cylinder. The sample should not be cored for at least 7 days and the cores should also be handled in the same manner as a cylinder.

Curing

After the mortar is placed, it must be cured. This curing shall consist of covering the patch with burlap or cotton mats and keeping them wet for 7 days. If it is not practicable to use mats, the surface of the patch must be kept wet by sprinkling the surface with water for 7 days. If it is determined that the above methods are impracticable due to isolated areas being inaccessible, they must be cured according to the requirements of 511.17, Method (b).

Inspection and Testing

After the curing of the patched areas has been completed and before they are accepted, they must be sounded and every 200 sq. ft. (20 m²) cored. All unsound areas, or areas that exhibit cracking, must be removed and replaced. The cores must be inspected for hollow areas, sand pockets, voids around reinforcing steel, and lack of bond to the underlying concrete. The cores are also to be tested for compressive strength. Any defective patches as determined by the cores must also be removed and replaced at the Contractor’s expense.

Documentation Requirements - 520 Pneumatically Placed Mortar

1. Unsound concrete removed plus 1/4 inch (1 cm)
2. 1 inch (2.5 cm) minimum clearance to reinforcing
3. 1 layer wire fabric for each 4 inches (10 cm) of patch depth
    a. Reinforcing fabric lapped 6 inches (15 cm) minimum
4. Surface cleaned by water or sand blast
5. Mortar composed of 3 parts sand to 1 part cement
6. Mortar placed as dry as possible
    a. No one coat greater that 1 inch (2.5 cm) in thickness
7. Wet burlap cure- 7-day minimum, or membrane cured with Engineer approval
8. Inspect and test per 520.11
    a. Sounding
    b. Core taken for every 200 square feet of repair
9. Measure patch area and pay by the square foot (square meter)

522 Sectional Corrugated Metal Arch Structures

Description (522.01)

This work consists of the sectional corrugated metal arch as described in 522. Excavation and concrete for structures are covered in 503 and 511 respectively.

Quality Control

Quality of the galvanizing should be examined. Some added thickness occurs at the bolt holes and may appear to be stripping when the bolts are installed. Peeling as evidenced by separation of galvanizing around bolts or near the edges of the plates when pried with a knife or impacted with a hammer is cause for rejection.

Corrugated metal arch structure plates, high strength bolts, ribs, and anchor angles should only be accepted from certified suppliers listed on the Office of Materials Management's web site. The shipments should be accompanied by a certification document (TE-24).

Assembly

Certified suppliers must provide assembly and installation procedures with the shipment. Shipments that do not include the assembly and installation procedures should not be accepted.

Documentation Requirements - 522 Corrugated Metal Structures on Footings

1. Be sure bearing angle or channel is at proper alignment and grade
2. Bolts with required nuts and washers placed
3. Backfill per 603.10
4. Measure length for pay

523 Dynamic Load Test

Description (523.01)

Except for H-piles driven to bedrock, bearing piles are driven to a required blow count to ensure that they have the ultimate bearing value shown on the plans. However, the relationship between the blow count and ultimate bearing value is dependent on many variables, including the pile type, material and length; pile hammer energy and performance; and soil properties. The simple formulas used in the past considered only one of these variables – pile hammer energy. Dynamic load testing measures the energy going into the pile from the hammer and accounts for many of the different variables to estimate the capacity of the pile with each blow of the pile hammer. Therefore, the Department uses dynamic load testing to determine the required blow count for the ultimate bearing value on every project that includes driving bearing piles.

The methods used in dynamic load testing (also called PDA testing after the name of the equipment - Pile Driving Analyzer) were developed in Ohio beginning in the 1960's. The Ohio Department of Transportation was involved early in its development, and began to apply the results of the research in their construction projects around 1968. Since 2002, the Department has used dynamic load testing for all pile driving (except piles driven to bedrock) and discontinued the use of the simple formula used previously.

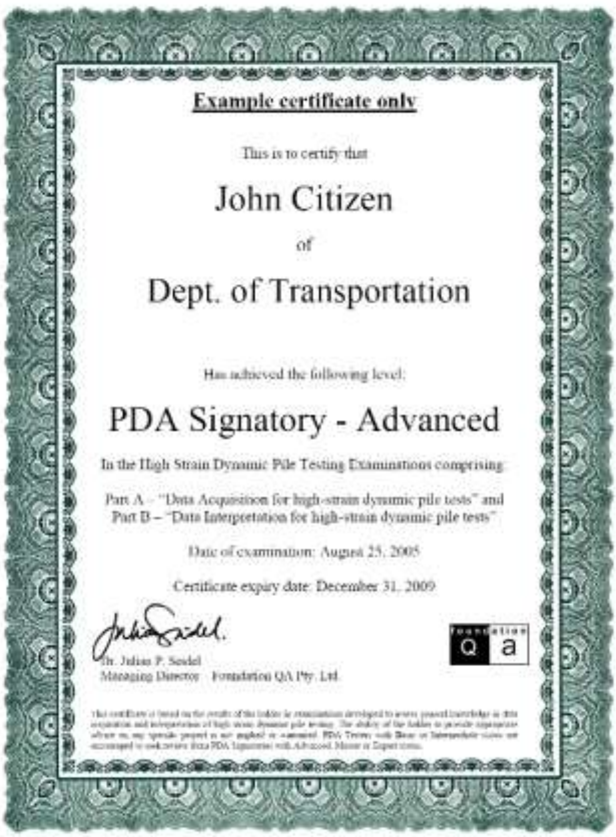
General (523.02)

Each dynamic load test consists of dynamically testing a minimum of two piles. If there are piles of different size, shape, or capacity, it will be necessary to perform dynamic load testing for each of these differing sizes, shapes, or capacities and there should be additional pay items in the contract to reimburse the Contractor for performing these tests.

Dynamic load testing is accomplished by connecting two sets of gages to a pile. One set of gages measures the strain in the pile at the top. The other gage measures the acceleration of the pile at the top. These gauges are then connected to a computer called a Pile Driving Analyzer (PDA). The PDA converts the measured strain and acceleration into force and velocity. By analyzing the way the force and velocity change with time, the PDA estimates the pile capacity for each blow of the pile hammer. After the PDA is connected to the pile, the Contractor begins driving the pile.

Once the dynamic load testing begins, the driving of the pile continues until the required ultimate bearing capacity is achieved. At this time the blow count, blows/ft (blows/meter), is noted. It is also necessary to record the stroke height of the hammer. In addition to performing dynamic load testing, the Contractor is also required to perform a Case Pile Wave Analysis Program (CAPWAP) on one of the piles tested. The CAPWAP analysis is a more refined method of analysis that takes into account the properties of the different soil layers. The results of the dynamic load testing and CAPWAP are then used to establish the driving criteria required to achieve the ultimate bearing capacity for the remaining piles represented by this test. Immediately after the dynamic load test has been completed the personnel performing the testing must inform the Engineer of the required driving criteria. This will include both the blow count and the stroke height. Within 48 hours after completing the test, the Engineer is to be given a written report with the results.

Prior to allowing the test to begin, the personnel performing the test must supply the Engineer with a copy of a certificate showing that they have a current Advanced PDA Certification in the PDCA/FQA Examination for high-strain dynamic load testing. An example is shown below.


Example certificate only

This is to certify that

John Citizen

of

Dept. of Transportation

Has achieved the following level:

PDA Signatory - Advanced

In the High Strain Dynamic Pile Testing Examinations comprising

Part A – "Data Acquisition for high-strain dynamic pile tests" and
Part B – "Data Interpretation for high-strain dynamic pile tests"

Date of examination: August 25, 2005

Certificate expiry date: December 31, 2009

Dr. Julian P. Seidel
Managing Director · Foundation QA Pty. Ltd

Example PDA Testing Certificate

If the designers suspect that the capacity of the pile could increase or decrease after it has been in the ground for some period of time, an additional test called a restrike could be specified. If a restrike is specified, the plans specify the minimum elapsed time from when the pile was driven until the time of the restrike. This waiting period could be anywhere from a day to a week of more. Each restrike test consists of dynamically testing a minimum of two piles, the same as the dynamic load test.

When a restrike is specified it is very important that, during the waiting period, the pile to be tested should not be disturbed in any manner until the PDA is properly hooked up and the test is ready to begin. This is due to the fact that disturbing the pile can cause the pile to partially or completely lose any change in capacity it has acquired during the waiting period.

The pile hammer used to restrike must be the same hammer used to perform the initial dynamic load test on the pile and must be thoroughly warmed up by applying at least 20 blows to another pile other than the pile being tested immediately before the test begins. When the test begins the first few blows are used to determine the capacity of the pile. Any results obtained after the first few blows have occurred will result in the pile returning to the capacity it had obtained prior to the required waiting period.

Documentation Requirements - 523 Dynamic Load Test

1. File a copy of the field technician's certificate showing that they have a current Advanced PDA Certification in the PDCA/FQA Examination for high-strain dynamic load testing.
2. Document the initial driving criteria received immediately after the dynamic load test is performed.
3. Receive a formal report within 48 hours including the information required in 523.04 A-D. Submit a copy of the report to the Office of Structural Engineering.

524 Drilled Shafts

Specification Changes

In the April 18, 2008, version of Supplemental Specification 800, 524.04.C was modified to allow casing to be rotated, tapped, or vibrated in order to remove it.

Description (524.01)

Drilled shafts are reinforced concrete columns that, for the most part, are built below the surface of the ground. They are designed to provide a foundation for structures and carry the entire load of the structure. They are sometimes referred to in the field as caissons.

Contractor's Installation Plan (524.03)

Prior to installing drilled shafts, the Contractor is required to submit a written installation plan to the Engineer. This plan should be closely reviewed for conformance with the specifications. Among other things, the plan should describe how the Contractor is proposing to excavate the hole and place the concrete.

If a permanent casing is specified, the casing should be installed to the prescribed depth before excavation begins. In some cases the Contractor may not have the required equipment to completely install the casing prior to excavation. If the Contractor is not able to completely install the casing prior to excavation, he is allowed to either excavate the material within the casing or excavate a pilot hole ahead of the casing. If the Contractor proposes to excavate the material within the casing to aid in the installation, it is important that the excavation does not proceed beyond the casing.

If the Contractor is proposing to either pump or tremie the concrete under water while utilizing a temporary casing, his plan should describe how he proposes to remove the casing while not disconnecting or breaking apart the tremie or pump hose. In order to ensure that the end of the pump or tremie hose is always embedded into the concrete his plan should also detail how he proposes to monitor the level of the top of the concrete and the bottom of the pump or tremie hose. If the Contractor does not include these provisions in his plan and encounters water in the field, he should be required to stop and resubmit a plan containing the necessary information. He should not be allowed to proceed with “verbal approval” as it is too difficult to document what was said versus what may have been intended.

Drilled shaft installation can be very complicated due to the fact that a large amount of work is being performed in an area with very little access. The plan should be very detailed and site specific. A generic or “canned” plan should not be accepted.

Types of Drilled Shafts

There are basically two types of drilled shafts:

1. End bearing
2. Friction.

End bearing drilled shafts derive most of their capacity through end bearing on a hard substrate such as bedrock.

Friction type drilled shafts derive most of their capacity through a combination skin friction with the soil along the perimeter of the drilled shaft, and end bearing on the substrate immediately below the drilled shaft. In order to obtain the required skin friction, it is important that the integrity of the soil be maintained during the drilling operation and prior to placing the concrete.

Methods of Excavation (524.04)

There are several different methods used to stabilize the sides of the excavation during the construction of the drilled shaft. Factors that impact the method chosen are types of soil, the elevation of the ground water, types of drilled shafts, plan requirements and equipment utilized by the Contractor.

Dry Construction Method

The dry construction method is accomplished by excavating the hole without the use of steel casing. The sides and bottom of the excavation should remain stable and should not experience any caving, sloughing, or swelling. It should be possible to visually inspect the excavation prior to the placement of concrete.

The excavation should be done in a relatively dry condition with very little ground water present. The flow rate of any water that might enter the excavation should be such that the elevation does not change by more than 12 inches (300 mm) per hour. At the time of concrete placement, there should be no more than 3 inches (75 mm) of water in the bottom of the excavation. Both the flow rate test and the amount water in the bottom of the hole should be documented.

Wet Construction Method

The wet construction method should be used at sites with or without casing and where a dry excavation cannot be maintained. This method consists of using either water or slurry to contain or prevent the seepage of ground water into the drilled shaft. With the use of slurry, this method may be used in lieu of a temporary casing to maintain the stability of the perimeter of the hole while advancing the hole to its final elevation.

If this method is used to excavate a hole for a friction-type drilled shaft, it is important to not compromise the integrity of the soil along the perimeter of the drilled shaft through the seepage of ground water. It is not only important to prevent the seepage of ground water into the excavation after it is completed, but it is also important to prevent ground water from seeping into the excavation during the drilling process. To prevent this, it will be necessary to continually pump either water or slurry into the hole during the drilling operation to maintain an elevation slightly higher than the elevation of the static water table.

Either a tremie or a concrete pump will be used to place the concrete when the wet construction method is used.

Unless waived by the Engineer, it is required for the Contractor to use a temporary surface casing to prevent soil at the top of the casing from sloughing and falling into the excavation. This casing should never be shorter than 10 feet (3.0 m) long. The temporary casing also aids in the proper alignment and positioning of the drilled shaft.

Temporary Casing Construction Method

Temporary casing may be used at sites where the dry excavation cannot be maintained and the Contractor elects not to use slurry.

It is important that the Contractor begins removal of the temporary casing while the concrete remains workable. Failure to remove the casing could result in a drilled shaft that is not capable of supporting the design load.

When the casing is being withdrawn, there is the possibility that fluid that might be trapped behind the casing will contaminate the concrete. To prevent this, it is important to maintain a head of concrete at least 5 foot (1.5 meter) in the casing. This minimum head may need to be increased to counteract any ground head that might be in the casing at the time it is withdrawn. Casing should be removed by pulling at a slow uniform rate. However, if the casing gets stuck, the Contractor may rotate, vibrate, or tap the casing to facilitate extraction. Rotating the casing may twist the reinforcing cage, so only rotate the casing enough to get it unstuck.

Friction Type Drilled Shafts (524.05)

Friction-type drilled shafts derive much of their capacity through the adhesion of the concrete with the surrounding soil. If the Contractor elects to use a temporary steel casing and fails to remove it, or he fails to protect the integrity of the soil adjacent to the drilled shaft, much of the capacity of the drilled shaft could be lost.

When drilled shafts extend below the top of the water table it is important that the water or slurry fluid inside the shaft excavation be maintained higher than the top elevation of the water table at all times. To accomplish this, it is not only important for the Contractor to add water or slurry fluid after the excavation is completed, but it is also important for him to add water or slurry fluid during the drilling operation. If this is not done, the surrounding ground water will begin entering the excavation and eroding the soil. This will result in the capacity of the drilled shaft being reduced.

The dry construction method can be used in construction of friction-type drilled shafts. It should be used when the bottom of the drilled shaft is above the water table and the excavation can be made without the sides or bottom of the excavation experiencing any caving, sloughing, or swelling. If the dry construction method results in the sidewall becoming softened or swelling, the Contractor shall over ream the sidewall to sound material.

If the Contractor elects to use slurry, a delay in placing the concrete could result in the sidewalls degrading due to slurry cake buildup. Any slurry cake buildup shall be corrected by reaming the sidewalls to sound material.

If a temporary casing is not used, and concrete is not placed the same day that the excavation is completed, the excavation shall be re-drilled 6 inches (150 mm) larger in diameter immediately prior to the placement of the concrete.

Casings (524.06)

If a temporary casing is used, it should be smooth and free of dried concrete and other foreign materials that might contaminate the fresh concrete. While the strength and thickness of the steel casing is not specified, it should be strong enough to withstand handling, installation and extraction stresses as well as the pressures exerted on it by the fresh concrete and the surrounding earth.

The outside diameter of the casing should be at least equal to the plan diameter of the drilled shaft. Many times the Contractor will elect to use a casing larger than the specified casing. Oversized casings are acceptable; however, all additional costs associated with the oversized casings should be borne by the Contractor.

Normally the diameter of the bedrock socket will be less than the diameter of the remainder of the drilled shaft. When the diameter of the bedrock socket is the same as the remainder of the drilled shaft, the diameter of the drilled shaft may need to be increased to permit the excavation of the bedrock socket. Again, increasing the diameter of the drilled shaft should be done at no additional cost to the State.

Slurry (524.07)

One potential method of excavating a hole through unstable or caving soils is through the use of slurry. The slurry should be added to the excavation during the drilling process, replacing the material that is being removed. This is accomplished by mixing the slurry with the material to be removed. The combination of slurry and soil is then pumped from the hole while clean slurry is added. The slurry that was pumped from the hole is then cleaned of foreign material and then replaced back into the hole. This process is continued until the original soil has been removed.

There are two different types of materials used to produce slurries. One type of material produces mineral slurry and the other type of material produces polymer slurry.

If the Contractor elects to use polymer slurry, he must first demonstrate the slurry's ability to prevent caving of the hole. If the slurry is not capable of stabilizing the perimeter of the hole while the hole is being excavated, it should not be allowed. This should be accomplished by the use of a separate trial hole. This trial hole should not be one of the production shafts and no separate payment should be made for the trial hole. The trial hole should be the same size and diameter as the largest production drilled shaft except the depth of the hole need not be more than 40 feet (12 meters). The slurry used in the trial hole should be the same as that used in the production shafts.

Reinforcing Steel for Drilled Shafts (524.09)

Reinforcing should be placed just prior to concrete placement. It should be placed as one continuous cage. If a casing is not used, care should be taken when lowering the reinforcing steel cage into the shaft that it does not drag down the face of the shaft and compromise the integrity of the exposed soil surface.

Spacing devices, commonly referred to as “donuts”, need to be installed at quarter points around the shaft to ensure that the required concrete cover is obtained. On the bottom of the shaft the Contractor can use plastic “shoes” to keep the reinforcing cage at the proper elevation. These shoes are normally 6 inches (152 mm) to 8 inches (203 mm) tall and about as big around as a pop can. In the past mortar blocks were wired to end of the longitudinal steel to accomplish this task, but they were unstable and the cage often “fell off” the blocks.

Concrete for Drilled Shafts (524.10)

The concrete used in the drilled shaft is a modified Class S. In order to aid the consolidation of the concrete without vibration it is necessary to increase the slump to 6 inches (150 mm) plus or minus 1 inch (25 mm). If the concrete is placed using a tremie, the slump should be increased to 8 inches (200 mm) plus or minus 1 inch (25 mm). Since the maximum water to cement ratio of the Class S concrete remains at .44, it will be necessary to achieve the additional slump through the use of a super-plasticizer.

If the Contractor is using the wet method or placing concrete under water or slurry, increase the cement content by 10 percent and place the concrete by either tremie or concrete pump.

If a temporary casing is used, it should be removed slowly and carefully. As the casing is removed, concrete that has been previously placed will fill the void left by the casing causing the top level of the concrete in the excavation to lower. As the level of the concrete drops, the concrete will tend to pull down on the reinforcing steel. If the casing is removed too quickly, the downward force of the concrete on the reinforcing steel will cause the reinforcing steel to be displaced.

Tremie (524.12)

A tremie may be used to place concrete in a wet hole. If concrete is placed in a wet hole it is important that the concrete not be placed into moving water. If concrete is placed into moving water, the water will have a tendency to wash the cement off of the sand and aggregate. To prevent moving water in the excavation, the level of water or slurry in the excavation must be equal to or higher than the level of the ground water.

The tremie must not contain aluminum parts that will come into contact with the concrete. In order that the concrete can pass freely through the tremie the minimum diameter of the tremie shall be at least 10 inches (250 mm). It is also important that the tremie be clean, smooth, and free of built-up concrete and other foreign material.

Prior to placing the tremie tube into the water, it is important to plug the end of the tremie to prevent the intrusion of water into the tremie. The tremie can be placed into the excavation after the plug is in place . After the tremie is filled with concrete, it should be raised up no more than one diameter of the tube. This allows the plug to be displaced and the concrete to begin flowing into the excavation. If the tremie is not plugged the tube will fill with water. When the concrete is dropped through the tube it would drop through the water that would tend to separate the cement from the sand and gravel.

During the placement of the concrete, the end of the tremie should always be at least 10 feet (3 meters) below the surface of the concrete to prevent the water from contaminating the fresh concrete. It is important to devise a method to determine elevation of the top of the concrete and the bottom of the tremie since the concrete will be under water and not visible. This method should be determined and agreed upon with the Contractor prior to the delivery of the concrete to the project.

In order to prevent air voids in the concrete when a tremie or pump is used, place the concrete in one continuous operation. If the Contractor is allowed to break apart the tremie tube or pump hose to facilitate the removal of temporary casing, the tremie tube or pump hose could get air voids in them that will be forced down into the drilled shaft concrete. If the end of the tremie is pulled out of the concrete prior to completely placing all the concrete the drilled shaft will contain concrete that will be contaminated by water. As a result the drilled shaft may not have the required strength and should be considered defective.

After the concrete placement has been completed, there will be a layer of concrete at the top of the drilled shaft, called “laitance,” that has been contaminated with water. This concrete should be removed either by overfilling the drilled shaft and causing the contaminated concrete to flow out of the drilled shaft or by shoveling off the concrete. If the contaminated concrete is shoveled off, the Contractor must place additional concrete to replace the concrete that was shoveled off.

Pumped Concrete (524.13)

A pump may be used to place concrete in a wet hole. If concrete is placed in a wet hole it is important that the concrete not be placed into moving water. If concrete is placed into moving water, the water will have a tendency to wash the cement off of the sand and aggregate. To prevent moving water in the excavation, the level of water or slurry in the excavation shall be equal to or higher than the level of the ground water.

Due to the adverse reaction of concrete with aluminum, the pump must not contain aluminum parts that will come into contact with the concrete.

In order to allow the concrete to pass freely through the pump, the minimum diameter of the pump pipe must be at least 4 inches (100 mm).

During the pumping operation the pipe used to convey the concrete to the bottom of the drilled shaft must be anchored to the steel casing or other suitable stationary object to prevent the pipe from undulating. Otherwise, the tendency of the pipe to undulate could cause it to pull out of the concrete that was previously placed.

In order to lubricate the pump equipment, grout should be first pumped through the hose prior to pumping the concrete. The grout should not be placed in the drilled shaft. This process does not need to be repeated as long as the process is continuous.

Prior to placing the pump pipe into the water, it is important to plug the end of the pipe to prevent the intrusion of water into the pipe. After the plug is in place, the pipe can be placed into the excavation. When the pipe is filled with concrete, the pressure of the concrete will dislodge the plug. If the pipe is not plugged and the concrete drops through the water, the water would separate the cement from the sand and aggregate.

During the placement of the concrete, the end of the pump pipe should always be at least 10 feet (3 meters) below the surface of the concrete to prevent the water from contaminating the fresh concrete. It is important to devise a method to determine elevation of the top of the concrete and the bottom of the pipe since the concrete will be under water and not visible. This method should be determined and agreed upon with the Contractor prior to the delivery of the concrete to the project.

In order to prevent air voids in the concrete when a tremie or pump is used, place the concrete in one continuous operation. If the Contractor is allowed to break apart the tremie tube or pump hose to facilitate the removal of temporary casing, the tremie tube or pump hose could get air voids in them that will be forced down into the drilled shaft concrete.

If the end of the pipe is pulled out of the concrete prior to completely placing all the concrete, the drilled shaft will contain concrete that will be contaminated by water. As a result the drilled shaft may not have the required strength and should be considered defective.

After the concrete placement has been completed, there will be a layer of concrete at the top of the drilled shaft, called “laitance,” that has been contaminated with water. This concrete should be removed either by overfilling the drilled shaft and causing the contaminated concrete to flow out of the drilled shaft or by shoveling off the concrete. If the contaminated concrete is shoveled off, the Contractor must place additional concrete to replace the concrete that was removed.

Inspection Records (524.15)

It is the Contractor's responsibility to provide the Engineer with all the necessary labor and equipment to obtain measurements of the drilled shaft. Since it is not possible to obtain these measurements after the concrete is placed, it is necessary to obtain these measurements prior to placing concrete.

Due to the risks involved, at no time should the Engineer ever go down into a drilled shaft for inspection or any other purpose.

A copy of form CA-S-1 should be filled put and submitted to the Office of Structural Engineering.

Method of Measurement (524.16)

The pay length of the drilled shaft is the required accepted length measured along the axis of the shaft. It should be measured from the required bottom of the shaft to the proposed top plan elevation. Any over excavation below the required bottom of the shaft should not be measured for payment.

Drilled shafts that extend into bedrock should be divided into two sections. The lower section is the length of the drilled shaft that extends into the bedrock or the bedrock socket. The upper section is the length of drilled shaft above the bedrock. If the top elevation of the bedrock is lower than indicated on the plans, the additional upper section or length of drilled shaft above bedrock should be measurement for payment. The Contractor should not be paid for any over excavation of the bedrock unless he is ordered to do so by the Engineer.

Documentation Requirements - 524 Drilled Shafts

1. Review Contractor installation plan
2. Holes accurately located to line and spacing
3. Documentation of flow rate of ground water into shaft to validate Dry Construction Method
4. Fill out form CA-S-1
5. Document drilling method- dry, wet, temporary casing, or permanent casing
6. Slurry use per 524.07
7. Shaft excavation clean on bottom
8. Reinforcing steel cleaned
9. Placement of reinforcing steel, center alignment with spacers, clearances, plumbness, etc.
10. Note concrete placement method- Pump, Tremie, or free fall. (524.10-524.13)
11. Notify Engineer when unexpected obstructions are encountered
12. Measure and pay per 524.16 & 524.17

526 Approach Slabs

Description (526.01)

An approach slab is designed to function as a bridge deck spanning the distance from the bridge abutment to beginning of the roadway pavement. As a result, it is designed and constructed similar to a bridge deck.

Materials (526.02)

The concrete used to construct the approach is the same class as the bridge deck and should be placed using the same specifications as the bridge deck concrete. If the project does not identify the class of concrete used for the superstructure, or if the deck is composed of prestressed box beams with an asphalt-wearing surface, Class S concrete should be used.

Setting Grades

It is important that the approach slab be constructed parallel to the surface of the bridge deck to provide a smooth ride from the approach pavement to the bridge deck. To accommodate the actual dead load deflection of the deck, which may vary from the anticipated dead load deflection, the approach slabs should not be placed until after the deck has been placed. The final grade of the approach slab can then be established by using a string line. One end of the string line should be secured at a distance of about 10 feet (3 meters) back on the deck and stretched over the proposed approach slab with the other end attached to a grade stake marked with the proposed pavement grade. The final grade of the approach slab can then be determined.

Dimensions

The contract plans will show the length of the approach slab. All other details are dictated by Standard Drawing AS-1-81. It will show the reinforcing and joint requirements as well as slab thickness and haunch details.

Documentation Requirements - 526 Approach slabs

1. Length, width, and depth of forms
2. Porous backfill exposed at abutment
3. Number of bars and clearance maintained on reinforcing steel. Tied per 526.03
4. Dowel bars if used
5. Surface finish

6. Amount of curing compound used
7. Measure length and width for pay

Face of deck or beams painted with primer prior to placing approach slab

600 Incidentals

603 Pipe Culverts, Sewers, and Drains

Description (603.01)

The types of pipe are specified in accordance with their application and intended usage. For a brief description of typical applications see section 603.02. For a more detailed description, see Ohio Department of Transportation's (ODOT) Drainage Design Manual and the plans.

Materials (603.02)

Type A Conduits

Type A conduits are sealed culvert cross drains under pavements, paved shoulders, and embankments. These culvert cross drains are used to convey water from one side of the roadway to the other. These culverts can be either smooth lined or corrugated. Type A conduits are under pavement and open at both ends.

Type B Conduits

Type B conduits are storm sewers under pavements, paved shoulders, and commercial or industrial drives. Storm sewers are used to convey water from one manhole or a catch basin to the other. Storm sewers are always smooth lined. Type B conduits have one or both ends closed with a drainage structure.

Type C Conduits

Type C conduits are storm sewers not under pavements or paved shoulders and commercial or industrial drives. Like the Type B conduits these conduits are connected to a manhole or catch basin and are always smooth lined. Type C conduits have one or both ends closed with a drainage structure.

Type D Conduits

Type D conduits are culverts placed under residential driveways or bikeways. These conduits can be either smooth lined or corrugated.

Type E Conduits

Type E conduits are farm drain headers in or outside the right-of -way or used for ditch elimination beyond the paved shoulder. These conduits can be either smooth lined or corrugated.

Type F Conduits

Type F conduits are other miscellaneous pipe where a butt joint or a short length jointed pipe would be undesirable. Outlets for underdrain or farm drains, house drain connections, pull box drains, or for steep portions of a median outlet under an embankment are examples of Type F applications. These conduits can be either smooth lined or corrugated.

Soil and Granular Embankment

The soil and granular embankment requirements are listed in CMS 203.02R. Recycled asphalt is not allowed for use as bedding and backfill material. If there is any doubt about the suitability of the proposed soil or granular embankment, send a sample to the district laboratory for classification.

Structural Backfill Type 1, 2 and 3

The Structural Backfill material requirements are listed in CMS 703.11. Type 1 is an Item 304 material without the fracture count requirement. Type 2 is a sand material. The Type 1 and 2 materials are allowed for all bedding and backfill operations. The Type 3 is an open-graded No.57 or No.67 material and is allowed to control severe ground water problems only.

Low Strength Mortar Backfill (LSM)

In some cases, the plans designate the use of LSM as bedding and/or backfill material. The requirements for LSM can be found in CMS 613. There are three Types of mixes. Type 1 mix is a mixture of cement, fly ash, sand, and water. The Type 2 mixture substitutes an entrained air additive for the fly ash. The Type 3 mixture is a mixture of fly ash and water. All three mixes may be used, or an alternative mix submitted for approval by the Contractor may be used if the plans do not call out a mix. The alternate mixes shall meet the criteria in CMS 613. Changes in the material type or amount or sand gradation are allowed, as long as the final mix has the required strength, fills the voids, and sets up.

Material Provisions (603.04)

General

All pipes, including plant inspected and certified materials are inspected for dimensions and condition after being delivered to the project. Where the dimensions fail to comply with the specified tolerances, or where the pipe includes defects described herein or in the specifications, the pipe is not approved for placement on the project.

Acceptance

Concrete pipe and thermoplastic pipe are accepted under the TE-24 system. Under the TE-24 system, the pipes are randomly inspected by an ODOT Inspector at the plant. But not all the pipe pieces are inspected at the plant.

Metal pipe are accepted under the TE-215 certification program. Under this certification program, the pipe is not inspected at the plant. The material is delivered with a certification card.

For further detail on the Certification Program contact the District Testing Engineer or refer to Materials Managements Sampling and Testing Program Manual.

Rejection and Checking of Pipe

All pipe should be inspected prior to the incorporation into the work. All pipe should be randomly checked for minimum diameters, spans, heights, or dimensions shown in the plans.

Any pipe may be rejected at any time whether approved under the TE-24 system, the certification program, or any other program. This would include material damaged during shipment or placement.

Examples for Rejections

The following is a list of reasons to reject the pipe in the field. Reference is made to the current edition of the Materials Managements Sampling and Testing Program Manual.

Non-Reinforced Concrete Pipe

1. Fractures or cracks passing through the wall or joints.
2. Minor flaws such as a single crack not exceeding 2 inches (51 mm) length at either end of a pipe, or a single fracture or spall in the joints not exceeding 3 inches (76 mm) around the circumference of the pipe or 2 inches (51 mm) in length into the joint, are not to be considered cause for rejection unless these defects exist in more than 5% of the entire shipment.
3. Defects that indicate imperfect mixing and/or molding. (Honeycombed or open texture).
4. Cracks sufficient to impair the strength, durability, or serviceability of the pipe. Any crack passing through the wall would be sufficient to impair the strength of the pipe because it lacks the reinforcing to resist loading.
5. Damaged ends or manufacturer’s defects that would prevent making a satisfactory joint.

Reinforced Concrete Pipe

1. Fracture or cracks passing through the wall, except for a single end crack that does not exceed the depth of the joint.

2. Defects that indicate imperfect mixing and/or molding. (Honeycombed or open texture).
3. Exposed reinforcing steel or reinforcing steel without minimum cover, except for spacers and vertical longitudinal wires in the bell and spigot of the pipe joint.
4. Damaged ends or a manufacture defect that would prevent making a satisfactory joint.

Precast Reinforced Concrete Box, 3-sided Flat Top or Arch Sections

1. Accuracy of the span or rise dimensions with internal dimensions varying by more than 1 % or 1½ inches (38mm), whichever is less.
2. Haunch dimensions cannot vary by more than 3/4 inches (19mm) from plan.
3. Wall thickness cannot be less than 1/4 inches (6mm) of the plan dimension.
4. Fractures or cracks greater than 0.01 inches (0.25mm) passing through the slab or walls.
5. Defects that indicate imperfections in proportioning, mixing, or forming.
6. Unsound concrete or spalls can be determined by sounding or by visual inspection. Areas extending completely through the wall or surface area with more than 1 square foot (0.1 square meters) of unsound concrete or spalls are cause for rejection. Smaller areas can be repaired (after inspection) with material meeting the requirements of 705.21 and on an approved list.
7. Honeycomb areas more than 2 square feet (0.2 square meters) or any honeycombing which extends more than one half through the wall thickness. Honeycombing less than 2 square feet (0.2 square meters) can be repaired by grout rubbing.
8. Patching or repairs not authorized by the Department.
9. Exposed reinforcing steel or reinforcing steel lacking minimum cover.
10. Damaged ends or manufactures defects that would prevent making a satisfactory joint.

Vitrified Clay Pipe

1. Fractures or cracks passing through the barrel or socket. A single crack at the spigot end of the pipe not exceeding 75 % of the depth of the socket, or a single fracture in the socket not exceeding 3 inches (76 mm) around the circumference or 2 inches (51 mm) lengthwise may be permitted.
2. Chips or fractures on the interior of the pipe exceeding 2 inches (51 mm) in length, 1 inch (25 mm) in width, and a depth of more than 1/4 of the thickness of the shell.
3. Cracks sufficient to impair the strength, durability, or serviceability of the pipe.
4. Any crack passing through the wall of the pipe would be sufficient to impair the strength of the pipe because it lacks the reinforcing to resist loading.

5. ***Thermo Plastic Pipe (Includes All Polyethylene and Polyvinyl Chloride Pipe)***

6. Any cuts, punctures, cracks, or separations in the interior or exterior of the pipe.
7. Deviation from true shape (usually out of round by more than 2% of the diameter) or deviation from straight centerline.
8. Any damaged ends or manufacturing defects that would prevent the sealing of the joints.
9. Non-uniform color or texture.

Metal Pipe (Includes All Steel and Aluminum Pipe)

1. Any cuts, punctures, cracks, or separations in the interior or exterior of the pipe.
2. Uneven laps.
3. Deviation from straight centerline.
4. Deviation from true shape (Usually out of round by more than 2% of the diameter of the pipe). Minor repairs such as minor bending of the metal, refinishing the galvanizing, or re-rounding may be allowed.
5. Ragged or diagonal sheared edges.
6. Loose, unevenly lined, or spaced spot welds.
7. Unfinished ends.
8. Bruised, scaled, or broken coating.
9. Excessive dents or bends in the metal.
10. Any damage or manufacturing defects that would impair the jointing of the pipe.

Excavation (Minimum Trench Widths) (603.05)

603.05A Method A

See Standard Drawing DM-1.4

A cut situation (Method A) is defined as a field situation where the top of the trench is above the top of the pipe. This is where the existing ground is above the top of the pipe.

603.05B Method B

See Standard Drawing DM-1.4

A fill situation (Method B) is defined as a field situation where the top of the pipe is above the top of the trench. In this situation the fill or new embankment is constructed to the spring line of the pipe, and then the trench is constructed.

Ground Water

The specifications require the Contractor to remove the ground water from the trench. This can usually be done by using pumps, deep wells, diversion ditches, or pipes. In some cases, pumping operations will not remove sufficient ground water to construct the project. As a last resort, the Projects Engineer may allow the Contractor to place Structural Backfill Type 3 below the pipe to help relieve the water flow. When permitted, the Structural Backfill Type 3 is only placed below the bottom of the pipe. This material is very porous and should relieve the water problems in most cases. This work is performed at no additional cost to the Department.

When using Structural Backfill Type 3 backfill material, the material on top of the Type 3 Material should be Structural Backfill Type 1 to prevent the fine portion of the surrounding soils or backfill from migrating into the void space in the Type 3 backfill material following construction.

Another alternative to relieving the water to construct the pipe as stated above is to use Item 613 Low Strength Mortar Backfill (LSM) to cut the water off. Sheet piling can also be used to cut the water off. The expense of both of these methods should be carefully evaluated. Unless designated in the plans, the cost of the LSM or sheet piling is the responsibility of the Department.

Foundations

The foundation of a conduit must uniformly support the conduit during construction and for the life of the conduit. Soft conditions and rock conditions are two situations that are important to evaluate in the field. Soft conditions are the most common situations that come up in the field. In general, if the workers can stand and work in the trench, the foundation is adequate for construction. If the material is too soft, then the Project Engineer should investigate the cause of the problem. Review all available soil borings in the area or dig test pits to find the extent of the soft material. Make certain that the proposed remedy is appropriate for both the construction technique and materials used in the work.

Sand or well-graded aggregate may be used to replace the soft material. Make sure that groundwater issues are addressed (as discussed above). It is rare that there is a need to undercut more than 2 feet (.6m) of material to restore support for the pipe. Corrections of soft conditions within 1 foot (.3m) below the bottom of the trench are at the Contractor’s expense except for undercuts shown in the plans. The correction made below this 1-foot (.3m) depth is the Department’s responsibility. When rock boulders are encountered, they should be removed to at least 6 inches (150 mm) below the pipe. When rock is found under the full length of the pipe, the rock should be removed to a 6 inches (150 mm) average depth below the pipe.

General

Minimum trench widths are specified to assure that adequate room is provided for the proper placement and compaction of bedding and backfill material below the springline of the pipe and to allow for the proper joining of the pipe sections.

Maximum trench widths are not specified for pipes. The Contractor will build to the minimum trench width to save on backfill material. Spot checks of the trench width are required to ensure proper widths, adequate working room and that the specifications are being observed. These checks need to be recorded on CA-P-1 Daily Pipe Inspection Form.

All trench walls shall be as vertical as practical to a height above the pipe.

The first step to determine the minimum required trench width is to determine the span (outside to outside at the widest point) of the pipe. This is easily measured in the field and should be recorded on the CA-P-1 Daily Pipe Inspection Form. Once the span is known, the minimum trench width (W) can be calculated. The following example illustrates a calculation for the minimum trench width.

Given: Plastic Pipe

Span= 38 inches (960 mm)

W = Minimum Trench Width = 1.25 Span+ 1 foot (.3m)

W = 1.25(38”/12”/’(960mm/1000 mm/m)) + 1 foot (.3m)

= 4.958 FT. (1.5m)

Bedding (603.06)

See Standard Drawing DM-1.4. The following tables are furnished to reflect the Standard Drawing. There are four different Types of Bedding. The Types of Bedding depends on the type of specified conduit. Table 603.A shows the different Types of Bedding.

Table 603.A – Bedding Types

Bedding Type	Structural Backfill Thickness	Middle one-third
Type 1	6 inches (150mm)	Do nothing
Type 2	6 or 3 inches (150 or 75mm)	Loosen
Type 3	0 inches (0mm)	Loosen
Type 4	0 inches (0mm)	Do Nothing

Type 1 bedding is required for all reinforced concrete box sections and 3-sided structures that are placed on a slab.

Type 2 bedding consists of the placement of a minimum depth of 3 or 6 inches (75 or 150mm) of structural backfill. See Table 603.B below for material type, pipe type, and the thickness of bedding required.

Furnish a loosened middle one-third for each case.

Table 603.B – Pipe Type

MATERIAL	PIPE TYPE	BEDDING	THICKNESS OF STRUCTURAL BACKFILL BEDDING
706.01,706.02,706.03	Type A	Type 2	3 inches (75mm)
706.01,706.02,706.03	Type B	Type 2	3 inches (75mm)
706.01,706.02,706.03	Type C	Type 3	0 inches (0mm)
706.01,706.02,706.03	Type D	Type 3	0 inches (0mm)
All Plastic and Metal	Type A	Type 2	6 inches (150mm)
All Plastic and Metal	Type B	Type 2	6 inches (150mm)
All Plastic and Metal	Type C	Type 2	6 inches (150mm)
All Plastic and Metal	Type D	Type 2	6 inches (150mm)

Type 3 bedding is only for Type C and D concrete conduit.

Type 4 Bedding consists of shaping the existing or natural ground to place the pipe. Type 4 bedding is required for only all Type E and F conduits.

The bedding that is extended 30% up around the conduit is compacted by shoveling, spudding, or flooding. It is absolutely critical that the material in this haunch zone (between the flow line of the pipe and the 30% diameter elevation) be compacted to a maximum density and all the voids are filled. The structural performance of a pipe relies significantly on the compaction of the haunch material.

Laying Conduit (603.07)

General

The construction of the pipe should always start at the outlet end of the pipe run. This procedure should only be changed under special conditions. This means that the work will progress up grade, which makes the jointing of the pipe easier. The Contractor is responsible for the accuracy of the pipe alignment and the grading. The Engineer should ensure the work is progressing in accordance with the plan.

Inlet End

All pipe inlets will be a normal fabricated end piece. For concrete pipe the inlet would be the bell section. The design is based on this type of inlet. If the bell is cut off the design is incorrect and flooding will occur. Box culverts are also designed for the bell at the inlet. Metal pipe has a square edge and can be cut to fit. The cut end is then coated to match the pipe coating. Plastic pipe can have either a square edge, or a bell end. Any inlet that does not have a normal fabricated end piece must be replaced.

Laying Conduit

The Contractor's surveyor or foreman usually lays out the location and the grade of the pipe. The starting elevation is usually established at the outlet end of the pipe run and carried forward to the inlet end of the pipe run. The pipe grade is established by using a string line, batter boards, or lasers.

Using Batter boards and String Line

When a string line or batter boards are used the following procedure is followed. The plan pipe grade is roughly established by using grade stakes at the surface of the pipe trench or at the bottom of the trench. The grade stakes are placed at 25 feet (7.5m) or 50 feet (15 m) intervals.

The grade stakes by themselves do not offer sufficient control for the Contractor to place the pipe. The stakes are generally offset too far from the pipe installation to be used directly. Longer grade stakes are used to establish the string line or batter board height to establish the actual construction grade line. The Contractor will place batter boards across the pipe trench and then pull a string line over the batter boards. The string line is set in place directly over the pipe centerline at the same slope as the trench bottom and pipe flow line. A level rod or a marked rod is used to measure the correct distance between the string line and the pipe flow line or trench bottom. This rod is used to keep the pipe or trench bottom on grade throughout the pipe run.

Using a Laser

On most construction projects a laser is used to maintain the pipe grade. A laser light beam is used in the trench or above the pipe trench. The laser light beam is established at grade directly over the pipe as the string line was used when using batter boards in the example above. Once this grade is established measurements are made to the pipe invert or the trench bottom to hold the grade throughout the construction. This method is the most convenient and is preferred by most Contractors.

Final Grade of large Pipe Structures

Pay particular attention when placing large pipe structures such as concrete boxes. The final grade should be accomplished by raking the granular material with a screed board. The screed board should be as long as the width of the box (Span + 2 times the wall thickness). Then attach a 4 feet (1.2 m) long level to the top of the screed board. Starting at the outlet end, the workers should screed the granular material, filling in low spots and leveling off the high spots. This special attention will expedite the setting of the box sections.

Alignment of large Pipe Structures

Once the centerline of the box sections is established, a string line or laser should establish the outside of the box sections. The string line or laser is established about 2 inches (50 mm) from the outside of one of the edges of the box sections.

Alignment can be easily monitored by measuring over from this line. If a string line is used, then it is usually attached to the footer re-steel.

Placement of Concrete Box and Pipe and Clay Pipe

The setting of the pipe or box starts at the outlet end of the trench, and construction continues to the inlet end (up-grade). It is easier to work upgrade with the help of gravity to hold the pipe or box sections together than to work downgrade. The tongue or spigot (male) end of the pipe or box is always downgrade. The bell or grooved (female) end of the pipe is always up-grade. The construction proceeds this way to minimize the bedding material trapped in the pipe joint and to maximize the hydraulic flow into the pipe or box.

The pipe or box construction may use chains, cables, spud bars, wooden blocks, or pipe pullers to place the sections of pipe together. The type of equipment used depends on the size of the pipe. The Contractor is responsible for placing the pipe or box at the required grade. The final position of the sections of pipe must form a smooth grade. If the Contractor cannot place the box sections together to within 1 inch (25 mm) then the Project Engineer should require the use of winches.

When it is necessary to field cut a pipe, the section cut must have a concrete cradle or collar. The cut section of pipe must not be an end piece. The final joint must be stable. The inlet end must have the groove or bell intact to maximize the hydraulic flow into the pipe or box.

Common Problems Associated with Box Culvert Placement

1. Standing water in the trench makes it difficult to determine the evenness of the bedding.
2. Most joint annular spaces are 1/4 inches (6 mm) to ½ inches (12 mm). If the bedding is irregular, lining up the tongue into the receiving bell will be difficult. Because boxes are wide and flat, any irregularities in the bedding can cause the tongue of the box not to be properly started into the bell. If this is apparent before attaching the winches and anchors, pull the box out of the way and check the bedding again.
3. If the trench conditions are unstable, the line and grade cannot be held and the area must be stabilized by the use of drainage (pumps) or the removal of unstable sub-soils.
4. Boxes that do not hang plumb may be caused by improper anchorage location. If using a four-part sling, longer or shorter clevises may help alleviate the problem. Be consistent in hooking the rigging to the box culvert.
5. Take care to ensure that both vertical portions of the tongue get started evenly into the bell of the previously set box to keep from pulling the box into its home position unevenly.
6. If footers or head walls are specified consult the supplier to determine if the actual lay length of the individual boxes plus joint creep will be greater than the culvert length shown in the design plans.

7. The Contractor is responsible for the accuracy of the pipe alignment and the grading. The Engineer should ensure the work is progressing in accordance with the plan.

Placement of Three Sided Flat Top and Arch Top Structures

The flat top and arch top structures require an approved shop drawing prior to installation. These details should be thoroughly examined prior to the installation of the sections.

The placement and jointing of these structures are approximately the same as concrete boxes, with the differences noted below.

The arch and flat top sections are placed on a footing designated in the plans. Newer designs will have the footing at zero grades. If needed, the sections can be placed on Masonite or steel shims to properly align the sections.

Place the sections by crane from the outlet end to the inlet end (Up-grade). The crane holds the sections in place while winches and/or spud bars are used to make the final placement.

When the sections do not completely come together, a gap tolerance of 1 inch (30 mm) per joint is desirable. The most important dimension is the top gap of the joint. The top elevation of the sections of the arch or flat top sections should be at approximately the same elevation. This maximizes the strength of the joint. If the jointing cannot be done successfully, then the use of winches should be considered.

Joining Conduit (603.08)

Type A, B, C, D, and F conduits are required to have sealed, banded, bell and spigot, tongue and groove, or bolted joints. Type E conduits are permitted to have open joints.

Metal Pipe 707.01 – 707.24

Corrugated metal pipe joints shall be sealed with coupling bands with bolts. The bands are placed around the first placed pipe and then the second pipe is brought into position. The two pipe sections should be within 1 inch (25 mm). Check the joint to ensure the ribs or dimples line up, then join the sections. The bolts are tightened sufficiently to securely close the band. For large diameter corrugated metal pipe, the band should be hammered in place by the use of a mallet to ensure the seating of the band. The permissible differences between adjacent sections is ½ inch (15mm) for conduits greater than 54 inches (1350 mm) and 0.109 inch (2.77 mm) in wall thickness. The permissible differences between adjacent sections is ¼ inch (7mm) for conduits less than or equal to 54 inches (1350 mm). Strutting is required for conduits greater than 54 inches (1350 mm).

Plastic Pipe 707.31

Thermoplastic joints may be sealed with a coupling band or by a gasket bell and spigot joint. The joint will not allow any infiltration by the backfill. Tightened sufficiently, use the cable ties with thermoplastic split couplers, to securely close the band. When bells with locking lugs are furnished place them so that all the detents or lugs lock into the corrugation valleys.

Joint Sealing of Concrete Pipe and Clay Pipe 706.01, 706.02, 706.04, 706.08

Concrete pipe and clay pipe are required to have sealed joints with one of the following:

1. Sealed bituminous pipe joint filler (CMS 706.10) (commonly known as "bear grease") is placed to completely fill the joints. After the joint filler is placed, trowel the material for a smoothed finish inside and out in place. It is common for this material to drip off top surfaces, but this should be kept to a minimum.
2. Preformed butyl rubber material (CMS 706.14) may be used. The joint must be primed on both sides prior to the installation of the butyl material. This material is placed completely around the joint. The material will overlap 6 inches (150mm) at the ends. The joint is sealed but the material may not completely fill the joint from the inside to the outside. The joint must be sealed from water and fine infiltration.
3. Resilient and flexible gasket joints (CMS 706.11 for concrete pipe, or CMS 706.12 for clay pipe) may be used.
4. Other materials may be used if approved by the Project Engineer.

Joint Sealing of Epoxy Coated Reinforced Concrete Pipe 706.03

1. Epoxy coated reinforced concrete pipe (CMS 706.03) must be sealed with fibrated coal tar joint compound placed in accordance with the manufacturers recommendation. After the joint filler is placed, trowel the material for a smooth finish inside and out in place. The outside of the pipe is completely sealed.
2. If the plans call out resilient and flexible gasket joints conforming to 706.11 or 706.12 then furnish these joints and test them as required.

Joint Sealing of Concrete Boxes 706.05

1. Concrete Boxes are required to have sealed joints with one of the following:
    a. Sealed bituminous pipe joint filler (CMS 706.10) (commonly known as "bear grease") is placed to completely fill the joints. After the joint filler is placed, trowel the material for a smoothed finish inside and out in place. It is common for this material to drip off top surfaces, but this should be kept to a minimum.
    b. Preformed butyl rubber material (CMS 706.14) may be used. The joint must be primed on both sides prior to the installation of the butyl material. This material is placed completely around the joint. The material will overlap 6 inches (150mm) at the ends. The joint is sealed but the material may not

completely fill the joint from the inside to the outside. The joint must be sealed from water and fine infiltration.

c. Resilient and flexible gasket joints (CMS 706.11 for concrete pipe, or CMS 706.12 for clay pipe) may be used.

d. Other materials may be used if approved by the Project Engineer.

2. Concrete Boxes are required to have the Outside and Inside Surfaces sealed

   a. There are no critical joints; each section is independent. The exterior joint gap on the top, the interior sides, and bottom gaps of the Precast Reinforced Concrete Box are filled with CMS 706.02 mortar before placing the membrane waterproofing or joint wrap.

Joint Filling the Outside Surfaces of Three-Sided Flat Top Sections 706.051

The critical joint is the top exterior. The top exterior joint of the Three-Sided Flat Top sections are designed with a keyway detailed in the shop drawings. This keyway is filled with a non-shrink mortar (CMS 705.22). All other joints see the specification.

Joint Filling the Outside Surfaces of the Three-sided Arch Sections 706.052

There are no critical joints; each section is independent. The joints of the arch sections have a 45-degree chamfer. The external side of the joint shall be cleaned prior to the installation of any sealing material. One continuous section of flexible plastic gasket (CMS 706.14) is placed from the bottom of the leg on one side to the bottom of the leg of the other. The chamfer section is primed at the project site prior to the installation of the flexible plastic gasket (CMS 706.14). The primer is a type that has been recommended by the flexible plastic gasket (CMS 706.14) manufacturer. Each joint, sealed with flexible plastic gasket (CMS 706.14), is covered with a 9-inch (225 mm) wide strip of Type 3 Membrane Waterproofing (CMS 711.29). A primer is placed on the external side of the joint under the area of the Type 3 Membrane Waterproofing. The primer used is as recommended by the Type 3 Membrane Waterproofing manufacturers. The plan or the shop drawing may allow other joint sealers.

Exterior Coatings and Waterproofing (603.09)

Areas In Contact With the Backfill Material

Membrane waterproofing is placed in accordance with the plans. Areas of the box, 3-sided flat top, or arch shall be clean prior to the placement of the (CMS 512) Sheet Type 2 Membrane Waterproofing. Place the Sheet Type 2 Membrane Waterproofing in all areas that are in contact with the backfill material. When asphalt is in direct contact with the top of the box sections, or Three-Sided Flat Top sections then use Sheet Type 3 Membrane Waterproofing. No joint wrap is required under the membrane.

Areas Not In Contact With the Backfill Material

Areas of the box, 3-sided flat top, or arch outside the limits of the granular backfill. The epoxy sealer is applied to the top surface and 1 foot (0.3 m) down the legs of the structure. This area includes the joint. The joint wrap is at least 9 inches (230 mm) wide and is one continuous roll per joint. The joint shall be clean prior to the installation of the joint wrap.

Backfilling (603.10)

General

Backfill materials are defined as all materials above the bedding material and below the subgrade of the pavement structure or the ground elevation. The backfill materials may be Structural Backfill Type 1 or 2, soil, or granular embankment. These backfill materials are required or an option depending on which type pipe is specified and whether the field situations are a cut or fill.

See Standard Drawing DM-1.4 for details.

Structural Backfill Type 1 and 2 are allowed for all backfill applications. There is an option to switch to a soil or granular embankment at certain heights above the pipe depending whether the pipe is located in a cut or fill. Structural Backfill Type 1 or 2 is required for specific width as measured from the outside diameter of the pipe or structure to the trench wall. The minimum height above the pipe for the Structural Backfill represents the location where the material may change to soil or granular embankment. The height of the Structural Backfill may be less than shown if the subgrade is closer to the top of the pipe than the minimum required. Example: The minimum Structural Backfill height required is 4 feet (1.2 m). If the subgrade elevation were 3 feet (0.9 m) above the pipe, then the height of the Structural Backfill would be 3 feet (0.9 m).

Compaction Equipment	Total Weight of Equipment	Height above Pipe	Required Width
No Hoe Rams but Small Equipment	Less Than or Equal to 1 ton (0.9 metric ton)	0 to 2 feet (0 to 0.6m)	3 times span or 12 Feet (3.6m)+ span Whichever is less
Hoe Rams Small Equipment Medium Equipment	Greater Than or Equal to 1 ton (0.9 metric ton) but Less Than or Equal to 8 tons (7 metric tons)	Greater Than 2 feet (.6m) but Less Than or Equal to 4 feet (1.2m)	3 times span or 12 Feet (3.6m)+ span Which Ever is Less
Hoe Rams Small Equipment Medium Equipment Large Equipment	Greater Than 8 tons (7 metric tons)	Greater Than 4 feet (1.2m)	No Restrictions

Type A, B Conduits

Cut Situations

In a cut, Structural Backfill Type 1 or 2 is required for Type A and B conduits for a height of 4 feet (1.2 m). See Standard Drawing DM-1.4

Fill Situations

In a fill, Structural Backfill Type 1 or 2 is required for a height of 2 feet (0.6 m) above the pipe and for a distance equal to 4 feet (1.2 m), or one span of the pipe, whichever is less (span is measured as the outside diameter of the pipe at the widest point). See Standard Drawing DM-1.4

Optional Backfill

In the cut and fill situations described above, Soil and Granular Embankment may be substituted above these heights to the subgrade or ground elevation.

Type C Conduits Except for Plastic Pipe, Type D Conduits Except for Plastic Pipe, and Type F Conduits Except for Underdrain Outlets in a Cut or Fill Situation

Place and compact the backfill in the trench with either Structural Backfill Type 1 or 2, Soil, or Granular Embankment. For these pipe types there are no changes in the width requirements for the trench between cut and fill situations. See Standard Drawing DM-1.4

Type C and D Conduits for Plastic Pipe in a Cut or Fill Situation

For Type C and D thermoplastic pipe, Structural Backfill Type 1 or 2 is required for 1 foot (.3m) above the pipe for cuts or fill situations. Structural Backfill may be substituted with soils and/or granular embankment above the 1-foot (.3m) height to the subgrade or ground elevation.

See Standard Drawing DM-1.4

Type E Conduit

Place and compact the backfill in the trench above the bedding with either Structural Backfill Type 1 or 2, Soil, or Granular Embankment to a height equal to two thirds of the conduit rise then place and lightly place and compact backfill to a height of 1 foot (.3m) above the conduit.

Type F Conduits for Underdrain Outlets in a Cut or Fill Situation

Place the backfill in the trench above the bedding with Granular Material as defined in CMS 605.02. See Standard Drawing DM-1.2.

Long Span Structures Type A, B, C, D

Long span Structures are defined as Precast Reinforced Concrete Boxes (CMS 706.05), Precast Reinforced Concrete, Flat Top Three-sided Culverts (CMS 706.051), or Precast Reinforced Concrete Arches (CMS 706.052) structures.

The following are trench specifications for new construction. Reconstruction plans may indicate other trench configurations.

Cut Situations

In cuts, Structural Backfill Type 1 or 2 is required for 4 feet (1.2 m) above the top of the structure or to a height equal to the subgrade (whichever is less), and to a width equal to 2 feet (0.6 m) measured from the outside of the structure to the trench wall.

Fill Situations

In a fill, Structural Backfill Type 1 or 2 is required for 2 feet (0.6m) above the top of the structure and for a width equal to 4 feet (1.2 m) measured from the outside of the structure to the trench wall.

Optional Backfill

In a cut or fill above the minimum heights specified soils and/or granular embankment may be used.

Placement and Compaction Requirements (603.11)

General

Trench conditions can change from location to location. The bottom and trench walls may change from rock to soft clay or silt. The compaction equipment used by the Contractor may change from the bedding to the backfill material. All backfill material lifts except Structural Backfill Type 3 are 8 inches (200mm) thick. Structural Backfill Type 3 is 12 inches (300mm) thick.

Soils Compaction Requirements

For soil embankment the density requirement is 96% of AASHTO T 99.

For soils that meet the requirements of CMS 603 the One-Point Proctor Method along with the Ohio Typical Density Curves can be used to establish the compaction requirements. The one point proctor and the moisture content of the proctor soil are used to find the curve that represents the tested soil. Once the curve is found, only 96% of the maximum dry density is required. The detailed procedures for compaction testing are explained in section for Supplement 1015.

Granular Embankment and Structural Backfill Type 1 & 2 Compaction Requirements

Controlling the compaction of granular embankment by using the Test Section Method is superior over any other method. The Test Section Method allows for the adjustment of the density requirements to meet the material, compaction equipment, and the trench condition changes. When the trench bottom or the trench walls are too soft, the fixed density requirement may not be physically achievable. This may not be a result of Contractor negligence but a result of field conditions. It is difficult to obtain fixed density in soft foundation conditions. A test section is used to establish the compaction controls.

Compaction acceptance and procedures are detailed in Supplement 1015.

According to 603.06, when Type 2 Bedding is used, the middle 1/3 of the pipe bedding is left uncompacted (or lightly compacted to hold the grade of the pipe). If you divide the span or the diameter of the pipe into 3 parts; the bedding below the middle 1/3 of pipe is left uncompacted or lightly compacted.

Structural Backfill Type 3

Due to physical differences between Type 1, 2, and 3, the compaction controls are different. The Type 3 material (#57's or #67's) is not conducive to compaction testing; using a procedural method controls the compaction requirements.

Compaction Requirements for Structural Backfill Type 3 (# 57 or #67)

There is no compaction testing requirements for the placement of the Type 3 material. The material is placed at a maximum lift thickness of 12 inches (300 mm). The material is then compacted to approximately 85% of the original lift thickness. The compaction should consist of vibratory plates, jumping jacks, or hand tamps. Although it may not seem like the compaction effort is accomplishing very much, it seats the material in place. To demonstrate the effectiveness of this compaction effort, fill a concrete mold with type 3 material and then weigh the filled mold. Then fill a second concrete mold using three equal lifts of type 3 material. Compact with a flat device after each lift is placed. Then weigh the second mold. The difference in weight will be about 20%. The same conditions exist in a pipe trench.

Documentation Requirements - 601 Slope and Channel Protection

1. Concrete riprap
    a. Size, spacing, depth, and clearance maintained on reinforcing steel
    b. Concrete items of 499 apply
    c. Joint width and depth and how filled if used
    d. Amount of curing compound used
    e. Dimensions of cutoff wall (length x width x depth)
    f. Measure length and width for pay
2. Crushed aggregate slope protection
    a. Measure depth of crushed aggregate placed
    b. Measure length and width for pay
3. Concrete slope
    a. Depth of concrete
    b. Depth increased from 6 to 18 inches (15 to 46 cm) on last 3 feet (1 m) of bottom edge
    c. Depth and spacing in both directions of joints
    d. Amount of curing compound used
    e. Measure length and width for pay
4. Dump Rock Fill
    a. Stone placed conforms to Type________ (A, B, C or D, 703.19)
    b. Measure length and width for pay
5. Rock Channel Protection
    a. Stone placed conforms to type ______ (A, B, C or D, 703.19)
    b. Large stone placed on a 6 inches (15 cm) bed of _______ (#3, #4 aggregate)
    c. Measure length x width x depth for pay
    d. Note type of filter used (if fabric), width of lap, and pin placement and length. If stone, note depth and material used.
6. Paved gutter
    a. Make drawing showing section of gutter
    b. Widths and depth of joint
    c. Spacing on joints
    d. Joint filler used
    e. Amount of curing compound required and used
    f. Base wet prior to placing concrete
    g. Measure length for pay as per 601.12

Documentation Requirements - 602 Masonry

1. Take adequate measures to keep concrete from freezing. State method used.
2. Blocks and brick wet before placing
3. Mortar composed of one part cement to two parts sand

4. Full mortar joints used
5. Method of cure
6. Measure length x width x depth for pay
7. Headwalls
    a. Form dimensions - height to invert, total height, width, and thickness
    b. Size and number, spacing and clearance maintained on reinforcing steel if required
    c. Quantity for pay from standard
    d. Method of cure
    e. Backfill placed in loose lifts of 4 inches (10 cm) or less and tamped
8. Precast Headwalls & Wing walls
    a. Must be pre-approved before use and produced by a certified precast concrete producer and shipped with a TE-24.
    b. Measure length x width x depth for pay
    c. Use non-shrink grout to fill void between conduit and wall

Documentation Requirements - 603 Pipe Culverts, Sewers, and Drains

1. Document on form CA-P-1 or CA-P-3 as appropriate.
2. Must be produced by a certified precast concrete producer and shipped with a TE-24.
3. Measure length for pay (Note: Pay through or to the center of all junctions such as manholes, catch basins, etc. as per 603.14 of the CMS)
4. Document the following on the CA-P-1 Daily Pipe Inspection Form for each run of conduit.
    a. List the equipment, number of passes, and lift thickness required for the bedding used
    b. List the equipment, number of passes, and lift thickness required for the backfill used
    c. List the type of the backfill material moisture density curve used if required
    d. List all the compaction checks of the bedding
    e. List all the compaction checks of the backfill
    f. List how the haunch material is compacted

Clearing Site and Restoring Damaged Sites (603.10) Documentation

1. Use CA-P-1 Daily Pipe Inspection Form for each run of conduit.
2. Note how the site was restored (type of pavement replacement)
3. Note how the excavated material was taken care of (removed and disposed or used)

Field Paving of New or Existing Pipes (603.11) Documentation

1. Use the CA-P-1 Daily Pipe Inspection Form for each run of conduit.
    a. Note either existing or proposed pipe being field paved
    b. Note height of cover placed before field paving
    c. Note any repairs that were done before the field paving
    d. Note type of reinforcement used
    e. Note how reinforcement was attached to the pipe
    f. Note the quantity of concrete furnished

604 Manholes, Catch Basins, Inlets, Inspection Wells, Junction Chambers, Precast Reinforced Concrete Outlets, Or Monuments

Description (604.01)

The types of structures are specified in accordance with their application and intended usage. For a brief description of typical applications see section 604.02. If you need a more detailed description, see Ohio Department of Transportation's (ODOT) Drainage Design Manual and the plans.

Materials (604.02)

1. Structure concrete, Class C is the precast material.
2. Brick and masonry units are the cast in place material.
3. Precast reinforced concrete manhole, catch basin, and inlet sections are per the material specification information with the Standard Drawings showing the dimensions.
4. Precast reinforced concrete outlet is per the material specification information with the Standard Drawings showing the dimensions.
5. Preformed expansion joint fillers is the material that can be used between the precast structures and a poured in place structure.
6. Epoxy-coated reinforcing steel is required only in the top of precast structures.
7. Gray iron cast frames, grates, and covers are per the material specification information and dimensions as shown on the Standard Drawing.
8. Angle steel welded frames and grates are per the material specification information and dimensions as shown on the Standard Drawing.
9. Steps are per the Standard Drawings showing the dimensions and locations.
10. A resilient and flexible gasket joint is the material that is used for the precast structures that are only on sanitary sewer runs.
11. Curing is the material that is used per the standard Drawing requirements.
12. Mortar is the material that is used per the standard Drawing requirements.

Construction Methods, General (604.03)

The drainage structures are placed before placing the storm sewers. Check that the drainage structures are at the locations and elevations shown on the plans and according to the proper standard drawing. Record these on the CA-P-3 Structure

Inspection Form. The locations and elevations shown on the plans may need to be adjusted in the field. Record these on the CA-P-3 Structure Inspection Form. The manhole castings are placed at the elevation and station with offset to the center of the casting. Record these on the CA-P-3 Structure Inspection Form. If this location or elevation is not attainable then adjust the structure as needed. Record these on the CA-P-3 Structure Inspection Form.

The manhole base is placed at the elevation with station and offset to agree with the pipe elevation with station and offset. Record these on the CA-P-3 Structure Inspection Form. If this location or elevation is not attainable then adjust the structure as needed. Record these on the CA-P-3 Structure Inspection Form.

Only a flat slab top for manholes as shown on the standard construction drawing is to be used. Record this on the CA-P-3 Structure Inspection Form. **All covers with lifting devices must remain in place after construction.** Record this on the CA-P-3 Structure Inspection Form.

If the structure elevation changes by more than 1 foot (0.3 m), the Department will pay for this change. Record this on the CA-P-3 Structure Inspection Form.

Ensure that the underdrain outlet pipe is thoroughly mortared to the precast reinforced concrete outlet.

All lateral sewer connections including drops and leads except pipe included in 603 is part of the structure for payment. Record these on the CA-P-3 Structure Inspection Form.

Ensure that the conduit is as shown on the standard construction drawings (that is, they do not protrude inside the structure walls). Record this on the CA-P-3 Structure Inspection Form.

Ensure that structure concrete or mortar cement is not freezing. Record these temperatures on the CA-P-3 Structure Inspection Form.

If the ambient temperature is 40° F (4° C) or less ensure that the precast concrete structure throughout the entire mass is a temperature of between 50 and 80° F (10 and 27° C) before the contractor places the mortar. Record these temperatures on the CA-P-3 Structure Inspection Form.

Ensure that all iron frames, tops, and covers of the type shown on the plans are placed on a mortar bed. Record this on the CA-P-3 Structure Inspection Form.

Ensure that all earth or debris resulting from construction operations that enter the manholes, catch basins, junction chamber, inlets, and precast reinforced concrete outlets is removed. Record these removals on the CA-P-3 Structure Inspection Form.

If reconstruction is specified, ensure the following are performed:

1. The existing castings are carefully removed and clean.

2. For manholes, remove the existing walls down to the spring line or below as necessary. Record the depth of removal on the CA-P-3 Structure Inspection Form.
3. For catch basins and inlets, remove existing walls below the window openings, grates, or any points of wall failure. Record the depth of removal on the CA-P-3 Structure Inspection Form.
4. Using the salvaged casting, reconstruct the structure to the new grade, conforming as nearly as practicable to the existing dimension and type of construction. Record this elevation on the CA-P-3 Structure Inspection Form.

If adjustment to grade is specified, ensure the following are performed:

1. Carefully remove the existing frame, adjust the height of supporting walls, and then reset the existing frame in a bed of mortar or structure concrete to the new grade. Record this work and elevation on the CA-P-3 Structure Inspection Form.
2. Ensure the existing cover or grate is removed and cleaned and then one of the following is done: Record this work and elevation on the CA-P-3 Structure Inspection Form.
    a. A new casting is installed to provide the proper elevation or
    b. An approved adjusting device that is on file at the Laboratory is installed to provide the proper elevation or
    c. An adjusting device approved by the Engineer is installed per the manufacturer's recommendations to provide the proper elevation.

Excavation and Backfill (604.04)

Ensure that the excavation is to dimensions that provide ample room for construction. Require the removal of unsuitable material below the structure bedding. The contractor must replace unsuitable material with Item 603 Structural Backfill. Record the material type and depth on the CA-P-3 Structure Inspection Form. The Department will provide compensation for this removal and replacement of unsuitable material below the bedding for precast structures, and below the structure for cast-in-place structures, according to the Contract or by Supplemental Agreement.

Backfilling follows the completion of the work as closely as the type of construction will permit. Ensure that the structure while backfilling is not disturbed. Backfill structures located within the pavement area with structural backfill to the subgrade according to Item 603, Type A or B conduit. Backfill structures located outside of the pavement area according to Item 603, Type C conduit. Record the material type and elevation depth on the CA-P-3 Structure Inspection Form for each structure.

Brick and Block Masonry (604.05)

Ensure that all brick and concrete block masonry units are thoroughly wet before laying them in the mortar, and that they are laid with full mortar joints.

Ensure that the concrete and mortar do not freeze. Do not set brick and masonry units having a temperature of 40° F (4° C) or less with mortar until heated. When required, heat to ensure that a temperature of 50 to 80° F (10 to 27° C) is obtained throughout the entire mass of the material. Record the temperature on the CA-P-3 Structure Inspection Form. Ensure that the exposed surfaces of all brick and block masonry are cured by covering them with wet burlap for 48 hours or by applying curing membrane according to Item 511. Record the curing type on the CA-P-3 Structure Inspection Form.

Precast Concrete Modular Construction (604.06)

Ensure that furnished precast bases are on a compacted structural backfill bed having a minimum thickness of 3 inches (75 mm). Ensure that the structural backfill bed is level and uniformly supports the entire area of the base. Record the material used and how that material was compacted on the CA-P-3 Structure Inspection Form.

Ensure that all openings in the structures are thoroughly filled with mortar. Ensure that all joints are sealed between modules with materials specified in Item 603 for Type A, B, C, D, or F conduit.

Ensure that median inlets are cured with the same materials and methods specified in 622.07. Ensure that the manufacturer of precast modular items is certified according to Supplement 1073.

Concrete (Cast-In-Place) (604.07)

Ensure that the structure concrete is placed and furnish as shown on the plans. Record all information on the CA-P-3 Structure Inspection Form as required by Item 511.

Method of Measurement (604.08)

The Department will measure Manholes, Inlets, Catch Basins, Monument Assemblies, Reference Monuments, Inspection Wells, Junction Chambers, and Precast Reinforced Concrete Outlets, whether new, reconstructed, or adjusted to grade, by the number of each type of structure complete and accepted. Record each type on the CA-P-3 Structure Inspection Form that is paid for that day.

Basis of Payment (604.09)

The Department will pay for accepted quantities at the contract prices. . Record the reference Item number on the CA-P-3 Structure Inspection Form.

Documentation Requirements - 604 Manholes, Catch Basins, Inlets, etc.

1. Catch Basin
   a. Pad dimensions (length x width x depth)
   b. Blocks wet prior to placing
   c. Mortar composition, one part cement to two parts sand by volume
   d. Full mortar joint used
   e. How cured
   f. Take adequate measures to keep concrete from freezing. State method used
   g. Backfill placed as per 603.10, 603.11
   h. Measure inside dimensions
2. Pre-cast catch basin or manhole
   a. Precast basin set on a bed of compacted granular material (type of granular material used)
   b. Must be produced by a certified precast concrete producer and shipped with a TE-24.
   c. All openings in structure sealed with (mortar or bituminous material)
   d. Backfill placed in 4 inch (10 cm) loose lifts and tamped
3. Manholes
   a. Pad dimensions - length x width x depth or diameter and depth
   b. Joints between riser section sealed by rubber gasket or mastic material
   c. Backfill placed in 4 inch (10 cm) loose lifts and tamped
   d. Steps are required
   e. All openings made in manhole sealed with concrete or grout
   f. Measure inside dimensions
4. Inlets
   a. Pad dimensions (length x width x depth)
   b. Blocks wet prior to placing
   c. Mortar composition, one part cement to two parts sand by volume
   d. Full mortar joints used
   e. how cured
   f. Take adequate measures to keep concrete from freezing. State method used.
   g. Backfill placed in 4 inch (10 cm) loose lifts and tamped
   h. Measure inside dimension.

5. Monument assemblies (as per standard drawing)
    a. Dimensions of concrete poured
    b. Diameter and depth of pipe placed
    c. Pipe filled with concrete sand compacted by flooding
    d. 1 inch (2.5 cm) diameter x 36 inch (91 cm) steel rod placed 3 inches (8 cm) minimum from bottom of pipe and 6 inches (15 cm) below pavement surface and on correct alignment
6. Reference Monuments
    a. Diameter and depth of hole drilled
    b. Top 6 inches (15 cm) formed
    c. Hole filled with Class C concrete
    d. ½ inch (1 cm) steel rod embedded in plastic concrete to a depth of 6 inches (15 cm) on correct alignment
    e. Top cured
    f. Document on CA-P-3.

605 Underdrains

Description (605.01)

The types of underdrains are specified in accordance with their application and intended usage. For a brief description of typical applications see section 605.02. If you need a more detailed description, see the ODOT Drainage Design Manual and the plans.

Materials (605.02)

Use approved granular material consisting of No. 8, 9, or 89 size air-cooled blast furnace slag, limestone, or gravel for underdrain backfill only but not for underdrain outlet pipes.

Pipe for 605 Rock-Cut Underdrains.

When the pay item description says Rock Cut Underdrains and the kind of pipe is not specifically itemized in the Proposal, then use one of the following:

1. Corrugated Polyethylene Drainage Tubing (Perforated) 707.31
2. Polyvinyl Chloride plastic Pipe 707.41
3. Polyvinyl Chloride Corrugated Smooth Interior Pipe (Perforated Per 707.31) 707.42
4. Polyvinyl Chloride Solid Wall Pipe (Perforated Per 707.31) 707.45

Provide the pipe type on the 605 CA-P-2 Structure Underdrain Form.

Pipe for 605 Pipe Underdrains

When the pay item description says Shallow Pipe Underdrains or Deep Pipe Underdrains and the kind of pipe is not specifically itemized in the Proposal, then use one of the following:

1. Perforated Concrete Pipe 706.06
2. Concrete Drain Pipe Extra Quality 706.07
3. Perforated Vitrified Clay Pipe 706.08
4. Clay Drain Tile Extra Quality 706.09
5. Corrugated Steel Underdrains, Type III 707.01
6. Corrugated Polyethylene Drainage Tubing (Perforated) 707.31
7. Polyvinyl Chloride plastic Pipe 707.41
8. Corrugated Aluminum Alloy Pipe and Underdrains, Type III 707.21

If the size and type of the underdrains required is a 6-inch (150 mm) shallow pipe underdrain, and the kind of pipe material is not specifically itemized, then use 4-inch (100 mm) 707.31 perforated corrugated polyethylene drainage tubing. An example would be “6-inch shallow pipe underdrains” listed in the description, then the contractor can furnish 4-inch 707.31 underdrains placed at the same location as the "6-inch shallow pipe underdrains". Provide the pipe type on the 605CA-P-2 Structure Underdrain Form.

Pipe for 603 Type F Conduit Underdrain Outlets.

The backfill requirements are as per 603. When the pay item description says "603 Type F Conduit Underdrain Outlets" and the kind of pipe is not specifically itemized in the Proposal, then use one of the following:

1. Corrugated Polyethylene smooth lined pipe 707.33
2. Polyvinyl Chloride plastic Pipe (non-perforated) 707.41
3. Polyvinyl Chloride corrugated smooth interior pipe 707.41
4. Polyvinyl Chloride solid wall pipe 707.45

Provide the pipe type on the 605 CA-P-2 Structure Underdrain Form.

Pipe for 605 Construction Underdrains

Corrugated Polyethylene Drainage Tubing (Perforated) 707.31 is the only pipe type permitted.

Provide the pipe type on the 605 CA-P-2 Structure Underdrain Form.

Pipe for 605 Prefabricated Edge Underdrains

Prefabricated Edge Underdrains 712.10 is the only pipe type permitted.

Provide the pipe type on the 605 CA-P-2 Structure Underdrain Form.

Pipe Underdrains Construction (605.03)

Construct underdrains as follows:

Excavation

UNDERDRAIN ID	6inches (150mm)	4 inches (100mm)
TRENCH WIDTH	14 inches (350mm)	10 inches (250mm)

Provide the trench width on the 605CA-P-2 Structure Underdrain Form.

If filter fabric is specified, note this on the 605CA-P-2 Structure Underdrain Form along with a sketch of how the fabric was placed and overlapped at the top of the trench.

Laying Underdrain

Lay the underdrain true to line and grade with close fitting joints. Use locking bands or smooth sleeve type couplers matching the underdrain material type to join 707.01, 707.31, 707.41, and 707.21. When bell and spigot underdrain is used, lay it with the bell end facing up grade. Set the underdrain on a solid bed shaped to fit the underdrain throughout its entire length. Make all necessary connections with branches, wyes, tees, transitions, and bends that match the underdrain material type. Close the upper ends of underdrains with suitable plugs.

Lay perforated underdrain so that the perforations are in the bottom half of the underdrain.

Provide the pipe joint type on the 605CA-P-2 Structure Underdrain Form.

Backfilling

Inspect the underdrains before placing any granular material. Place the granular material for the full width of the trench around the underdrain, and extend it to the bottom of the pavement or base as shown on the plans. If underdrains are placed outside of the pavement or base area, extend the granular material to within 4 inches (100 mm) of the finished grade. Fill the remaining depth of the trench with 203 Embankment material. Provide the pipe backfill material type on the 605CA-P-2 Structure Underdrain Form.

Protection

Place the pavement over the underdrain trench within 90 days after placing the trench backfill. If the trench remains open for longer than 90 days, remove and replace backfill contaminated by soil. Provide the dates when the underdrains were placed and the date the pavement was placed over the underdrain trench on the 605CA-P-2 Structure Underdrain Form.

Construction Underdrains (605.04)

Excavation

CONSTRUCTION UNDERDRAIN	4 inches (100mm)
TRENCH WIDTH	10 inches (250mm)

Provide the trench width on the 605CA-P-2 Structure Underdrain Form.

Trench depth and backfill

Construct the trench depth to that shown on the plans or 30 inches (750 mm). Backfill the full width and height of the trench with granular material. Provide the pipe backfill material type and trench depth on the 605CA-P-2 Structure Underdrain Form.

Outlet

Outlet the construction underdrains as possible into the ditch or drainage structures. There is no change in pipe types for the outlet. Provide the trench outlet location on the 605CA-P-2 Structure Underdrain Form.

Removal

Do not removed Construction underdrains at any time. If a construction practice requires the construction underdrains to be removed, then install replacements as soon as possible. Example would be if trenching for a culvert would cut the construction underdrains.

Provide the dates when the construction underdrains were placed on the CA-P-2 605 Structure Underdrain Form.

Prefabricated Edge Underdrains (605.05)

Install the prefabricated edge underdrains against the outside wall of a 4-inch (100 mm) trench, and backfill the trench adjacent to the pavement with granular material. Place the granular material in one or more lifts with a vibratory compactor run over the final lift to compact the granular material before placing the asphalt plug. Place the first layer of the granular material simultaneously with the trenching operation to hold the edge underdrains flush against the trench wall.

Splice the prefabricated edge underdrains as required before placing in the trench, using material furnished by the manufacturer and according to the manufacturer's directions. Require the manufacturer to furnish all material required for the splices, and furnish any equipment required for splicing. Construct splices to prevent separation of adjoining sections of the prefabricated edge underdrain panels. Provide the dates when the prefabricated edge underdrains were placed on the 605CA-P-2 Structure Underdrain Form.

Underdrain Outlets (605.06)

Construct outlets per 603 and document this work as required in 603. The manufacturer must supply outlet fittings that transition between the underdrains and the outlet pipe. These are included in the 605 pay items. Place underdrains and outlets on fractured slab projects, such as crack and seat, rubblized, or break and seat projects before fracturing the existing pavement.

Mark all underdrain outlets with a wooden lath prior to final seeding. Clean all debris from the outlets after final seeding. These are included in the 605 pay items.

Aggregate Drains (605.07)

Construct the aggregate drains after the completion of pavement.

Excavation

Excavate trenches for aggregate drains to a minimum width of 12 inches (0.3 m) and to the depth shown on the plans. Slope the bottom of the trench to drain and keep it free from loose particles of soil. Excavate the trench to provide a clean exposure of the granular pavement courses to be drained. Provide the dates when the aggregate drains were placed on the 605CA-P-2 Structure Underdrain Form along with a sketch.

Placing and Backfilling

Use granular material for the drains. Place the aggregate to a minimum depth of 8 inches (200 mm) above the bottom of the trench. Backfill the remaining depth of the trench with suitable embankment material according to Item 203. Provide how the aggregate drains were backfilled on the 605CA-P-2 Structure Underdrain Form.

Method of Measurement (605.08)

How were the underdrains measured? Example: station to station or by wheel or other. Provide this on the 605CA-P-2 Structure Underdrain Form.

Basis of Payment (605.09)

Note the length paid per day. Provide this on the 605CA-P-2 Structure Underdrain Form.

Documentation Requirements - 605 Underdrains

1. Edge drains
    a. Document on form CA-P-2
    b. Trench backfilled with granular material, document type of aggregate
    c. Measure as per 605.08
    d. Provide precast reinforced concrete outlet per 605.06 as required
2. Aggregate drains
    a. Width and depth of trench
    b. Trench backfilled filled with granular material, document type of aggregate
    c. Measure as per 605.08
    d. Ends re-opened after final seeding

606 Guardrail

Description (606.01)

This work consists of constructing or reconstructing guardrail, guardrail posts, bridge terminal assemblies, end terminals, and impact attenuators, including the furnishing, assembling, and erecting of all component parts and materials.

Guardrail shall be deep beam rail Type 5, 5A, or 8. Appurtenances shall include bridge terminal assemblies, end terminals, and impact attenuators. Construction of the various types of guardrail include the furnishing, assembling, and erecting of all component parts and materials, complete in place, at the location shown on the plans or as directed, and according to the manufacturer's recommendations where applicable.

Setting Posts (606.03)

The posts shall be set or driven plumb in a manner that prevents battering or distorting of the posts. The posts shall be trimmed that are set or driven more than 1-inch above grade. The trimmed posts shall be treated with a preservative material specified in 712.06.

Type 5 guardrail posts shall be spaced 6 feet, 3 inches on center measured along the centerline of the rail and constructed with either wood or plastic blockouts. Each end of Type 5 guardrail barricades shall be constructed without blockouts and with a flared end section.

Type 5A guardrail posts shall be spaced 3 feet, 1 1/2 inches on center measured along the centerline of the rail and constructed with blockouts. Each end of Type 5A guardrail barricades shall be constructed without blockouts and with a flared end section.

Type 8 guardrail posts shall be spaced 6 feet, 3 inches (1.905 m) on center measured along the centerline of the rail and constructed with blockouts.

Erecting Rail Elements (606.04)

The plans shall show to erect either standard design (single-faced) guardrail or barrier design (double-faced) guardrail.

Erect rail elements in a manner resulting in a smooth, continuous installation. Shop-curved rail shall be used on curves with radii from 5 to 70 feet (1.5 to 22.4 m). Do not allow straight elements to be bent or curved to fit a radius.

The bolts shall be tightened through expansion joints as tight as possible to prevent the rail elements from sliding past one another longitudinally. Ensure that the bolts long enough to extend at least 1/4 inch (6 mm) beyond the nuts.

Splice bolts that extend more than 1/2 inch (13 mm) beyond the nuts shall not be used. For double-faced guardrail, the bolts shall extend from 1/4 to 1 inch (6 to 25 mm) beyond the nuts.

Do not allow burning or welding in the field. The Engineer may approve making holes in the field, but only for special details in exceptional cases. The Engineer may approve field punching, cutting, and drilling if the Contractor demonstrates that its methods do not damage the surrounding metal.

The galvanized surfaces shall be repaired that have been abraded such that the base metal is exposed, including threaded portions of all fittings and fasteners, and cut ends of bolts as specified by ASTM A 780.

The guardrail shall be erected so that the bolts at expansion joints are located at the centers of the slotted holes. The rail elements shall be lapped in the direction of traffic. The plates at each splice shall make contact throughout the area of the splice.

Guardrail Rebuilt (606.05)

Unless otherwise shown on the plans, the rebuilt guardrail shall be of the same type and spacing of members as the existing guardrail.

The following materials shall be new: posts, blockouts, bolts, washers, and incidental hardware as necessary to complete the guardrail, except: (1) existing steel posts and blockouts that are not damaged and have a good galvanized coating may be reused, and (2) guardrail splice bolts that are undamaged and were not removed during salvage may be reused.

Impact Attenuators (606.06)

Before installation of the attenuator, all corresponding shop drawings, installation drawings and instructions from the manufacturer shall be made available for the Engineer’s inspection. Ensure the attenuator is installed as per manufacturer’s shop drawings.

The top of each foundation shall be graded at the same elevation as the adjacent travel lane and/or paved shoulder. The anchors for the attenuator shall be adjusted to avoid pavement joints.

Method of Measurement (606.07)

The Department will measure Guardrail, new or rebuilt, of the type specified by the number of feet from center-to-center of end posts, excluding anchor assemblies. If, however, end connections are made to masonry or steel structures, the Department will measure to the center of the normal post bolt slot. If rail element is used across a bridge, the Department will measure to the first post off the bridge.

The Department will measure Anchor Assembly of the type specified by the number each assembly furnished and erected complete.

The Department will measure Bridge Terminal Assembly of the type specified by the number of each assembly furnished and erected complete.

The Department will measure Impact Attenuator of the type specified by the number of each furnished and erected complete.

The Department will measure Guardrail Post of the kind specified by the number of each furnished and erected.

Basis of Payment (606.08)

The additional costs associated with furnishing and installing extra-length posts instead of standard-length guardrail posts are incidental to Guardrail Post, 8-foot (2.44 m) or Guardrail Post, 9-foot (2.75 m).

For the extra costs associated with furnishing and installing extra-length posts in lieu of standard-length guardrail posts, payment for 9-foot (2.75 m) guardrail posts is considered full compensation.

Documentation Requirements

Use Form CA-D-3A to document the following items:

1. Depth post driven, post spacing
2. All cuts and abrasions on wood post treated with application of approved preservative
3. Rail erected accurately to line and grade all hardware drawn tight
4. Anchor assemblies and bridge terminal assemblies
    a. Number, diameter, and depth of holes drilled
    b. Top 4 inches (10 cm) of concrete anchor formed
    c. Diameter, length, number of anchor bolts placed
    d. Number, spacing, size, and clearance maintained on reinforcing steel
    e. Top cured
    f. Measure and pay as per 606.07

607 Fence

Clearing and Grading (607.03)

Clearing and grading shall be performed as necessary to construct the fence to the required alignment, and provide a reasonably smooth ground profile at the fence line.

Post Assemblies (607.04)

During the curing period of the concrete encasement, the brace end, corner, gate, and pull or intermediate anchor posts shall be secured in final position. Do not require forms for post encasement.

For Type 47 and Type CLT fence, the maximum spacing between intermediate anchor post assemblies, or between end post assemblies and intermediate anchor post assemblies, are 660 feet (200 m).

Horizontal Deflection (607.05)

At points of horizontal deflection, the fence shall be constructed as follows:

1. **Type 47 Fence.** If the fence changes alignment by more than 1 degree but not more than 4 degrees, either steel line posts encased in concrete or wood posts without encasement shall be installed at all horizontal deflection points. If the change in alignment is more than 4 degrees and less than 30 degrees, an intermediate anchor post assembly shall be installed at the deflection point. If the change in alignment is 30 degrees or more, a corner post assembly shall be installed at the deflection point.
2. **Type CL Fence.** If the fence changes alignment by more than 1 degree but not more than 4 degrees, line posts encased in concrete shall be installed at all horizontal deflection points. If the change in alignment exceeds 5 degrees, a post brace and truss rod in each fence panel adjacent to the post located shall be installed at the angle point. If the change in alignment exceeds 5 degrees, the footings for all posts located at deflection points shall be constructed as specified for end posts.

Line Posts (607.06)

Line posts shall be set according to the following:

1. **Type 47 Fence.** Line posts spacings are not to exceed 12 feet (3.6 m) intervals. Line posts at the bottom of dips or depressions in the ground surface are to be anchored in concrete.
2. On tangents, line posts shall be placed so that the fabric, when installed on the side toward the highway, is 2 feet (0.6 m) from the Right-of-Way

line. If adjacent to Right-of-Way lines with less than 5740 feet (1750 m) radius (in excess of 1 degree curvature), line posts shall be constructed on chords so that the fabric, when installed on the side toward the highway, is not less than 2 feet (0.6 m) or more than 8 feet (2.4 m) from the Right-of-Way line.

3. **Type CL Fence.** The tops of driven line posts shall be protected by drive caps or other method to prevent distortion of the exposed end. Line posts are to be spaced at not more than 10-foot (3 m) centers, and placed so that, when the wire is fastened on the side toward the highway, it is 1 foot (0.3 m) from the Right-of-Way line.

Fabric (607.07)

The fabric shall not be erected until after 5 days from the time of setting the posts when using regular cement, or until after 3 days when using high early strength cement.

Type 47 fabric shall be stretched and fastened to line posts using galvanized ties. At a minimum, one tie shall be used for each of the top and bottom horizontal wires and one tie for each alternate horizontal wire below the top horizontal wire.

Chain-link fabric shall be fastened to the line posts using clips or bands spaced approximately 14 inches (0.4 m) apart, and to the top rail or top tension wire using bands or tie wires at approximately 24-inch (0.6 m) intervals or less. Successive rolls of fabric shall be joined by weaving a single picket into the ends of the rolls to form a continuous mesh.

Method of Measurement (607.09)

The Department will measure Fence, Type ___ by the number of feet (meters), complete in place. The Department will measure along the top of the fence from outside to outside of end posts, exclusive of gates and other openings.

The Department will count Gate, Type ___ by the number of complete units of the size and type specified.

Documentation Requirements - 607 Fence

1. Distance between line post
2. Depth line post driven
3. Diameter and depth of concrete used to encase post placed in dip section, fence not attached to post for minimum 5 day cure, 3 days for high early
4. Post for end, corner, gate, pull, and intermediate anchor assemblies driven to a depth of __________ (If not driven to grade, diameter and depth drilled for encasement)
5. Fabric clipped to post at top wire, bottom wire and alternate wires between
6. Document location and measure as per 607.09

Documentation Requirements - 608 Walks, Curb Ramps, and Steps

Sidewalk

1. Concrete Walks
    a. Depth and width of base material (if required)
    b. Wet subgrade if necessary and compact
    c. Slip formed or fixed form construction
    d. Were forms oiled?
    e. Depth of concrete
    f. Concrete used
    g. Spacing on joints – 5 foot (1.5 m) intervals
    h. Surface texture
    i. Curing (required and used)
    j. Expansion material was placed at full depth at _______________(location)
    k. Slope = _________(inches/ft [cm/m] cross slope)
    l. Measure length and width and pay in square feet
2. Asphalt Concrete Walks
    a. Depth and width of base material
    b. Compaction of base material
    c. Form check, depth and width
    d. Asphalt used and compaction
    e. Slope = _________(inches/ft [cm/m] cross slope)
    f. Measure length and width and pay in square feet
3. Crushed Aggregate Walks
    a. Form check, depth and width
    b. Crushed aggregate used
    c. Compaction
    d. Measure length and width and pay in square feet
4. Steps
    a. Form dimensions (riser and tread)
    b. Reinforcing steel (if required); number and size of bars/clearances
    c. Were forms oiled?
    d. Concrete used
    e. Curing (required and used)
    f. Surface finish
    g. Measure length of each tread and then add together for pay
5. Curb Ramps
    a. Form dimensions
    b. Concrete used
    c. Curing (required and used)
    d. Surface finish
    e. When added to existing walk, measure and pay by the square foot (square meter)
    f. When placed with new walk, pay each

Documentation Requirements - 609 Curbing, Concrete Medians, and Traffic Islands

1. Stone Curb
    a. Stone type
    b. Sizing of cut pieces
    c. Straight edge on top and exposed face?
    d. Ends dressed at right angles?
    e. Edge at gutter cut to spec?
    f. Subgrade compaction
    g. Granular base (if required)
    h. Batter set correctly?
    i. Construction of curb joints
    j. Measure length for pay and document location. (Station and plan location)
2. Cast-in-Place Concrete Curb and Combination Curb and Gutter
    a. Form dimensions or slip form (if slip formed, measure finished curb dimensions)
    b. Steel forms used?
    c. Forms oiled?
    d. Subgrade compacted and wetted
    e. Concrete placement
    f. Tie bars placed (if required)
    g. Joint spacing
    h. Joint dimensions
    i. Joints sawed or formed by metal plates
    j. Finishing
    k. Curing (required and used)
    l. Curing (required and used)
    m. Measure length for pay and document location. (Station and plan location)
3. Asphalt Concrete Curb
    a. Tack coat application rate
    b. Placement Method A or Method B used?
    c. Measure length for pay and document location. (Station and plan location)
4. Concrete Median and Traffic Island
    a. Form dimensions or slip form (if slip formed measure finished dimensions)
    b. Steel forms used?
    c. Forms oiled?
    d. Subgrade compacted and wetted
    e. Joint spacing
    f. Joint dimensions
    g. Joints sawed or formed by metal plates
    h. Finishing
    i. Curing (required and used)
    j. Measure and calculate square yards for payment

610 Cellular Retaining Walls

This specification covers to general types of retaining walls. The first are walls made up of layered and tiered precast reinforced blocks. The second are constructed with metal columns and front and rear metal filler panels. Both of these wall types are specialized and require Director's approval. Acceptable Manufacturers are sometimes indicated in the plan notes.

Documentation Requirements - 610 Cellular Retaining Walls

1. Director's approval is required
2. Manufacturer's wall type must be in successful commercial use for a period of at least 3 years
3. For galvanized metal walls the Contractor must furnish 3 copies of the Manufacturer's "Analysis and Coating Test Certificate".
4. State type size, and quantity of units
5. Precast concrete units, must be produced by a certified precast concrete producer and shipped with a TE-24.
6. Type of backfill used and how compacted.
7. Measure and pay as per 610.08 and 610.09 of the CMS

613 Low Strength Mortar Backfill

Documentation Requirements - 613 Low Strength Mortar Backfill

This section recommends minimum documentation and critical inspection requirements for Item 613. The following documentation requirements must be recorded in the appropriate sections of the CA-P-1 Pipe Construction Form and in the project daily reports. Specifications or other requirements waived by the Project Engineer shall be noted in the daily diaries.

1. Record on the CA-P-1 form how the pipe was anchored to prevent it from floating in the trench
2. Record how the LSM was brought up in the trench. Indicate if the LSM was brought up on both sides of the pipe evenly.
3. Indicate if forms or embankment was placed at ends of pipe to prevent the LSM from flowing into the ditch
4. Record if the LSM was brought up to grade line as specified in plans
5. A comparison needs to be made between the quantity installed and the quantity computed from the plans (*take-off quantity*). Record both the installed and take-off quantity on the CA-P-1 form. Measure and pay the computed amount of cubic yards (cubic meters) unless it is determined by the engineer that the amount used is reasonable for pay. Documentation of the take-off and installed quantities is an important part of the record particularly when paying less than the quantity delivered.

614 Maintaining Traffic

Description (614.01)

This work consists of maintaining and protecting vehicular and pedestrian traffic according to these provisions. For through traffic, the Special Provisions or the plans will designate whether the highway will be closed with detours, roads and run-arounds provided or whether traffic will be maintained through all or portions of the project.

Traffic Facilities (614.02)

Vehicular and pedestrian ingress and egress for all property adjacent to any improvement shall be provided at all times.

Contractor maintenance responsibilities, including pothole patching begins for a section of highway when the Contractor begins the Work in that section and ends with the acceptance of the Work under 109.11 or 109.12. The two directions of a divided highway are considered separate highway sections and the start of Work on one direction does not begin maintenance responsibilities on the other direction.

Traffic Control General (614.03)

The traffic control shall conform to the requirements of the plan, standard construction drawings shown on the plans, and the OMUTCD for Streets and Highways, hereinafter called the Ohio Manual, for the installation, maintenance, and operation of all traffic controls and traffic control devices. When the plans or standard construction drawings do not cover a specific traffic control situation, the necessary traffic control devices shall be placed according to the Ohio Manual and use the procedures required by the Ohio Manual.

The OMUTCD (Ohio Manual on Uniform Traffic Control Devices) has three levels of compliance to indicate the type of standard and whether it is mandatory, recommended, or optional:

- All mandatory conditions are listed under the section heading “Standard”
- All recommended conditions are listed under the section heading “Guideline”
- All allowed conditions are listed under the section heading “Option”
- A fourth grouping was added, “Support,” to include statements that were not mandatory, recommended or optional, but rather general information

Supplement 1061 prequalifies the portable changeable message boards. Only two panel of information shall be allowed.

Drums, signs, sign supports, barricades, impact attenuators, and other traffic control devices that are certified to meet NCHRP 350 safe-crash standards or as modified by Contract Documents shall be used. Do not allow heavy non-yielding devices or supports that do not conform to the current standards of NCHRP 350 unless allowed by Contract Documents.

Ensure the drums are furnished with Type G reboundable reflective sheeting complying with the requirements of 730.191. Ensure that owner identification markings on construction drums are no more than 1 inch (25 mm) in character height and are located at least 2 inches (50 mm) below the reflectorized bands or on the top or bottom horizontal surfaces of the drum. Ensure the drums are ballasted according to the manufacturer's recommendations.

If equipment, vehicles, and material are stored or parked on highway rights-of-way, they shall be located not less than 6 feet (2 m) behind existing guardrail or not less than 30 feet (9 m) beyond the traveled way unless otherwise permitted by the Engineer. At night if any such material or equipment is stored between the side ditches, or between lines 6 feet (2 m) behind any raised curbs, they shall be clearly outlined with dependable lighted devices that are approved by the Engineer.

Flaggers (614.08)

Whenever one-way traffic is established, at least two flaggers shall be used unless the Engineer authorizes otherwise, and signs, cones, barricades, and other traffic control devices shall be erected according to the Ohio Manual. Flaggers shall maintain positive and quick means of communication at the opposite ends of the restricted area.

Asphalt Concrete for Maintaining Traffic (614.13)

The Contractor may use either a Type 1 or Type 2 mix of Item 448 asphalt concrete PG 64-22, or an asphalt concrete surface course the Engineer approves. Surface course materials shall be placed where the Engineer directs for maintenance of the existing pavement, shoulders, or structures.

Where materials are placed in small quantities or under adverse conditions, the Engineer may waive specification requirements for placing and finishing if, in the judgment of the Engineer, it is determined that the Contractor can obtain satisfactory results in providing a smooth and durable pavement surface.

Performance (614.14)

If, in the opinion of the Engineer, the Contractor is not furnishing proper maintenance of traffic facilities and proper provisions for traffic control, the Department may take the necessary steps to place them in proper condition, and the Department will deduct the cost of such services from any money that may be due or become due the Contractor.

Method of Measurement (614.15)

The Department will measure Work Zone Marking Signs as the number of sign installations, including the sign, necessary supports, and all attachment hardware. The Department will include all other work zone signs under Maintaining Traffic unless separately itemized.

The Department will measure Work Zone Pavement Markings complete in place, by class and material, in the units designated.

The Department will measure line quantities as the length of the completed stripe, including gaps, intersections, and other sections of pavement not normally marked.

Basis of Payment (614.16)

Unless separately itemized, the lump sum price bid for Maintaining Traffic shall include the cost of removal or covering of conflicting pavement markings and layout, application and removal of pavement markings when required, maintaining the existing highway in a safe condition for public use, removing abrasive and salt residue remaining from snow and ice control performed by the Department or local governments, providing flaggers; and their equipment; and furnishing, maintaining in an acceptable condition, and subsequently removing the following work zone traffic control items as required by the Contract Documents:

1. Signs, supports, and warning lights.
2. Drums, cones, gates, barricades, and vertical panels.
3. Flashing arrow panels.
4. Work zone traffic signals.
5. Lighting for work zone signals and flaggers.

If traffic permanently damages beyond use, any of the following items, the Department will compensate the Contractor for the fair market value of the damaged item according to 109.05 provided the Contractor has pursued but failed to obtain compensation from the motorist. Follow the procedures given in 107.15 for compensation for traffic damage to completed permanent items of Work, to obtain compensation from the motorist before requesting compensation from the Department.

1. Flashing arrow panel.
2. Work zone signal, pole, or controller.
3. Lighting unit or pole.
4. Changeable message sign.
5. Work Zone Impact Attenuator

The lump sum price bid for Detour Signing includes the cost of the Contractor furnishing, installing, maintaining, and removing the detour signing shown on the plans and their necessary supports.

The Department will pay for the following items under their associated item numbers: 502 Bridges, 615 Roads and Pavement, 622 Portable Concrete Barrier.

The Department will pay for aggregate and calcium chloride authorized by the Engineer and used for Maintaining Traffic under Items 410 and 616.

Documentation

Use the ODOT Long Term Inspection Form (CA-D-8) for long-term projects that are under temporary traffic control 24/7. Below are the guidelines of how and when to fill out the form.

Purpose of form: To document the condition of the work zone traffic control.

When to review:

- At the beginning of each project;
- Immediately following a change to the work zone traffic control (construction phase change); and
- Weekly through the duration of the project. It is suggested that the review be performed on the morning of the day prior to the last work day for the week. (Example: If the project normally works Monday through Friday, then perform the review on Thursday morning; if the project normally works Monday through Thursday, then perform the review on Wednesday morning.)
- All inspections are to include a nighttime review (preferably twice a month).
- Following receipt of information regarding a reported crash.
- Who is to use this form:
- ODOT Project personnel – in accordance with the inspection schedule
- Contractor personnel – if a Worksite Traffic Control Supervisor is specified in the contract documents, the review is to be performed and documented on a daily basis.
- ODOT District Work Zone Traffic Manager – in conjunction with routine program responsibilities.
- ODOT County Managers – to document permit or ODOT maintenance work zones.

GENERAL:

"ODOT Project No:"

Self-explanatory; record all information accordingly.

Contractor

1. Fill in the contractor name who is in charge of the zone.

"Date"

1. Fill in the date when the zone was inspected.

"Time" & "AM / PM"

1. Fill in the time of the review.

"Weather"

This information in important since weather and ambient lighting conditions affect the visibility of pavement markings and signs.

1. Circle or fill in the weather conditions.

"Visibility"

Describe issues with visibility

"Received By:"
The ODOT inspector/engineer who received the inspection form, or who performed the inspected if no WTS is specified in the contract documents.
"Date"
1. The date the ODOT inspector received the form from the WTS or the date the inspector performed the review.

Section A: "Drive Through:"

Drive through the work zone at the posted speed and take note of the traffic's movements and reactions to the traffic control devices. Space for additional comments and/or recommendations if provided at the bottom of page 2.

"1. Work zone free of difficult or unexpected maneuvers?"

Based on the drive through and observation of the traffic, make a determination of the adequacy of the overall work zone traffic control. If problems are observed, check the box & record the observed problem in the comments section.

"2. Adequate warning of conditions?"

Do the signs provide adequate reaction time? If no, check the box & record the observed problem in the comments section.

"3. Is signing clear / uncluttered and properly spaced?"

Are the warning signs visible and easy to read and understand? If no, check the box & record the observed problem in the comments section.

"4. Traffic control devices sufficiently visible?"

Are all the traffic control devices (signs, cones, plastic drums, tubular markers, arrow panels, etc.) visible? If not, check the box & record the observed problem in the comments section.

"5. Is project free of traffic accidents"

Are all accidents if any being documented and reported to the project engineer?

"6. Equipment/materials properly stored off roadway"

Is equipment and materials properly stored according to specification?

"7. Are congestion points absent from within project limits"

Did you observe any congestion or delay (as defined by the policy)? If so, check the box and record the observed problem in the comments section.

"8. Work vehicles properly interacting with traffic"

Are work vehicles entering and leaving the work zone without causing any confusion with the travelling public?

Section B: "Signs/Lights"

"1. Working properly/visible?"

Are all of the signs and lights visible and appropriate?

"2. Are all permanent/temporary signs consistent with one another?"

"3. Proper size"

Are signs and fonts the proper size as per contract documents?

Section C: "Portable Changeable Message Signs/Arrow Panel"

"1. Application Meet Guidelines?"

Does the message on the PCMS is giving conflicting information or guidance. Note the message in the comments section. If there is more than one PCMS on the project, also note the location.

"2. Correct Placement?"

Based on your observations made during the drive through (Section A), was the PCMS/Arrow panel located correctly or necessary? Include your recommendation for the correct location or need.

"3. Delineated with No Cones / Drums"

Is the the PCMS/Arrow panel delineation with cones/drums?

"4. Dimmed At Night"

Is the PCMS is dimmed at night?

"5. All boards/signs working properly (bulbs correctly aligned, no bulbs out, etc)"

Self explanatory

Section D: "Drums/Barricades/PCB/Impact Attenuators

"1. Acceptable taper length"

Refer to Chapter 6, Section 6C.08 of the OMUTCD. Check the box if the taper length is too short for the conditions (speed & lane width). If not acceptable, note the location, deficiency & recommendation in the comments section.

"2. Spacing acceptable"

Refer to Chapter 6, Section 6F.55 of the OMUTCD. When using 42" reflectorized cones at night, the spacing between devices shall be 40' in the tangent section (the cones should not be used in the taper). Based on your observations made during the drive through (Section A), check the box applicable to that device if the space between devices exceeds the maximum length based on the conditions (speed). Note the location and recommendation in the comments section.

"3. Properly aligned/cleaned/secured?"

Based on your observations made during the drive through (Section A), check the box if the drums, cones or tubular markers are out of alignment in either the transition or tangent areas. Note the location and recommendations in the comments section.

"4. Adequate number of devices?".

Based on your observations made during the drive through (Section A), if hazards are not adequately protected or delineated, check the box under the letter heading for that device. Note the location and recommendations in the comments section.

"5. Object markers/barrier reflectors in-place/visible?"

Based on your observations made during the drive through (Section A), are the markers/ reflectors performing as intended?

"6. Attenuators in place?"

Based on your observations made during the drive through (Section A), are the attenuator placed in the appropriate location?

"7. Attenuators secured and in good condition?"

Based on your observations made during the drive through (Section A), are the attenuators placed according to contract documents and free from damage?

Section E: "Pavement Markings / Raised Pavement Markers (RPMs)

"1. Pavement markings visible and in good condition?"

Self explanatory

"2. Is striping free of conflict?"

Based on your observations made during the drive through (Section A), check the appropriate box if any conflicts are observed between the permanent and temporary pavement markings which could cause driver confusion. Note the location(s) in the comments section.

"3. RPM's in good condition, proper number and correspond to pavement markings?"

Based on your observations made during the drive through (Section A), check the box if additional raised pavement markers are needed to provide positive guidance to the motorists. Note the location(s) in the comments section.

Based on your observations made during the drive through (Section A), check the box if either existing or temporary raised pavement markers that do not correspond to the current pavement markings are observed. Note the location(s) in the comments section.

Videos/Photos of workzone:

Mark the box for documentation purposes and list the photogragher.

Corrective Action Needed

Note if any corrective action is needed in the comments section

Describe Traffic Accidents (if any):

Self explanatory

Damaged or Missing MOT items:

Document and missing or damaged MOT items that was witnessed during the review.

Lane Closures/ Rollong Road Blocks:

Document any lane closures/ rolling road blocks that occurred during the review.

LEO's:

Document the number of LEO's , the total hours the LEO's are present and what their activities are.

Inspected By:

Ensure that the form is signed and dated by the contractor's worksite traffic supervisor as specified in the contract documents.

The ODOT Short-Term Form (CA-D-7) is for those projects that are typically set up and torn down daily. Below is the guidelines of how and when to fill out the form.

For projects where the MOT is set up new each day, such as mill and fill operation, form CA-D-7 (Short Term Work Zone Review) should be completed each day with each new setup. (for maintenance, utility, permit and daily contract operations)

"County / Route / Section / Project No."

Self-explanatory; record all information accordingly.

"Date"

Fill in the date

"Time & AM/PM."

Fill in the time of the review.

Circle "AM or PM"

"Weather Conditions"

Fill in the weather conditions.

"TYPE OF OPERATION / TRAFFIC CONTROL"

Circle the type of Operation / Traffic Control that is being performed at the time of the review.

Use "Other" to document situations not described.

"WORK BY"

Document who is working on the roadway, in the case of a contractor or utility, include the company name.

"TRAFFIC CONTROL / SAFETY DEVICES"

(Signs, Flagger, Cones, Drums, Arrow Board, Signals, PCMS, Other....)

Used to describe the effectiveness of the traffic control devices. Drive through the work zone at the posted speed and take note of the traffic's movements and reactions to the traffic control devices.

"CONDITION"

Used to describe any inadequacies or deficiencies with the Condition of the Traffic Control and Safety Devices. If no inadequacies or deficiencies are noted check "NONE" and continue to Placement. If Conditions are not adequate record deficiencies and corrective action to be taken. When deficiencies have been corrected record date. Examples of items to review.

1. Are the traffic control devices legible?
2. Are they clean and reflective?
3. Do any of them need to be replaced?
4. Are any non-standard?
5. Are they the correct size?

"PLACEMENT"

Used to describe any inadequacies or deficiencies with the Placement of the Traffic Control and Safety Devices. If no inadequacies or deficiencies are noted check "NONE" and continue to Visibility. If Placement is not adequate record deficiencies and corrective action to be taken. When deficiencies have been corrected record date. Examples of items to review.

1. Are the traffic control devices appropriate?
2. Do they provide adequate reaction time?
3. Are any of the messages conflicting?
4. Are the maneuvers difficult or unexpected?

“VISIBILITY”

Used to describe any inadequacies or deficiencies with the Visibility of the Traffic Control and Safety Devices. If no inadequacies or deficiencies are noted check "NONE" and continue to Flagger. If Visibility is not adequate record deficiencies and corrective action to be taken. When deficiencies have been corrected record date. Examples of items to review.

1. Are all traffic control devices visible?
2. Are they easy to read?
3. Are they blocked by vegetation or other signs?
4. Do any need to be repositioned?

“FLAGGER”

Used to describe any inadequacies or deficiencies with the Flagger or the Flagger Operations. If no inadequacies or deficiencies are noted check "NONE" and continue to Traffic Flow Problems. If the Flagger or the Flagger Operations are not adequate, record deficiencies and corrective action to be taken. When deficiencies have been corrected record date. Examples of items to review.

1. Are the flaggers positioned correctly and highly visible?
2. Are they attentive to oncoming traffic?
3. Are they flagging properly?
4. Are they properly attired?
5. Are the paddles / flags visible and clean?
6. If temporary traffic signal, are signal heads visible?

“TRAFFIC FLOW PROBLEMS”

Review for evidence of crashes, incidents, congestion points, delays, violations of PLCM, etc. If no evidence is noted check "NONE" and continue to the CONFORMANCE / ADEQUANCY WITH TRAFFIC CONTROL STANDARDS section. Record any evidence of crashes, incidents, congestion points, If Traffic Flow Problems exist record corrective action to be taken. Examples of items to review:

1. Are lane closures in accordance with allowed hours (PLCM,)
    a. Permit, Plans, Contract)?
2. Is there evidence of skid marks and / or accident debris?
3. Is there damage or reoccurring damage to traffic control devices?

“CONFORMANCE / ADEQUANCY WITH TRAFFIC CONTROL STANDARDS”

Review for non-compliances with OMUTCD, SCD, plans or permit. If no non-compliances are noted check "NONE" and continue to INTERACTION OF WORK

VEHICLES AND TRAFFIC section. If the Standards are not adequate record corrective action to be taken. Examples of items to review.

1. Proper spacing between signs?
2. Is the taper rate and drum spacing correct?
3. Is there adequate buffer space?
4. Is the work area protected?

"INTERACTION OF WORK VEHICLES AND TRAFFIC"

Review the interaction of work vehicles entering and exiting the work zone. If no inadequacies or deficiencies are noted check "NONE". If interactions are not adequate or safe record deficiencies and record corrective action to be taken. Examples of items to review.

1. Is there excessive braking for vehicles entering or exiting the work zone?
2. Is there sufficient area in the work zone for work vehicles?
3. Is there excessive dirt or mud on the road?

"PROPER STORAGE OF EQUIPMENT AND MATERIALS"

Review the storage area of the equipment and materials in the work zone. If no inadequacies or deficiencies are noted check "NONE". If storage area is not adequate or safe record deficiencies and record corrective action to be taken. Examples of items to review.

1. Is the equipment and material properly protected or outside the clear zone?
2. Is the equipment and material to close to open travel lanes?

"MAINTENANCE OF TRAFFIC DEFICIENCES AND ACTION TAKEN"

Notification: Verbal / Written - To whom

1. Circle how corrective action information was provided.
2. Record to whom the notification was provided to.

"Correct by date"

Provide the date by which the corrections need to be made.

"Corrected in a timely manner"

1. Circle Yes if the corrections were made by the date established at the time of the inspection.
2. Circle No if the corrections were not made by that date.

"Date corrected"

Record date corrected.

"Section(s) requiring correction(s)"

Circle the letter which represents the section(s) which require remedial action.

"Field review by"

Note your name and the date of the review.

"Copy to: DWZTM / County Manager /Contractor / Construction or Other"

Circle the entity and note who the copy(s) of the report form was given to.

Daily Documentation Requirements - 614 Maintaining Traffic

1. Carry on inspector's diary (Form CA-D-3) items of work performed by contractor. Erecting barricade fences, traffic zones established, flagger, or off-duty patrolmen used to control traffic
2. What kind of sheeting do the signs have? G or H
3. All barricades and barrels are in good shape and have adequate reflectivity
4. When road is closed document all items used (barrels, barricades, signs, etc.). If a camera is available, taking a couple of snap shots is a good idea.
5. A statement should be recorded daily on the Inspector's diary that traffic control was adequate for work performed. Any accidents should be accurately documented
6. Locations required when placing temporary striping, reflectors, and barrier wall
7. Pay as per 614.16 of the C&MS

615 Roads and Pavements for Maintaining Traffic

Documentation Requirements - 615 Roads and Pavements for Maintaining Traffic

1. Document any work as if it were being performed as its own item (203, 442, 452, 616, etc.).

616 Dust Control

Documentation Requirements - 616 Dust Control

The minimum documentation and critical inspection requirements for Item 613 includes recording the following inspection points in the project daily reports. Specifications or other requirements waived by the Project Engineer should also be noted in the daily reports.

1. Measure or weigh water truck capacity to determine the water volume per load
2. The units of measurement can be converted using the following conversions: 1 ft^3 = 7.48 gal.; 1 lb. water = 0.12 gal.
3. Record the bag count or weigh bills for calcium chloride when used.

617 Reconditioning Shoulders

Because of the simplicity of this item of work, no detailed explanation of the item is required in this manual.

Documentation Requirements - 617 Reconditioning Shoulders

1. Materials.
2. Place location or stationing where material was used.
3. Shoulder preparation.
4. Average depth and width.
5. Spreading.
6. How was material compacted?
7. Attach initialed dated tape to tickets and convert as per Table 617.06-1 of the C&MS.
8. Measure and pay according to 617.06 and 617.07.
9. Document on CA-D-1, CA-D-2, and CA-EW-12. Do not duplicate the information on these forms unless necessary.

618 Rumble Strips on Shoulders

Because of the simplicity of this item of work, no detailed explanation of the item is required in this manual.

Documentation Requirements - 618 Rumble Strips on Shoulders

1. Document Type 2 or Type 3
2. Measure and document width and depth of cut
3. Dust properly controlled
4. How were grindings disposed?
5. Measure length for pay

620 Delineators

Delineators - General

This information is intended to serve as a guide for construction personnel where the Contractor furnishes and installs delineators. However, it may also be useful for maintenance personnel performing the same functions. Inspection procedures are outlined. This information points out the various important features and references the applicable specification or standard drawing.

Materials (620.02)

Make sure that all delineator materials used on a project are approved and are listed on the Qualified Product List at the following web site:

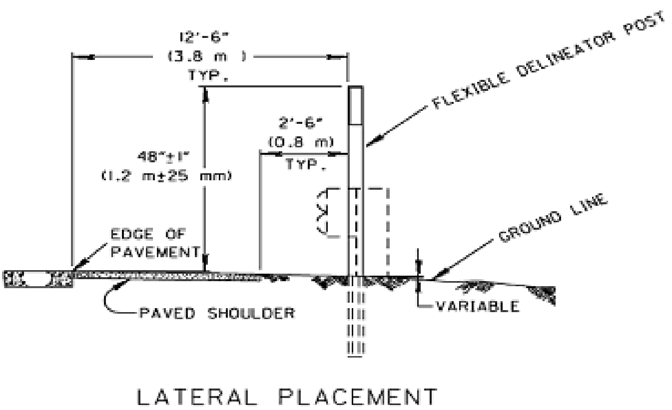
Item 720.01 Rectangular Reflectors

http://www.odotonline.org/materialsmanagement/qpl.asp?specref=720.01

Item 720.03 Flexible Posts

http://www.odotonline.org/materialsmanagement/qpl.asp?specref=720.0 3

Delineator Lateral Placement (620-3)



Delineator Lateral Placement, SCD TC 61.10

The top of the delineator post shall be 48 inches (1.2m) above the edge of the pavement.

The delineator post shall be placed 12 feet and 6 inches (3.8m) outside the outer edge of the pavement or the delineator post shall be placed 2 feet and 6 inches (0.8m) outside the outer edge of the shoulder.

Placement of Delineator on Curves and Tangent Sections

Delineators shall be spaced 400 feet (122m) apart on the tangent sections.

Delineators on the horizontal curves shall be spaced according to the table in the SCD TC-61.10.

Delineators should be provided on the outside of horizontal curves on interchange ramps.

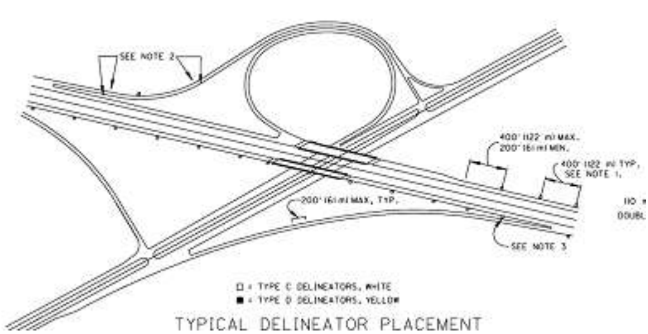
The color of the delineator reflector shall conform to the color of the pavement markings nearest the delineator.

SPACING ON RAMP
HORIZONTAL CURVES

RADII (FEET)		DEGREE OF CURVE (MAX)	SPACING ON CURVE (FEET)	TRANSITION * SPACING (FEET)
FROM	TO			
TANGENT	1201	5	200	200
1200	1001	6	100	200
1000	801	7	90	200
800	601	9	80	160
600	476	12	70	140
475	301	19	60	120
300	-	-	50	100

*FROM TANGENT TO 12° CURVE, TRANSITION SPACING = 200' TO 140' TO 70'
FROM 19° CURVE TO TANGENT, TRANSITION SPACING = 60' TO 120' TO 200'

Spacing for Delineators, SCD TC 61.10



Delineator Placement on Ramps, SCD TC 61.10

Delineator Installation (620.05)

Delineators shall be installed facing traffic except for red reflectors facing wrong-way traffic, if used.

Protective paper covering the face of flexible post-mounted reflectors shall not be removed until after installation.

Ensure that delineator posts are not more than 1:50 out of plumb. If soil conditions may cause the post to be out of plumb, the Contractor may drive a pilot shaft before installation.

Install the flexible posts using methods and equipment that conforms to the post manufacturer's recommendations.

Documentation Requirements - 620 Delineators

1. Document depth that post was placed on CA-D-3A
2. Document type of post and reflector on CA-D-3A
3. Total of each color and location where they were placed on CA-D-3A
4. Turn in total of all colors for pay on CA-D-3A

621 Raised Pavement Markers (RPM)

Raised Pavement Markers – General

This information is intended to serve as a guide for construction personnel where the Contractor furnishes and installs raised pavement markers. However, it may also be useful for maintenance personnel performing the same functions. Inspection procedures are outlined. This information points out the various important features and references the applicable specification or standard drawing.

Conduct 25 – 75% inspection during the installation activities which include daily start-up, intermittent, and end of day inspection. Additionally, conduct 80 – 100% inspection of all installed RPM's prior to final acceptance.

Materials (621.02)

Make sure that all RPM materials used on projects are approved and are listed on the Qualified Product List at the following web site:

Item 721.01 Raised Pavement Marker Castings

http://www.odotonline.org/materialsmanagement/qpl.asp?specref=721.01

Item 721.02 Prismatic Reflectors

http://www.odotonline.org/materialsmanagement/qpl.asp?specref=721.02

Item 721.03 Raised Pavement Marker Castings Adhesive

http://www.odotonline.org/materialsmanagement/qpl.asp?specref=721.03

Item 721.04 Prismatic Reflectors Adhesive

http://www.odotonline.org/materialsmanagement/qpl.asp?specref=721.04

Installation RPM Casting (621.04)

1. References
    a. Brochure for RPM Installation Procedure
    b. See Traffic Engineering Manual, Section 350-3 at the following web site:
    c. *http://www.dot.state.oh.us/Divisions/HighwayOps/Traffic/publications2/TEM/Documents/Part_03_071808_bookmarked.pdf*
2. RPMs shall be placed when the pavement surface temperature and the ambient air temperature are at least 40 °F (5 °C) and the pavement is dry.
3. RPMs shall not placed under the following conditions:
    a. On pavement surfaces with cracking, spalling, or failure of underlying base material.
    b. Within 1 foot (0.3 m) of active signal detector loop wires.

c. Over pavement markings except with the Engineer's approval.
d. Closer than 2 inches (50mm) to a pavement construction (transverse or longitudinal) joint or within an intersection.
e. Within 3 feet (1 m) of a bridge expansion joint.

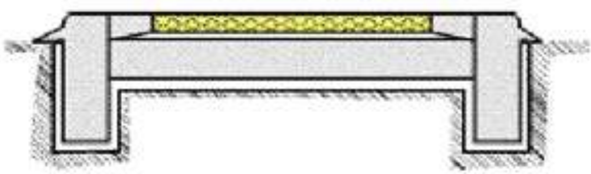
Brochure for RPM Installation Procedure

1. Casting Installation

Typical Saw Cut

a. Pavement must be cut to the dimensions for the casting being used.

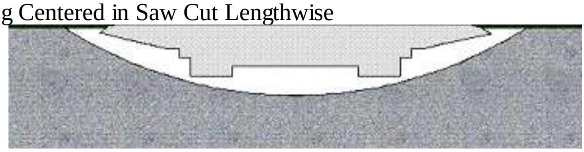
2. Casting in Saw Cut Without Epoxy



a. Each pavement cut must be inspected prior to adding epoxy.
b. When a casting is inserted in the cut without epoxy all 4 leveling lugs/tabs must contact the pavement surface.

All four keel-ends of castings must be below the surrounding pavement surface.

3. Casting Centered in Saw Cut Lengthwise



a. Each casting must be centered lengthwise and should have 1/8 inch (3 mm) clearance between pavement cut and casting for epoxy to bond properly.
b. Only the leveling lugs/tabs should be in contact with pavement surface after insertion of casting in pavement so that minimum

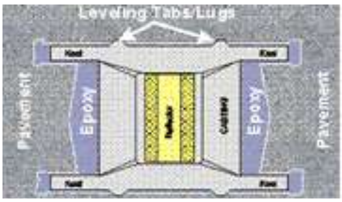
of 1/8 inches (3 mm) of epoxy is the bonding adhesive between casting and pavement.

c. The pavement cut must be completely dry and free of dust, dirt or any other material that will interfere with the adhesive bond.

d. Epoxy on the active reflector face must be removed immediately.

e. Saw cut – casting fit must be periodically checked as saw blades wear to insure correct dimensions are maintained

4. Properly Installed RPM with Epoxy Around Casting



a. Two component epoxy adhesive approved, must be on QPL is to be used to fill the pavement cut to within 3/8" of top of pavement cut, prior to placing casting.

b. After placing casting:

The 4 leveling lugs/tabs must be in contact with pavement surface.

The epoxy should ooze out from under the casting from all sides filling all voids around the casting and be level with pavement surface.

RPM Lens Replacement

1. References
    a. Brochure for RPM Installation Procedure
    b. See Traffic Engineering Manual Section 350-3 at the following web site:
    c. *http://www.dot.state.oh.us/Divisions/HighwayOps/Traffic/publications2/TEM/Documents/Part_03_071808_bookmarked.pdf*
2. Remove Reflector

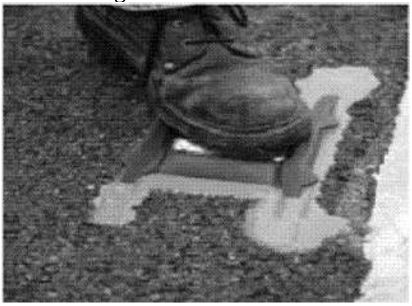
    a. Pry old reflector out of casting.
    b. Use eye protection when replacing reflector.
3. Clean the casting:

a. Scrape old pad material and adhesive out of reflector pocket, using an air hammer or wire brush.
b. Sandblast the casting pocket to remove all residual adhesive, rust, and other contaminants.
c. It is important that the casting is clean to ensure long-lasting performance.

4. Apply Adhesive

a. Peel the release liner from the back of the reflector.
b. Apply a wide bead (approximately 3/8 inch) of an adhesive (as approved ODOT QPL) in the center of the adhesive pad on the back of the reflector.

5. Install Reflector into Casting



a. Place the reflector into the casting pocket.
b. Apply foot pressure on the reflector for 1-3 seconds.
c. Adhesive must flow out around all edges of the reflector to indicate that the adhesive completely covers the entire bottom of the reflector and provides a uniform adhesive layer between the reflector and the casting.

Remedial Actions for Poorly Installed RPM Castings

This information is intended to serve as a guide for construction and/or maintenance personnel where the RPM castings are poorly installed. Also, it provides a guide to the necessary remedial action to fix the problem.

The RPM casting shall be installed properly according to the following references:

1. Item 621.03 “Layout”.
2. Item 621.04 “Installation of RPM Casting”.
3. Standard Construction Drawings TC-65.10 and TC-65.11.

The following information provides examples of defectively installed RPM castings and also describes remedial action to fix the problem:

Defective Installation: The RPM is installed with all four lugs/tabs not resting on the pavement such as shown in Figure 1 below:

Figure 1

Remedial Action:

Remove and reinstall the RPM casting at a new location.

New RPM location shall not exceed 25% of the specified RPM spacing.

If necessary to relocate the RPM to a distance greater than 25% of the RPM spacing, do not install the affected RPM.

Fill the old cavity on the roadway surface with epoxy or asphalt concrete from where the RPM casting is removed.

Defective installation: The RPM is installed but does not fill the voids with epoxy all around the casting or the RPM is installed but the epoxy is not all around the casting to the surface of the pavement such as shown in Figure 2.

Figure 2

Remedial Action:

Blow out dirt from around casting with compressed air.

Fill the voids and seal the RPM casting all around with epoxy as shown in Figure 3.

Figure 3

Defective installation: The RPM casting is installed near or on a longitudinal joint or crack on the roadway surface such as shown in Figure 4.

Figure 4

Remedial Action:

Seal all the cracks with epoxy up to nine inches (225 mm) from the RPM casting as shown in Figures 5, 6 and 7.

Figure 5

Figure 6

Figure 7

Defective installation: The RPM is installed but the epoxy adhesive is not hardened or the epoxy adhesive is not uniform gray in color such as shown in Figure 8.

Figure 8

Remedial Action:

Remove and reinstall the RPM casting at a new location.

New RPM location shall not exceed 25% of the specified RPM spacing.

If necessary to relocate the RPM to a distance greater than 25% of the RPM spacing, do not install the affected RPM.

Fill the old cavity on the roadway surface with epoxy or asphalt concrete from where the RPM casting is removed.

Defective installation: The RPM is installed on construction joints which have extensive failure such as shown in Figure 9.

Figure 9

Remedial Action:

Remove and reinstall the RPM casting at a new location.

New RPM location shall not exceed 25% of the specified RPM spacing.

If necessary to relocate the RPM to a distance greater than 25% of the RPM spacing, do not install the affected RPM.

Fill the old cavity on the roadway surface with epoxy or asphalt concrete from where the RPM casting is removed.

Documentation Requirements - 621 Raised Pavement Markers

1. Verify castings to be used are on the Qualified Products List (QPL) before permitting installation.
2. Verify the epoxy to be used to install the casting is on the Qualified Products List (QPL)
3. Make sure that the keels of the casting are placed into the slots so that the tips of the RPM snowplow deflecting surfaces on the keels are below the pavement surface and all four lugs (Tabs) on the keels of the casting are in contact with the pavement.
4. Check before placement of the epoxy, the saw cut is clean of all loose material and dry. Saw cut should have 1/8 inch (3 mm) clearance on all sides of the casting.
5. Verify ambient air temperatures are at least 40 degrees Fahrenheit (5 degrees Centigrade) and the pavement is dry.
6. Check epoxy is an A+B mixture, thoroughly mixed (grey color) and in accordance with manufacture's recommendations.
7. Check that sufficient epoxy is in and between the slots to ensure that all voids beneath and around the casting are filled.
8. Placement of RPM castings shall be 6" (152 mm) from any construction joint (Lateral or Longitudinal).
9. Location and / stations are per Standard Const. Drawing TC 65.10 and TC 65.11.
10. Check quantity totals for payment.
11. Document on CA-D-3B.
12. Verify RPM reflectors to be used are on the Qualified Products List (QPL) before permitting installation.
13. Verify the adhesive to be used to attach the reflector is on the Qualified Products List (QPL).
14. Verify that all dirt, dust, oil, grease, rust, moisture, parts of damaged reflectors, or any foreign matter is removed that impairs adhesion of the reflector to the casting.
15. Verify reflector area of the castings shall be sandblasted to 80% bare metal.
16. Verify the application of adhesive is in a single bead, sufficient to squeeze out on all sides of the reflector when pressure is applied, to seat the reflector and seal out moisture.
17. Document on CA-D-3B.

622 Concrete Barrier

Description

This work consists of furnishing and placing portland cement concrete barrier on the accepted and prepared subgrade, subbase course, or existing pavement. This item also consists of furnishing, placing, maintaining, and removing portable concrete barrier.

Placing Concrete (622.03)

The concrete barrier will be constructed by either cast-in-place, precast, or slip-form methods. For slip-form construction, conform to 609.04.C. For cast in place construction, conform to the proper SCD.

1. RM- 4.3 Single Slope Barriers
2. RM- 4.4 Single Slope Barrier Transitions
3. RM- 4.5 Single Slope Barrier, Type D
4. RM- 4.6 Concrete Barrier End Sections

Portable Concrete Barrier (622.04)

The individual sections of PCB shall not less than 10 feet (3 m) long. See SCD RM- 4.2, 32” Portable Concrete Barriers for details. If intending to use the barrier at one location on the project, the Contractor may slip-form barriers in place without joints, or with grooved or sawed joints to facilitate removal. Any barrier sections damaged during handling or by traffic shall be either repaired or replaced, for the life of the project.

Joints (622.04)

The joints for cast-in-place or slip-formed barrier shall be constructed of the type and dimensions and at the locations specified in the plans.

Contraction Joints.

The Contractor may construct unsealed contraction joints by either sawing, using metal inserts inside the forms, using a grooving tool, or using full-width 3/4-inch (19 mm) thick preformed joint filler conforming to 705.03. Joints shall either be sawed, tooled, or formed by inserts, a minimum of 1/8 inch (3 mm) wide and 3 inches (75 mm) deep. The joints should be sawed as soon as curing allows sawing to the required depth with minimal spalling of the concrete surface.

Expansion Joints.

The 3/4-inch (19 mm) preformed joint filler shall conform to 705.03 to construct expansion joints at the centerline of and around each bridge pier column and on either side of each sign support foundation.

Horizontal Construction Joints.

If and as shown on the plans, the Contractor may place horizontal construction joints.

Finish (622.06)

Check the surface of the barrier with a straightedge for irregularities of more than 1/4 inch in 10 feet (6 mm in 3 m) after the contractor has checked and made corrections. Document any findings on CA-D-3.

Curing (622.07)

Concrete Curing shall be according to 511.17, Method B and the following additional requirements. Ensure that the curing compound is approved. For small areas, allow the use of other acceptable methods.

Do not allow any load or any work that will damage newly placed concrete. A minimum of 36 hours of cure time is required on any concrete placed first at a horizontal construction joint. The Contractor may cure precast sections according to 515.15. The Contractor may also use radiant heated forms for curing.

The Contractor may use 511.17, Method A for curing of short sections of barrier (leave-outs); however, before the curing is completed for any leave-outs, material conforming to 705.07, Type 2 at the normal rate specified in 511.17, Method B shall be applied.

The Contractor may cure horizontal construction joints between the foundation and the upper portion of the barrier, and between portions of the upper barrier placed separately according to 511.17, Method A or B. The membrane should not be removed before placing the next portion of the concrete barrier.

Method of Measurement (622.08)

Measure Concrete Barrier by the number of feet (meters) along the centerline of the top of the barrier, including all transitions, end terminals, and bridge pier sections as specified, complete in place.

Measure Portable Concrete Barrier and Portable Concrete Barrier, Bridge Mounted by the number of feet (meters) for each application of the barrier placed according to the plans. Measure each re-use of barrier sections at a different location required by the plans separately.

Do not measure repaired or replacement barrier sections damaged during handling or by traffic.

Basis of Payment (622.09)

The cost of all inserts, sleeves, fittings, connectors, reinforcement, dowels, preformed filler, excavation, and backfill is incidental to these items.

Documentation Requirements

1. Form dimensions
2. Conform to section 609.04C if slip formed
3. Number and clearance maintained on reinforcing steel if any used
4. Joint spacing and thickness of expansion material used
5. Joints saw cut, formed with metal plates, or expansion material
6. Amount of curing compound required and used
7. Measure length for pay
8. Use form CA-D-3 for documentation

624 Mobilization

Documentation Requirements - 624 Mobilization

1. Document on CA-D-3A
2. Pay in accordance with 624.02.

625 Highway Lighting

General (625.01)

The following information does not alter or supersede the Contract Documents. It is provided as a guide for the ODOT personnel assigned to a project to help them with their work.

Electrical construction work must adhere to the Contract Documents which commonly include proposal notes, project plans, Standard Drawings, and Construction and Material Specifications. In addition there may be building or electrical codes or change orders that must be followed.

Contractor Prequalification

Only Contractors prequalified by the ODOT Office of Contracts for Work Type 43 - Highway Lighting shall be allowed to do the highway lighting items of work on the project.

Respect for Contractor

Contractors are prequalified for specialized work types. They bring expertise to the project and an independent perspective from the project management team. As the Contractor reviews plans and specifications, he wants to ensure that he can install material that will ultimately operate as the designer intended. The Contractor relies the Engineer to guide the project, to approve materials and work, and to ensure that he will be paid for work completed. It is important to remember that even when the roles of the project team and the Contractor conflict successful completion of the project relies on all those involved and the maintenance of good working relationships.

Protection of Utility Lines

The Contractor is to notify all utilities before construction work begins. Names and addresses of these utilities are given in the project plans. It is also the Contractor's responsibility to contact the Ohio Utility Protection Services (1-800-362-2764) to have utility locations marked in all areas where digging is involved.

Plan Discrepancy, Design Ambiguity, Consultation with Designer

When there is a question regarding the intent of the plan, the Engineer should:

1. Define the discrepancy or ambiguity.
2. Determine if more than the highway lighting is affected.
3. Identify the standard drawings and specification pertinent to the situation.
4. Determine potential solutions.

5. If the issue involves the location of the luminaires or light poles, the mounting height of the luminaries above the pavement, the luminaire to be used or the lamp to be used; the Engineer should consult ODOT's design office and the designer to ensure that the performance goals for the lighting system will still be met by the solution under consideration.
6. Consider the maintenance of the installation if the solution is implemented. Will parts not normally stocked by the maintaining agency be required or will tools and equipment not normally at the disposal of the maintenance crews be required or will special training of the workers be required?
7. Evaluate potential solutions for safety. Consider measures needed to keep errant vehicles from striking the item, the danger to those who must maintain the installation, the danger to traffic from the maintenance activities
8. Determine if applicable codes and regulations will be met. Commonly involved will be the National Electric Code, The National Electric Safety Code and Utility Company requirements. There may also be state and local building codes.

Materials (625.05)

Highway lighting items are found in 625 with detailed descriptions of materials in 725.

In general, all material furnished shall be new and of first quality (unless otherwise noted in the plans) and shall be identified either by a permanently attached name plate or by an indelible marking.

Before installation, all material shall be checked to determine that it is indeed the material that has been specified, that the appropriate material process has been completed and that all paperwork in hand.

Four procedures are commonly used to ensure that the correct materials are installed.

1. Qualified Products List (QPL)
2. ODOT Plant Sampling and Testing Plan (TE-24 Certification)
3. Certified Drawings or Certified Catalog Cuts
4. Project Inspection of Material

Qualified Products List

Lighting material which may be on a Qualified Products List:

1. Pull Box
2. Junction Box
3. Conduit
4. Wire and Cable
5. Ground Rod
6. Photocell

The Office of Materials Management maintains the Qualified Products Lists. The Engineer can verify that the material is on a Qualified Products List (QPL) through ODOT's Construction Management System (CMS). After verifying that the material being supplied is that specified by the contract and on such a list, the project may accept the material.

TE-24 Material Certification

Lighting material for which TE-24 Certification may be obtained:

1. Pull Box
2. Junction Box
3. Anchor Bolt

The ODOT Plant Sampling and Testing Plan (TE-24 system) is administered by the Office of Materials Management. This system was designed to allow certain material to be sampled, tested, approved and stocked for future use on ODOT projects. The material is inspected at the manufacturing or distribution site. Each approved lot of material is assigned a certification number and documented on Form TE-24. Material from the approved lot may then be transferred directly to an ODOT project or it can be transferred to other warehouses, such as a Contractor's storage facility, then transferred to a project at a later date.

Certified Drawings or Certified Catalog Cuts (625.06)

Lighting material requiring Certified Drawings or Catalog Cuts:

1. Luminaires
2. Luminaire Supports (Towers, Lowering Devices, Poles, Bracket Arms)
3. Power Service Equipment
4. Portable Power Units
5. Temporary Lighting Systems

The Contractor shall submit two copies of shop drawings or catalog cuts prior to the installation of the material. The submittal ensures that the State has a good record of the material installed should there be any question about the material meeting criteria or should additional or replacement units be required.

Each submittal shall identify the project and the bid reference number under which the item is being provided. Drawings or catalog cuts shall be clearly marked by circling or underlining to indicate the exact item and options being supplied. If a given item is to be supplied under multiple bid item reference numbers, separate and complete documentation packages shall be submitted for each bid item reference number. If multiple items are to be supplied under a single bid reference number, all the items to be supplied under said reference number shall be submitted as a package. The Contractor's cover letter for each package is to certify in writing that each manufactured item in the package conforms to all contract requirements for that item.

The submittal of certified drawings or catalog cuts does not relieve the Contractor from furnishing, additional information concerning the material as deemed necessary by the State.

Project Inspection of Material

The following materials are normally manufactured to standards that meet ODOT criteria and therefore do not have a QPL, do not normally have a TE-24 and shop drawings or catalog cuts are not normally required:

1. Exothermic Welds
2. Insulating Varnish
3. Split Bolt Connector
4. Expansion Fittings
5. Connector Kits
6. Splice Kits
7. Copper Crimps and Compression Connectors
8. Light Pole Decals
9. Circuit Identification Tags
10. Cable Grips
11. Wood Service Poles
12. Fuses for Control Center and Connector Kits
13. Photoelectric Cell and Bracket
14. Secondary Lightning Arrestor
15. Guy Anchors and Anchor Rods
16. Weather Heads
17. Watertight Hubs
18. Remote Ballast Enclosures and Mounting Brackets

Project inspection of material is used to verify that the material at hand is that listed on a QPL or described on a TE-24 or for which certified shop drawings or catalog cuts have been received and that the material complies with the requirements of the contract documents. For material not on a QPL which does not have a TE-24, and for which shop drawings or catalog cuts are not required, the project inspection of material is limited to comparing the material at hand with the requirements of the contract documents.

Luminaires (625.08)

A luminaire consists of a housing containing the reflector, refractor, lamp socket and lamp. Unless specified otherwise, the housing will also contain the ballast components (core and coil, capacitor, starter) required for the lamp being used. The housing may also have optional components such as fuses or a photocell when such has been specified. The housing is fitted with the necessary clamps or other provisions for attaching the luminaire to its support and terminal block for the incoming power.

Verify that the luminaire installed at each location is one of the luminaires listed in the plan for that location. Verify that the distribution, lamp type and lamp wattage are as specified in the plans. Instructions packed with the luminaire will explain the distributions that the luminaire is capable of producing and how to set any adjustments in the luminaire to provide each distribution. Verify that ballast is compatible with the circuit voltage and lamp.

Conventional Luminaire

The conventional luminaire used by ODOT is also known in the trade as an “Ovate” or “Cobra Head” fixture. It may be equipped with a flat or a dropped style refractor as specified.

Verify that the luminaire is properly leveled according to the instructions packed with the luminaire.

Side-Mount Roadway Luminaire

This luminaire reminds one of a floodlight.

Verify that the “tilt” has been set as specified in the plan according to instructions packed with the luminaire. Verify that the luminaire is oriented “normal” to the line of survey for the roadway being lighted unless the plans stipulate otherwise.

High Mast Luminaire

These luminaires are mounted on tall structures equipped with devices to bring the luminaires to ground level for servicing.

Verify that the luminaire is not “twisted” with regard to its bracket arm. There are three distributions commonly used. If the luminaire has a rotatable refractor, verify that it has been aligned properly.

Low Mast Luminaire

Low mast luminaires are the same luminaire as a high mast luminaire but installed as a fixed unit on a pole of more traditional height.

Verify that the luminaire is not “twisted” with regard to its bracket arm. There are three distributions commonly used. If the luminaire has a rotatable refractor, verify that it has been aligned properly.

Underpass Luminaire

Underpass luminaires are used to light roadways beneath bridge decks. Commonly they are wall mounted on a pier cap or abutment. Sometimes they may be ceiling mounted on the underside of the deck or to a panel attached to the deck supporting beams or pendant mounted on suspension pipes attached to the structure. Occasionally they will be post top mounted on short poles.

Verify that the luminaire has been attached to the structure at the location and in the manner specified.

Lamps

Verify that the lamp is one of the brands listed in the plan. Verify that the lamp type and wattage is compatible with the luminaire and its ballast. Unless specified otherwise for a particular installation, the lamps are to have clear envelopes. Do not substitute lamps with “frosted” envelopes. Verify that the installation date has been properly marked on the base of the lamp. Instructions packaged with the lamp explain how to use the dating provision built into the base.

Supports (625.09)

The inspection of the supports (poles, arms, towers, lowering devices, brackets, etc.) consists of two phases: inspection of the components and inspection of the completed assembly. While these may be done together, it is better if the components are inspected upon arrival at the project since there is then more time to obtain replacements or correct faults.

Inspection of Support Components

Three areas are examined in this phase: welding, galvanizing and compliance with shop drawings.

Inspection of Welds

Examine each weld for the following:

1. Each of the welds called for by the certified shop drawings is present and there is no weld present that is not shown on said drawings.
2. There is no misalignment of the parent material being joined by the weld.
3. There has been no warping of the parent material by the weld.
4. Each weld is of the type, size and continuity shown on the shop drawings.
5. Each weld is of full cross section without excessive concavity or convexity.
6. There is no over filling or cratering at either the beginning or the end of the weld.
7. There is no undercutting (a shallow groove melted into the base metal adjacent to a weld and left unfilled by weld metal) along any weld.
8. There is no porosity(pitting or pinholes) in any weld.
9. There is no crack or discontinuity in either the base metal or weld material along any weld.

Inspection of Galvanizing

Examine the galvanizing for the following:

1. There are to be no spots where the galvanizing is missing or loose and can be flaked off with a penknife.
2. There should be no ash that has been picked up from the top of the bath which usually appears as coarse lumps.

3. There should be no pimples from entrapped bath scum particles.
4. There should be no blisters from hydrogen gas absorbed during pickling being released and rupturing the surface of the galvanizing.
5. There should be no flux inclusions from flux picked up from the top of the bath during dipping and burned on during immersion.
6. There should be no lumps or runs of excess zinc from delayed run-off of molten metal trapped near surface discontinuities such as joints, seams or holes as the part was lifted from the bath.
7. There should be no rust stains from impurities from the pickling process weeping at seams and folds.
8. There should be no general overall roughness from over pickling or of excess zinc bath temperature and/or immersion time.
9. There should be no patches of dull gray coating from slow cooling of the heavier cross sections of the part after immersion.
10. The galvanizing should have a uniform appearance.

Excessive galvanizing faults and gross imperfections or overall poor workmanship may be cause for rejection of the support. Minor scratches in galvanized surfaces can be accepted.

Compliance with Shop Drawings

Supports are frequently shipped to the job site and stored prior to assembly and erection as components which gives opportunity for the components to get mixed up leading to improper assemblies since the basic design often does not prevent errors. Therefore, prior to beginning the assembly of a given support, it is necessary to check the major dimensions of the various components against the shop drawing for the support to verify that this has not occurred.

On poles, verify the length, base diameter, top diameter and wall thickness of each pole or section of the pole for poles shipped in multiple sections that are field assembled. Verify the length, width and thickness of the base plate along with the bolt circle diameter, bolt hole size and number of anchor bolt holes provided.

On bracket arms for conventional supports, verify the arm length and arm rise.

On lowering devices, verify the diameter of the luminaire mounting ring and number of luminaire arms on the ring. Also, verify the length of the power cord along with the wire size and number of conductors in the cord. Verify the diameter and length of each piece of hoisting cable.

Assembly of Supports

Support components stored in the field should be kept off the ground to prevent finish blemishes where the component lay in contact with a damp surface earth or water. Support components and assembled supports should be loaded, transported, unloaded, stored and erected in a manner avoiding damage to the factory applied surface finishes.

On multi-piece poles, verify that the sections to be assembled are the correct pieces for the pole at hand. Before tightening each telescopic joint between the sections, verify that the sections are properly oriented and that the male section has been marked to indicate when full insertion has been achieved. Verify that the process used for tightening the joint between sections is approved by the pole manufacturer and that the pole is not bent during the tightening process.

On each steel light pole used with an aluminum transformer base, verify that both the bottom of the pole base plate and the top of the transformer base were given a coat of zinc rich paint prior to assembly.

On each light pole, verify that the cable grip in the light pole is properly installed as shown in SCD HL-10.12 to prevent damage to the pole and bracket cable.

On each light tower, verify that the luminaire ring has the correct number of mounting arms and that each arm is attached such that when the tower is erected the arms will be in the positions relative to the roadway as shown on SCD HL-10.31. If the lowering device is equipped with top laches, verify that when the luminaire mounting ring is fully raised and latched, the latch indicator on each latch will be in the "extended" or "visible" position. Verify that all moving parts on the head frame assembly and hoist mechanism have been lubricated in accordance with the manufacturer's instructions.

Verify that all parts are in place and that all fasteners have been properly installed according to the manufacturer's instructions.

Verify that each hand hole door or cover closes with no excessive gaps.

Verify that a light amount of anti-seize or grease lubricant has been worked into the threads of each fastener holding each removable cover in place.

Erection of Supports

Prior to erection, verify that nuts can be easily turned by hand onto the threads of each anchor bolt.

When leveling nuts are to be used, verify that the leveling nuts are level before beginning the lift to set the support.

Each support should be lifted and set by crane with the hoist line attached at a point as far above the center of gravity of the support as possible, with a tethering cable from the lifting point to the base of the pole. The lifting point on poles made up of sections slip fitted together should be above the uppermost joint. Hoisting should be smooth and continuous without abrupt jerks. Light tension should be maintained in the hoist lines until an anchor nut has been threaded onto each anchor bolt far enough that the bolt is projecting though the nut by a full thread.

Verify that each support with a transformer base has been plumbed using leveling shims approved by the base manufacturer, installed between the base and the foundation according to the base manufacturer's instructions and limitations and that the anchor nut on each anchor bolt has been properly tightened.

Verify that each support with an anchor base installed directly on a foundation without leveling nuts has been plumbed using leveling shims approved by the pole manufacturer installed between the base and the foundation according to the pole manufacturer's instructions and limitations and that the anchor nut on each anchor bolt has been properly tightened.

Verify that each support with leveling nuts is plumbed by adjusting the leveling nuts and that both the anchor nut and the leveling nut on each anchor bolt has been properly tightened.

Verify that a light tower has been plumbed early in the morning when there is minimum heat effect from the sun.

Verify that each support has been plumbed when there is no appreciable wind.

Verify that the space between the top of the foundation and the base of the support has NOT been grouted.

When a high mast support (light tower) is equipped with a lowering device that has top latches, verify that the ring engages all latches simultaneously. This is often referred to as "leveling" the ring. It should be done following the manufacturer's directions. Generally the procedure is to place a block on each hoisting cable that is attached to the ring a few inches above the ring in such a manner that the block will slide along the cable when the block contacts the portion of the mechanism at the top of the tower. The ring is then raised until all blocks have made contact, but not fully raised. The ring is then lowered and the distance between each block and the ring measured. Hoisting cables are then adjusted to make the measurements equal. The process is repeated until no further adjustments are required. The blocks are removed and the lowering device operated several times through its full cycle watching all latches for proper operation.

Verify that support identification decals have the proper legend and that the decals are located approximately 7 feet (2.1 m) above the base of the pole facing oncoming traffic.

Foundations (625.10)

Foundation inspection normally consists of three parts: location, excavation and concrete placement.

Foundation Location

After the location of each foundation has been staked, verify that the location is that specified in the plan and that Ohio Utility Protection Service and all utilities in the area have been allowed at least 48 hours to mark their utility locations relative to the proposed foundation. Then verify that the location appears logical. Be alert for the following:

1. Installing the lighting item at the staked location will require removal of vegetation that shields adjacent property owners from the highway.
2. Installing the lighting item at the staked location will locate the item at the top of the back slope, in a cut cross section or at the bottom of the fill

in a filled cross section where guardrail is to be used to keep errant vehicles from going down the slope.

3. Installing the lighting item at the staked location will place the item under an overhead utility line or over an underground utility line.
4. Installing the lighting item at the staked location will require a graded access drive for the construction that has not been addressed in the plan.

The designer should be consulted prior to relocating any support more than 10 feet (3.0 m) or if two or more adjacent supports need to be relocated.

Excavation

Foundations are to be placed only in undisturbed soil or compacted embankment.

If a minor cave-in should occur, the Contractor may, with the approval of the Engineer, continue excavating using sleeving or casing. When bedrock is encountered, the Engineer may reduce the specified foundation depth.

If construction crews must leave the job site with a hole unfilled, it shall be covered and marked with cones, barrels or warning tape.

Placement of Concrete

Verify that the top of the foundation will be at the proper elevation.

Tops of foundations shall be finished smooth and level to enable proper plumbing of the light pole.

Verify that the anchor bolts are of the correct size and number and that each bolt is securely held in the correct position. The use of an anchor bolt setting template is encouraged. Verify that each anchor bolt will project the proper distance from the foundation.

Verify that conduit ells are present and that each ell is of the correct size and material and that each is properly oriented.

Verify that all reinforcing bars are present and that each is of the correct size and shape.

Verify that all items to be cast into the foundation, along with any forming aids, are secured in such a manner that they will not move out of position during the placement of concrete.

Verify that water encountered in the foundation excavation is pumped out before concrete placement. If this is not feasible, verify that the concrete is placed by the tremi-tube method.

Verify that the concrete is of the proper design, has been properly mixed, has the correct slump and is properly handled during placement. Verify that the concrete is vibrated to eliminate voids.

Verify that the top of the foundation is properly finished and that the concrete is properly cured.

Pull Boxes / Manholes (625.11)

Verify that each pull box is of the size and material specified.

Verify that each pull box is at the planned location unless the planned location puts the box in a low spot with respect to the surrounding surface. In such cases, notify the Engineer so that the Engineer, in consultation with the designer if necessary, may attempt to move the box to a location where it will be less likely to hold water.

Verify that a light amount of anti-seize or grease lubricant has been work into the threads of each fastener holding the cover in place.

Junction Boxes (Handholes)

Verify that each junction box is of the correct size and material and securely fastened in the correct location. Verify that a light amount of anti-seize or grease lubricant has been work into the threads of each fastener holding the cover in place.

Conduit (625.12)

Verify that each conduit run is of the correct size and material.

Verify that each cut end on each piece of conduit is reamed to remove rough edges.

Verify that all field cut threads on galvanized conduit have been coated with zinc rich paint.

Verify that each expansion or deflection fitting has a bonding strap for ground continuity when used with metal conduit.

Verify that each conduit run has been properly fastened in place.

Verify that the Contractor shall check each run of conduit by rodding (pushing a mandrel through the empty conduit) or pulling a cleaning puck through the conduit.

Verify that each run of conduit being left empty for future use contains a No. 10 AWG pull wire or equivalent.

Verify that each end of each conduit run is terminated either in a box connector that contains an integral bushing or with a separate bushing to protect cable pulled into the conduit.

Trench (625.13)

Verify that the trench did not deviate more than 6 inches (150 mm) from the line designated unless such deviation has been approved by the Engineer. Verify that the sidewalls and bottom of the trench do not have any protruding sharp rocks.

When duct cable is installed in the trench, verify that the backfill material within 2 inches (50 mm) of the duct cable does not contain pieces larger than 1/2 inch (13 mm).

Verify that the backfill is placed in compacted layers not to exceeding 4 inches (100 mm) in thickness.

When caution tape is specified, verify that the tape is installed 6" to 8" (150 to 200 mm) below grade.

Power Service (625.15)

Power service includes all equipment from the connection point to the utility company to the beginning point of the individual lighting circuits.

Verify that the power service location will be readily accessible both to maintenance personnel and to utility company personnel. There should be a safe parking area for service vehicles since the site will be visited regularly. The location should not be prone to standing or flowing water during rain events or to drifting snow. If the location appears unreasonable, involve the designer and the utility company as soon as possible, since moving a power service often means redesigning the lighting circuits.

Verify that the Contractor has been in touch with the utility company and become aware of any utility company requirements which may differ from the requirements of the Contract Documents.

Verify that the photocell is facing the north sky, unless otherwise stipulated by the plan, and that no artificial lighting source is disrupting its proper operation.

Verify that the conduits are neatly routed and fasten securely in place.

Verify that enclosures are securely mounted.

Verify that enclosure covers are in place and that fasteners for the covers have had anti-seize or grease worked into the threads.

Verify that moving parts of the switch gear have been lubricated and operate smoothly.

Verify that no debris has been left in enclosures and that the wiring in each enclosure is neat, orderly and tied into place where appropriate.

Grounding (625.16)

The conducting portions of those items containing electrical conductors are to be connected to each other and to earth electrodes to lessen the chance of injury and damage from unwanted electrical currents. Connecting the various conducting portions together to form the continuous path for the flow of stray electrical currents, often referred to as bonding, in ODOT's projects is generally an incidental to the construction. Installation of the earth electrodes and the connection of the conducting portions to those electrodes is often referred to as grounding and in ODOT's projects payment is somewhat related to the electrodes installed.

Ground Rods

Verify the ground rods specified have been installed. When additional rods have been added to lower the resistance, verify that the installation of each rod was approved prior to its installation.

Verify that the connection between the ground rod and the grounding cable is an exothermic weld. When additional rods have been added to reduce the resistance, verify that the additional connections are exothermic welds.

The normal ground rod item is for one rod driven into earth and the lead between the rod and the first connection and the associated connections. The earth resistance is then checked. When said resistance exceeds the specified limit, an additional rod is to be driven and connected to the first. The earth resistance of the pair is then checked. The process is repeated until the resistance of the group is lower than the specified limit. Payment is then made at the per rod price for each rod installed.

ODOT has reserved the right to approve the use of each additional rod before it is installed and may decline to install additional rods; thereby stopping the process at any point. When ODOT stops the installation of additional rods, it may decide to take another course of action to lower the earth resistance. If no additional action is taken, then by default the earth resistance becomes acceptable as it stands.

Exothermic Welds

An exothermic weld often has a rougher surface texture on the weld metal than one may be used to seeing, but the weld is not to have other signs of a poor quality weld such as porosity, cratering, cracking or undercutting.

Structure Grounding

Verify that each grounding electrode is acceptable before structure construction makes modification of the electrode or the installation of additional electrodes alongside impractical. Remember that if some of the electrodes are driven rods that such rods are incidental to the structure grounding system, not separate items. However, if due to high resistance, additional rods are driven, those rods are not incidental to the structure grounding system.

Verify that the necessary bonding jumpers are in place and functioning correctly before structure construction makes the installation of additional jumpers impractical.

Structures present special needs. Not only is it not practical to have a separate ground rod for each light pole or similar item mounted upon the structure, but also there are elements of the structure itself that need grounding. Thus the normal practice is to use bonding jumpers to connect all exposed metal items together and thence to the several electrodes frequently utilizing the main conducting portions of the structure as the main grounding buss. This means that electrodes are often under footers and bonding jumpers are frequently embedded in the structure. If something is left out or does not function as intended and it is not discovered until the final stages of construction, the grounding can become expensive, unsightly and less than desired. Unfortunately structure designers all too often include little in the way of specific details for the structure grounding. Therefore, it is imperative to be constantly thinking ahead to fully understand where each electrode and jumper is to be located and to verify that it is in place and functioning correctly at each stage.

Bonding Along Circuits

Verify that all of the conducting items containing the conductors of each circuit are bonded to form a continuous path back to the source of the circuit.

At light poles, verify that metal conduits entering the base of the pole are bonded to the pole.

At pull boxes, verify that the metal conduits entering the pull box are bonded together and that the metal lid and lid frame are bonded to the metal conduits.

At junction boxes, verify that the metal conduits entering the junction box are bonded to the box.

At the expansion and deflection joints in conduits of conducting materials, verify that a bonding strap has been install across the joint.

When non conducting conduit or duct is used, verify that a grounding conductor has been installed to provide for the continuous grounding path when necessary.

Wiring and Cabling (625.17)

Field wiring of highway lighting circuits is broken into three types.

Pole and Bracket Cable

Pole and bracket cable is the insulated single conductor used in a light pole (but not in a light tower) to connect from the distribution cable, up the pole and out the bracket arm to the light fixture (in a tower the electrical wiring from the base of the tower to the luminaires is a component of the lowering device).

Verify that each run of cable is of the size and type specified. The wire size and insulation are to be indelibly marked on the insulating jacket at frequent intervals along the length of the cable.

Verify that each run of cable is installed in a continuous piece without inline splices between the terminations shown on the plan.

Verify that the insulating jacket was not nicked nor portions shaved away as the cable was pulled into place.

Verify that the cable was not stretched as it was pulled into place. If the cable can be pulled back and forth by hand enough to move both ends, stretching probably did not occur.

Verify that a cable support was installed at the upper end of the vertical run of cable up the pole.

Verify that there is enough length on each end of the run for the cable to be routed properly to its termination and still remain slack.

Distribution Cable

Distribution cable is the insulated single conductor used to construct lighting circuits from the control equipment of the power service to the disconnect kits of a light pole, the terminal block of a light tower or the disconnect switch for underpass or sign lighting.

Verify that each run of distribution cable is of the size and type specified. The wire size and insulation are to be indelibly marked on the insulating jacket at frequent intervals along the length of the cable.

Verify that each run of cable is installed in a continuous piece without inline splices between the terminations shown on the plan.

Verify that the insulating jacket was not nicked nor portions shaved away as the cable was pulled into place.

Verify that the cable was not stretched as it was pulled into place. If the cable can be pulled back and forth by hand enough to move both ends, stretching probably did not occur. Unfortunately for the larger wire sizes and the longer runs commonly encountered in highway lighting circuits, the cable cannot be pulled by hand. Thus, the most common indication of stretching is when the length of pulling lead exiting the raceway is greater than the length of cable entering the raceway or the pulling forces are greater than normally encountered; both of which are not easily detected by other than experienced installers.

Verify that there is enough length on each end of the run for the cable to be routed properly to its termination and still remain slack.

All cables shall be labeled in accessible enclosures (pull boxes, hand holes, transformer base, device housing, etc.). A minimum of 5 feet (1.5 m) of extra cable shall be provided for each conductor at all terminal points.

Duct-Cable

Duct cable consists of insulated conductors, of the type used for distribution cable, installed into a duct and shipped as an assembly to the project. It is used in place of conduit and distribution cable to speed the installation of underground circuits.

Verify that the temperature of the duct-cable was above 32° F (0° C) throughout the installation process.

It is permissible to install duct cable when the outdoor air temperature is actually below those temperatures, but the Contractor must obtain authorization from the Engineer. The Contractor shall submit in writing his method of heating the duct cable and maintaining the duct cable at a uniform temperature throughout the installation process. To assure that the duct cable is heated uniformly, the heating process shall keep the temperature of the duct cable above 32° F (0° C) a minimum of 24 hours prior to installation. Under conditions such as the preceding where the temperature of the duct cable can be expected to vary widely during the installation process, the expansion and contraction of the duct cable must be taken into consideration. Typically, the duct cable length will decrease (or increase) one foot per thousand feet (0.3 m per 300 m) for each ten degree Fahrenheit (5.6 degree Celsius) decrease (or increase) in temperature.

Verify that the duct of the installed duct cable extends out of any conduit sleeve through which it passes enough to allow for the expansion and contraction in the duct due to seasonal changes in temperature. Typically a projection of two to three inches (50 to 75 mm) is appropriate at the usual installation temperatures for the lengths of run typical in ODOT's installations.

As received on the reel from the manufacturer, it will appear that the cables inside the duct and the duct are equal in length but in reality the cables are shorter than the duct. In order to reel the assembly onto the shipping spool both the cables and the duct were anchored to the spool. As the duct cable assembly is unrolled from the shipping spool, the cables will be drawn into the duct resulting in empty duct at the start of the run. For the assemblies typically used in ODOT's projects, leaving 25 feet (7.6 m) of duct for each 1,000 feet (300 m)of run to be installed at the start of the run, in addition to that required as slack for connections at the start of the run, will compensate for this. At the end of the run, only the slack amount for connections is required.

Verify that the insulating jacket of each cable within the duct has not been damaged when the duct was stripped to allow the connections to be made. Often the length of duct to be stripped is such that no protection can be slid over the cables and into the end of the duct which means that the cables within are saved from damage only by the skill of the person stripping the duct.

When a duct cable assembly has been passed through a conduit sleeve, verify that the duct has been sealed to each end of the sleeve by means of a molded boot or wrapped sealing pad.

Verify that the seal installed between the cables and the duct is installed in the same location and in the same manner as outlined under the installation of distribution cable into conduits.

Verify that there is enough length on each end of the run for each cable to be routed properly to its termination and still remain slack.

Conductor Identification

At each access point (pole base, pull box, junction box, switch gear enclosure, etc.) each conductor of each run of the field wiring (pole and bracket cable, distribution cable, duct cable) of each circuit is to be identified by applying a tag to the conductor indelibly marked to indicate the circuit and the use of that conductor within the circuit.

Connections (625.18)

This covers the connection of the field installed wire and cable to other such wire and cable and to the various items of equipment.

Sizing Conductor to Device Terminal

When the circuit conductor is of a larger size than the device terminals can accommodate, verify that the connection has been made by splicing a short piece of smaller wire onto the end of the large wire and then connecting the smaller wire to the device terminal. The smaller wire is normally identical to the larger wire in all aspects except for size. The smaller wire must be large enough to carry the current that the circuit protection will allow. It is not acceptable to cut back some of the strands of a conductor, so that the remaining stranded will fit into the terminal.

Crimped Compression Connections

Verify that the die in the compression tool was for the connector applied and that the connector is sized to match the wire to which it was applied and that the tool used was of a type that did not release the connector from the die once compression started until full compression was achieved.

Pull-Apart and Bolted Connections

Verify that the internal connector is properly applied to the conductors.

Verify that the insulating cover was cut to proper step for a snug fit over the insulation on each entry to the housing.

Verify that the internal parts are all present in good condition and are fully seated into the housing.

Verify that the male half of the housing is a snug fit and fully inserted into the female half of the housing.

Verify that a thin coating of the kit manufacturer’s approved non conducting grease has been used at the joint between the two halves of the housing, between the housing and each cable entering the housing and on other internal parts as show in the manufacturer’s instruction to allow the parts to slide smoothly into place and help seal out water.

Verify that there are no sharp bends in each cable where the cable enters the housing sufficient to cause the housing to pull away from the insulating jacket on the cable.

When the kit is to contain a fuse, verify that the fuse is of the proper ampacity.

Where the kit contains bolted connections, verify that the connections have been properly tightened before the housing was closed.

Verify that there is sufficient slack in the cables being connected to permit bringing connector kits outside of the pole, transformer base or junction box in which it is housed for servicing.

Unfused Permanent Connections

Verify that the internal connection is via a proper crimp compression connector.

Verify that the mold surrounding the connection is completely filled with resin.

Verify that the connection is positioned within the mold such that the resin properly surrounds the connection.

Verify that there are no voids in the resin.

Verify that no fillers have been used.

Verify that the resin has properly set.

Test Procedures (625.19)

There are a number of tests normally utilized to ascertain that the lighting installation has been well constructed and is in good operational order. For a particular test to have meaning, it must be properly conducted and the results properly interpreted.

Verify that the equipment used to conduct the test is in working order and calibration.

Grounding Electrodes

Verify that each specific grounding electrode meets the requirements of the earth resistance test.

The first key to conducting a successful test of a grounding electrode is to understand what constitutes the electrode. A single driven rod is an electrode. When that rod fails the earth resistance test and another rod is added, the electrode then becomes both rods together. However, in the case of a light tower where two rods are typically specified, the initial electrode is the two rods together rather than each rod separately. In structure grounding, the cluster of driven piles at the end of a pier footer should be considered as a single electrode with the cluster at the other end of that same footer considered as a separate electrode. A continuous grid of mesh, bars or cables laid beneath a footer is one electrode but separate grids under different portions of the same footer are separate electrodes. Wires buried in a radial pattern from a single pole constitute an electrode.

The second key to successful ground resistance is to understand the limitations of the various test instruments and procedures. The chosen procedure must be appropriate for both the electrode under test and the conditions in which the electrode is installed and the instrument must be capable of producing valid results for the situation at hand.

Circuit continuity

The key to the proper checking of circuit continuity is to remember the objective and to test one conductor at a time. The objective is to see that the conductor is connected to the desired device point and that the conductor has not been connected to any other devices. The difficulty is that the devices are scattered over a large area thus requiring the other conductors of the same circuit to be used as returns for the test signal. For the test to be of use often means that testing must start at one node in the circuit and test all connections along an isolated link from that node. Additional nodes and links are then added one at a time and the continuity of the conductors rechecked until the entire circuit has been verified.

Cable Insulation

This test is designed to verify that the insulation of each conductor in the circuit and permanent and bolted connections in that conductor are in good conditions be impressing a much higher than normal voltage on the conductor using the change in leakage current over time. Care must be used not to impress the test voltage on devices normally connected by the circuit since the devices would probably be damaged. Since the other conductors in the circuit must often be used as the return path, it is necessary to use care to ensure that the other conductors are not damaged while serving as signal returns and careful interpretation of the results to determine whether the leakage is from a conductor failing the test or from a failure in the return path.

Lowering Device Operation

This test is simply repeated operation of the lowering deice on a light tower to verify that is operates smoothly and correctly throughout its full range cycle of motions.

System Performance

The test uses the concept “infant mortality” to determine if the equipment is likely to operate satisfactorily throughout the projected life of the installation. The concept is the equipment is most likely to fail from manufacturing defects and installation in the first few hours of use and that once these hours are past it is likely to run the rest of its life with only normal maintenance. In conducting the test, it is important to recognize the significance of each component malfunction encountered and to properly interpret whether the malfunction indicates a need to extend the test period.

Provide information to maintaining agency

Ensure that each maintaining agency receives the documents pertinent to the maintenance and operation of the lighting units for which it is responsible. Typically included are:

1. A copy of the plan marked to show any changes made during the construction.
2. A copy of each certified shop drawing or catalog cut.
3. A copy of each instruction or parts manual supplied by each manufacturer.

Documentation Requirements

1. Luminaires
    a. luminaire has the distribution, lamp and aiming stipulated in the Contract Documents
    b. luminaire has been "leveled"
2. Supports
    a. support is the one stipulated for that location by the Contract Documents
    b. support is comprised of the correct components according to the certified shop drawings
3. Pull boxes
    a. pull box is the size and type stipulated for that location by the Contract Documents
    b. if supplied under plant sampling and testing program, that it has a TE-24
    c. drain is documented on form CA-P-1
4. Conduit
    a. conduit is the size stipulated for that location by the Contract Documents
    b. conduit is of the material stipulated for that location by the Contract Documents
    c. measure length installed
5. Trench
    a. location and depth is as stipulated by the Contract Documents
    b. there are no sharp rocks in backfill adjacent to duct
    c. backfill is placed in 4 inch (100 mm) lifts and mechanically tamped
    d. measure length installed
6. Grounding electrodes
    a. electrode is installed as stipulated for that location by the Contract Documents
    b. grounding conductor connected to ground rod with exothermic weld
    c. document ground resistance
7. Wire and Cable

a. wire size and insulation is as stipulated for that location by the Contract Documents
b. Measure length installed

626 Barrier Reflectors

Barrier Reflectors – General (626.01)

This information is intended to serve as a guide for construction personnel where the Contractor furnishes and installs barrier reflectors. However, it may also be useful for maintenance personnel performing the same functions. Inspection procedures are outlined. This information points out the various important features and references the applicable specification or standard drawing.

Materials, Qualified Product List (QPL) (626.02)

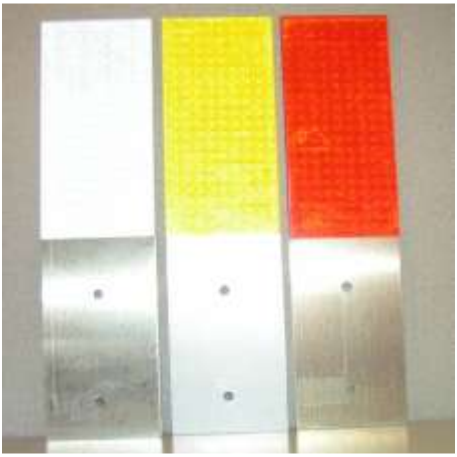
Make sure that all barrier reflectors used on a project are approved and listed on the Qualified Product List at the following web site:

Item 720.04 Barrier Reflector Type A & B

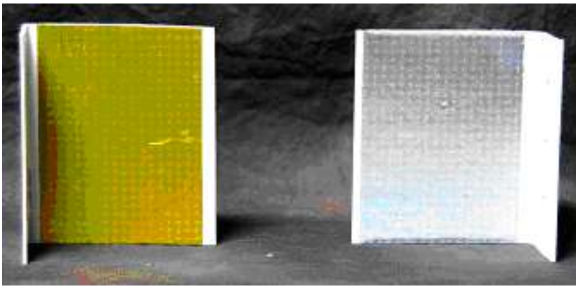
http://www.odotonline.org/materialsmanagement/qpl.asp?specref=720.04BO

Barrier Reflector Installation (626.04)

1. Ensure that the color of the reflector matches the color of the nearest edge line.
2. Ensure type A & A2 guardrail blockout reflectors are installed on the side of blockout away from traffic.
3. Ensure that the guardrail blockout reflectors are installed on the side of the blockout nearest the edge of the pavement.
4. Ensure that the guardrail blockout reflectors are installed so that the reflective surface is above the guardrail.
5. Ensure that the type B & B2 are installed with the top of the barrier reflector 26 inches(650 mm) above the near edge of pavement, except that the top of the barrier reflector is at least 3 inches (75 mm) below the top of the concrete barrier.
6. Ensure that the barrier reflector does not extend further than 5 inches (125 mm) in a horizontal direction towards the traffic lanes.
7. Ensure that loose concrete, rust, dirt and other loose materials are removed from the surface of the concrete barrier or guard rail using a wire brush. Apply adhesive to clean and moisture-free surface according to manufacturer's recommendations.



Barrier Reflector Type A and A2



Barrier Reflector Type B and B2

Documentation Requirements - 626 Barrier Reflectors

1. Document on CA-D-3A that installation performed as per 626.04
2. Document on CA-D-3A that material and products based on certified test data and all drawings
3. Document on CA-D-3A the types of barrier reflector for pay

630 Traffic Signs and Sign Supports

Description (630.01)

This information is intended to serve as a guide for construction personnel where the contractor furnishes and installs traffic control devices and appurtenances. However, it may also be useful for maintenance personnel performing the same functions. Inspection procedures for various types of traffic control devices are outlined, mainly in the form of check lists to assist project personnel in performing their duties. This information points out the various important features of each device and references the applicable specification or standard drawing. Illustrations are used for easy recognition of the device or feature being discussed.

Sign Service

Sign service shall comply with SCD's TC-32.10 and TC-32.11 and the plans. Additional information is provided in TEM Section 240-7.2 and C&MS Item 631.04. Basically, it consists of cable and equipment to provide a complete electrical service from either an underground source or an overhead direct drop to separately furnished disconnect switch with enclosure. The equipment could include a weatherhead, a conduit riser with necessary fittings, attachment clamps and cable. A thorough review of the plans should be made to determine the specific requirements of the maintaining agency for sign service.

When required, an electric meter base will be furnished by the applicable utility and installed by the contractor as part of the sign service work.

The sign service shall terminate at the meter base, if used; otherwise termination shall be at the switch enclosure. Sign service may be by:

1. Direct drop by means of a weatherhead and conduit riser routed to the switch enclosure;
2. Underground conduit and the pole interior to the enclosure; or
3. Underground and structure-attached conduit to the enclosure (for overpass mounted signs).

The conduit riser shall comply with Item 725 and the plans, and the weatherhead shall be threaded aluminum or galvanized ferrous metal 732.16.

The disconnect switch shall be a single-throw safety switch meeting the voltage and capacity requirements of the plans. The enclosure shall be a NEMA Type 4 ICS 1-110.15 with sufficient volume to accommodate an internal transformer when specified. The enclosure shall contain a solid neutral bar.

A ground wire shall be used as shown on SCDs TC-32.10 and TC-32.11 leading to a ground rod installed in accordance with TEM Section 240-7.3.

Foundations (630.05)

Staking

Sign support foundations shall be located so that the sign face is at a right angle to the roadway lanes served, unless the plans specify otherwise. An example of an exception is the W1-6 Large Arrow sign (black arrow on yellow background) which is located as shown in TEM Figure 298-24.

Foundations should be staked by the contractor in accordance with the locations shown on the plans.

The stakeout locations should be checked for:

1. The presence of obstructions which could restrict motorists' proper visibility of the sign from the point where they are expected to read the sign. Curved roadway locations should especially be checked.
2. Obvious conflicts with overhead power lines or other utilities. There should be available a proper safe clearance from overhead lines for construction operations, in compliance with the National Electric Safety Code and any local codes.
3. Possible conflict with underground facilities.

Foundation locations may be adjusted when necessary to overcome difficulties such as those shown in TEM Figure 298-24 and discussed herein, with the concurrence of the project engineer. Adjustment should not violate minimum clearance dimensions as shown on SCDs TC-42.10 and TC-42.20 and the OMUTCD.

Excavation

Foundations shall be placed only in undisturbed soil or compacted embankment and excavation shall be by an earth auger of the specified diameter to the specified depth. See TEM Figure 298-25 for a diagram of a foundation excavation.

If a minor cave-in should occur, the contractor may continue excavation using an increased diameter; or use sleeving, casing or other method approved by the project engineer. However, the foundation concrete will be measured as determined from plan dimensions. The contractor shall remove all extraneous material from the excavation before concrete placement. When subsurface obstructions are encountered, permission may be granted by the project engineer to replace the excavated material and relocate the foundation. When bedrock is encountered, that portion of the specified foundation depth within the bedrock may be reduced as much as 50 percent.

Placement

Anchor bolts and conduit ells shall be of the correct size and furnished with the support. At least one 2 inch (51 millimeters) minimum conduit ell shall be furnished and capped if unused. Anchor bolts, conduit ell(s) and EMT (Electric

Metallic Tubing) shall be oriented in the foundation according to the plans, conduit runs and ground rod location. All anchor bolts shall be provided with standard steel hex nuts, leveling nuts and plain washers. The nuts shall be capable of developing the full strength of the anchor bolts. Reinforcing bars, tie loops and tie bars shall be of the correct size and arranged with the anchor bolts into cages according to the applicable SCD TC-21.10 or SCD TC-21.20. A special foundation design will be required when soil with a load bearing capacity of less than 2,000 pounds per square foot (9700 kg/m²) is encountered.

Anchor bolts shall be vertical with their ends projecting the correct distance above the foundation surface in compliance with the plans. When the distance the anchor bolts project above the foundation surface is not specified, a rule of thumb is four times the bolt diameter. The anchor bolts shall be tied to the cage tie bars according to standard details.

The rebar cage shall be supported 3 to 4 inches (75 to 100 millimeters) above the bottom of the excavation by a piece of concrete block or similar material. The cage shall be positioned with a clearance of 3 inches (75 millimeters) from the excavation wall by similar blocking so that after concrete placement a full thickness cover is assured. A template and/or frame shall be used to rigidly hold the anchor bolts and conduit ell(s) in the specified pattern during concrete placement. A form shall be oriented according to the plans to shape the foundation into a square from the surface or grade shown to a nominal 6 inches (150 millimeters) below ground line. The template and form may be combined. Gaps of 6 inches (150 millimeters) or less between the foundation and adjacent paved surfaces shall be eliminated by increasing the formed foundation.

Water encountered in the foundation excavation shall be pumped out before concrete placement.

If this is not feasible, concrete should be placed by the tremie-tube method.

Concrete conforming to Item 499 and Item 511 shall be placed and vibrated to eliminate voids. Care should be exercised during vibrating to avoid disturbing the anchor bolts, conduit ell(s) and reinforcing cage.

Forms may be removed as soon as the concrete has hardened sufficiently so as not to be susceptible to damage, 511.16.

Minor earth caving external to the hole which may have occurred during excavation using sleeving or casing should be corrected after concrete placement by backfilling and tamping in accordance with 203.

Joint filler complying with 705.03 shall be placed between the formed foundation and adjacent paved surfaces.

Supports and poles may be erected, signs installed and span wire load applied only after the concrete has aged sufficiently to be in compliance with 630.

Curing and Loading

Curing and loading of concrete for traffic control devices shall comply with 511.17.

Concrete for foundations of sign supports shall be cured, have bracing removed and be loaded only when the concrete has achieved the age shown below:

	AGE OF CONCRETE IN DAYS	
	WITHOUT BEAM TEST	**WITH BEAM TEST ****
Curing	7	5
Removing Bracing	7	3
Loading*	14	7

* No load shall be applied or other work done that will damage new concrete or interfere with its curing.

** Beam test specimens shall be poured from the same batch, immediately before, during or after foundation pour. Specimen configuration shall be to ODOT requirements. Specimens when tested shall have at least an average modulus of rupture for two tests of not less than 650 pounds per square inch (4.5 MPa).

Overhead Supports in General (630.06)

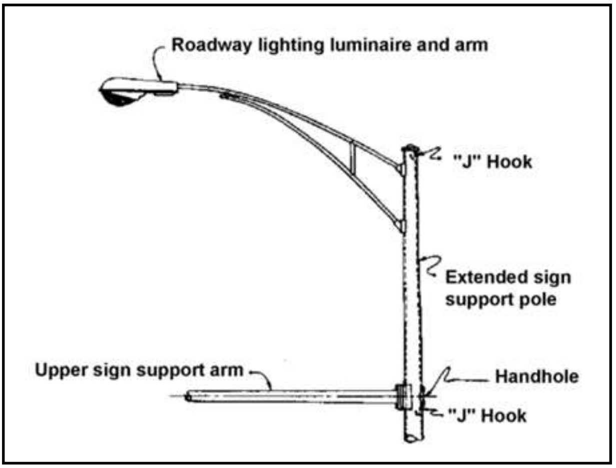
General

Various general aspects of overhead sign supports are addressed in this section. TEM Table 297-7 provides an overall summary of the structure types, allowable sign area on each and the span or arm length.

Pole and Support Inspection

This inspection checklist covers the general features of strain poles, mast arm type signal supports and overhead sign supports. Features pertaining only to specific pole or support types will be found in the sections of this manual covering exclusively those poles or supports.

1. When poles and supports of the combination type are specified, they are to provide extra length as necessary for a highway lighting function and welded-on bracket arm plate(s) complying with SCD HL- 10.12 or SCD HL-10.11, for attachment of a separately furnished luminaire arm. An upper handhole and an additional internal J-hook are to be furnished.



2. Supports may be of an alternate design utilizing all non-tapered tubing structural members.
3. Poles and supports should be inspected when received if possible, but certainly prior to erection.
4. General dimensions should be checked first, including pole length, base diameter, top diameter, and wall thickness. Similar mast arm dimensions should also be checked. Wall thickness is most easily measured with calipers at the end. Caps on poles may have to be removed.
5. Orientations of the various appurtenances should be checked against the plan's orientation diagram if such is available; otherwise orientations may be determined from certified shop drawings and the intersection drawing.
6. Base plate dimensions should be checked including thickness, bolt circle diameter and bolt hole size. Base plates may be plate or cast steel according to 730.04.
7. A handhole with ground lug is to be furnished, with a cover plate complying with 730.05 and a stainless steel chain complying with 730.10.
8. Blind half-couplings shall be provided where required. Sharp edges shall be rounded to prevent damage to cable or wires. Blind half-couplings shall be plugged when not in use. Couplings may be for signal or interconnect cable entrance or for attaching supports for traffic control equipment and for hubs for controller cabinets. Entrance couplings shall be threaded for use with threaded weatherheads.
9. An internal J-hook shall be furnished and located as indicated on the plans.
10. A pole cap conforming with 730.06 shall be furnished, and in place before final inspection.

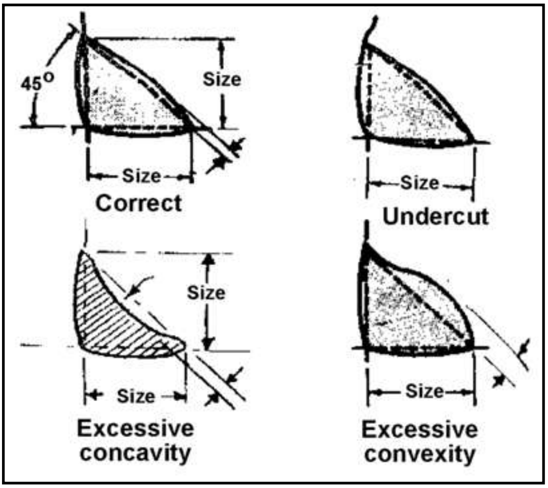
11. An arm cap conforming with 730.07 shall be furnished for chords or mast arms.
12. All strain poles and overhead sign and signal supports shall be grounded (even if no power is available).
13. Welding and galvanizing shall be inspected in accordance with 630.
14. Supports are to include sign brackets, U-bolts and clamps. When required by the plans, supports are to include luminaire support arms, bracing rods, other necessary structural members and signal hanger clamps with clevis.
15. The correct number and size of anchor bolts and conduit ells shall be furnished for placement in the foundation.
16. Anchor bolt diameter and length shall be according to the plans and SCD TC-21.10 or TC- 21.20. Anchor bolt ends may have an L-bend or be fitted with a tapped steel plate. Threaded ends shall not to be damaged and shall be galvanized at least 2 inches (50 millimeters) beyond the threads. The galvanizing should be in good condition, and absent or damaged galvanizing should be repaired by the application of two coats of zinc-rich paint. Galvanizing thickness should permit the turning of nuts by a wrench without difficulty. Loose rust on anchor bolts should be removed.
17. All anchor bolts shall be provided with standard steel hex nuts, leveling nuts and plain washers. The nuts are to be able to develop the full strength of the anchor bolts.

Inspection of Welds

All welds of supports shall be inspected visually as soon as possible following support delivery. Welds should be inspected for flaws and imperfections under good lighting conditions using a magnifying glass as necessary. Evidence of any of the following faults or other imperfections such as warping and misalignment may be cause for rejection of the support. The following features of welds should be checked:

1. A check should be made for the actual presence of all welds called for by the certified shop drawings and standard drawings.
2. Welds on tapered tubes, pipe or structural shapes shall be continuous around the joint. Welds requiring terminations shall be of the correct length.
3. Welds shall not exhibit cracks or discontinuities in base metal or weld material and shall not show evidence of porosity, showing up as pitting or pinholes. The galvanizing layer may cover such flaws, but their existence should be checked.
4. Welds shall be full cross section without excessive concavity or convexity. Required weld terminations shall be filled to full section without depressions or craters.
5. There should be no evidence of undercut, a condition where a shallow groove is melted into the base metal adjacent to a weld and left unfilled by weld metal.

6. Base plates shall be welded to two ply poles with AWS prequalified welds in conformance with 730.04.
7. Arm attachment plates shall be welded inside and outside with fillet welds. Each fillet weld shall be equal to the wall thickness of the respective tubing.



Inspection of Galvanizing

The galvanizing cover of supports shall be inspected visually as soon as possible following delivery. The galvanizing should be inspected externally and internally for flaws and imperfections in daylight or strong artificial light. In accordance with 513.26, supports shall be loaded, transported, unloaded, stored and erected in a manner avoiding damage to any feature including the galvanizing. Supports stored in the field should be kept off the ground to prevent the galvanizing from contacting water which may result in a premature oxidation condition. The galvanizing should have the appearance of a uniform application. Supports should be checked for assurance that the following flaws or imperfections do not exist:

1. Loose or bare spots in the galvanizing where improper preparation has prevented metal adherence in the molten zinc bath. Poles should be rejected if the point of a penknife can flake off the galvanizing layer.
2. General overall roughness, a symptom of over-pickling or of excess zinc bath temperature and/or immersion time.
3. Pimples, due to entrapped bath scum particles.
4. Blisters, due to hydrogen gas absorbed during pickling and coming out at the time of galvanizing.
5. Flux inclusions, picked up from the top of the bath when dipping and burnt-on during immersion.
6. Ash, usually in course lumps picked up from the top of the bath.

7. Patches of dull gray coating, due to the slow cooling of heavier cross sections of supports after immersion.
8. Excess zinc lumps or runs, due to delayed molten metal run-off from surface discontinuities such as joints, seams or holes.
9. Rust stains, due to the weeping of impurities from the pickling process at seams and folds.

Excessive galvanizing faults and imperfections combined with general poor workmanship may be cause for rejection of the support. Gross imperfections may lead to the suspicion of inadequate protective cover which may require inspection with a magnetic instrument. Items 1 through 6 may be cause for rejection. Items 7 through 9, if extreme, may also be cause for rejection, because of poor appearance even if the protection of the support is not affected.

After erection, supports should be given a final inspection for any damage to the galvanizing due to improper handling in the erection process. Damage due to slings, etc., which is more serious than superficial brightening is to be repaired by the contractor with the application of two coats of zinc-rich paint.

Weight of Supports

TEM Tables 297-8a through 297-8f provide information on the weight of various overhead sign supports. For all structures, the weight of the pipe support has been given where pipe has been frequently used in place of tapered tubes. In general, the tapered tube support will be lighter than the pipe support. The support numbers listed may be preceded by I-129, 815, 844 or other designation instead of TC.

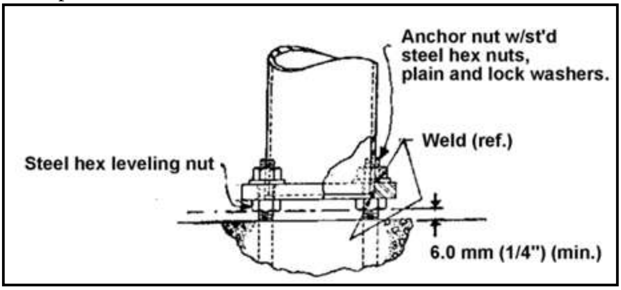
For estimating purposes, a 10 x 10 foot (3.0 x 3.0 meter) sign (excluding the sign lighting) weighs approximately 250 pounds (113 kilograms).

Assembly and Erection Procedure

Erection procedures pertaining to specific pole or support types will be found in the sections of this manual devoted exclusively to those poles or supports. In general the following assembly and erection procedure applies:

1. To minimize erection time and the hazard to workers and road users where traffic is maintained, supports should be erected with mast arms attached, and horizontal sign support members (over the roadway) should be prewired for lighted signs or other traffic control devices. See the notes in plans for traffic maintenance requirements when span-type sign support members are erected.
2. Support components shall be assembled with their threaded fasteners tightened in accordance with 630.06. Fasteners ½ inch (13 millimeters) or greater shall have anaerobic adhesive applied to the threads according to the manufacturer’s recommendations. Nuts shall be tightened by the “turn of the nut” method.
3. The “turn of the nut” method shall be in accordance with 513.20. Nuts shall be made snug tight by the effort of a person using an ordinary spud wrench followed by an additional 1/12 to 1/6 turn.

4. Leveling nuts shall be placed on the anchor bolts, initially clearing the foundation surface by at least 1/4 inch (6 millimeters) and forming a horizontal plane.



5. Poles or supports shall be raised into position with equipment of adequate lifting capacity and used in a manner preventing damage to attached appurtenances (signs, brackets, luminaries, etc.) and to the galvanizing. The weight of poles or supports is given in TEM Tables 297-8a through 297-8f for the use of the contractor in the erection procedure.
6. With the pole or support’s base plate resting on the leveling nuts, the plain washers and anchor nuts shall be placed on the anchor bolts, the support plumbed in a vertical position or raked as required, and anchor nuts given a preliminary tightening.
7. After any necessary leveling nut adjustments are made to assure that supports are essentially vertical after attachment of signs, sign lighting equipment or signals the anchor nuts shall have anaerobic adhesive applied and be final tightened in accordance with the instructions for assembling fasteners given in the foregoing paragraphs 2 and 3.
8. Anchor nuts are not to be covered with bolt covers or a cover base regardless of support location (Item 630.06B).
9. Poles or supports which are prewired before erection should be checked to determine if the erection procedure has disturbed the wiring. Wire for lighted signs should be supported by looping wire over the J-hook in the vertical support member (Item 631.05). Cable supported by cable support assemblies should be checked to determine if the sling is over the J-hook and if the adjustment is proper to eliminate strain on the cable jacket.

Overhead Sign Supports By Type

General

The previous section addressed general assembly and erection guidelines for strain poles and supports. The following sections provide additional information specific to various types of supports. For the most part the information is provided in a checklist format.

Span Wire Support

Span Wire sign supports shall comply with SCD TC-17.10 and the plans. These sign supports consist of strain poles, messenger wire with accessories and sign hangers. Strain pole size and type, anchor base or embedded, shall be as specified.

1. Strain poles shall be inspected in accordance with 632 and general features of the poles shall be inspected in accordance with 630. Welds shall be inspected according to 630 and the galvanizing shall be inspected according to 630.
2. Erection shall be in accordance with the general procedure given in 630 except as hereafter noted.
    a. For the initial rake of strain poles of the anchor base type or embedded type poles, see 632.
    b. The upper messenger wire shall be assembled with its accessories according to the standard drawing. Preformed guy grips are not permitted because wind loads on the signs can cause failure of the grips. Alternate methods of attaching messenger wire to strain poles may be used:
        i. Span wire clamp with clevis, anchor shackle and thimbles on the messenger wire, or
        ii. Messenger wire wrapped twice around the strain pole and secured with a 3-bolt clamp of the proper size.
    c. The upper messenger wire shall be fitted with its signs, furnished under other items of work, and the vertical clearance to sign bottoms adjusted within clearance limits over the roadway. The sag of the upper messenger wire shall be between 4 and 5 percent.
    d. It is essential that the lower messenger wire have more slack than the upper wire. The sag should be approximately 3 inches (75 millimeters) greater than the upper wire. This sag adjustment shall be made before the sign hangers are attached to the lower wire.
    e. Sign hangers shall be clamped snugly to the lower wire by U or J bolts. In the case of back-to-back signs, the lower messenger wire running in between the sign hangers, is clamped between bolted spacers that are slightly thinner than the messenger wire (see SCD TC-17.10).

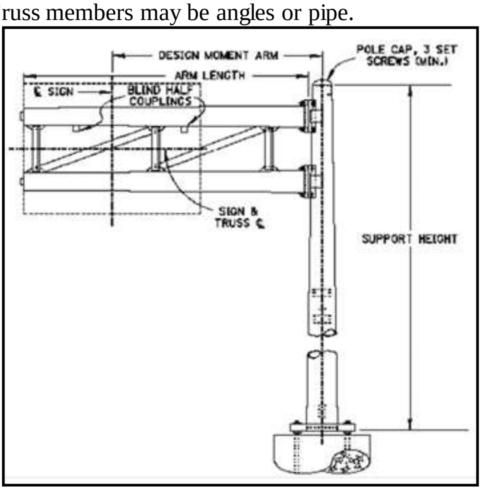
Single Arm Support

1. Single arm supports shall comply with certified shop drawings, SCD TC-16.20 and the plans.
2. Welds, galvanizing, and general features of the support shall be inspected in accordance with 630.
3. For arms of two telescoping pieces, a 15-inch (400 millimeters) overlap is required. The overlapped arms shall be secured with a stainless or galvanized steel hex head through-bolt with nut.
4. Arm caps shall cover at least fifty percent of the end area (Item 730.07).

5. A minimum of two brackets shall be provided for each sign, each attached to the arm by steel clamps with carriage bolts. The clamps should be able to be tightened in a manner to firmly grasp the arm so as to prevent sign rotation.
6. If signs are lighted, disconnect switch enclosure mounting brackets may be required on the support.
7. Erection shall be in accordance with the general procedure given in 630, except as hereafter noted.
    a. The contractor may choose to attach the signs and any sign lighting items before erection.
    b. Signs are installed at the same elevation. For this purpose, adjustment is provided by two pairs of slotted holes in the sign bracket for attachment of the arm clamp.
    c. Contact between galvanized clamp flanges and aluminum sign brackets shall be prevented by the use of chloroprene gaskets.
    d. Initial rake shall be adjusted so that under the load of signs, the pole will assume an essentially vertical position and the arm rise will be within the limits specified on the standard drawing, 3 inches (75 millimeters) minimum, 12 inches (300 millimeters) maximum.

Cantilever Support

1. Cantilever supports shall comply with certified shop drawings, SCD TC-12.30 and the plans.
2. Welds, galvanizing, and general features of the support shall be inspected in accordance with 630.
3. Supports with arm lengths18 feet (5.5 meters) and over shall have truss members. Truss members may be angles or pipe.



4. One blind half coupling shall be welded to the top chord approximately 12 inches (300 millimeters) beyond or outside of the first sign bracket for a sign less than 20 feet (6.1 meters) long. A second blind half coupling

shall be welded near the second sign bracket for signs 20 feet (6.1 meters) or longer.

5. Erection shall be in accordance with the general procedure given in 630, except as hereafter noted.
    a. The contractor may choose to attach the sign(s) and any sign lighting items before erection.
    b. Signs are centered vertically on the chords.

Center-Mount Support

1. Center-mount supports shall comply with certified shop drawings, SCD TC-9.30 and the plans.
2. Welds, galvanizing, and general features of the support shall be inspected in accordance with 630.
3. Sign clearance above the roadway shall be a minimum of 17 feet (5.2 meters).
4. Arms may be either square or round tube. The arm attachment design shall be in accordance with standard details for either square arms or round arms with separate cradle.
5. A blind half coupling shall be located on the pole.
6. Erection shall be in accordance with the general procedure given in 630, except as hereafter noted.
    a. Signs are centered vertically on the arms.
    b. Signs may be mounted laterally on the support in an eccentric position. However, a minimum of 2 feet (0.6 meter) of sign length shall remain to one side of the pole centerline.
    c. The contractor may choose to attach the sign and any sign lighting items before erection.

Semi-Overhead Support

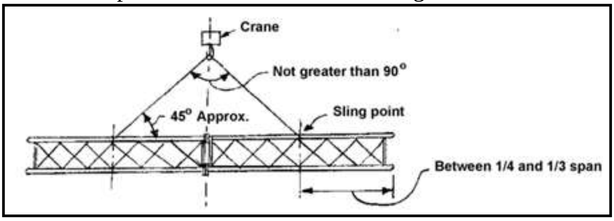
1. Semi-overhead supports shall comply with certified shop drawings, SCD TC-9.10 and the plans.
2. Welds, galvanizing, and general features of the support shall be inspected in accordance with 630.
3. Sign clearance above the ground shall be at least 10 feet (3.0 meters) unless a lower height is approved by the project engineer to provide sign visibility through preceding overpass structure(s).
4. Arms may be either square or round tube. The arm attachment design shall be in accordance with standard details for either square arms or round arms with separate cradle.
5. A blind half coupling shall be located on the pole.
6. Erection shall be in accordance with the general procedure given in 630, except as hereafter noted.
    a. Signs are centered vertically on the arms.
    b. Signs may be mounted laterally on the support in an eccentric position. However, a minimum of 2 feet (0.6 meter) of sign length shall remain to one side of the pole centerline.

c. The edge of the sign shall be back at least 2 feet (0.6 meter) from the edge of the curb.
d. The contractor may chose to attach the sign and any sign lighting items before erection.

Span Truss Support

1. End frames for span truss supports shall comply with certified shop drawings, the plans and SCD TC-7.65 for aluminum trusses and SCD TC-15.115 for steel trusses.
2. Welds, galvanizing, and general features of the support shall be inspected in accordance with 630.
3. Handholes shall be oriented on the end frame downstream vertical member on the side away from the direction of traffic.
4. The size of truss members shall be in accordance with standard details. Truss member joints may be of two different designs.
5. Switch enclosure mounting brackets shall be in place and a chase nipple installed on both end frame vertical members which are away from the direction of traffic.
6. An angle shall be furnished and welded onto the end frame, near the top, to support the lower chords of the span box. Stainless steel U-bolts shall be used with aluminum trusses and galvanized steel U-bolts with steel trusses.
7. End frame vertical members shall be furnished with steel clamps and a separate tee or angle (alternate) for supporting the upper chords of the span box. Stainless steel U-bolts shall be used with aluminum trusses and galvanized steel U-bolts with steel trusses.
8. An internal J-hook shall be in each end frame in the downstream vertical member.
9. When using an aluminum truss, the following shall apply:
    a. Aluminum trusses shall comply with certified shop drawings, SCD TC-7.65 and the plans.
    b. Welds shall be inspected according to 630.
    c. End caps shall be on each end of chords. The top front end caps shall be tapped for wiring.
    d. A blind half coupling shall be welded to the front top chord of the truss approximately 12 inches (300 millimeters) beyond or outside of the first sign bracket for each sign. Sharp edges shall be rounded to prevent damage to wires.
    e. Span length shall be in accordance with shop drawings and the plans.
    f. Span box camber shall be in accordance with standard details.
    g. Flanges between span box sections may be cast or fabricated with forged flanges as an alternate.
    h. Flange attachment hardware shall be stainless steel bolts and nuts.

    i. Supports shall be furnished with necessary sign brackets, U-bolts, luminaire support arms, bracing rods and other necessary structural members

10. When using a steel truss, the following shall apply:
    a. Steel trusses shall comply with certified shop drawings, SCD TC-15.115 and the plans.
    b. Steel truss checking instructions are the same as those for aluminum trusses, except as hereafter listed.
        i. The galvanizing shall be inspected according to 630.
        ii. Flanges between span box sections shall be forged.
        iii. Flange attachment hardware shall be galvanized steel bolts and nuts.
11. See the notes in the plan for traffic maintenance requirements when span type sign support members are erected.
12. The base plates of end frames shall be placed on anchor bolt leveling nuts, plain washers and anchor nuts placed, the frames plumbed into a vertical position in both longitudinal and lateral directions, and nuts made tight in accordance with 630.
13. Truss camber shall be correct. The various truss sections shall be assembled in the arrangement and sequence shown on the shop drawing.
14. Trusses may be assembled into a total span while lying on blocks with wedges. Flanges on truss section ends may be aligned by driving in the wedges as necessary. All flange bolts are then assembled and made tight.
15. Two cranes may be necessary when lifting very long trusses or the heavier steel trusses. For reference, truss weights are given in 630.
16. Care should be taken in the attachment of slings. Trusses should be lifted at positions of a quarter to a third of the total span. Slings should be attached to the top chords and the horizontal diagonals.
17. 

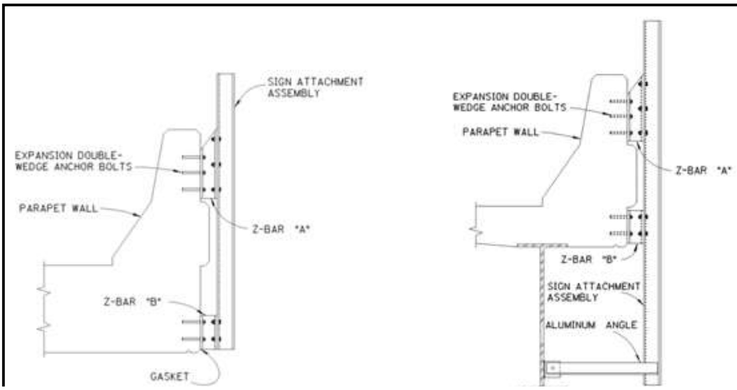
18. Trusses may be easily overstressed by poor handling, and care should be taken when moving assembled trusses for temporary storage, during transportation to the erection location and in the erection procedure.
19. Trusses shall not be erected unless at least one sign is in place within eight hours, or the trusses are fitted within the same period with damping devices approved by the project engineer (630.06 B).
20. Attachment of the box truss to the end frames shall be by four U-bolts. Aluminum trusses shall be attached by 5/8 inch (16 millimeters) stainless steel bolts according to SCD TC-7.65 and steel trusses shall be attached

by 3/4 inch (19 millimeters) galvanized steel bolts according to SCD TC-15.115.

21. The contractor may choose to attach the sign(s) and any sign lighting items before erection.
22. Signs are centered vertically on the chords (not considering the height of Exit Panels).

Overpass Structure-Mounted Support

1. Overpass structure-mounted supports shall comply with the plans and SCD TC-18.24 for flush type supports and SCD TC-18.26 for skewed type supports.
2. Overpass structure-mounted supports include sign brackets and two different kinds of steel Z-bars which are fastened to bridge concrete. For steel beam bridge mounting, aluminum angles at the bottom are to extend between sign brackets and short galvanized steel angles bolted to the bridge steel. For overpass structures essentially perpendicular to the roadway underneath, sign brackets are flush mounted to Z-bars for direct sign viewing. For overpass structures skewed to the roadway underneath, a wedge-shaped box structure is inserted between the sign brackets and Z-bars to provide for direct sign viewing.
3. The number of sign brackets will vary according to the bracket spacing as required by SCD TC-22.20. Bracket details are also shown on the standard drawing.
4. The number of aluminum frames in skewed supports shall equal the number of sign brackets. Frame details shall be in accordance with standard details and are to include two angles placed diagonally.
5. Front upper and lower members of skewed supports shall be aluminum angles with a length equal to the sign length.
6. The skewed support structure shall be internally braced by two aluminum angles extending diagonally and horizontally through the interior.
7. For bridge clearance above a roadway of less than 17 feet (5.2 millimeters), the sign clearance above the bottom of the bridge shall be 3 inches (75 millimeters) minimum without, or 15 inches (400 millimeters) minimum with, sign lighting fixtures on the lower edge of the sign.
8. Supports shall be mounted on the overpass structure so the sign is horizontal regardless of bridge slope (630.06 D).
9. Expansion double wedge steel anchor bolts shall be used to fasten the support's Z-bars to the overpass structure concrete parapet. Intended locations of anchor bolts are to be approved by the project engineer before any field drilling. Z-bars "A" are used at the top and Z-bars "B" at the bottom of parapet concrete.



10. For a steel beam bridge mounting, aluminum angles at the bottom shall be fastened to short galvanized steel angles bolted to the bridge steel.
11. Chloroprene gaskets shall be used to prevent contact between aluminum sign brackets or support frames and steel Z-bars or bolted-on angles.
12. If the sign extends more than 4 feet (1.2 meters) above or below the attaching Z-bars, intermediate sign brackets shall be provided.
13. For precast beam bridges, aluminum angles at the bottom shall be fastened to short steel angles and two expansion double wedge steel anchor bolts shall be used.
14. After sign erection, the sturdiness of the support to bridge attachment should be checked.

Ground-Mounted Sign Supports

General

This section provides additional information, generally in the form of checklists, about various ground-mounted supports. TEM Section 221 addresses general guidelines about sign supports and TEM Section 240-5 provides additional design information about ground-mounted supports.

Posts

1. Ground-mounted sign supports of the post type shall be U-channels or square posts of the number specified and be as shown on SCD TC-41.20.
2. Post lengths appearing on the plans are approximate and the contractor is responsible for determining the exact length of required posts before cutting to length (630.06A).
3. No. 4 U-channel posts consist of two No. 2 posts bolted back to back. No. 6 U-channel posts consist of two No. 3 posts bolted back-to-back. Back-to-back posts are assembled by 5/16 inch (8 millimeters) steel bolts, lock-washers and nuts on 4 inch (100 millimeters) centers below the

ground line and 16 inch (400 millimeters) centers above the ground line. No. 4 and No. 6 U-channel posts cannot be installed in exposed locations.

4. Posts should have a line of paint 48 inches (1.20 meters) from the end, which will be in the earth. The mark when driven to a distance of 6 inches (150 millimeters) above the ground indicates a post driven to the proper depth.
5. If it is necessary to cut posts to correct length in the field, the cut end should be covered with two coats of zinc-rich paint and the cut end driven in the earth or embedded when required (except for back-to-back posts).
6. Posts shall yield when hit and shall be driven to a depth of 42 inches (1.05 meters). Posts are typically not to be embedded in concrete unless specified in the plans or ordered by the project engineer to overcome problems such as adverse soil conditions or generally prevalent bedrock close to the surface. The driven depth has been established to assure best yielding characteristics. Deeper depths are not beneficial in this regard.
7. Caution shall be used when driving posts in areas of buried cable.
8. Posts shall not to be driven in drainage ditches.
9. Posts shall be installed vertically and at right angles to the edge of pavement, unless otherwise required. Exceptions may be NO PARKING signs and STOP signs located at intersections with curved approaches. In this situation STOP signs should be placed perpendicular to a line from the viewing point where they are normally recognized and stopping action would begin.
10. Posts shall be driven without bending, distortion or end mutilation. Mutilation may be prevented by the use of a driving cap. Posts should be checked to see if the paint mark is 6 inches (150 millimeters) out of the ground after driving.
11. Posts located in paved areas shall be driven through a hole provided by sleeving or core drilling. After driving, the hole shall be patched with asphalt concrete or approved bituminous material.
12. At locations where posts cannot be driven, the post may be moved at no additional cost to ODOT, when approved by the project engineer.
13. Typical vertical and horizontal clearances of signs are shown on SCDs TC-42.10 and TC- 42.20.

"One Way" Sign Supports

Square posts which are capable of supporting signs at right angles to other signs on the post are designated as "one-way" sign supports for the most common application. This is shown on SCD TC-41.50.

Standard Beams

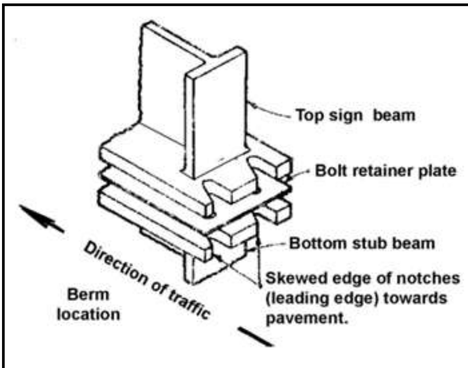
1. Ground-mounted sign supports of the non-breakaway beam type shall be rolled steel, wide flange sections of the size and weight specified (from the list on SCD TC-41.10). Non-breakaway beams shall be protected by guardrail or concrete barrier installed for another purpose. Inspection of beams of the breakaway type is covered in 630.

2. Beam lengths appearing on the plans are approximate and the contractor is responsible for determining the exact length of required beams before fabrication (630.06 A).
3. Galvanizing shall be inspected in accordance with 630.
4. Beams shall be embedded in a concrete foundation in accordance with SCD TC-41.10.
5. Beams shall be raised into position with equipment of adequate lifting capacity and in such a manner as to prevent damage to the galvanizing. The beams shall be braced in a plumb and square position until the concrete has cured. The age of the concrete before it is considered cured and before signs are permitted to be erected is to be in accordance with 630.

Breakaway Beams and Connections

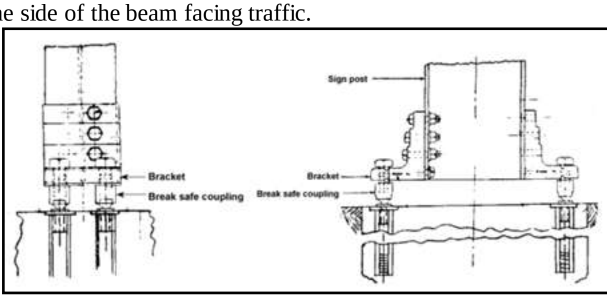
1. Ground-mounted sign supports of the breakaway beam type shall be rolled steel, wide flange sections of the size and weight specified (from the list on SCD TC-41.10).
2. Beam lengths appearing on the plans are approximate and the contractor is responsible for determining the exact length of required beams before fabrication (630.06 A).
3. Beams shall use a slip base design. Alternate designs of breakaway connections are permitted.
4. Base plates shall be fabricated to standard details and welded-on with a bead equal to the beam flange and web thickness respectively, but not less than 1/4 inch (6.4 millimeters).
5. Welding and Galvanizing shall be inspected in accordance with 630.
6. All portions of beams should be shop assembled, in accordance with SCD TC-41.10.
7. The beam upper portions shall be joined by the bolts attaching the fuse and hinge plates. The plates shall be fabricated to standard details with the fuse plate having notched holes at the bottom and the hinge plate having unnotched holes. The steel hex head bolts, with washers under both head and nut, shall be tensioned in the shop to the final specified value. For S4x7.7 (S100x11.5) beams only, malleable iron beveled washers are used under bolt head and nuts.
8. Torque limiting nuts may be used instead of conventional nuts on the fuse and hinge plates (SCD TC-41.10, Note 5).
9. The beam lower portions should be joined by steel hex head bolts inserted with their nuts uppermost. A galvanized bolt retainer plate shall be sandwiched between the base plates. Flat washers shall be used under both bolt head and nut as well as under the bolt retainer plate. Bolts shall be snug tightened for delivery to the site with final torquing to be done after erection.
10. Torque limiting nuts may be used instead of conventional nuts on the base plates (SCD TC-41.10, Note 5). The nuts shall be snug tightened, but not to the point where the upper area shears away.

11. Base plate skewed notches should point toward the roadway along the path of typical vehicle collision. The skewed notches of both base plates should match.



Base Plate Orientation

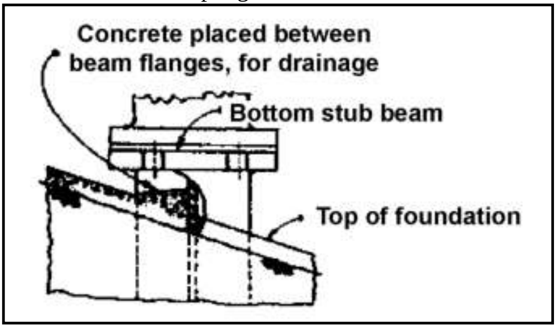
12. For beams located in medians, the base plates should be welded-on upside down as compared with those of beams located on the right side of the roadway, so the base plate skewed notches will point toward each roadway along the path of vehicle collision from either direction of traffic.
13. For beams located in medians, fuse plates shall be used on both sides of the beam.
14. For beams located on the right side of the roadway, fuse plates shall be on the side of the beam facing traffic.



15. For the alternate design, special foot brackets shall be bolted to the upper beam portion, and four couplings incorporating a breakable reduced section are connected between the foot brackets and threaded anchor inserts embedded in the foundation. The couplings permit use of the design in medians where collision can occur in either direction of traffic.
16. The alternate design uses four hinge/fuse plates incorporating a thinned section and bolted where the beam is cut through just under the sign. The pair of plates on the impact side of the beam sever upon impact and a pair

on the opposite side bend to allow the beam to swing upward out of the path of the impacting vehicle.

17. Beams should be erected in a single unit because they are easier to plum, square and brace when the entire assembly is raised and set in concrete.
18. Beams shall be erected in accordance with the procedure given for non-breakaway beams in 630.
19. A sloping concrete foundation top surface is required on the high ground side to prevent a water pooling pocket and permit drainage as per SCD TC-41.10. For the alternate design, the foundation top shall be level in the area of the breakable couplings.



20. When a supplemental panel is required below an extrusheet sign, the panel is fastened by sign backing assemblies to the parent sign. The panel shall be separated from the sign by the width of the fuse plate plus 1 inch (25 millimeters). This is to permit unhindered hinge plate bending in the event of a vehicle collision.
21. After the foundation concrete is cured, base plate nuts shall be loosened in turn and retightened with a torque wrench in a systematic manner to the specified maximum torque shown in the table on SCD TC-41.10, also shown in TEM Table 297-9. Torque wrenches used should be calibrated daily.
22. When torque limiting nuts are used on base plates, the nuts shall be loosened in turn and tightened in a systematic manner until the upper area shears away, assuring that the correct torque has been applied.
23. At least four weeks following the erection of signs on breakaway beams, the breakaway feature shall be inspected by the contractor for evidence of shifting or loose fasteners.
24. All loose fasteners shall be re-torqued to specified values. Base plate fasteners shall be loosened and re-torqued even if no shifting or looseness is detected. However, if the base plate connection was made with torque limiting nuts, re-torquing will only be required if looseness can be detected. Re-torqued conventional nuts at this time shall have anaerobic adhesive applied, or as an alternate, new torque limiting nuts of the proper range may be used.

Signs

General

Signs should be inspected when received on the job site if possible, but certainly prior to erection.

The signs should be inspected for conformance with the plans, certified shop drawings, catalog cuts and material specifications.

Flatsheet signs are typically of aluminum sheet cut into geometric shapes of the size specified.

Dimensions and thickness are to be as shown on SCDs TC-52.10 and TC-52.20. Bolt holes are to be drilled or punched (630.04).

Extrusheet signs are fabricated of aluminum sheet and extrusions, joined by spot welding and assembled by bolts (SCD TC-51.11). As an alternative, panels extruded in a single operation may be used (SCD TC-51.12). Extruded panels and spot welded panels shall not be used in the same sign. There shall be no appreciable deviation from flatness on the face of an assembled sign.

Overlay signs are of aluminum sheet of the thickness specified and used to cover the legend of extrusheet signs. Signs with overlays should be checked for any loose rivets holding the overlay sign.

All signs shall be reflectorized by being covered with the appropriate grade of sheeting. The sheeting shall be of the correct color, firmly attached and free of tears, wrinkles, blisters or blemishes.

Sign legend shall be in accordance with the plans, certified shop drawings and the OMUTCD.

The type of copy on extrusheet signs shall be as shown on the certified shop drawings. Available types of copy are listed in TEM Table 297-6.

All signs shall be identified on the reverse side by decals as described in 630.

Extrusheet signs shall also to be identified by information in a detachable form on the back (see Item 630.04).

Sign Storage

Signs shall be suitably protected and identified for shipment and storage. Extrusheet signs shall be kept rigid by backbracing or crating and the sign face covered with protective material. The backbracing shall extend sufficiently below the sign lower edge to keep the sign off the ground.

Extrusheet and flatsheet signs shall be stored in a vertical position.

Signs must be stored in such a manner that the packaging paper or cardboard material does not get wet. If the packaging material or slip sheeting should become wet, the paper should be removed immediately from contact with sign faces to prevent damage to reflective sheeting on the faces.

In the case of signs furnished by ODOT for erection by the contractor, the contractor shall be responsible for the storage and care of the signs after their transfer (630.08).

Sign Copy

TEM Table 297-6 provides information about the sign copy used, type, material used, design features, etc.

Sign Identification Decals

All signs shall be identified on the reverse side by decals of Type F white reflective sheeting (730.18) with silk screened numerals. Information shall be coded by screened-on or punched-out numerals before decal application and shall include: sheeting manufacturer and year of sign fabrication. At the time of erection, month and year of erection shall be scratched out by the contractor. This procedure is described in 630.04, which also contains an illustration of the decal. Decals for overlay signs may be on the front surface.

The following codes shall be used on the decals to identify the manufacturer of the sheeting.

0 - Avery Dennison

1 - Minnesota Mining and Manufacturing Company (3-M)

2 - Sakai Trading-New York, Inc.

3 - Nippon Carbide Industries (USA)

4 - Morgan Adhesives Company

5 - American Decal and Manufacturing Company

6 - Stimsonite Corporation

7 - Reflexite North America

Sign Erection (630.07)

General

This section provides information on erection of the signs. Assembly and erection of various types of overhead sign supports are addressed in 630.04 and 630.05 and ground-mounted supports are addressed in Section 630.06.

Ground-Mounted Flatsheet Signs

When erecting ground-mounted flatsheet signs the following provisions apply:

1. Typical vertical and lateral clearances of ground-mounted flatsheet signs are shown on SCD TC-42.20.
2. Flatsheet signs shall be fastened to posts by 5/16 inch (8 millimeters) hex head steel bolts with a 3/8 inch (10 millimeters) ID x 1 1/4 inch (32 millimeters) OD wide washer under the bolt head and using a lock washer and hex nut. For U-channel posts, at each bolt a bearing plate shall be used behind the sign is used to reinforce the sign, as indicated on SCD TC-41.20. The hardware and bearing plates are furnished with the signs.
3. Posts supporting groupings of flatsheet signs in multiple arrangements will require the use of sign backing assemblies made up of bolted together short sections of posts. Sign backing assemblies are furnished with the signs unless separately itemized.
4. Flatsheet signs mounted so as to be read by motorists using bridges shall be erected on special steel posts in accordance with SCD TC-41.40.
5. Street Name signs shall be erected on square supports in accordance with SCD TC- 41.40.

Ground-Mounted Extrusheet Signs

When erecting ground-mounted extrusheet signs the following provisions apply:

1. Typical vertical and lateral clearances of ground-mounted extrusheet signs are shown on SCD TC-42.10.
2. Mounting clips and other attachment hardware shall conform with SCD TC-51.11.
3. Supplemental panels erected under ground-mounted extrusheet signs mounted on nonbreakaway beams shall be fastened directly to the beams. The panel shall be separated from the parent sign by 1 inch (25 millimeters) to conform with SCD TC-42.10. When the panel is too short to reach between the beams, the panel may be fastened to the parent sign by sign backing assemblies.
4. Supplemental panels erected under ground-mounted extrusheet signs mounted on breakaway beams shall be fastened to the parent sign by sign backing assemblies. The panel shall be separated from the parent sign by the width of the fuse plate plus 1 inch (25 millimeters).
5. Exit Panels erected above extrusheet signs shall be attached by sign backing assemblies furnished with the Exit Panel.
6. The signs should be checked after erection to verify that the beams extend to the top of the signs and that the signs are horizontal and the clearances satisfactory.

Overhead Signs

When erecting overhead signs the following provisions apply:

1. The clearance above the roadway for the bottom of overhead signs shall be a minimum of 17 feet (5.2 meters), or as shown on the plans.

2. Overhead signs shall be vertical or horizontal regardless of the sag of supporting messenger wire, mast arm rise, chord camber or overpass slope.
3. Signs erected on span wire supports shall be attached in accordance with SCD TC- 17.10.
4. Signs erected on single arm supports (SCD TC-16.20) shall be installed so their bottom edge is at the same elevation. Sufficient adjustment for this purpose is provided by the two pair of slotted holes in the sign brackets for the attachment of the arm clamps. The clamps shall be tightened sufficiently to prevent sign rotation about the arm.
5. Signs mounted on semi-overhead supports (SCD TC-9.10) shall be erected so that their edge clearance from the curb line is at least 2 feet (0.6 meter).
6. Extrusheet signs over 8 feet (2.4 meters) in height may be delivered in two pieces for assembly in the field (630.08).
7. Extrusheet signs erected on supports with two arms shall be centered vertically.
8. Mounting clips and other attachment hardware for extrusheet signs shall conform with SCD TC-51.11.
9. Signs mounted on center-mount supports (SCD TC-9.30) may be mounted laterally on the support in an eccentric position when required by the plans. However, a minimum of 2 feet (0.6 meter) of sign length shall remain to one side or the other of the vertical member centerline.
10. Overlay signs erected in the field over existing extrusheet signs shall be attached by blind rivets at spacings as required in 630.04.
11. Flatsheet signs used in connection with signals supported by span wire shall be fastened to the messenger wire by special attachments in accordance with SCD TC-41.41.
12. Flatsheet signs used in connection with signals supported in a swinging condition on mast arm supports shall be fastened to the arm by a special attachment in accordance with SCD TC-41.41.
13. Exit Panels erected above extrusheet signs shall be attached by sign backing assemblies furnished with the Exit Panel.
14. Extrusheet signs shall be attached to rigid overhead supports using sign brackets in accordance with SCD TC-22.20. Signs extending more than 4 feet (1.2 meters) above or below an attachment point require the use of intermediate sign brackets.

Sign Inspection

After sign erection, the contractor shall inspect all signs under both day and night conditions. Any necessary adjustments in lateral position or orientation to correct visibility deficiencies shall be made to the satisfaction of the project engineer (630.13).

Overhead Guide Signs should typically be centered over the lane(s) to which they apply. Down arrows on the signs should normally be centered over the proper lane as viewed by the road user.

The maximum displacement of a down arrow from the center of a lane should not be more than 2 feet (0.6 meter).

Overhead Guide Signs situated on curved roadways and incorporating down arrows may have the arrow(s) adjusted within the sign and/or the entire sign moved laterally so the arrows when seen from a typical viewing distance on the curve will appear to be over the proper lane(s).

Night conditions inspection is to assure that each sign has visible and uniform reflectivity. Any signs not having proper reflectivity should be noted and cleaned or replaced by the contractor.

631 Sign Lighting

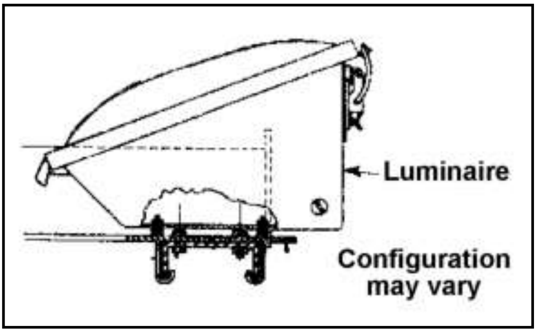
General

Sign lighting is not necessary for overhead guide signs when Type H or J reflective sheeting is used for the reflective legends. Therefore, for new installations, sign lighting will normally not be used.

Guidelines and design information on sign lighting are addressed in TEM Sections 212 and 240-7.

This section provides additional information about what to look for when installing sign lighting.

1. Check certified shop drawings, catalog cuts, etc. for luminaires, ballasts, switches and enclosures.



2. Luminaires for mercury vapor sign lighting shall comply with 731.01 and shall consist of a housing containing a reflector, lamp socket, wiring and a door containing a glass lens or refractor, meeting the following requirements:
    a. The housing shall be adequately reinforced cast aluminum with a natural finish or painted gray.
    b. The reflector shall be highly reflective aluminum.
    c. The lamp socket shall be a porcelain shrouded mogul screw with lamp grips and a large center spring providing firm contact with a lamp base.
    d. The door shall be an aluminum frame either cast with a natural finish or a formed extrusion with an anodized finish. The door shall be hinged securely to the housing and provided with a spring loaded latch. Hinges shall be stainless steel and designed so that unintentional door separation is impossible. Latches shall be stainless steel and are not to require tools for opening.
    e. A flexible readily removable gasket shall be attached to the housing or door so a waterproof seal is formed when the door is closed and the gasket compressed. The glass lens shall be

mounted within the door and sealed with elastic cement or a gasket.

f. The glass lens shall be borosilicate or equivalent, able to withstand hail or the thermal shock of freezing rain.

g. Drainage weep holes shall be provided in the housing or door depending upon the luminaire's bottom or top position on a sign.

3. Mercury vapor lamp sizes shall be as specified. Ballast type shall match the specified lamp wattage. Lamp watts and ANSI code are shown in TEM Table 297-11 and SCD TC-31.21.
4. Sign lighting shall be controlled by a disconnect switch within an enclosure. The switch shall be a two-pole minimum, single throw, fused safety disconnect type rated at 600 volts and 30 amperes (C&MS Item 631.06). The fuse size shall be as specified. A solid neutral bar shall be provided.
5. The enclosure shall be weatherproof and lockable, complying with NEMA standard Type 4 ICS 1-110.15. Enclosure size shall be as specified (See SCD TC-32.10).
6. Each enclosure shall be furnished with at least one padlock. Padlocks shall have a corrosion resistant body and a corrosion proof steel shackle. All padlocks for a project are to be keyed alike from an appropriate master key number obtained by the contractor from the maintaining agency.
7. Sign service to the enclosure shall be in accordance with the plans. Service wiring cable size shall be as specified, single conductor rated at 600 volts and not less than Number 4 AWG (631.04). Sign service underground from a pull box to a foundation mounted support, or to a support mounted on a concrete median barrier, is shown on SCD TC-32.10. Sign service from a direct drop is shown on SCD TC-32.11.
8. Sign wiring from the disconnect to the luminaires shall be the size specified, single conductor rated at 600 volts and not less than Number 10 AWG (631.05). The wiring shall be fully protected within enclosures, support interiors, junction boxes, rigid or flexible conduit and luminaire housings. Wiring shall be continuous from the disconnect switch to a junction box mounted on the sign support or overpass structure. The junction box shall permit disconnection of wiring when a sign and its lighting equipment is removed as a unit. A junction box shall be installed for each sign. Wiring shall be continuous from the junction box to the first luminaire on a sign and continuous between additional luminaires on the sign.
9. Luminaire ballast shall be located within the luminaire (integral) or in a weatherproof housing attached to or beside the luminaire (contiguous). Wiring to the ballast shall be continuous with permitted disconnection at the sign support junction box (see paragraph 8).
10. The wiring routing for wired signs shall be as shown on SCD TC-31.21.
11. Luminaire supports complying with SCD TC-31.21 are specified for new installations. Support arms are of welded tubular design incorporating an attachment flange and a luminaire support plate. The arms are bolted to a

continuous rectangular galvanized steel tube forming the lower portion of the sign's glare shield. The face of the rectangular tube shall be covered with non-reflective sheeting complying with 730.20 so as to match the color of the glare shield sheeting. Support arms shall not be mounted upside down or in any other manner than that permitted by the SCD.

12. Luminaires shall be adjusted to a proper aiming angle according to the manufacturer's instructions and inspected at night to determine if they are providing uniform illumination to the sign face.

Sign Lighting Inspection and Testing

1. In accordance with 631.11, sign lighting and electrical signs shall meet the requirements of the following tests as required by 625.19 and performed by the contractor:
    a. Ground rod resistance to ground (see 632).
    b. Cable insulation (Megger) test (see 632).
    c. Ten-day performance test (see 632).
2. During the ten-day performance test, failure of lamps, ballasts and transformers may be corrected by replacement of the faulty component but will not require restart of the entire test period.
3. The contractor should perform a circuit test on all sign lighting cable and wire conductors to determine if there are any short circuits, cross circuits or other improper connections. Circuit testing may be done in accordance with 632 .
4. The test results shall be reported to the project engineer in the test information required by 625.19. The test results should be documented.
5. During the ten-day performance test, a night inspection shall be performed by the contractor and final adjustments made to sign lateral positions and the aiming angle of luminaires to the satisfaction of the project engineer (631.11). The adjustments are to eliminate excessive brightness and glare and to obtain optimum sign face reflected brightness, uniformity of illumination, visibility and legibility.
6. Following successful completion of a ten-day performance test and after there has been a partial or final acceptance of the project, the contractor should turn over to the project engineer all manuals, diagrams, instructions, guarantees and related material. The project engineer should transfer the material to the maintaining agency. For ODOT-maintained signs, the material should be given to the appropriate ODOT District Office.
7. After the project has been accepted by ODOT, the project engineer should immediately notify the maintaining agency that as of a certain exact time and date, the agency is responsible for the maintenance.

Documentation Requirements – 630 / 631 Traffic Signs and Sign Supports

1. Ensure signs and supports are in compliance with plans and approved catalog sheets
2. Document depth, diameter, or foundations
3. Document steel and clearance maintained (if used)
4. Document support stubs (if placed)
5. Document anchors - diameter and depth (if used)
6. Document size and depth driven of drive post used
7. Document curing used on concrete
8. Measure appropriate units for foundations and/or supports used and turn in for pay
9. Document type, size, background sheeting and legend sheeting for signs
10. Measure signs and turn in for pay as per 630.14

632 Traffic Signals and 633 Signal Controllers

General (632.01)

This information is intended to serve as a guide for construction personnel where the Contractor furnishes and installs traffic control devices and appurtenances. However, it may also be useful for maintenance personnel performing the same functions. Inspection procedures for the various type traffic control devices are outlined, mainly in the form of check lists to assist project personnel in performing their duties. This information points out the various important features of each device and references the applicable specification or standard drawing. Illustrations are used for easy recognition of the device or feature being discussed.

Qualified Products List (QPL)

All 632 and 633 devices should be checked against the Qualified Products List before they are incorporated into a project.

Foundations (632.14)

See Item 630 for additional information relative to concerns in the installation of foundations for poles and controller cabinets.

Electrical Appurtenances

General

This section will be used to provide additional information about various electrical appurtenances involved in the traffic signal installations, such as pull boxes, conduit and ground rods.

Pull Boxes

Pull boxes shall be of the specified sizes (see SCD HL-30.11 and the plans), typically 18 inches (460 millimeters) or 24 inches (610 millimeters), and the specified material.

The word on the cover should be “TRAFFIC” when the pull box is part of a traffic signal system unless the plans require the word “ELECTRIC” or other marking. The word shall be formed on the surface or displayed on an attached metal plate in accordance with 725.06, 725.07 or 725.08.

The location of pull boxes shall be as shown on the plans. However, pull boxes in low drainage areas may be adjusted to eliminate drainage problems, or feasible methods of positive drainage may be used in accordance with 603 and details on SCD HL-30.11, with the approval of the Engineer.

Pull boxes located in sidewalks, traffic islands and curbed areas close to the roadway, where wide turning vehicles could drive over them, may be adjusted to eliminate the problem, or a concrete pull box with a heavy duty lid may be used with the approval of the Engineer.

Trench

Trenching shall be in accordance with 625.13 and as shown in TEM Figure 498-7. Any change in dimensions will require approval by the Engineer.

Trenching may be in earth or in paved areas, according to plan details. Trenching and subsequent restoration of surfaces in paved areas shall be in accordance with SCD HL-30.22.

Trenching work in paved areas shall be divided into two pavement depths for payment; less than 6 inches (150 millimeters) and 6 inches (150 millimeters) or greater, as described in 625.20.

The trench in paved areas may be 4 inches (100 millimeters) wide when cut by a Vermeer type trencher. In this case, the trench shall be backfilled with concrete full depth, except that the bottom 4 inches (100 millimeters) above the conduit may be 625.13 tamped backfill.

Conduit

Metal conduit shall comply with 725.04, with sizes according to the plans. It shall be made from domestically produced steel, and the domestic steel content of the conduit shall be certified by the manufacturer or supplier before it is approved for installation.

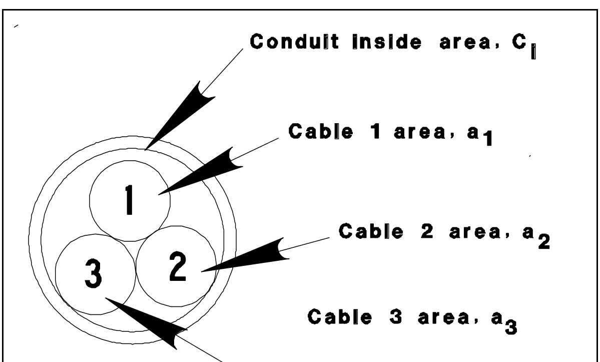
The routing of loop detector wire in conduit through curb or under shoulder shall be as shown on SCD TC-82.10.

Conduit containing cable and/or wire shall have the terminal at the high end completely sealed in an approved manner, with removable sealing compound or a molded plastic or rubber device compatible with the conduit, cable jacket and wire insulation, according to 625.12.

After placement, a conduit which will not have cable or wire pulled into it during construction shall have a pull wire installed in it, and the terminal at the high end shall be sealed with removable sealing compound, a molded plastic or a rubber device, according to 625.12.

Difficult pulling and possible jacket skinning may occur when an attempt is made to install too many cables or wires within a given conduit. The reason could be design error in new systems or attempts to insert an excess number or size of cable or wire in existing conduit.

Good electrical practice requires that the combined cross section of all cables and wire within a conduit should be less than (or equal to) 40 percent of the conduit inside area:



$a1 + a2 + a3 + \text{etc.} \leq 0.40Ci$

a = cable or wire across section area, sq. in. (mm^2)

Ci = conduit inside area, sq. in. (mm^2)

A calculation can be made using the above formula. The cross section area of conduit, cable and wire is shown in TEM Table 497-1.

Ground Rod

A ground rod shall be driven below groundline near the foundation of every strain pole and overhead sign or signal support whether there is power in the vicinity or not, as shown on SCDs TC-21.20, TC-32.10 and TC-32.11.

Ground rods shall comply with 725.16 and be installed in accordance with 625.16. A ground wire of insulated 600-volt No. 4 AWG 7-strand soft drawn copper shall be attached by an exothermic weld. The typical exothermic weld procedure is described in 632.

Insulating varnish shall be applied to the weld and any exposed conductor.

Exothermic Weld

The following procedure is typical and may be used unless the manufacturer's instructions differ.

1. The end of the ground wire shall be in an un-flattened, unbent, clean and dry condition to assure a good weld.
    a. Bent and out-of-round conductor wire will hold the mold open causing weld material leakage. A cable cutter should be used to make un-deformed ends. If a hacksaw is used, the insulation should first be peeled, as the saw tends to coat the cable with plastic material, which must be cleaned off.
    b. Corroded cable shall be cleaned. Oily or greasy cable should be cleaned with a solvent that dries rapidly and leaves no residue. Very greasy cable can be "cooked out" by dipping into molten solder.
    c. Wet cable can cause the blowing of molten metal out of the mold, and the cable should be dried by a hand torch or a quick drying solvent such as alcohol.
2. Ground rod ends which have been mutilated in driving can hold the mold open and should be cut off. Rod ends shall be clean and dry.
3. The weld mold shall be clean before use. Damp or wet molds can cause porous welds and should be dried by heating.
4. The cable shall be inserted into the side of the mold so the cable is 1/8 inch (3 millimeters) back from the center of the tap hole. The mold shall be placed on the ground rod so the cable sits on top of the rod (see TEM Figure 498-8). A clamp or locking pliers should be used on the rod to keep the mold from sliding down during the welding process, and the conductor should be marked at the mold surface so it can be verified that the conductor has not shifted before the weld is made.
5. The steel disk shall be inserted into the crucible and the cartridge contents poured on top, being careful that the disk is not upset. The cartridge should be tapped when pouring, to make sure the starting powder comes out and spreads evenly over the welding powder. A small amount of starting powder should be placed on the top edge of the mold under the cover opening for easy ignition.

   a. The proper cartridge size is marked on the mold tag and is the approximate weight of the powder in grams.
   b. If the proper cartridge size is not available, two or more small cartridges or part of a larger cartridge can be used.
6. The mold cover will be closed and the starting powder ignited with a flint gun. If it is necessary to hold down the cover during the flash of igniting powder, a long tool should be used and the hand should be kept away.

Power Service for Traffic Signals (632.24)

General

Power service for traffic signals shall comply with SCD TC-83.10 and the plans. It shall consist of the equipment needed to provide a pole-attached wiring raceway and disconnect switch, for use with separately furnished power cable routed from the service point to the controller cabinet. As shown in TEM Figure 498-9, unless otherwise specified, the equipment includes a weatherhead, a conduit riser with necessary fittings and attachment clamps when required, and a disconnect switch with enclosure (632.24).

A thorough review of the plans should be made to determine that the specific requirements of the maintaining agency for power service have been satisfied.

A ground wire shall be used as shown on SCD TC-83.10, leading to a ground rod installed in accordance with 632.

The LB type fitting under the controller cabinet (SCD TC-83.10) may have to be installed before erecting the pole because of interference with the foundation.

Electric Meter Base

When required, an electric meter base shall be furnished by the applicable utility and installed by the Contractor as part of the power service work.

Conduit Riser and Weatherhead

Power cable is the only type cable or wire permitted through the power service conduit riser.

The conduit riser shall terminate at the meter base, if used; otherwise, termination shall be at the switch enclosure. From there conduit connection to the controller cabinet is as shown on the plans. Conduit connection could be:

1. immediately to the controller cabinet on the same pole;
2. downward by underground conduit and possibly a pull box to a nearby foundation-based controller cabinet;
3. upward by another riser on the pole to span wire and a remote cabinet location.

The conduit riser shall comply with 725.04 and the plans, and the weatherhead shall be threaded aluminum or galvanized ferrous metal (732.16). Risers on painted poles shall be painted to match the poles.

Disconnect Switch

The disconnect switch shall be a UL listed single-throw safety switch or circuit breaker, meeting the voltage and capacity requirements of the specifications. The amperage rating of the fuse or circuit breaker shall be 5 to 10 amperes greater than the peak load rating of the equipment service. The enclosure shall be a UL listed water tight lockable stainless steel NEMA Type 4, supplied with UL listed conduit hubs, and the enclosure shall contain a solid neutral bar normally grounded to the enclosure (732.21).

Pole and Support Inspection - General

See 630 for information about pole and support inspection.

Traffic Signal Supports (632.16)

General

This section will be used to provide additional information about traffic signal supports. Various types of overhead signal supports are also depicted in TEM Table 497-4.

Strain Pole Type Support

Strain poles shall comply with the certified drawings, SCD TC-81.10 and the plans.

They shall be galvanized unless paint is specified in the plans, and the general features should be inspected in accordance with 630.

When strain poles of the embedded type are specified, they shall include an extension for embedment below groundline and a welded-on ground sleeve. The pole extension shall be sufficient to reach within 3 inches (76 millimeters) of the foundation depth as specified in the table in SCD TC-21.20, or the extension may be a minimum of 6 feet (1.8 meters) if a reinforcement cage is provided as also shown on the SCD. The cage shall overlap at least 24 inches (610 millimeters) of the pole extension and reach to within 3 to 4 inches (76 to 102 millimeters) of the foundation’s specified depth. A special foundation design is required when soil with a load bearing capacity of less than 2,000 pounds per square foot (9700 kilograms per square meter) is encountered. Any soil with significant content of clay and/or sand is likely to have a bearing capacity smaller than 2000psi (9700 kg/m2). If any such soil or soil layer is encountered during foundation excavation, arrangements should be made for standard soil bearing capacity tests of the soil at the foundation location. See Section 503, Excavation for Structures, for additional information on bearing capacities of soil materials.

Embedded poles normally do not include a handhole or blind half couplings for internal wiring.

When shown on the certified drawings, and as permitted by 732.11, strain poles may be tapered tubes with a cross section which is circular or a regular polygon of six or more sides, or may be a type consisting of straight sections with a tapered effect accomplished by the use of reducers.

Strain poles used to support traffic signals or signs (SCD TC-17.10) shall be furnished with one or more span wire clamps with shackles for attachment of messenger wire (see SCD TC-84.20).

The messenger wire may be attached by wrapping twice around the pole and securing with a three-bolt clamp, as shown in SCD TC-84.20, when used on round, tapered steel strain poles.

Erection of these poles shall be in accordance with the general procedure given in Section 630, except as noted in this section.

For the initial rake of strain poles of the anchor base type, leveling nuts shall be adjusted to provide a rake of one-eighth to one-half inch per foot (11 to 42 millimeters per meter) of pole in the direction opposite to the contemplated span wires and are to be made snug tight. Further adjustment may be necessary to assure that the strain poles are essentially vertical after the application of span wire load.

For the initial rake of strain poles of the embedded type, poles shall be embedded in concrete to provide a rake of one-eighth to one-half inch per foot (11 to 42 millimeters per meter) of pole in the direction opposite to the contemplated span wire and braced. The age of the concrete before it is considered cured, before the bracing may be removed, and before the permitted application of span wire load, shall be in accordance with 630.

Single Arm Support

Single arm supports shall comply with the certified drawings, SCD TC-81.20 and the plans. General features of the support shall be inspected in accordance with 630, and except as noted in this section, erection of the support shall be in accordance with the general procedure given in 630.

Welds shall be inspected according to 630 and the galvanizing inspected according to 630.

For arms of two telescoping pieces, a 15 inch (380 millimeters) overlap is required. The overlapped arms shall be secured with a stainless or galvanized steel through-bolt with hex head washer and nut(s). Arm caps shall cover at least 50 percent of the end area (732.11).

An arm clamp with clevis shall be furnished at each signal position, as well as a hole with a rubber grommet for the outlet of signal cable.

The installation of small signs and their attachment to the arms should be checked. Any possible interference between swinging signals and signs should also be checked.

Blind half couplings shall be located on the pole of the support for mounting pedestrian signal heads or controller cabinets when required by the plans.

Signal heads shall be installed so that their bottom surface is 16 to 18 feet (4.9 to 5.5 meters) above the roadway. The signals shall be installed at essentially the same elevation. Drop pipes should be used only when necessary to maintain the clearance between 16 to 18 feet (4.9 to 5.5 meters). If the clearance without a drop pipe will be slightly over 18 feet (5.5 meters), it is permissible to omit the drop pipe, with the maintaining agency's approval.

Initial rake shall be adjusted so that under the load of signals, the pole will assume an essentially vertical position and the arm rise be within the limits specified on SCD TC-81.20, i.e., 3 inches (76 millimeters) minimum and 12 inches (300 millimeters) maximum.

Sag and Vertical Clearance

TEM Figure 498-13 illustrates sag guidelines and vertical clearance standards for traffic signals.

Signal Span Messenger Wire and Appurtenances

General

This section will be used to provide additional information about signal span messenger wire and appurtenances.

Signal Messenger Wire and Cable

Messenger wire and accessories shall comply with SCD TC-84.20 and 732.18. Messenger wire diameter shall be in accordance with the plans.

The height at which the messenger wire is to be attached to the pole will, in some instances, be shown on the plans. In cases where this is not shown, the Contractor is responsible for determining the proper attachment height. This determination shall consider the relative elevation of pavement to pole foundation top, the desired clearance between pavement and the bottom of each signal, i.e., 16 to 18 feet (4.9 to 5.5 meters), the sag in the messenger wire (3 to 5 percent), and the height of each signal.

Alternate methods of attaching messenger wire to strain poles may be used, as follows:

1. Span wire clamp with clevis, anchor shackle and thimbles on the messenger wire,

2. Messenger wire wrapped twice around the strain pole and secured with a three-bolt clamp of the proper size, when used on round, tapered strain poles.

If the messenger wire attachment to strain poles makes use of the alternative with pole clamps and anchor shackles, the wire is to be hooked through the shackle using a thimble and secured with a three-bolt clamp. A preformed guy grip shall not be used for messenger wire attachment at the pole. Guy grips of the proper size may be used at bull rings (aerial corners)

Thimbles with a correct groove size for the messenger wire (or the wire and eye of guy grips) are to be used at anchor shackles and bull rings. When three-bolt clamps are used, the wire tail is to be served as shown in the Section on Messenger Wire. See the Section on Messenger Wire for the installation procedure for preformed guy grips.

Thimbles with a correct groove size for the messenger wire or the preformed guy grip shall be used to connect to anchor-type shackles or to bull rings at span wire aerial corners.

Messenger wire sag shall comply with 632.22 and the Section on Sag and Vertical Clearance.

The signal cable shall be attached to the messenger wire by lengths of preformed lashing rod.

The lashing rod shall be the proper internal diameter to snugly hold the cable, but not cut into its jacket. See the Section on Wire Lashing for further information.

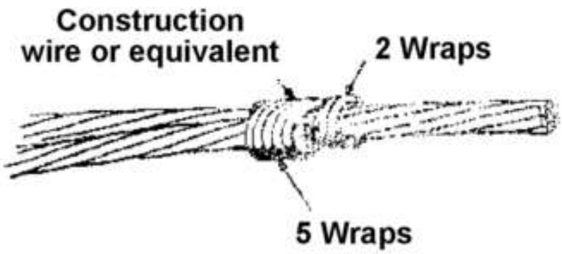
A drip loop shall be formed in the signal cable at each weatherhead, and should extend at least 6 inches (150 millimeters) below the weatherhead (see TEM Figure 498-14).

Cables or groups of cables up to a maximum of four, hanging within pole interiors, shall have their strain relieved by cable support assemblies as described in 632, TEM Figure 498-14 and SCD TC-84.20.

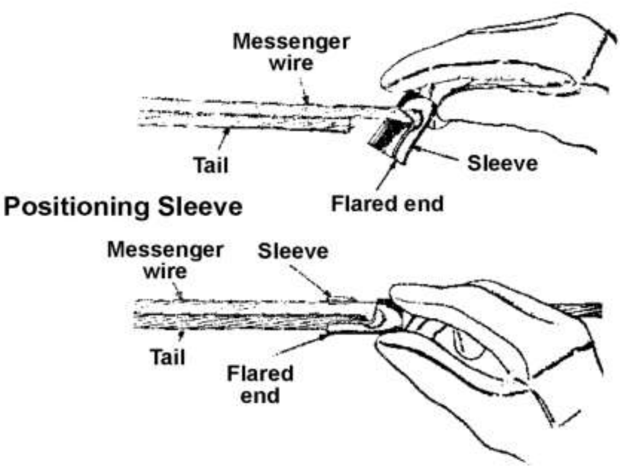
Messenger Wire Served Ends

Messenger wire may be attached to various accessories by looping the wire to make an eye.

The wire end shall be secured by a three-bolt clamp, and the cut wire end or tail shall be “served” with construction wire or clamped with a sleeve device as shown on SCD TC-84.20. The following illustrations show both serving methods for the wire tail:



Serving With Wire



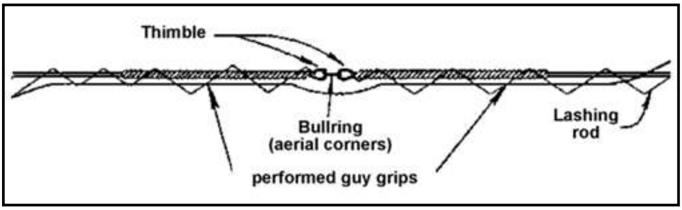
Sleeve in Position

Serving With Strand Sleeve

Preformed Guy Grips

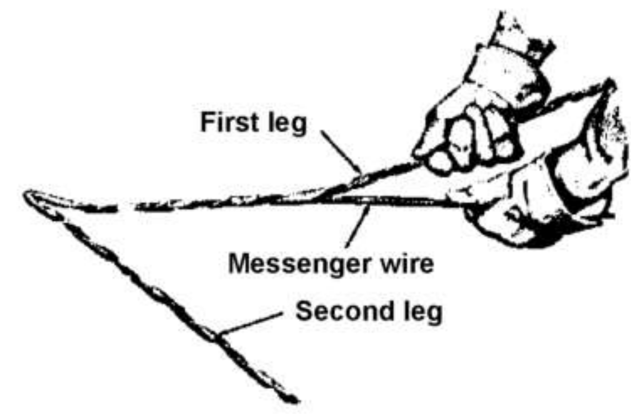
Preformed guy grips are made of helically shaped high-strength steel wire. They are available in sizes fitting the outside diameters of messenger wire and form an eye permitting attachment to various accessories.

As shown in SCD TC-84.20, they should be used at bull rings of span wire aerial corners (see the following illustration). Thimbles are used in the eye of grips in accordance with standard details in the SCD.

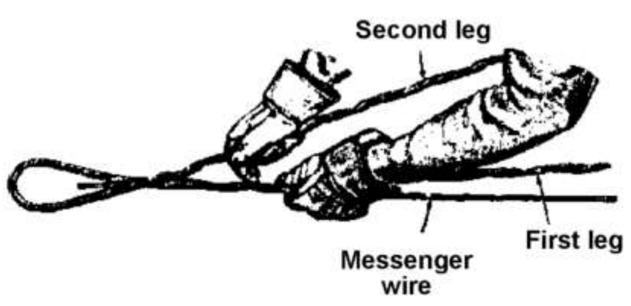


Grips are installed on an end of the messenger wire by wrapping a first leg of the grip to the messenger wire. In most cases, the accessory to which the grip is to be attached must be inserted in the eye of the grip with a thimble before the second leg of the grip is wrapped. The second leg is then applied to the combined first leg and messenger wire. The following illustrations show the wrapping sequence.

Guy grips shall not be used on messenger wire used for span wire sign supports. In this application, wind load on the signs can cause failure of the grips (see SCD TC-17.10). Guy grips shall not be used for attachment to signal strain poles (SCD TC-84.20(5)).



Applying First Leg



Applying Second Leg

Cable and Wire

In certain instances, the plans will assign a color code usage for each cable, or a typical usage by color code. All connections should be made observing these assignments, and any deviations, if determined necessary, should be recorded. When a color code usage is not provided, good electrical wiring practice would still dictate that color code wiring on the project be consistent.

Typically, white is reserved for the neutral or common leg of a circuit. The following provides additional information about various types of cable and wire contained in Table 732.19-1:

1. Signal cable is used as the electrical connection between signal heads and the controller cabinet at an intersection. The cable may be either IMSA 19-1, which has a jacket of polyvinyl chloride, IMSA 20-1, which has a polyethylene jacket, or IPCEA S-61-402. The number of conductors and wire gage shall be as specified on the plans. Conductors shall be of copper and stranded, and conductor insulation shall be color coded. Splices are not permitted in signal cable (632.23), and the cable should be scanned to be sure that there are none.
    a. As temperatures decrease, signal cable gets stiffer and harder, becoming brittle when below freezing. In very cold weather, the cable should be handled with care so as not to damage the jacket or insulation when unreeling, flexing and installing. The method of measurement of signal cable is shown in TEM Figure 498-16.
2. Interconnect cable is used as the connection between intersections for systems of signals (although there is no significant difference between signal and standard interconnect cable).
    a. The cable may be either IMSA 19-1, IMSA 20-1 or IPCEA S-61-402 as in signal cable, or twisted pair/shielded interconnect cable conforming to RUS PE-39 may be required by the plans.
    b. Twisted pair/shielded cables are less prone to pick up induced current as a result of nearby electrical devices or magnetic fields, and are necessary for certain types of communication systems which may be used to interconnect signals. The number of conductors and wire gage shall be as specified. It should be noted that in the case of twisted pair/shielded cable, the number of conductors is typically referred to as the number of pairs (pair count), i.e., six conductor cable would be referred to as a three-pair cable. Conductors shall be of copper and are usually solid.
3. Interconnect cable of the integral messenger type is aerial self-supporting cable with a "figure 8" cross section. The cable may be either IMSA 19-3, which has a jacket of polyvinyl chloride, or IMSA 20-3, which has a polyethylene jacket. Shielded versions, IMSA 19-4 and IMSA 20-4, may be required by the plans. The number of conductors and wire gage shall be as specified. Conductors shall be of copper and stranded, and conductor insulation shall be color coded.
    a. Twisted pair/shielded interconnect cable of the integral messenger type conforming to RUS PE-38 may also be required by the plans.
4. Loop detector wire is laid in turns in saw slots cut into the pavement and routed by the groove to the edge of pavement and to a pull box. The wire is single-conductor No. 14 AWG.
    a. The conductor shall be of copper and stranded. Loop detector wire consists of detector wire inserted into a flexible plastic

tubing (732.19) meeting specifications IMSA 51-5. The tubing shall encase the wire completely from the splice at the lead-in cable through the entire loop turns and back to the splice.

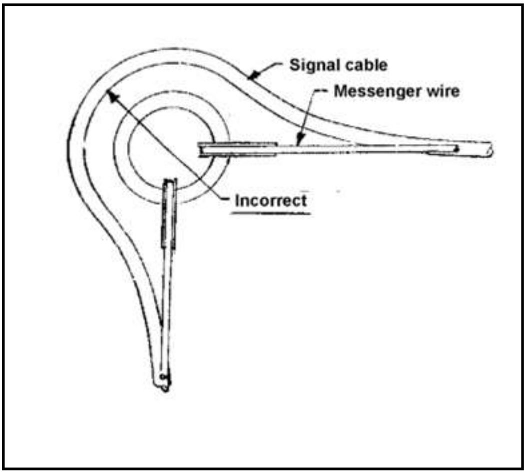
5. Lead-in cable for detector loops is spliced to loop wire and routed to detector units in the controller cabinet. The cable shall be two-conductor No. 14AWG with jacket of 0.04 inch (1 millimeter) minimum black polyethylene and insulation of polyethylene. Each conductor shall be stranded copper. The conductor pair shall be twisted and shielded.
6. Lead-in cable for magnetometers is spliced to the lead which is a part of magnetometer probes and routed to detector units in the controller cabinet. The cable is four-conductor No. 18 AWG with a jacket of 0.026 inch (0.66 millimeter) minimum high density polyethylene and a low capacitance insulation. Each conductor shall be stranded copper, and insulation shall be color coded. The four conductors shall be twisted.
7. Power cable is used as the connection between the service pole or service drop and the controller cabinet. The cable normally is two-conductor and UL:RHH/RHW/USE type. The wire gage shall be as specified. Conductors shall be color coded, of aluminum and stranded.
    a. Stranded copper may be substituted with an AWG one gage higher (wire one size smaller).
    b. When specified, power cable may be three conductor. Single conductor cables may be substituted for a two (or three) conductor cable, but color coding should still be provided.
8. Service cable is used to bring power to the vicinity of an isolated intersection. The cable is normally two-conductor (duplex) and XHHW type or cross-linked polyethylene with a 0.045 inch (1.14 millimeter) minimum jacket. The wire gage shall be as specified. The cable is aerial self-supporting with one conductor being an uninsulated ACSR (aluminum conductor, steel reinforced) messenger wire. An insulated conductor of stranded aluminum is twisted around the messenger. Stranded copper with an AWG one gage higher (wire one size smaller) may be substituted for the aluminum conductor. Three-conductor (triplex) may be specified where two insulated conductors are twisted around the messenger wire. The uninsulated messenger serves as the grounded neutral of the power supply.
9. Ground wire is used to connect signal or sign supports to ground rods. The wire shall be single-conductor No. 4 AWG made of seven-strand soft drawn copper with white insulation and rated at 600 volts. The wire is used as part of the 625.16 Ground Rod item.

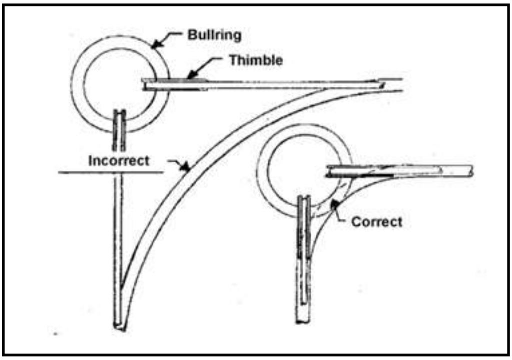
Lashing of Overhead Cable

A preformed helical lashing rod shall be of the proper internal diameter to tightly secure overhead cable(s) to the messenger wire. A lashing rod should not be loose or so tight as to be impressed deeply or cut into the cable jacket. If either deficiency is observed, the proper internal diameter may be determined by the following formula: C approx. = (0.85) (D+m), where C is the lashing rod internal diameter, D is the cable jacket diameter and m is the messenger wire gage (all dimensions in inches (millimeters)).

For groups of several cables of varying diameter, the internal diameter of the lashing rod may be best determined by a graphic layout to scale.

Signal cable routed on messenger wire should neatly pass the bull rings in its path. Also, signal cable routed around an aerial corner formed in the span wire at a bull ring should have a radius in its routing small enough to form a tangency with the bull ring.





Cable Support Assemblies

As shown in TEM Figure 498-14, a cable support assembly makes use of a flexible tubular wire mesh device called a cable grip which has a gentle holding action over its length and which is used to eliminate strain or damage to the jacket of cable(s) hanging in the interior of poles.

The support assembly consists of the grip attached to a single “U” eye support bale and a sling when necessary. The grip may be used on an individual cable or a group of cables up to a maximum of four (see 632.21). The grip shall be the proper size and strength for the cable(s), of stainless steel or tin coated bronze, and may be either a “closed” or “split with rod” type. The split type is used when a cable end is not available. In this application, the grip mesh is not a continuous tubular weave, but is split for wrapping around the cable(s) and is secured by a rod which is inserted through alternate weaves at each side to form a tube.

The support’s bale shall be hung over the pole J-hook if sufficient length is available; otherwise, a sling shall be made of messenger wire, clamps and thimbles. The sling wire is to be passed through the bale eye, adjusted to the proper length and hung on the J-hook.

Pole interiors should be checked by removing pole caps to verify that cable support assemblies are in place, hung on the J-hook and properly adjusted to eliminate cable jacket strain.

Aerial Interconnect Cable

For aerial interconnect cable, the following standards and guidelines apply:

1. Aerial interconnect cable and accessories shall comply with SCD TC-84.20 (illustrated in part in TEM Figure 498-15). Interconnect cable may be supported on separate messenger wire or be the integral messenger self-supporting type with a "figure 8” cross section, if specified on the plans.
2. Metal poles with messenger wire supported interconnect cable are to be furnished with pole clamps. The pole clamp may provide clevis(es) to which the messenger is attached and terminated, or may provide a stud to which a clamp assembly can be bolted.
3. Messenger wire ends are to be looped and secured with three-bolt clamps or a messenger vise, or a preformed guy grip dead end may be used (see 632). If clamps or vises are used, the wire tail shall be served (see 632). Thimbles with a correct groove size for the messenger wire shall be used to connect to the clevis of the pole clamp.
4. When messenger wire is to be grounded to a metal pole, a ground clamp, an insulated ground wire and a bolt tapped into the pole shall be used (also see item 10 in this section).
5. Wood poles with interconnect cable shall be fitted with through-bolts holding a clamp assembly or with a thimble eye-bolt to which the messenger may be attached and terminated.
6. The clamp assembly shall be suitable to the type of cable support, either messenger wire or self-supported cable with "figure 8" cross section. Clamp assemblies for "figure 8" interconnect cable differ slightly from those intended for use with separate messenger, inasmuch as the clamp

used with "figure 8" must allow a small gap for the web of the "figure 8" cable which joins the messenger to the cable.

7. When messenger wire or "figure 8" cable is to be grounded on a wood pole, a ground clamp and an insulated ground wire stapled to the pole and covered by a molding shall be used (also see Item 10 in this section). The ground clamp used with "figure 8" cable shall be a type with teeth to penetrate the jacket over the messenger. The ground wire shall be bonded to an existing ground wire or to a ground rod.
8. Standard interconnect cable shall conform to C&MS Table 732.19-1 and have the number of conductors and wire gage specified. There is no difference between standard interconnect cable and signal cable, only in the application. Interconnect cable of the shielded type may be specified in the plans. The interconnect cable should be marked with the correct nomenclature. Solid conductors are not permitted (732.19) unless specified in the plans. Splices may be used on long lengths of interconnect cable (632.23) and shall be accomplished only in weather tight splice enclosures. Splice enclosures may be either aerially located on the messenger wire or be a pole-mounted box type (see SCD TC-84.20). Where the aerial enclosure is clamped to the span, it should be within 2 feet (0.6 meter) of a pole to improve accessibility. No measurement allowance is given for splices.
9. Aerial interconnect cable is to have a sag between three to five percent of pole spans or is to match existing utility lines.
10. Messenger wire supporting interconnect cable, and the integral messenger of self-supporting type cable, is to be grounded in cable runs at the first and last poles and on intermediate poles at intervals not to exceed 1200 feet (366 meters) (also see item 4 of this section for grounding on metal poles, and item 7 for grounding on wood poles).
11. As temperatures decrease, interconnect cable gets stiffer and harder, becoming brittle when below freezing. In very cold weather, the cable should be handled with care so as not to damage the jacket or insulation when unreeling, flexing and installing.
12. Standard interconnect cable may be attached to supporting messenger wire by lengths of preformed lashing rod or by spinning wire. Lashing rods shall be of the proper internal diameter to snugly hold the cable but not cut into its jacket (see 632).
13. Aerial interconnect cable of the integral messenger self-supporting type (with a "figure 8" cross section) shall have its wind stability increased by being twisted or spiraled once every15 feet (4.6 meters) of span. This is done by clamping the tensioned cable to every other pole and then going to intermediate poles and twisting the cable before tightening their attachment clamps.
14. When the interconnect cable is attached to a pole and continues in a relatively straight line past the pole, this is an intermediate support; whereas, if the interconnect cable turns at the pole, it is a corner or turning point. Certain types of clamps may be well suited for intermediate support applications, while other designs are required for corner clamps. The clamps shown on the left side in SCD TC-84.20 are

usually not suitable for corner clamps if the change of direction is more than about 10 degrees. See SCD TC-84.21 when the change of direction is more than about 10 degrees.

Method of Measurement for Cable and Wire

TEM Figures 498-16 through 498-20 illustrate the method of measurement for signal cable, interconnect cable, detector lead-in cable, power cable and service cable, respectively. 632.29 also specifies the method of measurement for cable and wire.

Signal Equipment and Wiring

General

This section will be used to provide additional information about other signal equipment and wiring.

Controller Cabinet

While the layout of controller cabinets may vary, the following requirements and guidelines apply:

1. The prewired cabinet should be checked against certified drawings, the wiring diagram for the cabinet and the plans.
2. The cabinet should be fitted with a small door-in-door (police door) unless otherwise specified. The cabinet should be in good condition, revealing no evidence of damage, with its material free of cracks and pinholes. The doors and seals should fit properly. The cabinet exterior should appear as metallic aluminum unless a color is specified. The cabinet interior may be similar to the exterior or may be flat white. The method of cabinet mounting should be as shown on the plans and the cabinet should be securely mounted.
3. Cabinets equipped with solid state controllers shall be provided with a suitable number of sturdy adjustable metal shelves to mount the specified equipment and to provide the required space for designated future equipment (733.03).
4. The equipment shall be arranged for easy withdrawal and replacement, without the necessity of disturbing adjacent equipment. The permanent location of equipment within the cabinet, as well as the shelves themselves, should allow free circulation of air and not restrict air flow from fan ducts or vents. Components on shelves and devices on the door shall be arranged so that a 1 inch (25 millimeter) minimum space separates them when the door is closed. This minimum space shall not be compromised by plugs, wires, controls or similar items. Terminals and panel-mounted devices with exposed contact points located next to shelf mounted equipment shall be provided with spacers, shelf lips or other

means to assure that component units cannot be accidentally moved into contact with any exposed electrical terminal points. A minimum 4 inches (100 millimeters) clear area from the bottom of the cabinet should be reserved for the routing of cables. No shelf, component or panel-mounted item shall be located in the bottom 6 inches (150 millimeters) of cabinets, with the exception that terminal blocks only in pedestal or pole mounted cabinets may be installed as close as 4 inches (100 millimeters) to the bottom.

5. Ready accessibility should be provided for items such as load switches, flasher, relays, terminal blocks and fuses which are mounted on or plugged into panels on the cabinet back or sides. Switches, controls and indicator lights should be easily operable and visible without having to move equipment from their positions.
6. Major equipment items should bear a name plate, brand or indelible marking for identification as to type, model, catalog number and manufacturer’s name or trademark.
7. The furnished controller unit should be checked for the correct type, number of phases, and available control functions required by the plans. Controller units should be furnished with all auxiliary equipment necessary to obtain the operation shown in the plans.
8. When specified, other equipment may be a part of the prewired cabinet, such as: a coordinator, an on-street master, interconnection equipment, preemption equipment, time clock or weekly programmer, and special relays.
9. Furnished detector units should be checked to see if the correct quantity is installed, and the proper type used with each loop and each detector phase. When multi-channel detector units are furnished, the plans may require the provision of special cabinet wiring and an adapter harness to allow single channel detector units to be readily substituted.
10. The prewired cabinet should also be checked for the following auxiliary equipment:
    a. A forced air ventilating fan automatically controlled by a thermostat shall be furnished.
    b. A conflict monitor shall be furnished. When the plans so specify, according to 733.03, an increased capability monitor shall be furnished. The minimum number of monitor channels, related to the number of phases for the intersection, should conform to 733.03.
    c. Load switches should be provided in sufficient quantity for the interval sequence shown in the plans. The switches shall be solid state NEMA triple signal type with input indicator lamps. The minimum number of load switch sockets furnished, related to the number of phases for the intersection, shall conform to 733.03.
    d. A flasher (or flashers) shall be solid state NEMA type.
    e. Relays required for the proper operation of the specified equipment shall be furnished.

f. Lightning protection devices shall be furnished for the protection of solid state controllers. They should be located on the incoming power line and on loop detector leads where these connect to the terminal block. When solid state coordinators are furnished, they should be protected by devices across each conductor and ground on the interconnect cable (see 733.03(A.2.f.)).

g. A convenience outlet and lamp shall be furnished. The outlet should contain at least one standard three-wire plug receptacle of the ground-fault circuit-interrupting type. The lamp should be an incandescent type, located in the upper part of the cabinet, and controlled by a switch.

h. A main power breaker shall be furnished. The fan, convenience outlet and lamp should be wired on a branch of the AC+ power line preceding the main breaker, so that these may be operated independently of the main breaker control. This preceding branch should itself contain an auxiliary breaker rated at 15 amp.

i. A radio interference filter should be installed in the incoming AC+ power line between the main breaker and solid state equipment. If the equipment furnished does not provide signal and flasher circuit switching at the zero voltage point of the power line sinusoid wave form, filters should also be provided for the load switches and flasher.

j. A manual control cord with push button should be furnished only when the plans so require (733.03). The cord should be at least 5 feet (1.5 meters) long.

k. Switches required for the proper operation of specified equipment should be furnished and labeled as to function and setting position. The following switches should be grouped behind the small door-in-door (police door): signal shutdown switch, flash control switch and an automatic/manual transfer switch (when manual control is specified).

l. Terminal blocks should not be obstructed by other equipment. Terminal points should accept spade type wiring terminals except for incoming power terminal points which may be either the type to accept bare wire or spade terminals. Contact between adjacent terminal points may be either by bus bar or by wire jumpers with spade terminals.

11. The incoming power bus should be fed from the line side of the incoming 120 VAC power line after the circuit has passed through the main power breaker. A signal bus relay should control power to the bus supplying power for the signal load switches. The requirement for radio interference filters (733.03) should be adhered to, with the buses supplying load switches and flashers being filtered if load switches do not switch at the zero voltage point of the power line sinusoid wave form. A common terminal bus insulated from the cabinet should be furnished for the connection of the neutral wire of the incoming 120 VAC power line. This

common bus should have sufficient terminal points to accommodate all potential cabinet wiring as well as field wiring. A separate common terminal, insulated from the panel, should be used for the interconnect common (if interconnection is a part of the system).

12. The cabinet should include a ground bus bar with an adequate number (at least three) of ground terminal points (733.03). This bus bar should be grounded to the cabinet. The ground bus bar will normally be bonded to the common terminal bus using at least a No. 8 AWG copper wire.
13. Wiring bundles should be neatly arranged and grouped as to voltage and function, and they should be lashed or restrained so that they do not interfere with the access to equipment, including terminal blocks or buses. The harnesses should be of sufficient length and should be easily traced through the cabinet. All conductors should be stranded, with labeled spade type terminals or plug connectors. The wiring should be color coded, with solid white for the AC common, black for the AC line side power (AC+), and solid green or white with green stripes for the safety ground.
14. Incoming cable and wire should be identified by tags or bands (632.05). The size, material and method of tag or band identification should be in accordance with 725.02, except that marking may be by indelible pen on plastic tags instead of embossed letters. The identification on the tags or bands should conform to the wiring diagram for the cabinet and its intersection, with typical abbreviations in accordance with the Table in 632.05 (reproduced in Table 497-2).
15. Two copies of the schematic and wiring diagram for each cabinet and its intersection should be furnished by the Contractor. The diagrams are to be updated to reflect any changes made during construction. The diagrams should be neat and legible, on durable paper, and folded in a moisture-proof envelope fastened to the cabinet interior.

Cable and Wire Identification

As noted in 632.05, cables and wires shall be identified as shown in TEM Table 497-2.

Vehicular Signal Heads and Wiring

Illustrations of the signal head visors, hangers and wiring discussed herein are presented in TEM Figure 498-21.

1. Signal heads shall conform to the plans, 732.01 and SCD TC-85.20. Signal heads shall have the correct number of faces (one-way, two-way, three-way or four-way) and each face shall be made up of the correct number of optical sections (one, three, four or five). Sections shall be of the correct lens size, i.e., 8 or 12 inches (200 or 300 millimeters), color and ball or arrow configuration. Arrow lenses are only to be the 12 inch (300 millimeter) size. It should be noted that arrow lenses are made in Rights, Lefts and Throughs (up). The use of the proper arrow lens should be checked.

2. Lenses shall be aligned properly in their frames so their optical configuration directs most of the light to the forward sector.
3. As noted in TEM Section 420-4.2, signal heads shall have a yellow finish, unless otherwise specified in the plan.
4. Cutaway type visors (732.01) shall be fastened to each optical section, unless open bottom tunnel visors or other types are specified, and the interior finish of the visors shall be flat black.
5. Signals should be clean and the assembly tight. Gaskets should be in good condition and lens door hinges and latches should be in good working order. All openings not used for mounting purposes shall be closed by waterproof caps.
6. Five-section faces, arranged in accordance with SCD TC-85.20 and the plans, are to use galvanized pipe, elbows and tubular hardware, painted to match the signal head.
7. Swinging signals shall be installed in a plumb condition. A balance adjustor should be used only when necessary to achieve plumb (632.06).
8. Swinging signals suspended from a mast arm shall be fitted with a universal hanger permitting swinging in both longitudinal and transverse directions (632.06).
9. When specified by the plans, disconnect hangers shall be used with signal heads.
10. Drop pipes, 1 1/2 inch (38 millimeter) diameter galvanized pipe, are a source of trouble and are aesthetically unattractive; therefore, they are intended to be used only when they are necessary to permit signals to be suspended above the roadway within a clearance of 16 to 18 feet (4.9 to 5.5 meters). Signals supported by span wire, with sag required between 3 and 5 percent (SCD TC-84.20), shall be brought to proper clearance by adjusting the attachment height of the span wire to the poles. Because of the 2 foot (0.6 meter) clearance tolerance, drop pipes should not be necessary in most cases.
11. When the plans so specify, backplates shall be fitted to signal heads.
12. Signal cable shall be routed into the interior of heads through the entrance fitting using a grommet. The cable shall be routed to each face’s terminal block, which is typically in the yellow indication section but may be in the green section. Conductors shall be fitted with spade type terminals and shall be fastened securely to the correct terminal points. Conductors shall be identified according to the wiring diagram. Signal cable shall not be spliced, either between signals or in signal face interiors.
13. External signal cable shall to be fashioned into a drip loop extending at least 6 inches (150 millimeters) below the entrance fitting but shall not chafe on the signal.
14. Lamps may be either incandescent (732.04.B)or light emitting diode (LED) (732.04.C) as specified in the plans Incandescent lamps shall have a clear glass envelope and a rated life of 8000 hours. Lamp sockets shall be rotated so as to position the open portion of each incandescent lamp filament in an upward position. All vehicular signal lamps shall be prequalified in accordance with 732.04(B) & (C).

15. Each face of a signal head shall be oriented to its approach of traffic and its locking device securely tightened. Orientation or aiming of standard signals should be done so that the maximum light intensity from a standard signal is directed slightly below the horizontal center; thus, on a level approach, the face of the signal should be essentially vertical. When an approach to a signal is on a grade, the signal may be tilted slightly to point the signal axis parallel to the grade of the approach. Horizontal aiming should orient the axis of signal display parallel to the centerline of the approach for straight approaches when the signal is over the roadway. When the approach roadway is curved, or when a signal is not over the roadway, the axis should be directed at a point on the approach which is 175 to 625 feet (54 to 191 meters) in advance of the intersection, the distance being dependent on the speed of approaching traffic. For convenience, OMUTCD Table TS-1 has been reproduced in part as TEM Table 497-3.
16. When a vehicular traffic signal head has been erected and faces approaching traffic, it shall either be in operation as a stop-and-go signal or a flasher, or it shall be covered or bagged. This is an OMUTCD requirement (OMUTCD Section 6B-19) and cannot be ignored. Typically, the plans will contain an item for “Covering of Vehicular Signal Heads” which will require the contractor to cover, maintain the covering, and subsequently remove the covering when the signal is ready to commence operation.
17. Normally, the plans will provide the “covering” item for each new signal head, but will not provide them for any existing heads which are to be removed. The intent is that “covering” will be necessary for the new heads until they and their associated controller and wiring have been checked by circuit testing (see 632), while any existing signals at the intersection will continue to control traffic. When the new signals are uncovered and placed in operation, the existing signals can be quickly removed. Specific maintenance of traffic requirements in any plan may require a different means to assure the unused signals are not exposed to traffic.

Optically Programmed Signal Heads

Programmed heads (see TEM Section 420-4.6) shall conform to certified drawings, 732.02 and 732.03, and the plans. They are to have the correct number of optical sections making up each face. Programmed heads have many points of similarity to regular heads. Items 2, 3, 5, 11, 12, 13, 16 and 17 of 632 also apply to these signal heads. For more detailed information, see publications by the manufacturer.

Each optical section shall be fitted with a visor (732.02 and 732.03) and the interior surface of visors shall have a flat black finish.

Programmed heads shall be mounted in a manner permitting little or no motion. If mounted on a mast arm, a rigid adapter shall be used. Heads of more than three vertical sections mounted on a mast arm shall be fitted with pipe backbracing, as shown on SCD TC-85.20. The pipe shall be a minimum of 17 inches (430 millimeters) behind the signal center axis so that adequate clearance is provided for the programming procedure. If heads are supported by span wire, a tether messenger wire shall be attached to a fitting in the bottom of the signal's lower section.

Customarily the manufacturer's representative will program the signals, but in accordance with the plans, the contractor is responsible for the correct aiming and masking of the signal so as to be visible to drivers or pedestrians only in the area indicated on the plans.

Signals are pre-tilted to cover most situations. The yellow indication section should be aimed first and the other sections aimed similarly. The housing shall be opened and the lamp collar and diffuser removed. The roadway inverted image should be observed on the surface of the glass with the eye held a distance of 2 feet (0.6 meter) behind. The image observed is where the optics are pointed. The tilt of the integral adapter shall be adjusted so the horizon appears at the lower third of the glass. The adapter screws are then to be tightened. All sections shall be at the same tilt angle.

The signal shall be rotated horizontally so the image on the glass covers the proper roadway lane(s). The bolts of the mounting adapter shall be loosened and the signal rotated around its serrated surface. The movement of traffic should be examined on the glass. When the roadway image appears correct, that is, pointed in the direction where it should be seen, all screws may be tightened. All sections of the signal should now be adjusted and rigid in their mountings, properly aimed and ready for masking.

The yellow indication section of the signal should be masked first since it transmits a brighter image. The other colors can then be masked identically.

Masking requires the use of opaque tape furnished by the manufacturer. The tape shall be applied to the glass, up to the edge, and squeegeed flat to remove air bubbles. The tape initially should be applied horizontally to the glass to cover the image of the sky and that portion of the roadway which is distant. After this is done, tape should be applied to the images on the sides of the lane(s) where the signal is not to be visible. In many cases, signal visibility is desired for a left turn lane only, and visibility to the adjacent through lane should be masked. Excess tape extending beyond the edge of the glass should be trimmed away, taking care not to cut on the surface of the glass.

The reduced area on the glass should be checked to verify that its image is the only area in the roadway which should see the signal. The lamp collar and diffuser may now be replaced and the housing latched.

The boundaries of the area in the roadway where the signal is to be visible should be explored on foot to verify that the head is properly programmed.

Pedestrian Signal Heads

Pedestrian signal heads shall conform to 732.05, certified drawings, the plans and SCD TC-85.10. Signals shall have the correct type of light source and lettering height in accordance with the plans (632.08).

Housings shall have a black finish, unless otherwise specified (732.05). Visors shall be fitted over each message, except one type may have the entire face protected by a flat black sunshade fastened close to the lens. The interior surface of visors shall be flat black finish. Signals should be clean and the assembly tight. Gaskets should be in good condition and lens door hinges and latches in good working order.

Housings shall be positioned with a minimum set back of 2 feet (0.6 meter) from the curb and a height of 8 to 9 feet (2.4 to 2.7 meters) above the sidewalk for adequate clearance. The heads shall be oriented toward their crosswalk and locked securely in position.

Lamps for pedestrian signal heads may be either incandescent (732.04.A) or light emitting diode (LED) (732.04.C) as specified in the plans .

Pedestrian push buttons shall conform to Section 404-2, certified drawings, and 732.06. Push button housings shall have a yellow finish, unless otherwise specified. The push button shall be positioned 3.5 to 4 feet (1.1 to 1.2 meters) above the sidewalk.

Push buttons on metal poles shall be installed over a 3/4 inch (19 millimeters) maximum field drilled hole with edge protected by two coats of zinc-rich paint and a rubber grommet inserted.

The push button housing curved back shall be positioned over the hole, wiring routed through to the electrical mechanism and the housing secured by stainless steel screws. Unused holes in the housing shall be plugged. Push buttons on wooden poles shall have their wiring in conduit connected to a fitting of the signal support.

Signal head supports (conduit and fittings) on wooden poles shall be grounded, using a ground clamp and an insulated ground wire stapled to the pole and covered by a molding.

If specified in the plans, pedestrian signal heads may be covered in accordance with 632.25.

OMUTCD Section 2L-3 addresses standards for the signs used where push buttons are provided to actuate pedestrian signals. The sign legend shall conform to the plans.

Loop Detector Slot and Wire

TEM Figures 498-23 and 498-24 illustrate details related to the following discussion of loop detector slots and wiring.

1. Slots cut into the pavement forming rectangular detection loops shall be in accordance with the plans and SCD TC-82.10.
2. The slots shall be a minimum of 3/8 inch (9.5 millimeters) in width and shall have a minimum depth of 2 inches (50 millimeters) in concrete and 4 inches (100 millimeters) in asphalt concrete. SCD TC-82.10 requires that loop corners be made at a drilled or bored hole, about 1 1/4 inches (32 millimeters) in diameter, and with the same depth as the saw slot. Any sharp edges at the saw slots and the holes shall be chiseled out.
3. The slot depth shall accommodate the specified number of turns of wire laid so that the uppermost wire has a covering of at least 3/4 inch (19 millimeters). The number of wire turns shall comply with the plans and the table in SCD TC-82.10 (also shown in Figure 498-23). A separate slot leading from the loop to the pavement edge is typically cut for each loop.
4. When permitted by the Engineer, loops installed in new asphalt concrete may be sawed and the loop wire(s) embedded with sealant in a subsurface course with subsequent covering by the surface course.
5. Some plans may specify the use of preformed loops placed on the pavement for covering by a surface course of asphalt concrete.
6. If the problem of loop installations in brick streets is encountered, the Engineer should consult with the local traffic engineer for recommendations.
7. Loop locations may be adjusted to avoid manholes. Loops should not be placed across pavement joints. Instead, lateral and longitudinal adjustments should be considered, with the approval of the project engineer. If joint crossing is unavoidable or major pavement cracks are encountered, the following techniques may be used (see Figure 498-24).
    a. In Technique A, the loop wires are laid over the joint or crack within a 3 inch (75 millimeter) square or circular hole cut to slot depth. The wires are laid in an "S" shape and the hole filled with elastic joint material or asphalt concrete.
    b. In Technique B, the slot at the joint or crack is saw cut to twice-normal width and depth. The wires are laid so as to conform to the deepened slot which is injected with soft setting butyl rubber up to the depth of the original slot. The original slot depth and the remaining perimeter of the slots are embedded with standard sealant cured to a flexible state.
    c. In Technique C, the slot at the joint or crack is enlarged. The wires are encased in a length of plastic tubing which should be large enough to loosely hold all wires and may be slit lengthwise to facilitate construction. Before placing it in the slot, the ends and the longitudinal slit are to be taped shut to prevent the entry of loop sealant. The enlarged slot is then filled with loop sealant.
8. Before loop wire is placed, all slots shall be brushed, blown clean of loose material and completely dry.
9. Loop detector wire shall be single-conductor No. 14 AWG insulated wire, type IMSA 51-5 with stranded copper conductors, unless otherwise specified. The wire should be marked at intervals with the wire gage, UL

label and type. The detector wire is contained inside a flexible plastic tube, as required by IMSA 51-5.

10. The correct turns of loop wire (TEM Figure 498-23), up to a maximum of four, shall be placed in the slots, to comply with 632.23 and the plans. The wire shall be pushed to the bottom of the slots with a blunt wooden tool (or equivalent) to avoid damaging the insulation.
11. The wires with tubing at the pavement edge or curb shall be led into a conduit of the size shown in SCD TC 82.10. Care should be taken to prevent excessive slack at the point where the wires enter the conduit. The high end of the conduit shall be sealed in accordance with SCD TC 82.10.
12. The detector wire shall be twisted in the conduit leading from the pavement edge to the pull box. The flexible plastic tubing shall cover the wire completely from the splice at the lead-in cable, through the entire loop turns and back to the splice. The tubing provides extra protection from abrasion and allows the wire to slide inside the tubing in case of pavement shift or cracks, thus minimizing the possibility of breakage. Since wire/tubing includes an air pocket, it will tend to float to the surface when sealant is applied to the slot. For this reason it is usually necessary to wedge short lengths of the tubing, or similar devices, into the slot to wedge down the tubing/wire. These are usually needed at 1 to 2 foot (0.3 to 0.6 meter) intervals.
13. The slots shall be completely filled with approved sealant and left undisturbed until cured to a flexible state. Sealants on the ODOT prequalified list shall be used, in accordance with the manufacturer's recommendations. Materials which set up to a hard or brittle state are not acceptable.
14. Detector loops are measured as "each" loop installed and the item includes wire, pavement cutting and sealant.

Loop Detector Lead-In Cable

Unless otherwise specified, loop detector lead-in cable (Table 732.19-1) shall be two conductor No. 14 AWG twisted pair shielded, with a jacket of black polyethylene 0.04 inch (1 millimeters) thick minimum, and polyethylene insulation with conductors of stranded copper.

Within the pull box, loop wire ends shall be joined to the conductors of the lead-in cable by soldering and covered with insulating material (see TEM Figure 498-25). An approved, poured epoxy waterproof splice kit shall be used. It is understood that epoxy splice kits are easily damaged by freezing temperatures encountered prior to mixing. Damaged epoxy components may sometimes be recognized if either of the components has turned or is streaked milky white.

Lead-in cable shall be routed to the controller cabinet, fitted with soldered spade type terminals and fastened to the correct points of the terminal block. The lead-in cable's shielding shall be grounded to the ground bus within the cabinet.

If a pull box is not specified on the plans, the splice between the loop wire and lead-in cable shall be made in the first entered pole or pedestal, except where the controller cabinet is mounted on the pole or pedestal. If the controller cabinet is mounted on the pole or pedestal, the loop wires may be routed directly into the cabinet and no lead-in cable is necessary.

Loop detector lead-in cable is measured in accordance with Section 632-9 and TEM Figure 498-18.

The poured epoxy splice in the pull box is included.

Magnetometer Probes and Lead-In

Magnetometer sensor probes (TEM Figure 498-26) may be set in the pavement, or under and in bridge decks in accordance with SCD TC-82.10 at the locations shown on the plans.

Although core drilling may be performed after concrete placement, it is preferred that probe holes in new concrete be formed by pouring concrete around a vertical piece of capped vinyl-chloride or other non-metallic tubing. Probe holes in existing concrete must be core drilled. Probe installations under bridge decks may be as shown in Figure 498-26. The lead from probes should be in non-metallic conduit. Probes in bridge slabs should be centered in the reinforcing steel grid square which is nearest to the probe's plan location. The center of a grid square may be located by the use of a Pachometer metal locator. The procedure for use of such an instrument is given in Section 632-10.10.

Probe holes in pavement and bridge decks shall be approximately 3/4 inch (19 millimeters) greater than the probe diameter. The probe shall be set so as to have a covering of at least 1 ½ inches (38 millimeters). However, deeper placement may be used if recommended in the manufacturer's instructions.

The probe lead, which is a part of the probe(s), is to be led from the probe(s) to the edge of pavement, to the bridge parapet wall or under the bridge deck, depending on the design used.

When in pavement and bridge decks, the slot for the lead shall be a minimum of 3/8 inch (9.5 millimeters) in width and have a depth of 2 inches (50 millimeters) in concrete and 4 inches (100 millimeters) in asphalt concrete.

Probe holes and slots are to be brushed, blown clean of loose material and completely dry. The probes are to be set and leads pushed to the bottom of slots with a blunt wooden tool (or equivalent) to avoid damaging the insulation. Probe holes and slots are to be completely filled with approved sealant and left undisturbed until cured to a flexible state. The sealant should be the same as for loop detector slots, as given in 632.

Probe leads in slots at the pavement edge or curb shall be led into a 3/4 inch (19 millimeters) conduit connecting to a roadside pull box. Care should be taken to prevent excessive slack at the point where the lead enters the conduit. The high end of the conduit is to be sealed in accordance with SCD TC-82.10.

Unless otherwise specified, lead-in cable (Table 732.19-1) shall be four-conductor No. 18 AWG color coded, twisted, with a jacket of 0.026 inch (0.66 millimeters) minimum high density polyethylene and a low capacitance insulation with conductors of stranded copper.

Within the pull box, the probe lead ends shall be joined to the conductors of the lead-in cable by soldering and covered with insulating material. An approved poured epoxy waterproof splice kit shall be used. The kit should be the same as for loop detector lead-in cable as given in 632.

Lead-in cable shall be routed to the controller cabinet and fitted with soldered spade type terminals and fastened to the correct points of the terminal block. The shielding of lead-in cable shall be grounded to the ground bus within the cabinet.

The installation of magnetometer probes includes: the probe(s) and lead, the provision of probe holes and pavement slots when used, sealant for the probe holes and slots, and plastic conduit where required. Probes are measured as individual units with the attached lead. Several probes may be on a single lead.

Magnetometer lead-in cable is measured in accordance with 632 and TEM Figure 498-19. The poured epoxy splice in the pull box is included.

Use of Pachometer Instrument

A Pachometer is an instrument used to detect the location of metal such as reinforcement bars under a concrete cover. The instrument is a magnetic detector which operates on the principle of the change in magnetic flux due to the presence of ferrous metal.

A probe is connected to the instrument and is passed over the concrete surface being examined. The instrument will indicate when the pole of the probe is parallel to and directly over the axis of a reinforcing bar. Use of the instrument will, therefore, outline the sides of a grid square for accurate magnetometer probe location in the center.

Signal Performance Tests and System Checks

General

Traffic control signal components and the entire system shall be tested as required by various specifications to assure proper operation before acceptance. Ground rods shall be tested for satisfactory low resistance to ground. A circuit test should be performed on all conductors to make sure there are no shorts, crosses and high resistance or other improper connections. A cable insulation or Megger test shall be performed on all conductors to verify the integrity of the insulation covering. All traffic control equipment in the controller cabinet should be checked for correct settings and all controls manipulated for assurance of an operable system.

Finally, the traffic control system shall successfully pass a ten-day performance test, which will give an opportunity for any hidden flaws to reveal their presence.

As a final "housekeeping" check, equipment should be observed for any evidence of unattached ground wire, unlatched or unbolted doors, etc.

The results of the various tests are to be entered by the contractor on test report forms (TEM Form 496-6) as required by 632.28.

Ground Rod Test

All ground rods shall be tested by the Contractor for earth resistance to ground, as required by 632.28(B).

Short-Circuit Test

Before the performance of any cable insulation (Megger) test or the ten-day performance test, a short-circuit test shall be performed by the Contractor using a volt-ohmmeter or other approved instrument (TEM Form 496-6 and 632.28(C)). Short-circuit tests shall be conducted with all electrical loads, power sources, equipment grounds, and earth grounds disconnected (see TEM Figure 498–28).

Signal cable routed to signal heads may be tested with connection made to the lamp sockets, but without the lamps being installed.

Each conductor shall be measured against every other conductor and ground to assure that no short-circuits, cross-circuits, or other improper connections exist. Continuity should not exist between any conductor and any other conductor including ground.

Circuit Continuity Test

Each circuit branch shall be disconnected and tested by the Contractor for continuity by temporarily jumpering each branch at its termination and measuring the temporarily looped circuit for assurance that no open circuits exist (TEM Form 496-6 and C&MS 632.28(D)). This testing is illustrated in TEM Figures 498-29 through 498-32. Each circuit branch should be according to plan, with no high resistance connections and with the proper identification.

Lead-in cable for loop detector wire shall be tested before and after the cable is spliced to the loop wire.

Circuit continuity of signal cable may be done by applying 120 volts to each outgoing circuit and observing that only the specific lamps are lighted.

Cable Insulation Test (Megger Test)

This testing is illustrated in TEM Figures 498-33 and 498-34.

1. Each conductor of cable or wire terminating at the controller cabinet shall be tested by the Contractor for insulation resistance measured to ground (TEM Form 496-6 and C&MS 632.28(E)). A listing of the resistance reading for each conductor is to be included in the test results furnished to the Engineer.

2. Cable and wire insulation can be faulty but the imperfections can be easily overlooked, leading to eventual electrical failure of the wiring. Weakening of insulation properties may be caused by poor storage conditions and stress due to rough handling during installation. Dirt is especially troublesome, since it is an electricity conductor and can penetrate small cracks in the insulation.
3. Insulation testing shall be performed with all conductors disconnected from their points on the terminal block in the cabinet so there is no chance of any voltage being present, and to prevent damage to any connected equipment. One Megger instrument terminal shall be attached to a termination of jumpered together ends of conductors or to the end of a single conductor cable or wire undergoing testing. The other Megger instrument terminal shall be attached to the cabinet ground bus bar.
4. Insulation resistance shall be measured for the wire of roadway loops after the embedding of the wire with sealant in slots.
5. The meter pointer of the Megger instrument (or equivalent indication) should be adjusted to zero and the test switch activated. Test duration should be as recommended by the instrument manufacturer.
6. The insulation resistance measured to ground for each conductor shall not to be less than 10 megohms. Cable or wire not meeting this reading shall be replaced.
7. After completion of the cable insulation test, all cabinet wiring shall be connected in accordance with the wiring diagram. The Contractor shall demonstrate to the satisfaction of the Engineer that all circuits are continuous and operating correctly, free from shorts, crosses and unintentional grounds.

Functional Test

Before energizing the traffic signals the following functional checks should be made:

1. The incoming AC voltage should be checked.
2. Operation of the following equipment should be checked: cabinet ventilating fan, fan thermostat, and convenience outlet with lamp (when furnished). The filter(s) used with the fan should be unobstructed.
3. Timing settings on solid state controllers should be varied over their ranges and all functions activated to verify that the controls are operable without fault.
4. Timing settings in accordance with the plans should now be entered on the controller, time clock, etc. and checked for corrections. On some projects, timing settings will be provided by the maintaining agency and are not listed in the plans.
5. An agreement should be reached with the contractor and the maintaining agency on the procedure to be followed in the event of a signal failure prior to acceptance.
6. Before signals are energized to control traffic, the maintaining agency should be notified and given an opportunity to check the installation and timing settings.

After energizing the traffic signals the following functional checks should be made. In the event the signals are controlling traffic at the time, these checks should be made with caution to protect the safety of workers, pedestrians and drivers.

1. The function of all cabinet switches should be checked, including the power on/off switch and manual control (when furnished).
2. The traffic signals (and controller indicator lights) should be observed to verify that the controller is timing consistently the intervals and phases set into the controls. A stopwatch is suggested, especially to check critical short intervals. All controllers functions should be activated to verify that operation is proper.
3. The detector units should be investigated to determine which pavement loop(s) or other type sensor is associated with which unit. The visual indication of units (light, meter, etc.) should be observed to determine that each vehicle (truck, car, motorcycle, etc.) entering sensor areas is properly detected on the associated unit and that no extraneous calls occur when the sensor area is vacant. When a detector unit is set for "presence," a detection call should continue as long as a vehicle is positioned over the associated sensor. Concurrent with detection, the appropriate controller indicator light should also exhibit the detection.
4. The flasher switch should be activated to cause the signal heads to flash. Their indications should be checked to verify if they are correct. The flasher switch is then to be returned to the normal or signal mode and a check made of the resumption of normal stop-and-go operation.
5. The conflict monitor should not be activated by normal signal operation or by the manipulation of cabinet switches. If at any time the monitor is activated, the contractor is required to determine the cause of the problem and make appropriate changes and adjustments before beginning the ten-day performance test. The Contractor should test the conflict monitor by artificially causing a number of different conflicting indications and checking that at each test the monitor causes the signals to begin flashing and places the controller in a "stop timing" mode. Artificial conflict may be caused by touching a jumper wire between two load switch outputs that would signal a traffic conflict. Other methods of artificially caused conflicts may be used at the discretion of the contractor.
6. Signals which are interconnected should be observed to determine if offset relationships are maintained in accordance with settings during all periods of the day.
7. When preemption equipment is furnished as part of the cabinet installation, the proper functioning of the equipment should be checked. The equipment should be activated and observations made to determine if the required sequence of intervals and phases is called for in a correct and safe manner.
8. On projects having equipment furnished for future use only, the equipment should be checked to verify that it is properly installed and operable in a correct manner.

Some signal control equipment, such as time clocks (or switches) and weekly programmers, are intended to vary the timing patterns at different periods of the day or days of the week. To determine if these required changes are occurring at the proper times, it is necessary that observations be made to check the operation at transition times over a period of several days.

The change in timing shall not be extremely drawn out or abrupt. The accuracy of time clocks and weekly programmers should be checked. Programmed changes should occur within five minutes of scheduled times for clocks of the electromechanical type and within one minute for clocks of the solid state type. No significant cumulative clock error should be noted during the ten-day performance test.

After successful completion of the ten-day performance test, and after a partial or final acceptance of a project, the Contractor is to turn over to the Engineer all manuals, diagrams, instructions, guarantees and related material, as required by 632.05. It is recommended that the Engineer list this material in the project diary as a permanent record of the transfer. The Engineer should transfer the material to the maintaining agency. For ODOT-maintained signals the material should be given to the District Roadway Services Manager.

After a traffic control system project has been accepted by ODOT, the Engineer should immediately notify the maintaining agency that as of a certain exact time and date, the agency is responsible for the operation and maintenance of the system.

Ten-Day Performance Test

Before acceptance of the traffic control system, the Contractor shall furnish all personnel and equipment required to successfully operate the system continuously for ten consecutive days without major malfunction or failure (632.28(G)).

At least seven days prior to the beginning of the performance test, the Contractor shall notify the Engineer of the starting date. The Engineer will notify the maintaining agency (632.28(G)).

The Contractor shall arrange with the utility supplying the power for purchase of the energy required to conduct the test. All costs of personnel, equipment, electrical energy and incidentals required to perform the test are to have been included in the contract unit prices for the respective items tested.

Minor failures such as lamps, a single detector or an individual signal head, etc. shall be immediately replaced or repaired and will not cause restart of the test.

A major malfunction or failure, such as a master or local controller, interconnect equipment, etc. will cause termination of the test, and after replacement or repair of the malfunctioning or failed equipment, the beginning of a new ten-day test.

Items which have been repaired or which are replacements are to be monitored by the Contractor for a period of ten days to provide assurance of their reliability.

The complete test results are to be furnished to the Engineer on test reporting forms in accordance with 625.19. The Contractor is to record in the test results the beginning and end of the test, and the method and date of the correction of each fault.

The Engineer should record the following events in the project diary: the date of the beginning of the ten-day performance test, a day-by-day record of faults as they occur during the test, and the date of the successful completion of the performance test.

Final Signal Installation Check

After all wiring is completed and all testing completed and accepted, a final inspection of the traffic control system should be performed to assure a neat and workmanlike appearance.

1. All spare conductors should be connected to the ground bus bar in the controller cabinet.
2. All ground wires should be properly connected.
3. The spade type ends of conductors should be sound. After all testing is completed, they should be reinstalled on their correct points of terminal blocks and tightened.
4. A visual check should be made for any signs of arcing, melted insulation, etc.
5. All debris from wiring work or packaging materials should be cleaned from the bottom of cabinets.
6. Cabinet vents should be checked to assure that they are unobstructed and all filters should be clean and in place.
7. Duct sealing material shall be used to seal the conduit entering the cabinet from the base.
8. All doors on the optical sections of vehicular and pedestrian signal heads shall be closed and latched.
9. No wires or cable should be visible under the base plates of poles and pedestals.
10. The handhole covers on poles and end-frames shall be securely fastened.
11. Pedestals with transformer type bases shall have the access door securely fastened.
12. The covers on pull boxes shall be securely bolted.

Documentation Requirements - 632 Traffic Signal Equipment

1. Review certified drawings prior to work commencement
    a. Document depth and width of cut for detector loop wire in pavement
        i. Cuts blown clean
        ii. What kind of material used to fill cuts after loop placement
    b. Foundations
        i. Excavate as per 503.04

            ii. Perform concrete work as per 511
            iii. No load applied for 14 days, 7 days with beam break of 650 pounds or more
        c. Document each type of equipment installed as per certified drawings provided by supplier and as per individual specifications included in 632.
2. Test as per 632.28
3. Measure and pay per 632.29 and 632.30

Documentation Requirements - 633 Traffic Signal Controllers

1. Review certified drawings prior to starting work
    a. All electrical parts of sufficient capacity and marked per 633.03
    b. Diagrams and manuals furnished to engineer before installation. Documents modified upon completion of work
        i. Controllers tested and pre-qualified as per 633.06
        ii. Individual items provided and documented as per items 633.07 thru 633.17
        iii. Test in accordance with Item 632.28
        iv. Measure and pay as per 633.18 and 633.19
        v. Record Serial numbers for all LED signal lamps installed in the project

632/633 Supplemental Information

Please refer to the Traffic Engineering Manual (TEM) for a complete list of forms, supplementary information, and updates. The following figures are examples of typical installations, and forms.

Form 496-3. Traffic Signal Controller Timing Chart for Actuated Signals

Intersection ______________________________

Maintaining Agency ______________________________

Start Up

Start In: ○ y/r flash or ○ all red

Time for Flash or All Red: ________

First Phases(s): * ______ & *______

Color Displayed ○ Green; ○ Yellow

Dual Entry ○

Rest In Red: Ring 1 ○ Ring 2 ○

Overlap	A	B	C	D
Phases				

Interval or Feature			Controller Movement No.							
Intersection Movement			1	2	3	4	5	6	7	8
Minimum Green (Initial)		(Sec.)								
Added Initial		*(Sec./Actuation)								
Passage Time (Preset Gap)		(Sec.)								
Time Before Reduction		*(Sec.)								
Minimum Gap		*(Sec.)								
Time To Reduce		*(Sec.)								
Maximum Green I		(Sec.)								
Maximum Green II		(Sec.)								
Yellow Change		(Sec.)								
All Red Clearance		(Sec.)								
Walk		(Sec.)								
Pedestrian Clearance		(Sec.)								
Recall	Maximum	(On/Off)								
	Minimum	(On/Off)								
	Pedestrian	(On/Off)								
Memory		(On/Off)								
Call to Non Actuated		No. 1								
		No. 2								

* Volume Density Controls

Form 496-3 Traffic Signal Timing Chart

Form 496-4. Traffic Signal Detector Chart

Loop Designation	Size ft. (m)	No. of Turns	Pulse or Presence	Delay (sec.)	Extension (sec.)	Override Phase	Connect to Detector Unit (unit-channel)	Associated Controller Phase

Form 496-4 Traffic Signal Detector Chart

Form 496-5. Coordination Timing Chart

	Timing Program (Cycle No.)						
	1	2	3	4	5	6	7
Description							
Time Period in Effect							
Cycle Length (sec.)							
(1) Offset (reset) No. 1 (sec.)							
(1) Offset No. 2 (sec.)							
(1) Offset No. 3 (sec.)							
(2) Force-off							
(2) Force-off							
(2) Force-off							
Length of Hold-Release or Yield (Permissive) (sec.)							

1. Offsets are measured from incoming master synch pulse time to hold - release (yield) at end of major street phase, which is phase(s) numbered _______. End of major street phase is end of green/beginning of yellow, except where pedestrian timing is provided, in which case it is end of green plus walk/beginning of green - plus flashing don't walk.

2. Force off is measured from the hold - release (yield).

Form 496-5 Coordination Time Chart

Form 496-6. Report of Electrical Tests

DATE ___ / ___/ ___ SHEET ____ OF _____

PROJECT NO. _____________ COUNTY ________ ROUTE _____ SECTION _________

Short Circuit Test 632.28(C)				Circuit Continuity Test 632.28(D) (Zero or Negligible Ohms Required)			
Pairs Measured	Ohms	Pairs Measured	Ohms	Pairs Measured	Ohms	Pairs Measured	Ohms

Form 496-6 Report of Electrical Tests

Cable Insulation (Megger) Test 632.28(E) (All Conductors of Cables Jumpered Together)		
Locations Cabinet/Pull box	Type of Cable	MegOhms 10 Min.

Ground Test For Traffic Signals 632.28(B) and 625.19	
Ground Rod Location: Station of Pole or Cabinet	Resistance Ohms

Functional Test: 632.28(F)	OK
Incoming AC 120 Volts	☐
Cabinet Fan, Thermostat, Convenience Outlet, and Lamp Operation	☐
Controller timing set as per plan or approved by the Engineer	☐
Switches	☐
Controller functions	☐
Detector Units detect all vehicles	☐
Detector Units do not give extraneous calls	☐
Flash Switch Transfer	☐
Monitor is not activated by normal operations	☐
Monitor is not activated by manipulation of cabinet switches	☐
Monitor activated by artificial conflict	☐
Signal transfers to flash when monitor is disconnected	☐

Table 497-1. Cross Section Area of Conduit, Cable and Wire

Specification or Material	No. of Conductors AWG	Cross Section Area, Sq. In.
IMSA 19-1 or 20-1	2/C # 14	.10
	3/C # 14	.13
	4/C # 14	.16
	5/C # 14	.19
	7/C # 14	.22
	9/C # 14	.33
	12/C # 14	.41
	15/C # 14	.48
	18/C # 14	.55
	25/C # 14	.82
	2/C # 12	.12
	3/C # 12	.16
	4/C # 12	.19
	5/C # 12	.23
	7/C # 12	.30
	9/C # 12	.40
	12/C # 12	.50
	15/C # 12	.58
	18/C # 12	.74
	25/C # 12	1.00
UL: RHH/RHW/USE	1/C # 14	.053
	1/C # 12	.061
	1/C # 10	.075
	1/C # 8	.107
	1/C # 6	.138
	1/C # 4	.173
	1/C # 2	.229
Belden	2/C # 14	.08
PE Jacket, Shielded	2/C # 14	.11

Conduit Cross Section Area

Nominal Diameter, in.	1/2	3/4	1	1 1/4	1 1/2
Inside Diameter, in.	.622	.824	1.049	1.380	1.610
Inside Area, sq. in.	.30	.53	.86	1.50	2.04
Nominal Diameter, in.	**2**	**2 1/2**	**3**	**3 1/2**	**4**
Inside Diameter, in.	2.067	2.469	3.068	3.548	4.026
Inside Area, sq. in.	3.36	4.79	7.39	9.89	12.73

Table 497-1. Cross Section Area of Conduit, Cable and Wire

Specification or Material	No. of Conductors AWG	Cross Section Area, Sq. In.
IMSA 19-1 or 20-1	2/C # 14	.10
	3/C # 14	.13
	4/C # 14	.16
	5/C # 14	.19
	7/C # 14	.22
	9/C # 14	.33
	12/C # 14	.41
	15/C # 14	.48
	18/C # 14	.55
	25/C # 14	.82
	2/C # 12	.12
	3/C # 12	.16
	4/C # 12	.19
	5/C # 12	.23
	7/C # 12	.30
	9/C # 12	.40
	12/C # 12	.50
	15/C # 12	.58
	18/C # 12	.74
	25/C # 12	1.00
UL: RHH/RHW/USE	1/C # 14	.053
	1/C # 12	.061
	1/C # 10	.075
	1/C # 8	.107
	1/C # 6	.138
	1/C # 4	.173
	1/C # 2	.229
Belden	2/C # 14	.08
PE Jacket, Shielded	2/C # 14	.11

Conduit Cross Section Area

Nominal Diameter, in.	1/2	3/4	1	1 1/4	1 1/2
Inside Diameter, in.	.622	.824	1.049	1.380	1.610
Inside Area, sq. in.	.30	.53	.86	1.50	2.04
Nominal Diameter, in.	**2**	**2 1/2**	**3**	**3 1/2**	**4**
Inside Diameter, in.	2.067	2.469	3.068	3.548	4.026
Inside Area, sq. in.	3.36	4.79	7.39	9.89	12.73

Table 497-2. Cable Wire and Identification

Cable	Tag
Ground Power (2 wire) 1 ø 120 volt	GND AC+ AC- or ACN
Power (3 wire) 1 ø 120/240 volt Neutral wire	AC+1 AC+2 AC- or ACN
Phase A Phase 1 Phase 1 northbound left turn lanes	ø A ø 1 ø 1 NBLT
Phase A, pedestrian signal	ø A PD
Overlap, phase A + C Overlap, phase 1 + 6	ø A + C ø 1 + 6
Detector lead-in, phase A Detector lead-in, phase 1 Detector lead-in, phase 1 northbound left turn lanes	DET A DET 1 DET 1 NBLT
Detector lead-in, phase A (call type) Detector lead-in, phase 1 (call type) northbound thru lanes	DET A CALL DET 1 CALL NB-THRU
Detector harness *	DET A
Interconnect	IC
Preemption, fire	PE FIRE
Preemption, railroad	PE RR

* For the detector harness, the tag shall be placed next to the MS plug at the detector amplifier.

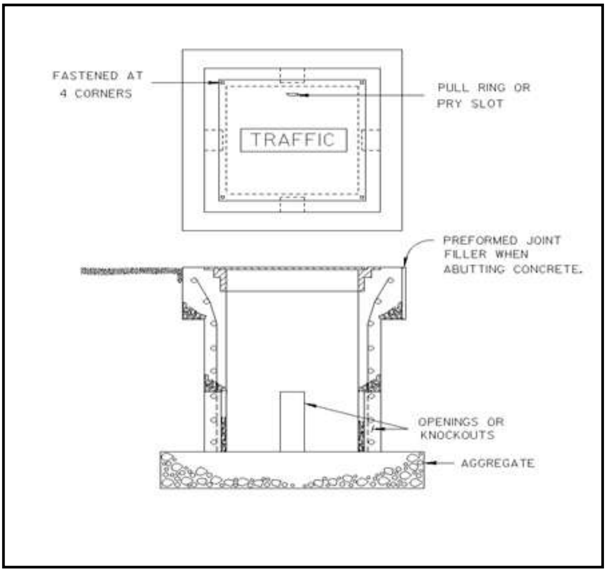


Figure 498-6. Concrete Pull Box

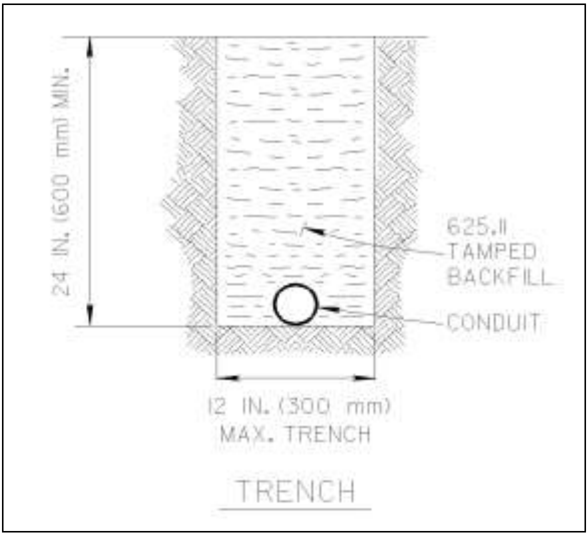


Figure 498-7. Trench Details

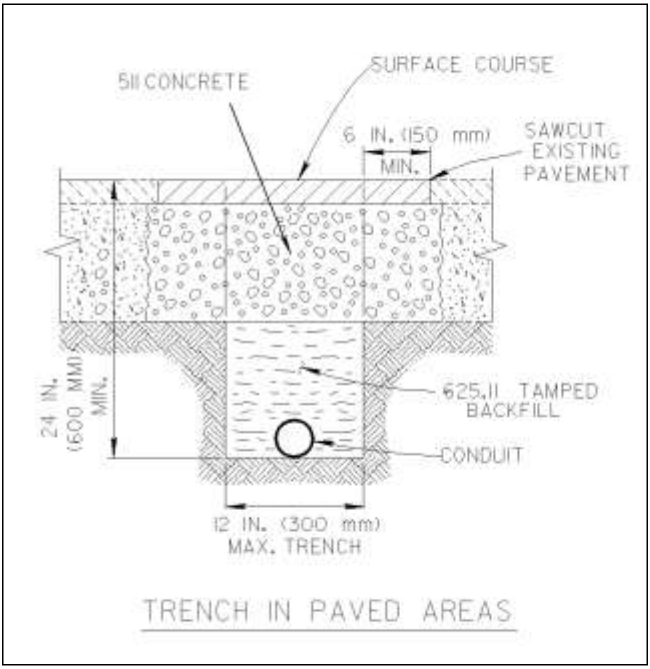


Figure 498-7. Trench Details

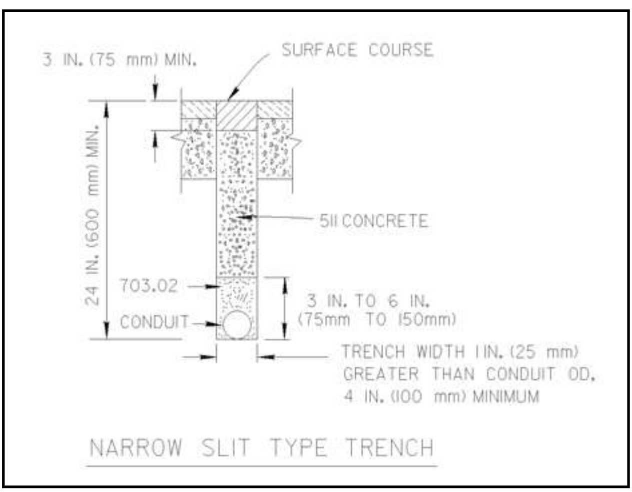


Figure 498-7. Trench Details

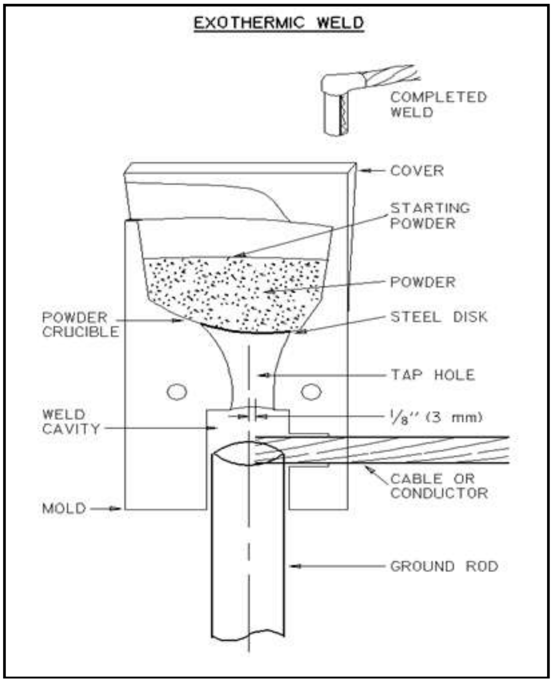


Figure 498-8. Exothermic Weld

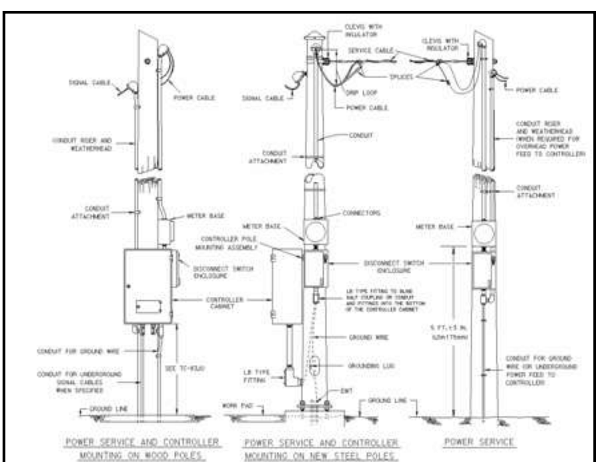


Figure 498-9. Power Service

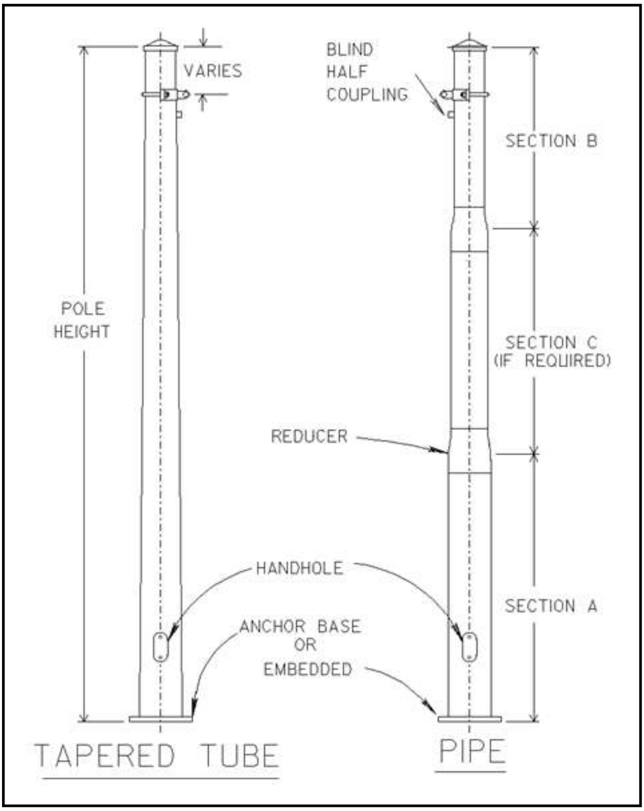


Figure 498-10. Strain Pole Supports

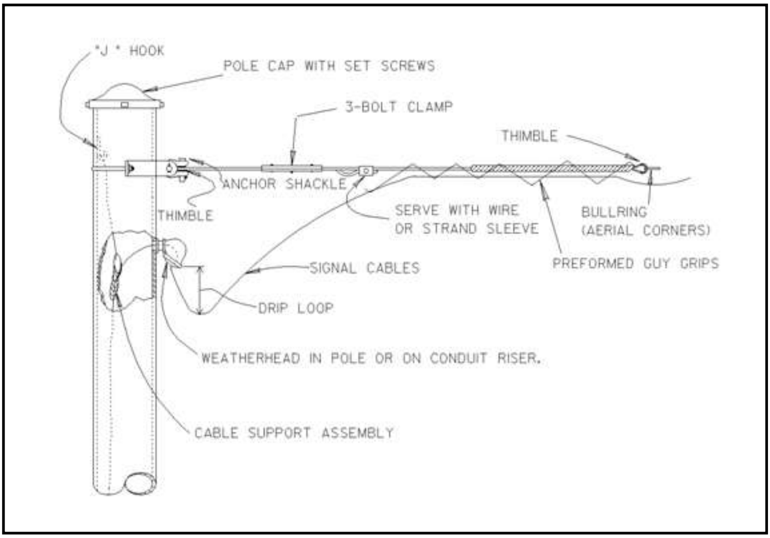


Figure 498-11. Strain Pole Attachment Details

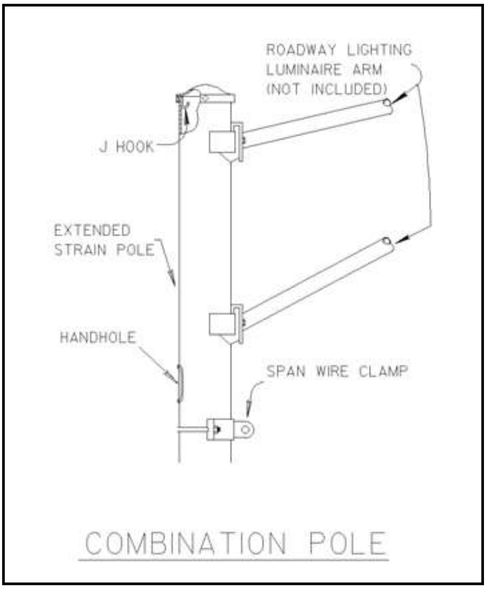


Figure 498-12. Single Arm Support

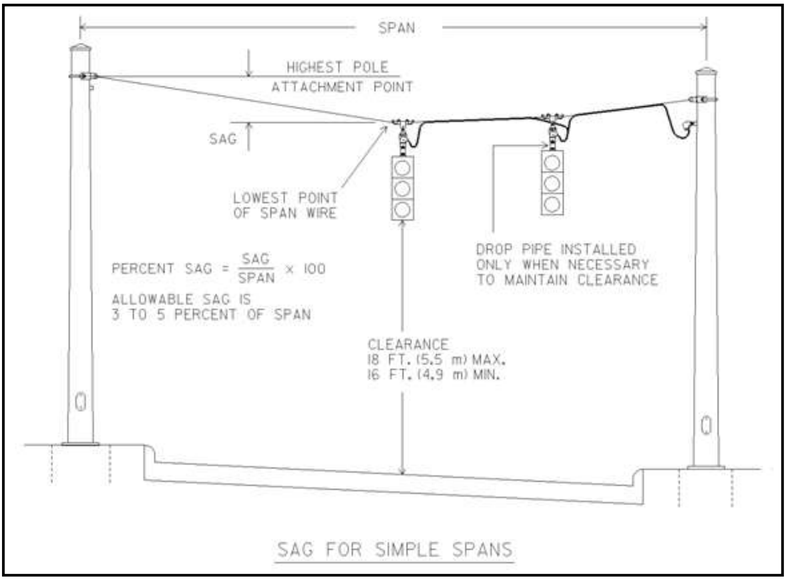


Figure 498-13. Sag and Vertical Clearance Diagram

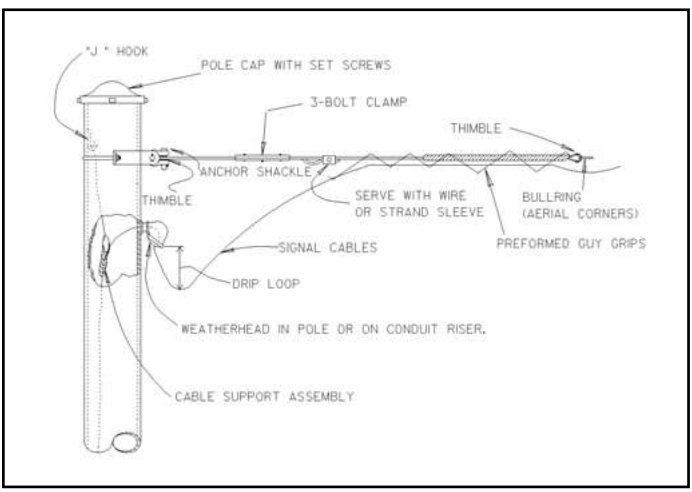


Figure 498-14. Cable Support Assembly

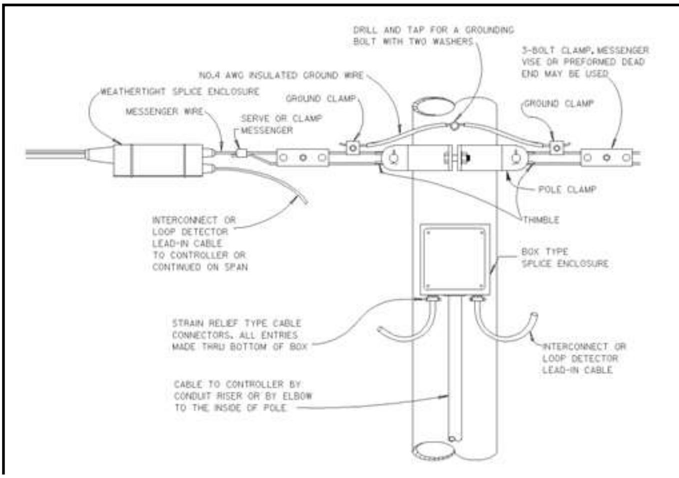


Figure 498-15. Aerial Interconnect Cable

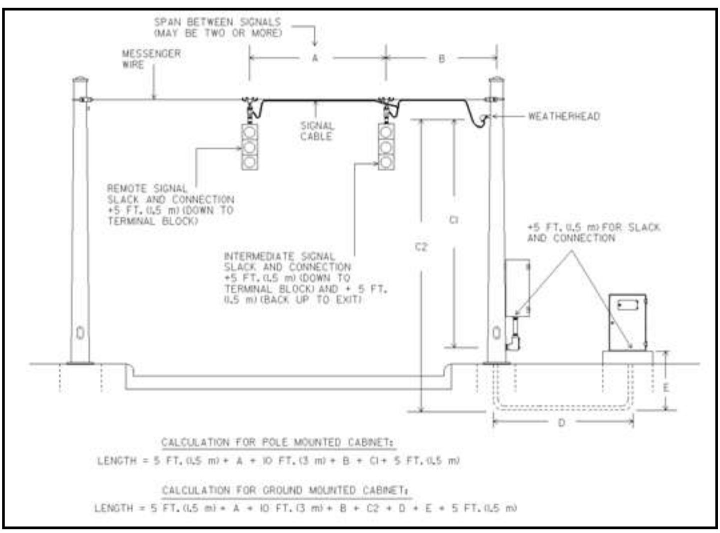


Figure 498-16. Method of Measurement for Signal Cable

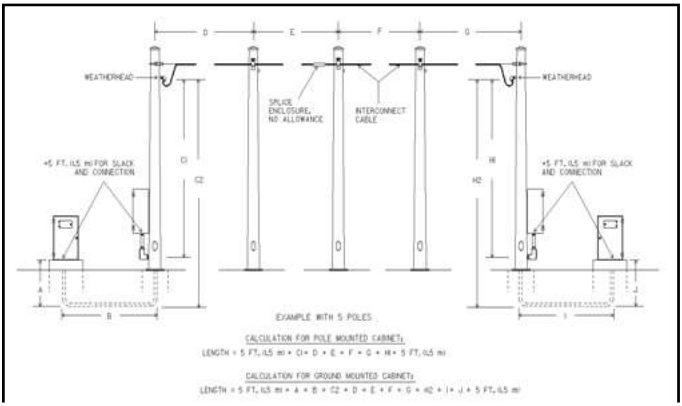


Figure 498-17. Method of Measurement for Interconnect Cable

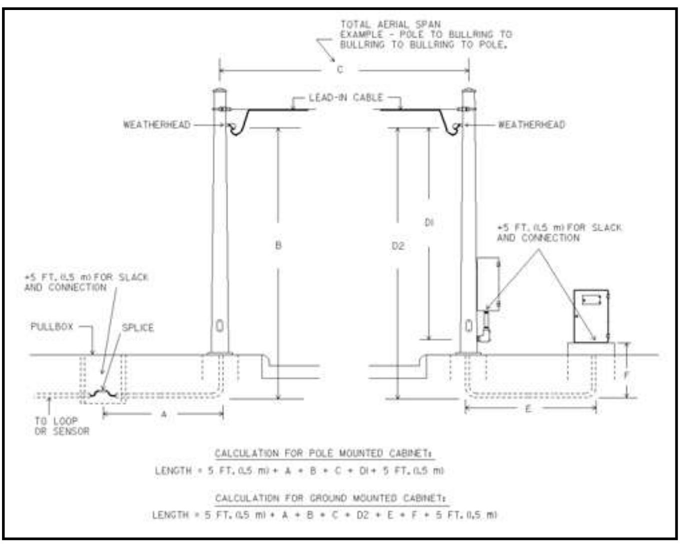


Figure 498-18. Method of Measurement for Detector Lead-In Cable

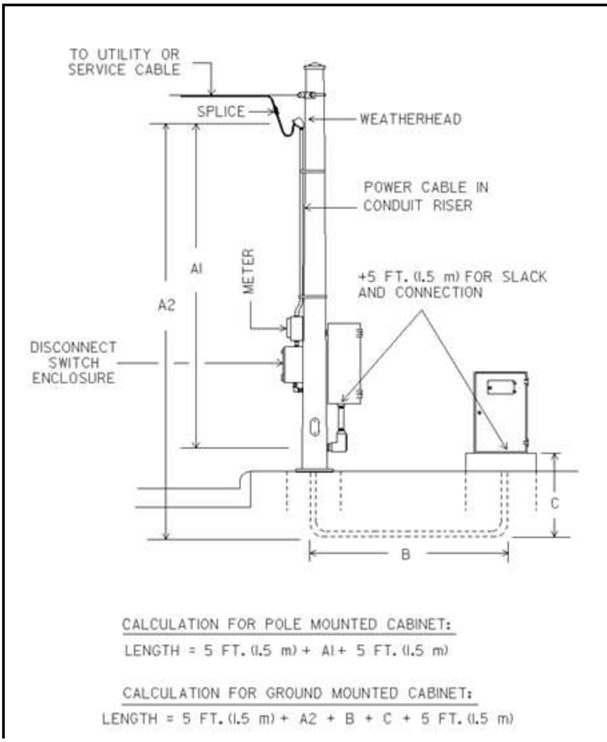


Figure 498-19. Method of Measurement for Power Cable

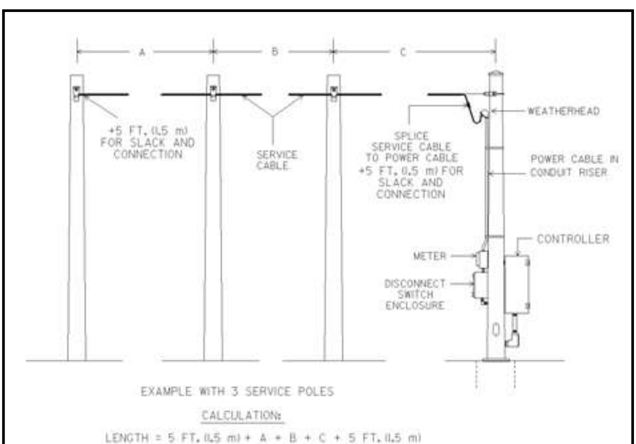


Figure 498-20. Method of Measurement for Service Cable

Figure 498-21. Vehicular Signal Heads

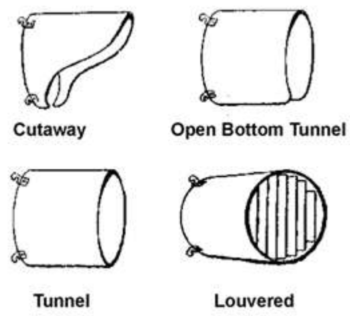


Figure 9.3b

Visors for Signal Heads

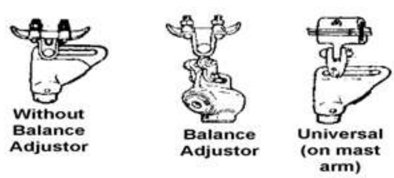


Figure 9.3d

Hangers for Signal Heads

Figure 498-21. Vehicular Signal Heads

Figure 9.3d

Wiring a Signal Head

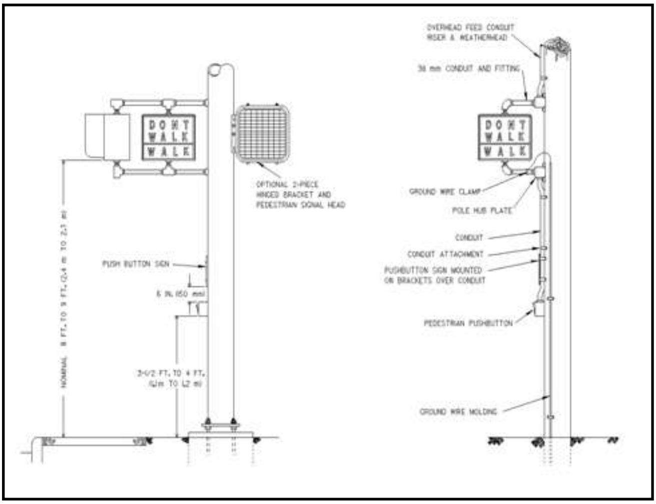


Figure 498-22. Pedestrian Signal Heads

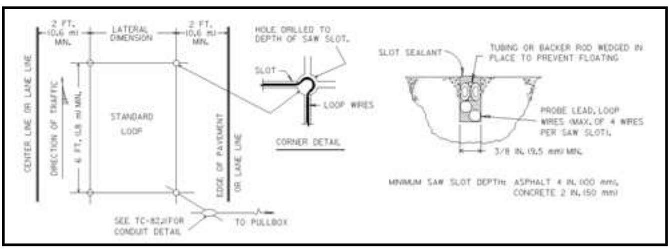
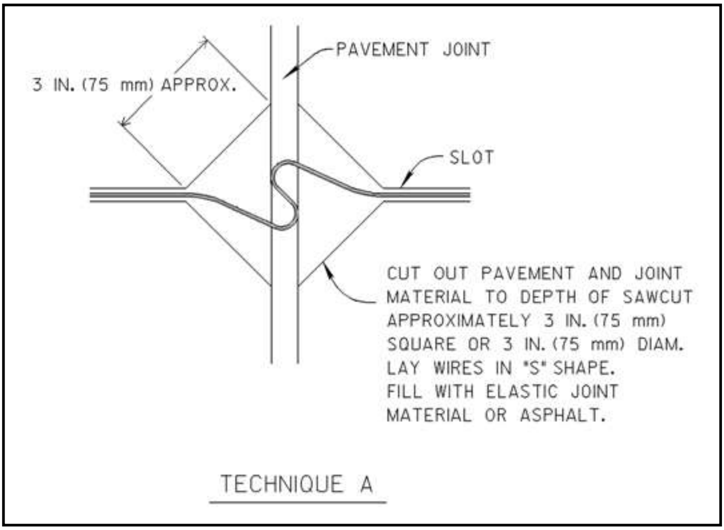


Figure 498-23. Loop Detector Placement and Installation

Loop Perimeter feet	(meters)	Number of Turns
40	(less than 12)	4
40-160	(12 to 49)	3
over 160	(over 49)	2

Loop Construction



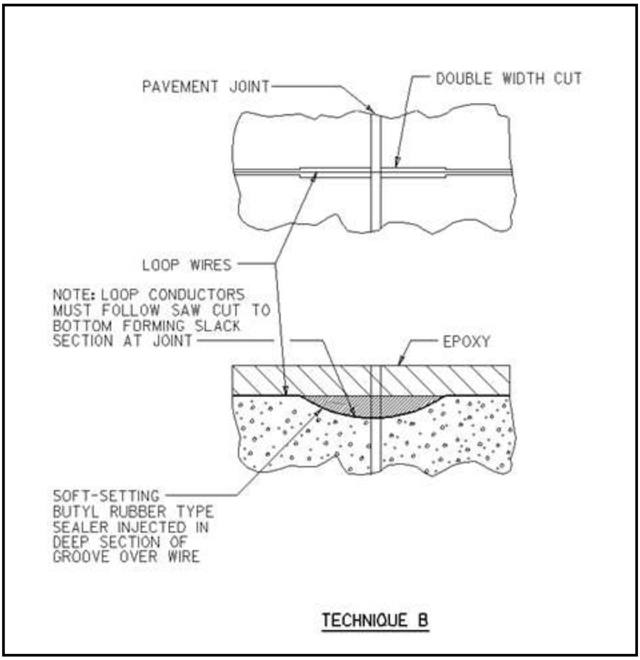


Figure 498-24. Loop Detector Slots and Wiring

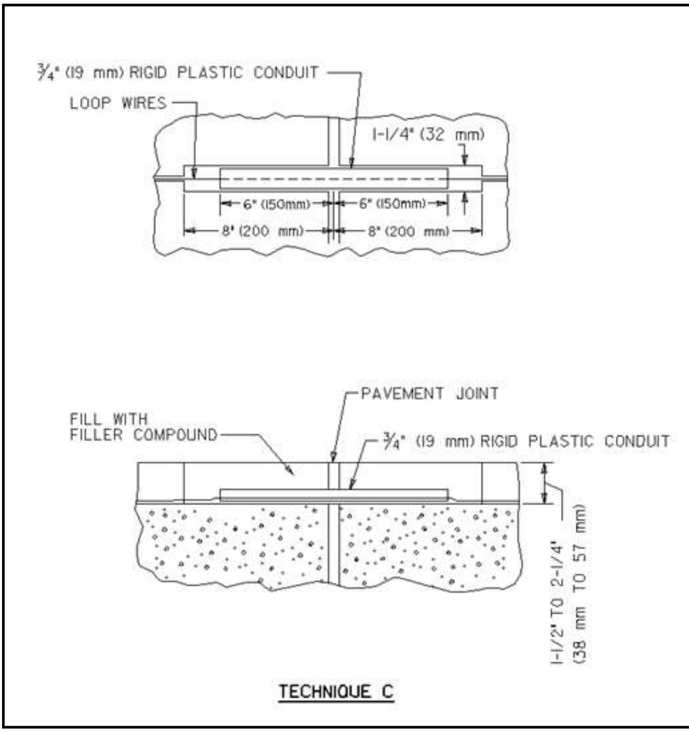
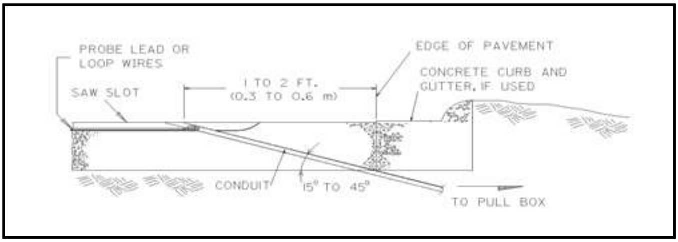
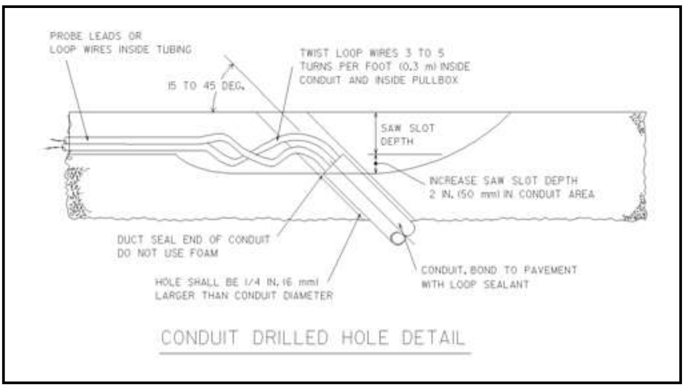


Figure 498-24. Loop Detector Slots and Wiring





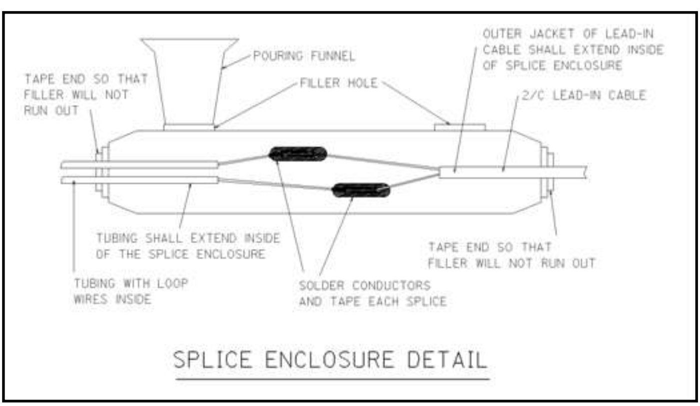
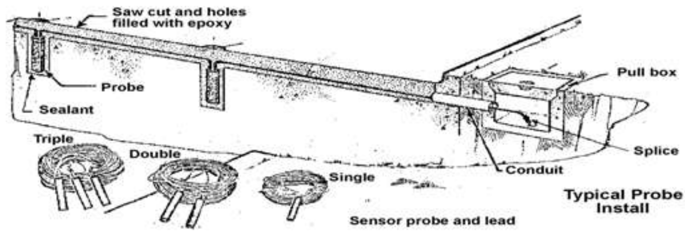
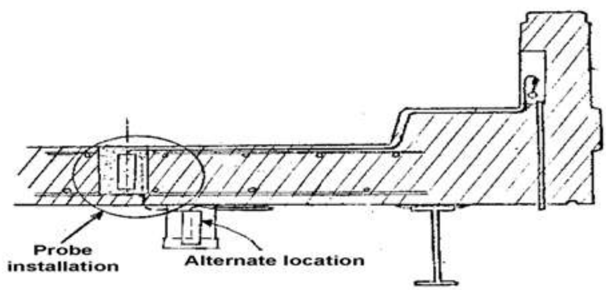


Figure 498-25. Loop Detector Wiring



Figure



Figure

Figure 498-26. Magnetometer Probes and Lead-In

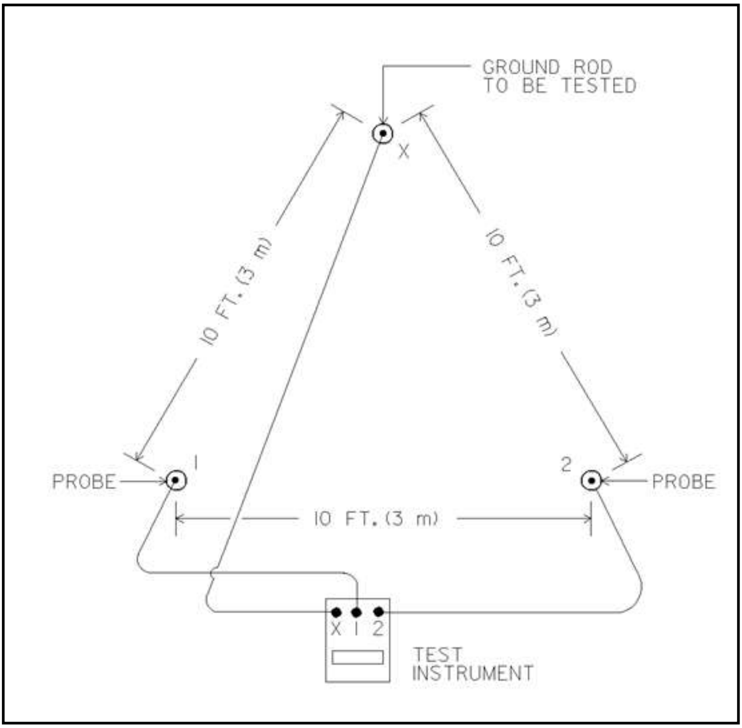


Figure 498-27. Ground Rod Testing

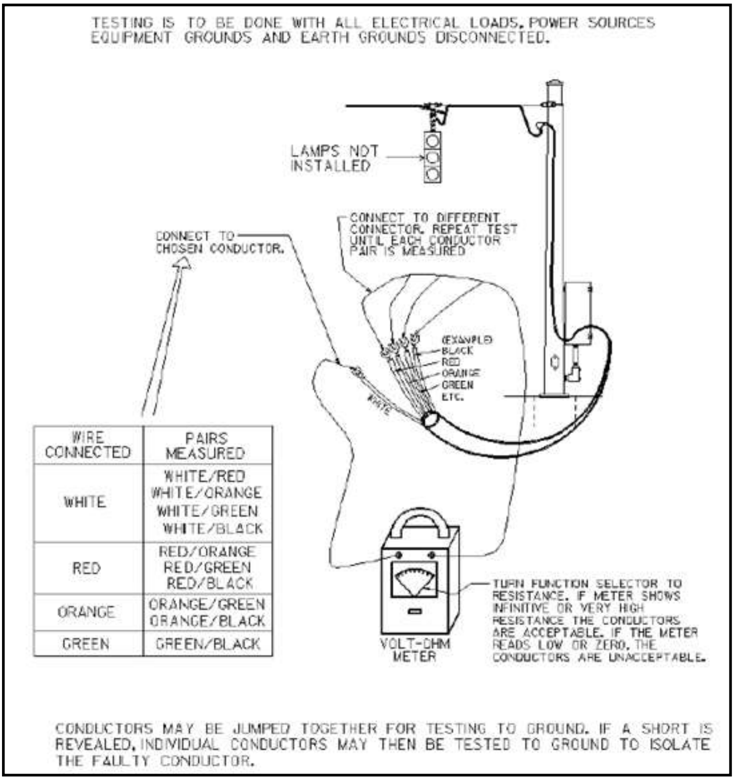


Figure 498-28. Short-Circuit Test

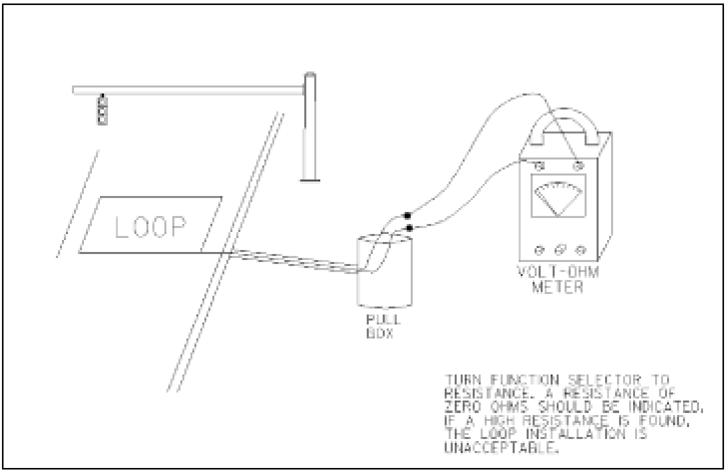


Figure 498-29. Circuit Continuity Test of Loop Wire (Before Splice to Lead-In Cable)

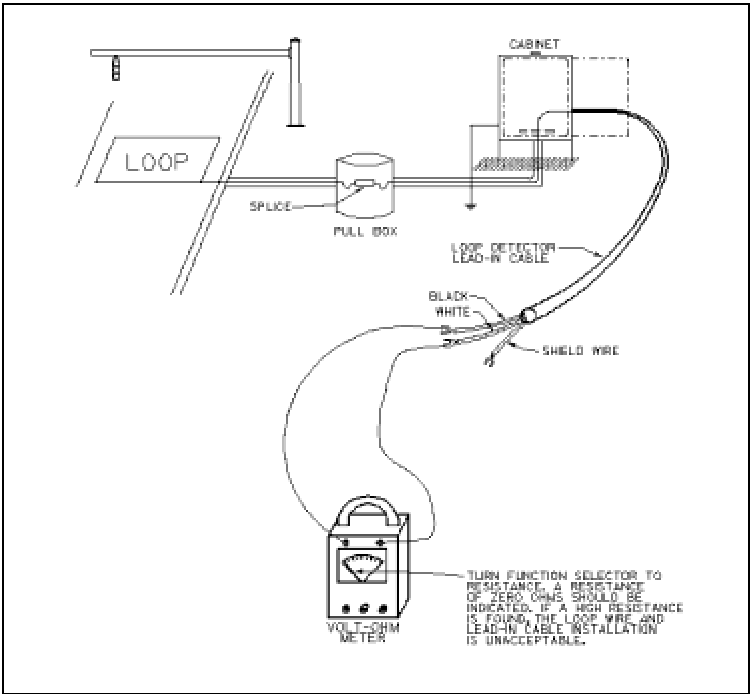


Figure 498-30. Circuit Continuity Test of Loop Wire and Lead-In Cable

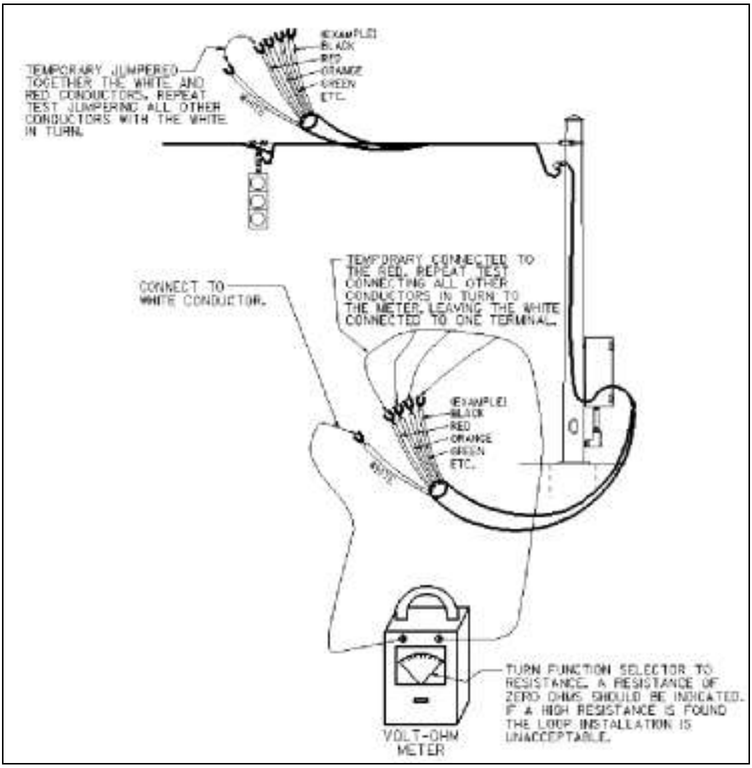


Figure 498-31. Circuit Continuity Test of Signal Cable Disconnected from Heads or Other Cables Such as Interconnect and Loop or Magnetometer Lead-In

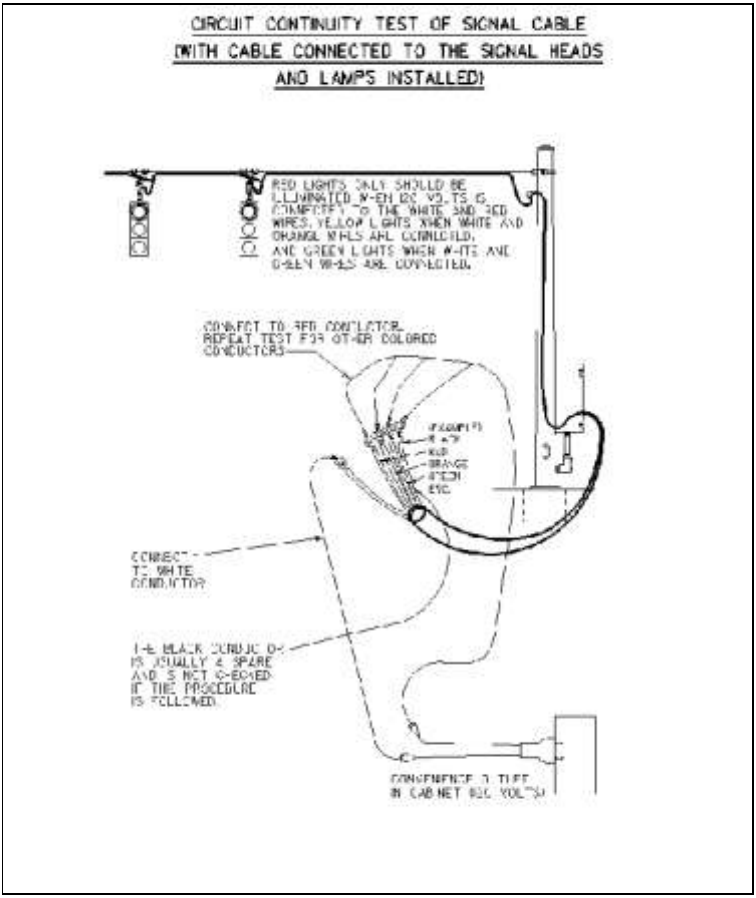


Figure 498-32. Circuit Continuity Test of Signal Cable With Cable Connected to the Signal Heads and Lamps Installed

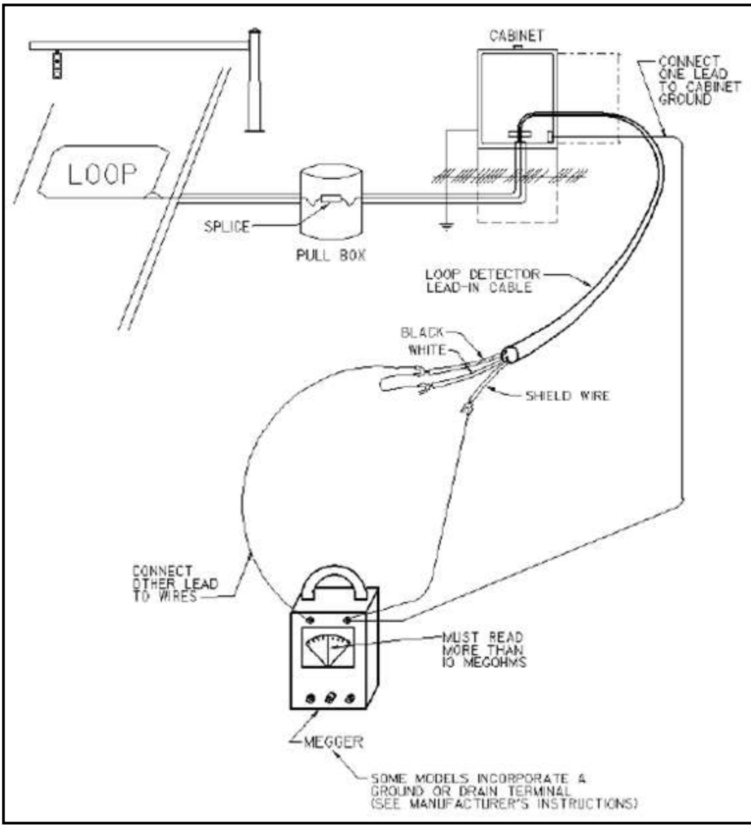


Figure 498-33. Cable Insulation Test (Loop Detector Wire)

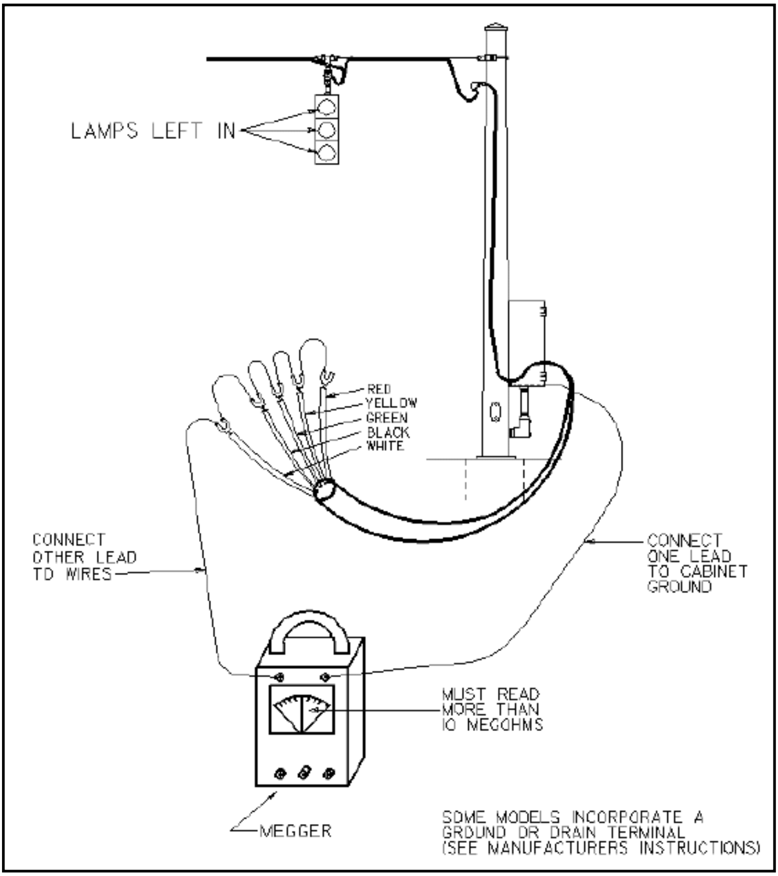


Figure 498-34. Cable Insulation Test (Signal Cable)

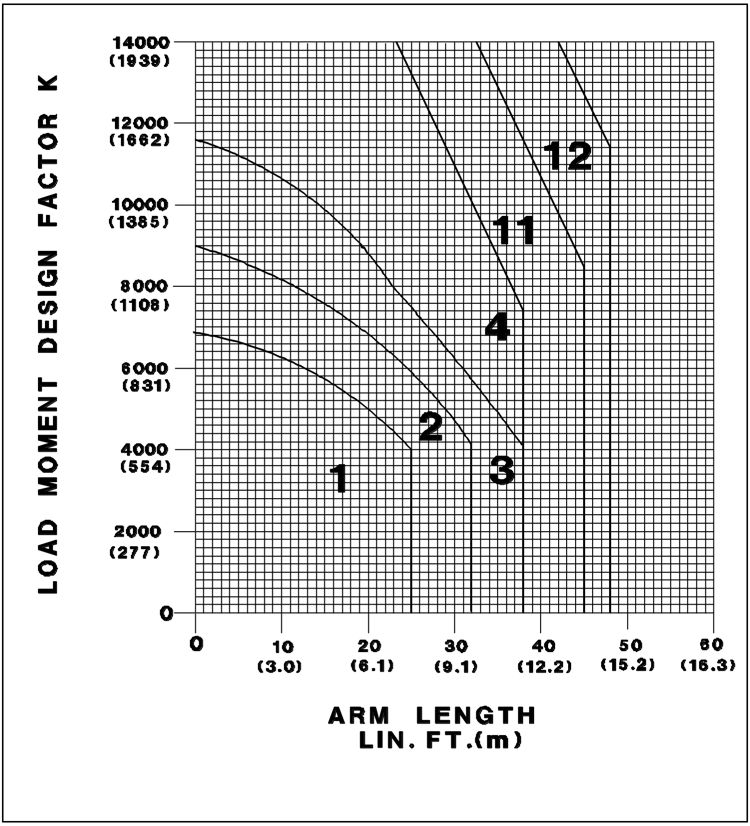


Figure 498-35. SCD TC-81.20 Signal Support Design Chart

From Sheet No. *	Reference Street * Station & Offset *	Pole No.	Design No.	Pole Height ft (m)	Foundation Elev. * Span Wire Attach. Ht. *	Index Line Angle (Deg.)	Angles (Deg.) from Index Line							
							Pedestrian Signals	Pedestrian Push buttons	Controller	Power Service	Cable Entrance 12" (0.3 m) from	Luminaire Bracket	Interconnect Pole Splice Box	2" (51 mm) Capped

* See ***Section 441-8***.

Notes:
1. All angles are measured clockwise.
2. The index line goes through the center of the handhole.

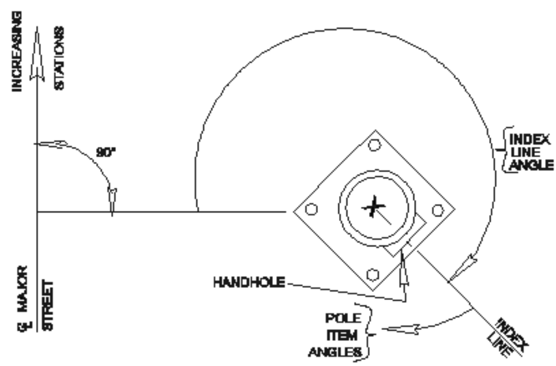
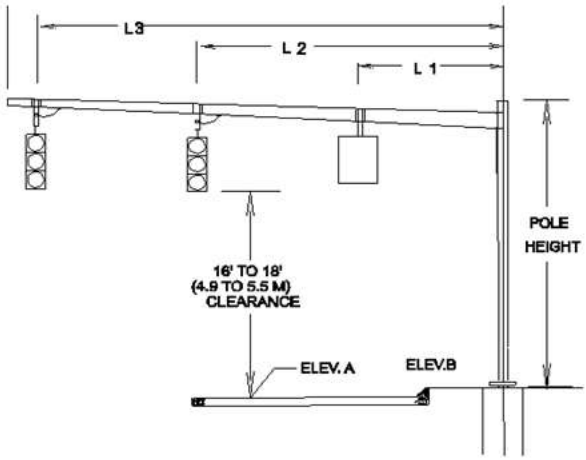
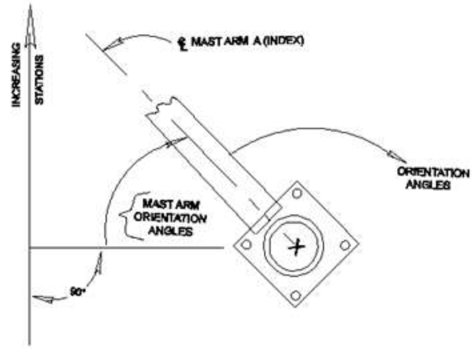


Figure 498-36. Plan Details for Strain Poles



Support No.	Signal Support Type TC-81.20								Elevation	
	Design No.	Pole Height ft. (m)	L ft. (m)	L1 ft. (m)	L2 ft. (m)	L3 ft. (m)	L4 ft. (m)		A	B

Figure 498-37. Plan Details for Signal Supports - Arm Lengths (table is continued in Figure 498-38)



Notes:
1. All angles are measured clockwise.
2. Base plate is oriented square to Mast Arm A (largest arm) even if the support has two arms.

Mast Arm A Angle (Deg.)	Orientation Angles (Deg.) from Mast Arm A							
	Mast Arm B	Pedestrian Signal	Pedestrian Button	Power Service	Controller	Luminaire Bracket	Handhole	Cable Entrance 12" (0.3m) from top

Figure 498-38. Plan Details for Signal Supports - Mast Arm Orientation (table continued from Figure 498-37)

638 Water Mains and Service Branches

Documentation Requirements - 638 Water Mains and Service Branches

1. State that materials conform to 638.02
2. Document clearance between pipe and walls of trench - 6 inches (15 cm) minimum, 12 inches (30 cm) maximum. Ensure proper clearance between water line and any utility crossing or underground structure
3. Grade shaped to receive bell
4. Type of sheeting and bracing used to support and protect adjacent utilities
5. Type and thickness of bedding
6. State that trench was kept free from water
7. State that pipe was carefully handled
8. Tracer tape installed 1 foot (.3 m) above top of pipe extending full length
9. Joints installed according to manufacturer's recommendation
10. Perform and document backfill as per 603 type B and C conduits
11. Document hydrostatic testing and disinfection as per 638.09 and 638.10
12. Measure as per 638.19 and 638.20

640 Pavement Markings

641 Pavement Markings - General

This information is intended to serve as a guide for construction personnel where the contractor furnishes and installs traffic control marking devices. However, it may also be useful for maintenance personnel performing the same functions.

As per 641.06 the Contractor shall establish references points to ensure proper placement of restored markings on projects where resurfacing or other operations will result in obliteration of the existing pavement markings.

Please refer to the Traffic Engineering Manual for a complete list of forms, supplementary information. Updates are available on the following ODOT web site:

http://www.dot.state.oh.us/Divisions/HighwayOps/Traffic/publications2/TEM/Documents/Part_03_071808_bookmarked.pdf

Pavement Marking Materials (641.02)

Pavement marking materials used on the construction projects shall be as listed on the Approved List.

Approved List for pavement marking materials is maintained by the Office of Material Management (OMM) and is available on the web site.

http://www.dot.state.oh.us/Divisions/ConstructionMgt/Materials/Pages/PAVEMENT-MARKING-After-2004.aspx

The appropriate type of glass beads shall be applied according to C&MS 740.09 for different types of pavement marking materials.

Application of Pavement Marking Materials (641.03)

Pavement marking materials shall be applied according to C&MS Items 640 and 740 as follows:

Data Logging System (DLS) (641.04)

The Datalogger system can be verified in the field using the following method.

DLS Verification Testing

The Section provides information on Data Logger Systems (DLS) for long line striping trucks, the reports generated by DLS and how to use the reports to verify compliance with specifications.

Background

In 2003 the Department began an initiative, in partnership with the striping Contractors and material suppliers, to return ODOT's pavement marking system to acceptable performance levels.

One of the elements of this initiative was the introduction of data logger systems (DLS) for striping trucks used for our annual maintenance marking contracts, most of which used waterbased paint. ODOT had two purposes for adopting DLS technology, which was in its infancy:

- monitoring material application conditions so that ODOT can determine likely causes of material failures and
- providing striper operators with real-time indications of actual application parameters which allow them to maintain application rates at spec without over-applying, and thus wasting, materials.

DLS were used on all of ODOT's annual maintenance contracts for 2004 and 2005.

With adoption of the 2005 Construction and Material Specifications, a significant expansion of DLS was instituted for the 2006 construction season. This expansion required DLS use on all long line striping trucks for not only paint but for polyester, epoxy, thermoplastic and Class I work zone markings for contracts sold under the 2005 C&MS.

Additional modifications were made with the January 19, 2007 Supplemental Specification 800 version which clarified when DLS are required, addressed security issues and revised bead application rate measurement. These modifications will be adopted in the 2008 Construction and Material Specifications scheduled for release April 18, 2008.

DLS Requirements

The requirements for DLS are contained in C&MS Section 641.04 and Supplemental Specification 800 (current version).

According to Item 641.04, for long line pavement markings striping equipment for traffic paint, polyester, epoxy and work zone marking Item 642 shall be equipped with a computerized Data Logging System (DLS) to document for long line markings only as follows:

1. Measure and record application vehicle speed to nearest 0.1 MPH (0.16 KMH)
2. Measure and record weight and/or volume amount of material used by color
3. Measure and record weight of glass beads

4. Measure and record pavement surface temperature
5. Measure and record air temperature
6. Measure and record dew point
7. Measure and record humidity
8. Calculate and record average material application rates and film thickness over the section painted.
9. ODOT provides standard DLS spreadsheets, which prescribes the correct DLS report format and content

Beginning with projects sold under the 2005 C&MS, striping trucks which apply centerline, lane line, edge line and all Class I work zone markings must be equipped with and use a DLS which records environmental conditions and material application parameters during striping operations.

Beginning with projects sold under the January 19, 2007 SS 800 revision, this specification was clarified to require a DLS whenever the length of marking exceeds 0.5 miles of continuous line equivalent. This clarification was added based on ODOT's experience in the 2006 season which indicated that a minimum amount of materials need to pass through the DLS equipped truck before the data is representative of the actual application. This amount of material is normally 8 – 10 gallons, which is equal to that applied on one-half mile of edgeline, two miles of lane line or one-quarter mile of double yellow centerline, all of which equal 0.5 mile continuous line equivalent. Marking sections less than the 0.5 miles of continuous line equivalent do not require use of DLS.

DLS are not required for any markings applied by hand, with push carts, for channelizing lines or Class II work zone markings.

Bead application rates are now expressed in pounds per 100 square feet for all materials.

When the Striping Truck Arrives on the Project

- Each district should establish one individual as District DLS Contact to receive DLS Reports for all striping activities. Check with the District Construction office for the email address of the District DLS Contact to provide to the contractor.
- Make sure every vehicle in the striping train has the correct maintenance of traffic equipment and signs. See SCD MT-99.20M and plan notes.
- Check the driver's door or the door of the DLS unit to confirm the presence of the DLS calibration sticker. It should be signed and carry a date no more than one year old. Every DLS must be calibrated once each year.
- Make sure that there are adequate TE-24s to cover all materials needed for the job.
- Make arrangements with the Contractor's crew foreman to get DLS Short Reports for each day's work. DLS Short Reports for each day's work are to be provided to ODOT the next working day and, when requested by ODOT personnel, at any time for route sections completed so far that day. You should have a report for each day worked. The DLS

specification requires the Contractor to furnish ODOT with a paper copy of the DLS Short Report which should be retained to compare to the electronic file which you will receive later.

- The Data Logger System shall be verified by field personnel. Field personnel shall randomly verify the components of the DLS. The purpose of this is to verify that the striping truck is actually placing the material that the DLS printout shows. Field personnel should try to verify the DLS of every paint contractor at least once per construction season. If field personnel believe that the DLS printouts are not accurate, then more field checks can be taken.

How to field verify the Data Logger System

Striping Truck With DLS System

Electronic Control Box

Sensors

Sensors such as temperature sensors, located at appropriate locations on the striping truck, provide temperature data.

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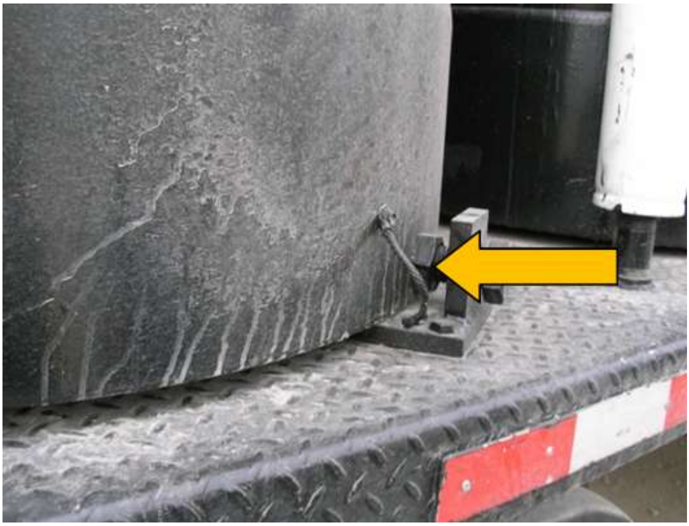
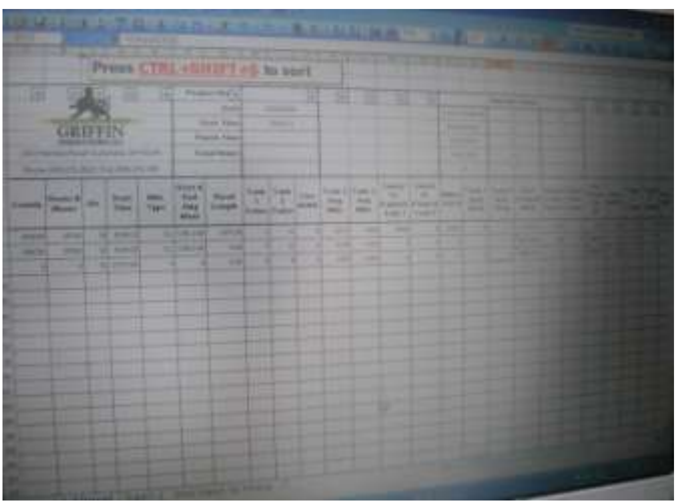
Gauges

Gauges provide data and help monitor the temperatures of striping material in the tanks.



Glass Bead Tank Load Cells

Glass bead tanks are mounted on load cells. Load cells are the basis of bead weight calculations.



DLS Electronic Data Sheet

1. DLS data is automatically recorded and stored electronically.
2. DLS data includes:

a. Sensor data
b. Distance data
c. Ambient conditions
d. Material quantities

3. Verification test results will be compared to the contractor's electronic sheet data.

Calibration Sticker Check

Check for the presence of the annual calibration sticker.

Calibration Sticker

Evidence of the annual calibration shall be a signed and affixed sticker to the inside of the driver's door of each striping truck.

YEARLY CALIBRATION

1. As per C&MS 641.03, each DLS shall have an annual calibration.
2. Items to be calibrated include:
    a. All mechanical and electrical components
    b. Software
    c. Function and output
3. Calibration will be confirmed by the manufacturer..

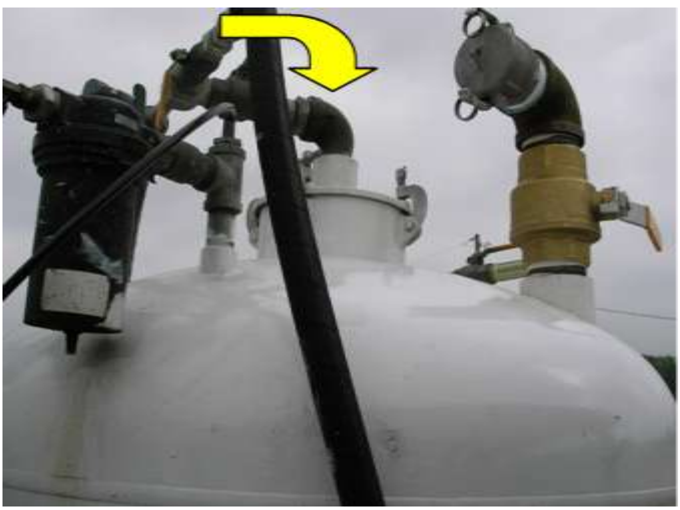
The Plate Test

The Plate Test

1. Place an aluminum plate around 24 in. x 8 in. under the paint gun of the striping truck. Aluminum plates are supplied through the Office of Materials Management (OMM), Chemical Section.
2. Allow the striping truck to stripe over the plate in order to get a stripe of the desired thickness on the plate.
3. Send the striped plate to the OMM, Chemical Section for film thickness testing. After converting dry film thickness to wet film thickness, the difference obtained from the plate should be no more than 5% from the DLS reading.
4. Send the contractors DLS average mils applied data as comparison for the film thickness testing results. See picture below.
5. Note: Be careful not to damage the paint stripe on the plate.

Average Mils Applied

The Bead Weight Test



The Bead Weight Test

1. Check and record the bead weight on the DLS electronic data sheet W1.
2. Obtain an object of known weight, minimum of twenty (20) pounds, i.e. a fifty pound bag of glass beads.
3. Place the weight on top of the bead tank. Keep the weight in position on top of the tank and check and record the new weight W2, on the DLS electronic data sheet.

Subtract W1 from W2 to get the known weight of the object used.

W2 – W1 = weight of the object of known weight used.

Correct test results confirms the proper operation of the bead tank load cells as well as the accuracy of the data on the spreadsheet. The difference should be no more than 5%.

The Bead Weight Test

The Infrared Thermometer Test

The Infrared Thermometer Test

Use a hand-held Infrared Thermometer to measure road surface temperature, ambient temperature, and/or striping material temperature.

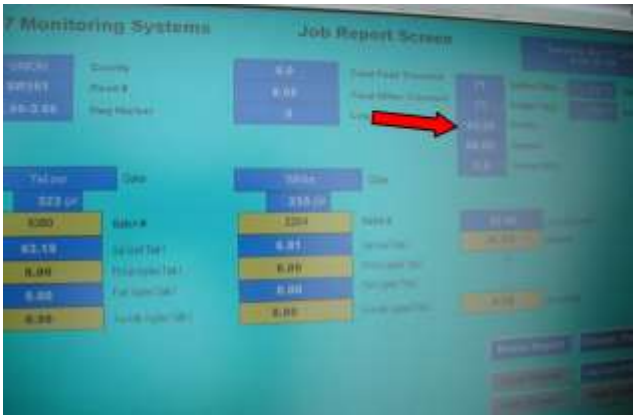
1. To operate the infrared thermometer, follow the manufacturer's operating procedures.
2. Compare temperature readings to the data on the appropriate DLS electronic screen.
3. Temperature readings on the DLS screen should be within +/- 5% of the thermometer readings.

The Infrared Thermometer Test

The Humidity Test

The Humidity Test

1. Measure the ambient humidity with the use of a Sling Hydrometer.
2. To operate the sling hydrometer, follow the manufacturer's operating procedures.
3. Compare humidity readings to the data on the appropriate DLS electronic screen.
4. Humidity readings on the DLS screen should be within +/- 5% of the hydrometer readings.



The Humidity Test

The Distance Traveled Test

The Distance Traveled Test

1. Testing the Distance Traveled data on the DLS Electronic Data Screen can be done using a distance wheel like the one shown in the picture.
2. To operate the distance wheel, follow the manufacturer's operating procedures.
3. Compare distance readings to the data on the appropriate DLS electronic screen.
4. Distance readings on the DLS screen should be within +/- 5% of the distance wheel readings.
5. DLS distance data can also be checked using mile markers and an accurate odometer.

The Distance Traveled Test

SUMMARY

1. The specified annual calibration of the data logger system is the primary check of the operation of the systems.
2. The tests described above are meant to be done in a random fashion to:
    a. Verify proper operation after calibration.
    b. Verify correct millages are applied..
    c. Determine if the system is the cause of suspicious developments in the field application of the striping material.
3. One or all of the tests may be used to check the DLS operation.

What To Do When The DLS Fails

With any electronic system, occasional failures will occur. The DLS manufacturers have made their systems reliable but we still experience problems, especially when both the crew and the systems are new. As striping crews gain experience with the systems, we expect fewer failures.

If the DLS fails during the day, allow the Contractor to complete the day’s work and document the application quantities and make the calculations for gallons of material per mile and pounds of beads per 100 sq ft from the quantities used provided by the Contractor with your confirmation of accuracy. The Contractors are expected to repair the DLS before resuming work. See C&MS Section 641.04, paragraph three.

If you have any significant issues regarding DLS use, please call Dan Groh, CO Construction 614-387-1162 or Larry Stormer, D03, 419-207-7092 for further assistance.

DLS Reports

The DLS Report is an Excel spreadsheet which contains data on environmental conditions and material application parameters recorded during striping operations.

ODOT has developed standard DLS Reports for four different types of striping trucks:

- Weight-Based DLS – for pressure tank trucks (CA-T-1, CA-T-2)
- Stroke-Based DLS – for pumper trucks (CA-T-3, CA-T-4)
- Flow-Based DLS – for either type but using material flow meter (CA-T-5, CA-T-6)
- Thermoplastic DLS – for thermoplastic trucks. Note the thermoplastic DLS is an abbreviated report as we cannot yet measure material used, although beads used and environmental conditions are recorded. (CA-T-7, CA-T-8)

Two versions of the DLS Report are contained in each Excel file: **DLS Short Report** and **DLS Full Report**. The **DLS Short Report** is an abbreviated format containing only critical application information which can be easily printed on 8.5 x 11 paper using in-truck printers. **DLS Full Reports** contain all project, application and environmental data.

Delivery of DLS Reports

Each district should establish a **District DLS Contact** person, who will receive email copies of the DLS Reports, and provide that person's name and email address at the preconstruction meeting.

The paper copy of the **DLS Short Report** covering all route sections completed each day must be provided to ODOT personnel the next working day. A paper copy of the **DLS Short Report** may be requested from the Contractor by ODOT personnel at any time during striping operations for those route sections completed so far that day. The paper copy of the **DLS Short Report** should be retained by the project and compared to the **DLS Full Report** for the same route sections which will be provided to ODOT personnel by the Contractor at a later time as described below.

DLS Full Reports contain all project, application and environmental data and can be provided to ODOT by any one of the following methods, which should be agreed upon at the preconstruction meeting:

- hand delivery of paper report
- fax delivery of paper report
- e-mail an electronic version of the Excel spreadsheet file

Within two weeks of the date of application of markings requiring documentation with the DLS, the Contractor is required to furnish the District DLS Contact an electronic version of the Excel spreadsheet file of the DLS Report in ODOT standard DLS Report format by e-mail at the e-mail address provided at the preconstruction meeting. Note that this file will contain both the DLS Full Report and the DLS Short Report on separate sheet tabs.

At the end of the project, the Contractor is required to furnish the District DLS Contact all DLS Excel spreadsheet files in ODOT standard DLS Report format. Note that this file will contain both the DLS Full Report and the DLS Short Report on separate sheet tabs.

DLS Report Security

ODOT has established a method to monitor accuracy of DLS Reports. This method is based on comparison of the paper copy DLS Short Reports for daily production to the DLS Full Report for the same day. Note that the DLS Short Report does not contain all project or environmental information but does contain all information necessary to monitor correct application rates and speed.

The Contractor is required to provide ODOT personnel with a paper copy of the DLS Short Report for each day's production the next working day. ODOT personnel may also occasionally request a copy of the DLS Short Report during the day for those route sections completed so far that day. On projects with only partial days of striping work, ODOT personnel should request the DLS Short Report immediately after the Contractor finishes the striping operation. Printing of the DLS Short Report soon after completion of the striping operation will minimize the opportunity for tampering.

ODOT will keep these paper reports and compare them to the DLS Full Report that is received later. Any differences in sections, lengths, quantities or application rates between the Short Report and Full Report should be considered suspect and will be investigated more closely. There should be no valid reason for any differences between these reports beyond the complete listing of route sections between partial day and full day reports.

Pay Items

Pay items are plan quantity. If there is a significant variance between the actual and plan quantities, meet with the ODOT project personnel to address the issue. Please note that per C&MS Section 641.12, Method of Measurement, pavement markings are designed, measured and paid "end-to-end", including gaps, intersections and other sections of pavement not normally marked. This provision applies to all types of roadways and lines.

The DLS is being used for two purposes, neither of which is to measure pay item quantities:

1. To monitor environmental conditions and material application parameters such as temperatures, and
2. To monitor actual application rates of marking materials and glass beads for purposes of determining deficiencies in accordance with Section 641.11.

How Data is Entered Into DLS Reports

Each report has three different types of cells, which are color-coded:

1. One type contains data which may be manually entered during striping operations (yellow) – [note that this information may also be entered into the job screens of the DLS console and come into the Report without additional manual entry],
2. one type contains data which must come directly from the DLS (green), and
3. one type contains values that are calculated by the spreadsheet (rose) from data provided by the DLS.

The DLS Short Report and the DLS Full Report will have one row for each section painted, by route, by direction, even if the section length is less than 10 miles. **(A route section is a contiguous section of highway without breaks with the same route number designation in one direction of travel.)** A new route section is not started at 10 miles if the route and direction stay the same even ~~if~~ when the section length exceeds 10 miles. Whenever material or beads are loaded, the route section is ended. Start a new route section, for that route, to complete the route or, if needed, until reloading. See centerline example on page 8.

Depending on how the Contractor sequences work, the route sections will generally match the plan sub-summary.

How To Read a DLS Report

The Contractor is required to provide a DLS Short Report for each day's work. It should be furnished to the Project the next working day after striping occurs. A paper copy of the DLS Short Report is printed each day or upon demand of ODOT personnel from the in-truck printer. This copy should be compared to the DLS Full Report which is provided to the District DLS Contact person within two weeks of application.

Check general project information:

Check the date box in upper left corner for correct information. **Note the yellow color indicates manual entry.**

Project Name	256-04
Date	7/16/2004
Start Time	7:00 AM
Finish Time	6:00 PM
Total Hours	11

Check crew names and day's production boxes in center and right upper parts of report.

Employee Name	

	Miles
Days Total CL	
Days Total LL	
Days Total WEL	
Days Total YEL	
Days Total CHAN	

Next, check to make sure each cell in the body of the report contains data. There should be a row for each route section, by direction, striped. Start with the yellow columns on the left side. **Note the rose color indicates a value calculated by the spreadsheet. Manual entry of values in rose colored cells is not permitted.**

County	Route Number / Name	Direction	Start Time	Marking Type	Start Hwy SLM	End Hwy SLM	Road Length	Tank 1 Color	Tank 2 Color	Line Width
ROS	50	WB	9:45:41	CL	0.00	10.36	10.36	Y	Y	4.00
ROS	50	WB	9:59:05	CL	10.36	20.82	10.46	Y	Y	4.00
ROS	50	WB	10:35:58	CL	20.82	21.79	0.98	Y	Y	4.00
CLI	104	NB	13:42:10	WEL	0.00	13.09	13.09	Y	W	4.00
CLI	104	SB	14:33:35	WEL	13.09	0.00	13.09	Y	W	4.00

Then check the yellow columns on the right to confirm that the correct material and bead batch numbers have been entered. These should be supported by TE-24s.

Paint1 Batch No	Paint2 Batch No	Bead1 Batch No	Bead2 Batch No
MP20341	MP20341	64.00	mnbvcxzas
MP20341	MP20341	64.00	mnbvcxzas
MP20341	MP20341	64.00	mnbvcxzas
MP20341	MP20341	65.00	mnbvcxzas
MP20341	MP20341	66.00	mnbvcxzas

All of the above information is manual entry into either the report or the DLS console and is the same for Section 614 Class I markings using 740.02 paint, 642, 643, 644 and 646 materials, for all types of trucks and for all types of DLS.

Check for proper material application rates – varies by type of material:

For Section 614 Class I markings using 740.02 paint, 642, 643 and 646 materials only:

Next, review the application thickness (which is the average mil thickness over the section), distance painted (Linear feet from gun counters and equivalent miles painted calculated by spreadsheet [linear feet / 5280]), gallons used and gallons per mile applied (gallons used / equiv miles painted). Compare the actual gallons per mile applied to the requirements in Section 614.11, 642.04, 643.04 or 646.05. Determine any deficiencies per Section 641.11. **Note the green color indicates values which come directly from the DLS and rose color indicates values calculated by the spreadsheet. Manual entry of values in these cells is not permitted.**

Tank 1 Avg Mils	Tank 2 Avg Mils	Linear Feet Painted	Equiv Miles Painted	Tank 1 Gallons Used	Tank 2 Gallons Used	Gals Paint per Mile Applied
0.00	18.70	85089.00	16.12	0.00	274.58	17.04
0.00	20.17					22.19
0.00	20.30					22.82
0.00	20.08					22.10
[illegible]	[illegible]					[illegible]

If using 642 Type 1, this section is deficient: 22 gal/mi is required; mil thickness is also deficient: 20 mil is required.

For Section 644 materials only:

Present technology does not permit measuring the material usage of hot thermoplastic. Determine pounds per mile from field measured amount of material used and the equivalent miles painted from the DLS report. Determine any deficiencies per Section 641.11.

Linear Feet Painted	Equiv Miles Painted
54700.80	10.36
55228.80	10.46
5068.80	0.96
69115.20	13.09
69118.80	13.09

Check for proper glass bead application rates – the same for all materials:

Check the weights of beads used and the actual pounds per 100 sq ft (weight of beads used / 100 sq ft of markings applied). The spreadsheet divides the sum of pounds of beads used by the linear feet painted multiplied by line width in inches divided by 12 inches divided by 100.

$$Lbs\ \ per\ 100\ \ sq\ \ ft = \frac{\sum \ \text{LbsBeadsUsed}}{\text{LinearFt Painted} \times \left(\frac{4''}{12''}\right) \div 100}$$

Compare the actual pounds per 100 sq ft applied to the requirements for Section 614.11 Class I, 642.04, 643.04, 644.04 or 646.05 contained in Supplemental Specification 800, 1/19/07 revision. Determine any deficiencies per Section 641.11.

Bead 1 Lbs Beads Used	Bead 2 Lbs Beads Used	Lbs Beads per 100 Sq Ft
3322.00	0.00	11.71
2554.07	0.00	15.33
263.14	0.00	16.17
0.00	2632.00	[illegible]
0.00	[illegible]	[illegible]

For 642.04 Type 1, the requirement is 15# / 100 sq ft. First route section is deficient.

Check for proper application speed – the same for all materials:

The maximum travel speed of the striping equipment is limited to 10 mph (to insure the equipment is capable of applying the required quantities) unless the Contractor has furnished documentation that this specific truck is capable of applying the required quantities at higher speeds to project personnel. Larger material piping, high capacity guns and large spray tips can be used to achieve higher travel speeds while still applying the required quantities. These modifications are specific to each truck and must be documented to ODOT project personnel's satisfaction to permit travel faster than 10 mph.

Check the average speed of application:

Avg MPH
14.8
15.0
14.7
14.9
15.0

This striper has been equipped with high capacity guns and tips which permit travel up to 15 mph.

Check to confirm the material temperatures and environmental conditions have been recorded:

The average material temperatures and environmental conditions over the section painted are recorded in the remaining green columns. These values are the average of all readings recorded over the section painted. **There are slight differences between DLS types.**

Pump 1 Temp	Pump 2 Temp	Humidity	Dew Point	Air Temp	Road Surface Temp
102.00	73.00	55.00	48.00	73.00	76.00
110.00	79.00	59.00	44.00	78.00	83.00
109.00	80.00	86.00	64.00	[illegible]	[illegible]
90.00	114.00	62.00	52.00	[illegible]	[illegible]

For weight, stroke and flow based systems, this data is recorded.

Most sprayed materials (paints, polyester and epoxy) can be heated slightly to improve flow and spraying characteristics. ODOT does not specify minimum or maximum temperatures but defaults to those recommended by the material manufacturer.

Thermoplastic materials have temperature requirements for both pavement and air temperatures and material temperatures. See Section 644.04 for specific requirements. These values are the average of all readings recorded over the section painted.

Kettle 1 Temp	Kettle 2 Temp	Mat'l 1 Temp @ Applic'n Point	Mat'l 2 Temp @ Applic'n Point	Humidity	Dew Point	Air Temp	Road Surface Temp
438.00		405.00		55.00	48.00	73.00	76.00
420.00		403.00		59.00	44.00	78.00	83.00
439.00		410.00		86.00	64.00	78.00	90.00
	440.00		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	430.00		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

For thermoplastic based systems, this data is recorded. More temperatures are recorded as they are critical to long-term performance.

Kettle temperature cannot exceed 450 degrees and material at point of application must be between 400 and 440 degrees. If thermoplastic material is overheated in the kettle or applied below 400 degrees, it will not perform as intended and should be considered unsatisfactory and must be replaced per Section 641.11 and 644.05.B. <u>Thermoplastic applied when pavement and air temperatures are below those specified in Section 644.04 will not bond adequately to the pavement and applications should not be made under those conditions.</u>

Check to confirm the weight per gallon (for liquid materials – all DLS types) and stroke information (for stroke-based DLS) has been recorded:

Weight per Gallon	Volume per Stroke Calibration Value	Number of Strokes
13.26	0.81	339
13.80	0.81	258
13.19	0.81	26
13.85	0.81	269
13.11	0.81	156

Weight per gallon, per batch, is entered into the DLS console during job setup for liquid materials for all DLS types and reported here as recorded data. Note the weight per gallon may vary per batch.

For stroke-based DLS only, stroke calibration is entered into the DLS console during setup and reported here as recorded data. Number of strokes is recorded during striping. This information is used by the DLS to calculate gallons used.

If You Need Further Assistance

Questions on DLS reports can be answered by ODOT district personnel who have inspected annual maintenance striping contracts. Should it be necessary, please contact Dan Groh, Central Office Construction 614-387-1162 or Larry Stormer, District 3, 419-207-7092 for further assistance.

642 Traffic Paint

1. Material Type, 740.02
    a. Traffic paint type 1, Fast dry, water-based paint
    b. Traffic paint type 2, Fast dry, alkyd-based paint
2. Glass beads, 740.09 Type A
3. Application of Traffic Paint, Item 642, Type 1 and 2
    a. Traffic paint shall be applied when the pavement and air temperature are 50° F (10° C) and above.
    b. Glass beads 740.09 Type A shall be applied at the rate of 15 pounds per 100 square feet (7.3 kg per 10 square meters) traffic paint applied.
    c. Glass beads 740.09 Type A shall be applied at the rate of 7.5 pounds per 100 square feet (3.7 kg per 10 square meters) of type 2 traffic paint applied.
    d. Type 1 traffic paint shall be applied at the rate of 22 gallons per mile (50 liter per km) of 4 inch (100 mm) solid line and/or at 1.33 gallon per 100 square feet (0.51 liter per square meter).
    e. Type 2 traffic paint shall be applied at the rate of 16 gallons per mile (37 liter per km) of 4 inch (100 mm) solid line and/or at 0.94 gallon per 100 square feet (0.38 liter per square meter).
        i. Except increase Traffic Paint Type 2 by 25 percent for the first application to new asphalt pavement
    f. Striper equipment speed shall be according to the paint manufacturer's recommendations
    g. Coning of line required because pavement marking is not track free in 2 minutes or less.

Documentation Requirements - 642 Traffic Paint

1. General requirements per 641
2. Material as per 740.02 and 740.09, SS 1047 and SS 1089
3. Temperature above 50° F (10° C)
4. Location and/or stationing where work performed
5. Measure in appropriate unit and turn in for pay
6. Use form CA-D-3A to document information

643 Polyester Pavement Marking

1. Material Type, 740.03
2. Glass beads, 740.09 Type B
3. Application of Polyester, Item 643
    a. Polyester shall be applied when the pavement and air temperature are 50° F (10° C) and above.
    b. Polyester shall be applied in 2 components (catalyst and resin) in proportions as recommended by the manufacturer.
    c. Glass beads 740.09 Type B shall be applied at the rate of 16.5 pounds per 100 square feet (8kg per 10 square meters) of paint used.
    d. Polyester shall be applied at the rate of 16 gallons per mile (37 liter per km) of 4 inch (100 mm) line and/or at 1 gallon per 0.94 square feet (0.38 liter per square meter)
    e. Striping equipment speed shall be not less than 7 miles per hour (11 km/hr).
    f. Dry time is 45 minutes and less.
        i. Coning is required to protect the line until track free.
        ii. If tracking continues after 45 minutes cease marking operation until tracking problem is corrected.

Documentation Requirements - 643 Polyester Pavement Marking

1. General requirements per 641
2. Material as per 740.03 and 740.09, SS 1047 and SS 1089
3. Temperature above 50° F (10° C)
4. Location and/or stationing where work performed
5. Measure in appropriate unit and turn in for pay
6. Use form CA-D-3A to document information

644 Thermoplastic Pavement Marking

1. Material Type, 740.04
2. Glass beads, 740.09 Type C
3. Application of Thermoplastic, Item 644
    a. Thermoplastic shall be applied when the pavement surface and the ambient air temperature are 50° F (10° C) and rising for pavements less than a year old.
        i. At the end of the construction season if the surface temperature is 50° F (10° C) or less, apply Traffic Paint Type 2.
    b. Thermoplastic shall be applied when the pavement surface and the ambient air temperature are 70° F (21° C) and rising for pavements one year or older.
    c. Temperature of thermoplastic at the point of application shall be at least 400° F (204° C) and not more than 440° F (227° C).
    d. Glass beads, 740.09 Type C shall be applied at the rate of 12 pounds per 100 square feet (6kg per 10 square meters) .
    e. Thermoplastic material shall be applied at a thickness of 125 mils(3.2 mm)
        i. . Use an applicator that has a shoe that rides on the pavements and extrudes the thermoplastic.
    f. Thermoplastic shall be applied at the rate of 2340 pounds per mile (650 kg per km) of 4 inch (100 mm) line and / or at 133 pounds per 100 square feet (650 kg per square meter).

Documentation Requirements - 644 Thermoplastic Pavement Marking

1. Ambient air temperature, type, and condition of existing pavement. Also pavement temperature
    a. Temperature requirements are outlined in 644.04
2. Location and/or stationing where work performed
3. Amount of thermoplastic and beads required and used. Thermoplastic pavement marking 740.04, glass beads Type C 740.09
4. Location and/or stationing where work performed
5. Measure in appropriate unit and turn in for pay
6. Use form CA-D-3A to document information

645 Preformed Pavement Marking

1. Material Types, 740.05 and 740.06
2. Type A, Item 740.05 shall be used for permanent markings.
    a. Type A1 material, 0.090 inch (2.28 mm) thick shall be applied with pre-coated adhesive layer.
    b. Type A2 material, 0.060 inch (1.52 mm) thick shall be applied with pre-coated adhesive layer.
    c. Type A3 material, 0.020 inch (0.50 mm) thick shall be applied with pre-coated adhesive layer.
3. Type B Item 740.06, 0.015 inch (0.38 mm) thick, shall be used for Work Zone Pavement Markings.
    a. Type B, Type II material (non-removable)
4. Type C Item 740.06, 0.030 inch (0.76 mm) thick, shall be used for Work Zone Pavement Markings.
    a. Type C Type I material (removable)
5. Glass beads, None
6. Application of Preformed Pavement Marking, Item 645
    a. Preformed Pavement Marking shall be applied according to the manufacturer's recommendations packed with material.

Documentation Requirements - 645 Preformed Pavement Marking

1. Ambient air temperature, type, and condition of existing pavement. Also pavement temperature
    a. Temperature requirements are outlined in 645.03 or per manufacturer's recommendations
2. Location and/or stationing where work performed
3. Pavement markings applied per manufacturer's recommendation. Materials as per 740.05 and 740.06
4. Measure in appropriate unit and turn in for pay
5. Use form CA-D-3A to document information

646 Epoxy Pavement Marking

1. Material Type, 740.07
2. Glass beads, 740.09 Type D
3. Application of Epoxy Pavement Marking, Item 646
    a. Epoxy shall be applied at a surface temperature of 50° F (10° C) and above.
    b. Epoxy shall be applied in components, Part A and Part B, in proportions recommended by the manufacturer.
    c. Cleaning and surface preparation shall be done according to Item 646.04 for different pavement types and manufacturer's recommendations.
    d. Glass beads 740.09 Type D shall be apply at the rate of 31 pounds per 100 square feet (15 kg per 10 square meter).
        i. Glass beads shall be applied in a double-drop system with Size I, large gradation, first and Size II, regular graduation second in equal amounts by weight in the same pass.
    e. Epoxy shall be applied at the rate of 22 gallons per mile (50 liter per km) of 4 inch (100 mm) line and / or at 1 gallon per 80 square feet (0.51liter per square meter).

Documentation Requirements - 646 Epoxy Pavement Marking

1. Same as 644
2. Materials as per 740.07, and 740.09
3. Use form CA-D-3A to document information

647 Heat-Fused Preformed Thermoplastic Pavement Marking

1. Material Type, Item 740.08
    a. Type A90 is 90 mil (2.29 mm) thick.
    b. Type A125 is 125 mil (3.18 mm) thick.
    c. Type B90 is 90 mil (2.29 mm) thick.
    d. Type B125 is 125 mil (3.18 mm) thick.
2. Glass beads, 740.09
    a. Type A and B shall contain intermix beads throughout. Drop on glass beads are not required unless using a non-surface beaded markings.
3. Application of Heat-Fused Preformed Thermoplastic Pavement Marking, Item 647
    a. Heat-Fused Preformed Thermoplastic Pavement Marking shall be applied only as auxiliary markings according to the manufacturer’s recommendations.
    b. Apply primer sealer on portland cement concrete pavements if recommended by the manufacturer.

Documentation Requirements - 647 Heat Fused Preformed Plastic Pavement Marking

1. Same as 645
2. Materials as per 740.08 and 740.09. State type of material used, A, B, or C
3. Use form CA-D-3A to document information

Construction Inspection during Pavement Marking Installation

Refers to Item 641, Pavement Marking - General

Before the application of marking material, pavement surface should be clean and dry by using:

1. Power broom
2. Air jets (guns)

Approve the premarking for long lines and auxiliary markings to ensure proper layout placement.

Center lines shall be "T" marked to establish no-passing lines.

Example of Premarking

District shall provide center line paint logs.

As per Item 641.06 the Contractor shall establish references points to ensure proper placement of restored markings on projects where resurfacing or other operations will result in obliteration of the existing pavement markings.

Example of measurement of markings

Marking lines shall be applied to the width specified ± ¼ inch. (6 mm).

Pavement markings shall be free of uneven edges, overspray and other visible defects.

Example of uneven edge line placement

Pavement marking lines shall be placed as per SCD TC-73.10 as follows:

1. Edge lines shall be applied 6 inches (150 mm) from the pavement edge.
2. Lane lines shall be applied 2 inches (50 mm) to left of joint.
3. Center lines shall be applied 2 (50 mm) inches from joint.

Pavement marking lines shall be straight or smoothly curved true to the alignment of the pavement.

1. If deviation is greater than 3 inches (75 mm) in 100 feet (30 meter), it shall be corrected.

Gaps shall be filled that were not marked as a result of template use for spray-applied auxiliary markings with marking material after the template is removed.

1. For extruded thermoplastics gaps may be left.

Example of retroreflectivity check

Pavement marking lines shall be sharp, well defined and uniformly retroreflective.

1. To check for retroreflectivity put sun over shoulder.
2. If it is not sunny:
    a. A well beaded line in the daylight will appear dull.
    b. While an unbeaded line will be shiny.
3. Review lines at night for retroreflectivity if possible.

652 Placing Stockpiled Topsoil and 653 Topsoil

Documentation Requirements - 652 Placing Stockpiled Topsoil and 653 Topsoil

1. Topsoil free of grass, brush, and roots
2. Opened up before seeding

656 Roadside Cleanup

Documentation Requirements - 656 Roadside Cleanup

1. Clean up all debris outside excavated and fill areas and disposed of in accordance with 105.16 and 105.17
2. Prune trees 6 inches (15 cm) or less in accordance with item 666
3. Measure area for payment

657 Riprap for Tree Aeration

Documentation Requirements - 657 Riprap for Tree Aeration

1. Document material outlined in 657.02
2. Document tree wells in fill sections (657.02) and cut sections (657.04)
3. Place hand laid riprap on 12:1 slope
4. Measure area for payment

658 Tree Root Protection

Documentation Requirements - 658 Tree Root Protection

1. Aggregate
    a. Number 4 or 467 limestone as per 658.02
2. Placement of aggregate for trees not welled as per 658.04 and 658.05 for trees that are welled
3. Measure volume for pay

659 Seeding and Mulching

Documentation Requirements - 659 Seeding and Mulching

1. Measure area to be seeded prior to start of operations and setup test sections
2. Exclude area to be seeded at contractor's expense
3. Fertilizer incorporated to a depth of 2 inches (5 cm) by________________________ (harrowing, disking, etc.) Type of fertilizer placed as outlined in 659.04
4. Calculate and document seed mixture required and used
5. Rocks and other foreign material larger than 3 inches (8 cm) removed. 1 inch (2.5 cm) and larger removed in front of residences, commercial properties, and between curb and sidewalks
6. If broad cast seeding, rake and roll flat areas, and track slopes with dozer.
7. Mulch should be placed within 48 hours after seed has been sown
8. Agree with Contractor on areas to be paid by both the State and Contractor

Note: Use from CA-EC-2 for field dimensions and calculations

660 Sodding

Documentation Requirements - 660 Sodding

1. Prepare area according to 659
2. Sod placed on prepared area and covered with 1 inch (2.5 cm) minimum straw
3. Pin sod on slopes of 2:1 and steeper if the strips are more than 6 feet (2 m) wide
4. Measure and pay per 660.10 and 660.11

661 Planting Trees, Shrubs, and Vines

Description (661.01)

This item of work involves furnishing plantings (trees, shrubs, vines and other materials) and planting them according to the plan details, these specification requirements and applicable Standard Construction Drawings.

Labeling (661.03)

All plantings delivered to the project must have legible labels indicating detailed information of the botanical genus and species name, the common name, the size or age of each plant variety. The labeling must state the quantity in the individual bundles, boxes and bales. These labels must be removed before the completion of the establishment period.

Plant Inspection Guidelines (661.04)

General Appearance

The general appearance of a plant is the quickest way to judge its health and vigor. Be sure that the plant:

- is healthy, typical of their species or variety and have a normal growth habit
- meets the minimum dimensions given in the General Notes
- container is not cracked or severely dented
- container is weed free
- is generally symmetrical with no large gaps in the branching structure
- has no broken limbs
- is free of excessive bark damage

- The foliage of the plant should be:
- erect and firm (except for weeping type plants)
- a uniform green color (except for fall color)
- vigorous, healthy and robust
- free of wilting, yellowing and browning.

NOTE: Inspection of the plants before unloading from truck will save time and effort. Plants do not need to be individually inspected; a random inspection will be OK. The source of supply should be verified from the shipping ticket and compared to the plant material list (CMS 661.05) as submitted earlier. Plants not meeting specifications or that differ in source of supply is justification for non-acceptance.

Problem Signs

Substantial amounts of brown or yellow foliage indicate the plant may be experiencing stress or shock. (Be aware that some trees, depending on whether they are deciduous or evergreen, may change color during the fall.)

Wilted foliage probably indicates a lack of water during shipping or storage. All plants must be completely covered during shipping (CMS 661.07). A thorough watering should restore the foliage to a healthy appearance within a couple of days. If not, the plant should be monitored for a few more days to see if it recovers before planting. If the condition does not improve, reject the plant. Broken and dead limbs indicate poor growing or handling conditions.

Testing for Dead Plants or Limbs

It is not always easy to tell if a plant is alive, particularly during the winter if the plant is a deciduous variety and has shed its leaves. Some of the techniques listed below will help to determine if a plant (or a part of the plant) is alive.

- Using your fingernail, pocket knife or other sharp object to scratch the bark on the trunk or limbs. A living plant will be light-green and moist just below the soft bark. If the bark is hard and the scar is brown, that part of the plant is dead. A random check of other areas will help to determine if the plant is vigorous and healthy.
- Wrinkled bark that is off -color is an easy visual clue to dead parts of a plant.
- Healthy limbs are flexible. They can be bent without breaking. Dead limbs are dry and brittle.

Container Grown Plants

The roots of a container grown plant should:

- be growing throughout the growing medium
- bind all the soil together
- be white in color and moist; dark brown or blue black roots indicate damaged or dead roots.

Testing for adequate root system: ***Inspecting the root systems of plants is very important***. It is not necessary to test all the plants; random checks will be sufficient if all the plants are from the same grower. If the plants are provided from more than one supplier or grower, be sure to random-check each group. Also inspect any plants that appear different or out of character with a group of like plants.

- For shrubs, hold the plant at the base of the trunk and gently lift the plant a few inches out of the container. If the entire contents of the container moves and holds its shape in a firm mass of roots, the plant is properly "rooted-out" and ready for planting.
- For trees, lay the container on its side, hold the tree at the base of the trunk as close to the soil level as possible and gently slide the tree from the container a few inches. If soil is left in the container or if the root system is not growing throughout the entire container, the plant is not ready for planting and should be considered for rejection.

This method is not possible for large trees. Instead, dig two to three inches into the soil at the very edge of the container and look for a firm mass of small roots.

Root-Bound Container Plants

If plants have been growing in their container for a long time, the roots will wrap around the inside of the container. These roots need to be cut or sliced prior to planting. These cuts should be made along the sides and bottom. Cutting these circling roots will enable the plant to produce new root offshoots and grow without problems.

Checking Container Sizes. The size of large plastic containers may be indicated on the handle. Since these are nominal volume sizes only, there may be some variation in actual size even though the containers from two different growers are labeled as being the same volume. Refer to Appendix for the minimum acceptable size ranges for containers without sizes printed on them or for wooden or metal containers.

Soil Condition in Containers. Check for the following soil conditions:

- The soil level should be within a couple of inches of the top of the container. It should be a light (by weight) soil mix of mostly bark mulch and perlite or vermiculite (small white or silver particles that help hold water).
- If you see clay, burlap or wire in what is supposed to be a container grown plant, inspect closer to determine if the plant has been dug from the field and then placed in the container. The root development test described previously should determine this. A containerized plant in lieu of a container grown plant is not acceptable and must be rejected.

B & B Plants (Balled & Burlapped)

Inspect the rootball of B&B material for:

- a firm, tight ball with no roots protruding outside the wrapping

- wrapping that is snug and free of rips and holes
- cracked balls or balls that are soft and look like a bean bag (these should be rejected)
- damage to the base of the trunk caused by wire or string used to secure the wrapping
- moist soil

Soil Condition of the Rootball. The soil in a B&B rootball will almost always be clay or a tight, sandy clay. This is necessary so that the soil will hold its shape during digging, as well as hold water during shipping and storage. Rootballs that are mostly sand may crack and break easily, possibly exposing roots to heat and dry air. Plants with a sand rootball should not be accepted.

The rootball must be moist and shaded for protection at all times when shipping or storing.

Measuring Caliper. This is measured 6 inches above the ground (or top of root ball) up to and including 4 inch caliper size and 12 inches above the ground for larger sizes. Measurement should be taken with "pincher" type caliper or diameter tape.

Proper Habit of Growth:

If a particular habit, i.e. single stem, multiple stem, etc., has been specified, be sure to obtain plants that conform to this requirement. Height of branching should bear a relationship to the size and kind of tree, also, so that the crown of the tree will be in good balance with the trunk as the tree grows. Example: 2 in. caliper = 12 to 14 ft. average height; 16 ft. maximum height.

Shade and flowering trees should have top growth symmetrically balanced. Shade trees should have a single leader. The branching should be well developed and characteristic of the species. Example: 3/4 in. caliper= 7 or more branches.

Multi-stem trees can be defined as Clump or Shrub form. Clump form is a tree having two or more main stems arising from the root crown. Shrub form has multiple stems arising from the root crown in the manner of a shrub. Multi-stem trees are measured by height; taken from the ground level (or top of root ball) to the average uppermost point of growth of the plant.

Evergreen trees and shrubs should be full foliaged plants with uniform density. Sheared plants, such as pines sheared for Christmas trees, must be avoided unless specified. Most evergreen shrubs, such as juniper and yew, are measured by spread and should be the average of the plant. Evergreen trees like pines and spruces are measured by their height.

Deciduous shrubs should be well branched and full with no large holes from missing branches. Most are broad upright type plants and are measured by their height. Well grown material should have a height equal to if not greater than the spread. However, the spread should not be less than two-thirds of the height.

Rejected Plants:

Plants rejected for the project should be removed as soon as possible. They should be marked to preclude the possibility of their installation on the job. Since discarded plants are the property of the contractor, they should not be marked or mistreated in such a way as to make them unfit for other uses.

Insects

Do not allow the contractors to deliver any plants to the site that are infested with harmful insects, Harmful insects are those that eat or bore into the plant including:

- caterpillars
- borers
- aphids
- scale
- mealy bugs
- bagworms

When inspecting for insects, look for:

- the insects themselves. Most insects that suck plant juices usually do so from the undersides of leaves, particularly tender new leaves. Be sure to check these areas: aphids & mealy bugs
- leaves that have holes or portions chewed out of their margin: caterpillar
- small bag-like structures hanging from limbs:
- bagworms
- holes in the bark that looks like shotgun holes:
- borers
- discolored bumps along a stem that look like shells:
- scale

Beneficial insects can include Lady Bugs and Butterflies. If insects are found, and it is unknown whether they are harmful or beneficial, the inspector can call the local County Extension office.

PLANT DAMAGE - TREES AND SHRUBS

Things To Look For	What It Means	Action To Take
Minor amounts of breakage of small, twiggy growth.	Normal shipping damage. Should excessive.	Damaged twigs should be not be pruned.
Many small limbs broken.	Poor handling. Should not be excessive.	Broken limbs should be pruned. Reject if breakage is excessive.
Minor amounts of nicks and scratches.	Normal shipping damage. Should not be excessive.	None.
Gashes in trunk that are 1/8"(.3mm) deep or less and less than 1" (2.5cm) long.	Poor handling. Should not be excessive.	Treat with pruning paint. Reject if damage is excessive.
Gashes longer and deeper than the above.	Excessive damage. May stress plant and lead to loss of plant	Reject the plant.
Broken limbs 3/8" (lcm) in diameter or larger.	Poor handling. Damage done to larger limbs is more critical.	Broken limbs should be pruned. Reject if major limb or more than one.
Central leader (main trunk) is broken or cut.	Poor care or may have been pruned to meet specifications.	Reject the plant.
Limb partially broken or cut and has be wrapped or repaired.	Someone tried to repair evidence of poor handling.	Reject the plant.

Inspection during Planting

The purpose of this part is to serve as a guide for an inspector who may not have the experience to determine that planting operations at the construction site are being properly completed in conformance with contract plans and specifications and good horticultural practices.

Planting stock should be inspected upon delivery. This will insure that the plants delivered meet the requirements of the contract planting plans and specifications.

If plants are delivered before the site is ready for planting, a location should be chosen to store the plants until time to plant. This site should be away from construction traffic and protected from direct sun and wind. Asphalt or concrete areas are not acceptable as storage locations. Plant root balls should be covered entirely with mulch approximately 3 inches deep. Plants should be watered as necessary (see watering table) while in this temporary location.

Preliminary Preparation:

1. The inspector and contractor should jointly review and become familiar with all plan sheets, quantities, details, specifications, and other provisions of the contract. At this time, questions or interpretations can be answered or problems resolved through discussion with the landscape architect, horticulturist, or other authorized persons.
2. Sources of materials other than plants required for planting operations should be submitted for approval prior to use in the planting operation.

Some of the materials that may require approval prior to use are topsoil, peat materials, (peats, mosses, humus, and related projected), compost, fertilizer, lime, mulch, stakes, wire and hose, and wrapping material.

3. The inspector (or approved other) should check and approve the stakeout of all planting areas and planting pit locations prior to excavation. Minor relocation of planting areas and pits can be done at this time to avoid utility lines, rocky outcrops, drainage ditches, existing plants or impervious or wet soil conditions. If minor relocations of plantings are not possible, the inspector should contact the landscape architect to adjust the design requirements.

Site Preparation:

Prior to installing plant stock at the construction site, the following preparation must be completed according to the requirement of the contract plans and specifications.

1. Excavation of planting pits, pockets, or beds to the required size and depth and spaced as shown on the plans.
2. Onsite preparation of backfill mixture as called for by contract specifications. The backfill mix must consist of the following (CMS 661.11):
    a. One part excavated soil
    b. One part sphagnum peat moss, shredded pine bark or EPA rated Class IV compost
    c. One part sand
    d. A slow release commercial fertilizer (0-20-20 or equal) added at a rate of 5 pounds per cubic yard (3kg/m) to the backfill mix.

Planting Operation (661.12)

Unless in conflict with the contract specifications, the following check list of horticultural practices may be used by the inspector. This information pertains to new or replacement nursery stock and not to large, mature plants.

1. Plantings should be performed only during the specified planting season (see CMS 661.06). Planting must be done between September 15 and June 1.
2. The inspector should check for proper positioning of the plants. After plants are set, burlap and any twine should be loosened, laid back and cut away, if bulky, without damaging the ball. Non biodegradable materials should not be used in lieu of burlap.
3. Check for correct depth of the plant crown. Depth of crown will vary for different soil conditions. See SCD LA-1.2 for details.
4. Place approved backfill material around plant roots or plant balls, being careful not to damage the ball or the fine root system. Backfill which is frozen or too wet is not acceptable.
5. Eliminate air pockets in the backfill by filling, tamping, and watering as required by the specifications. It is best to water plants thoroughly before backfilling. Container plants should be moist at the time of planting.

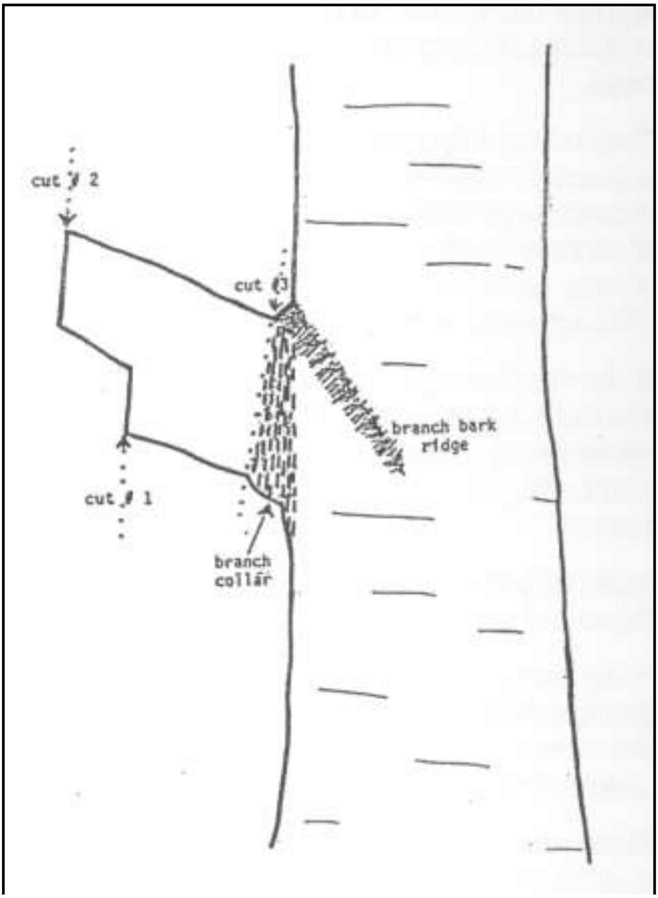
6. When the above operations have been completed, unless otherwise specified, place a berm of soil around the perimeter of the pit to form a basin or saucer to facilitate watering and retention of moisture.
7. Mulch all plants to the specified depth with approved material (CMS 661.13). The use of mulches prevents rapid temperature fluctuation, reduces moisture loss, and aids in weed control.

NOTE: Installation can directly affect a plants survival rate. Concentration on the installation process is critical to a project's success or failure. Because the nature of this work is based upon the end result, i.e. plants live or die, inspectors need to watch the installation closely. If the inspectors have any questions during the installation work, they should contact the project designer or other knowledgeable personnel as soon as possible.

Pruning, Wrapping, and Bracing (661.14, 661.15 and 661.16)

All plants should be pruned, wrapped and braced as specified.

1. Drive stakes solidly into the ground and guying installed to prevent movement of the plant until the root system is firmly established in the new planting location. See SCD LA-1.2 for details.
2. Wrap trunks or stems of plants from the root crown to the lower limbs with approved material to protect against drying or other physical damage. Wrapping should not be done prior to planting on deciduous trees.
3. Plants should be pruned at planting time to restore a balance between the root and top growth. Tops should be pruned to compensate for the partial loss of roots when the plant was removed from the nursery, and in a manner that will retain the characteristic shape of the plant.
4. Broken or damaged branches must be removed. The central leader of a deciduous tree should never be trimmed or removed. Deciduous trees with competing leaders should not be accepted for the project.
5. Prune all broken, torn, or damaged roots, leaving a clean cut surface to help prevent rot and disease.
6. Prune deciduous shrubs if only branches are broken during installation. Coniferous evergreens normally should not be pruned except for broken branches, unless otherwise specified or directed.
7. Trees may be pruned before planting to save time and trouble. At this time, hand clippers can be used to cut closer than can be done with pole pruners - usually used for trees in an upright position. Pruning may be done under inspector's supervision prior to planting.
8. The planting operation is complete by watering all plants as specified.
9. See pruning diagram below:



Pruning Diagram

LANDSCAPE INSTALLATION INSPECTION CHECKLIST

Project No.:______________________ Date: ____________

County: __________ Route: ________ Section: ______________

Contractor: ______________________________________

Certified Landscape Technician: ______________________________________

Inspector: ______________________________________

Y	N	ITEM	Remarks
		Plant Installation: General Condition	
		Plant identification (proper species, tag, certification)	
		Overall foliage, condition (shape, leaf color, wilt, scorch, etc.)	
		Leaf discoloration (spots, splotches)	
		Evidence of pruning (needed or properly performed)	
		Insects (chewing damage, presence of insects)	
		Condition of trunks and limbs (gashes, breakage)	
		Soil conditions in container or rootball (moist, dry)	
		Root system (rooted throughout, healthy white color)	
Y	N	Size Specifications	
		Container size	
		Rootball size	
		Height	
		Spread	
		Caliper	
		Plant Delivery. Storage & Handling	
		All plants delivered on trucks are completely covered during transit	
		Rootballs and containers protected from direct sun	
		Handling and unloading from truck is done by the rootball or container and not by truck.	
		Are plants adequately watered	
		Plants are healed in until planted	
Y	N	Plant Installation	
		Plant location staked in field	
		Plant spacings conform to plan notes	
		Plant pit or bed preparation conforms to details	
		Plant is properly placed in pit	
		Rootball relation to finished grade meets spec	
		Rootball supporting devices removed (twine, wire, etc.)	
		Backfill mix meets specifications	
		Backfill placed in lifts and properly watered	
		Fertilizers added if specified	
		Plant is properly watered during installation	
		Watering basin conforms to details	
		Tree supports installed according to details(stakes, guy wire)	
		Vegetation barriers installed according to details	
		Mulch installed according to details	
		Tree trunk is wrapped to first branch	

Period of Establishment (661.17)

Warranty Periods

Landscape projects normally include a period of establishment. During this time, all plantings on the projects shall be under the care of the contractor. This period begins immediately upon completion of the planting operation for any plant or species group and continues until October 1, but no less than one growing season (i.e. June 1 to October 1).

The stress caused by improper handling may not show its effect immediately. Plants (particularly large trees) may be under stress for months before showing obvious signs. By then, it is difficult to relate the damage to the plant installation phase rather than the maintenance it has received. Again, this points out the need for care early in the installation to make sure that the quality of plants is the highest and the care they receive is the best.

During the establishment period, the contractor must water, re-mulch, re-stake and cultivate as necessary. The contractor is required to perform two weeding and mowing programs around trees, guy stakes, shrubs and bed edges so as to remove all weeds and grasses from the planted and mulched areas. The first program should begin around June 15 and the second approximately 8 weeks later.

Plant Establishment Period – Final Inspection

This inspection should be done about September 15 and include a plan-in-hand review of each planting area or bed to determine the arrangement, number and species of plants called for on the planting plans are present. If all plants have been properly installed, there should be minimal settlement of the backfill. Proper mulch depth should also be checked as this will affect plant survival.

The contractor must remove all stakes, guy wires and wrapping material from plantings just prior to final inspection except for any replacement plantings that have not been through their establishment period. (CMS 661.18)

Since this inspection is of major importance to the ultimate success if the project, the contractor, inspector and designer should be members of the inspection team.

All plants rejected during the inspection should be removed and replaced by new plants which meet all of the requirements of the project and specifications. The final acceptance of the project should not have been completed until all plant replacements have been satisfactorily made.

ESTABLISHMENT CHECKLIST - FINAL INSPECTION

Y	N	Item	Remarks
		Foliage	
		Leaf wilt or browning	
		Leaves healthy and green	
		Yellowing	
		Spots of discoloration	
		Evidence of insect damage	
		Web or cocoons- caterpillars present	
		Disease Present	
		Remarks:	
		Tree Trunk and Limbs	
		Damage at the base of trunk	
		Broken limbs that need to be pruned	
		Dead limbs- no leaves present	
		Damage from insects, birds, rodents or animals	
		Sucker growth- prune out	
		Straighten plant if needed	
		Misc.	
		Planting Pit and Rootball	
		Exposed roots- mulch is needed	
		Settled backfill- replace as needed	
		Animal damage	
		Moisture level of soil- water if needed	
		All stakes, guy wires and wrapping removed	
		Weeds in mulch	
		Leaning trees- straighten if needed	
		Plant Replacement	
		Dead and missing plants replaced	
		Vandalism or vehicular damage	
		Ground Cover & Shrub Bed Area	
		Weeded	
		Dead shrubs- replace if needed	
		Straighten if needed	
		Misc.	
		Remarks:	

Plant Substitution List

Occasionally, landscape contractors may need to make recommended substitutions to the plant material list. This can occur if the plants are not available locally, there's not enough to meet the project requirements, or the specified size is no longer available. These substitutions should be pre-approved by the designer before the contractor purchases the plants.

Listed below is a chart to keep records on these substitutions.

Specified Plant	Substitution

Method of Measurement and Basis of Payment (661.19 and 661.20)

Measurement is done by counting the number of each species and size that was completed and accepted.

The contractor is paid 50 percent of the bid price of each item when it is delivered to the project and is paid the other 50 percent after each item is planted.

At the end of the establishment period, after the final inspection, the Department will determine the actual number of living plants. The Department will pay an additional 20 percent of the bid price for all living plants at the end of the establishment period. The Department will not pay this additional 20 percent for plantings that did not survive the establishment period and the contractor must replace all plants not surviving the original establishment period. The Department will extend the establishment period for plants replaced but there will be no additional payment.

661 APPENDIX I – SHADE TREES

Height relationship to caliper

Caliper (inches)	Avg. Height Range (feet)	Maximum Height (feet)	Minimum Diameter Ball (inches)
3/4	6 to 8	10	14
1	8 to 10	11	16
1 1/4	8 to 10	12	18
1 1/2	10 to 12	14	22
1 3/4	10 to 12	16	24
2	12 to 14	16	24
2 1/2	12 to 14	16	28
3	14 to 16	18	32
3 1/2	14 to 16	18	38
4	16 to 18	22	42
5	18 and up	26	54

Tree caliper is measured 6 inches above ground level up to and including 4-inch caliper size and 12 inches above the ground for larger sizes.

CONTAINER SPECIFICATIONS – Shade Trees

Tree sizes and acceptable container sizes:

Height	Container Size
12 in. 18 in. 2 ft. 3 ft.	#1
2 ft. 3 ft. 4 ft.	#2
4 ft. 5 ft. 6 ft.	#3

All container grown plants shall be healthy, vigorous, well rooted and established in the container in which they are sold.

An established container grown tree shall be a tree transplanted into a container and grown in that container sufficiently long for new fibrous roots to have developed so that the root mass will retain its shape and hold together when removed from the container.

661 APPENDIX II - DECIDUOUS SHRUBS

Height	Minimum Diameter Ball (inches)
12 in.	8 in.
18 in.	9 in.
2 ft.	10 in.
3 ft.	12 in.
4 ft.	14 in.
5 ft.	16 in.
6 ft.	18 in.
7 ft.	20 in.
8 ft.	22 in.
9 ft.	24 in.
10 ft.	26 in.

Plants dug to the specifications in the above table should have the center of the stem or cluster of stems of the plant in the center of the ball.

661 APPENDIX III - CONIFEROUS EVERGREENS

Broad spreading and Globe Types (ex. Taxus media)

Height	Minimum Spread	Minimum Diameter Ball
6 in.	6 in.	
9 in.	9 in.	8 in.
12 in.	10 in.	8 in.
15 in.	12 in.	10 in.
18 in.	15 in.	10 in.
2 ft.	18 in.	12 in.
2 1/2 ft.	21 in.	14 in.
3 ft.	24 in.	16 in.
31/2ft.		18 in.
4 ft.		21 in.
5 ft.		24 in.

CONTAINER GROWN SPECIFICATIONS

Height I	Container Size
6in. 9in. 12 in.	#1
12in. 15in.	#2
18in. 2 ft. 2 1/2 ft.	#3

CONIFEROUS EVERGREENS

Conicals, Broad Upright and Columnar

(ex. Pinus, Picea and Thuja)

Height	Spread	Minimum Diameter Ball
12 in.	8 to 12 in.	10 in.
15 in.	9 to 15 in.	10 in.
18 in.	12 to 18 in.	10 in.
2 ft.	15to21 in.	12 in.
2 1/2 ft.	18 to 24 in.	12 in.
3 ft.	21 to 30 in.	14 in.
4 ft.	2 1/2 to 3 ft.	16 in.
5 ft.	3 to 4 ft.	20 in.
6 ft.		22 in.
7 ft.		24 in.
8 ft.		27 in.
10ft.		34 in.
12 ft.		34 in.

Ball sizes should always be of a diameter and depth to encompass enough of the fibrous and feeding root system as necessary for the full recovery of the plant.

Plants dug to the specifications in the above table should have the center of the stem or cluster of stems of the plant in the center of the ball.

CONTAINER GROWN SPECIFICATIONS

Height	Container Size
6in. 9in. 12 in. 15 in. 18 in.	#1
12in. 15in. 18in. 2 ft.	#2
18in 2 ft. 2 1/2 ft. 3 ft. 3 1/2 ft	#3

661 APPENDIX IV - BROADLEAF EVERGREENS

Spreading and Dwarf Types

(ex. Buxus and Cotoneaster)

Spread	Minimum Diameter Ball (inches)
18 in.	10 in.
2 ft.	12 in.
2 1/2 ft	14 in.
3 ft.	16 in.
3 1/2 ft.	18 in.
4 ft.	21 in.

CONTAINER GROWN SPECIFICATIONS

Height	Container Size
6in. 9in. 12 in.	#1
12in. 15in.	#2
18in. 2 ft. 21/2ft.	#3

All container grown plants shall be healthy, vigorous, well rooted and established in the container in which they are sold. They shall have tops of quality and in a healthy growing condition.

Cone and Broad Upright Types

(ex./IexandRhodoendron)

Height	Minimum Diameter Ball (inches)
18 in.	10 in.
2 ft.	12 in.
3 ft.	14 in.
4 ft.	16 in.
5 ft.	20 in.
6 ft.	22 in.

CONTAINER GROWN SPECIFICATIONS

Height	Container Size
6 in. 9 in. 12 in. 15 in. 18 in.	#1
12 in. 15 in. 18 in. 2 ft.	#2
18 in 2 ft. 2 1/2 ft. 3 ft. 3 1/2 ft.	#3

661 Landscape Watering

When watering by hand, attention should be given to the type of device used to apply the water. If the water is applied at too high a rate, the force of the water will displace mulches, soil and expose roots. All equipment used to direct water into the watering basin should have a flow-control device that will break the impact of the water so that it will flow gently into the basin.

Water should not be applied to where runoff will occur. If the plant is newly planted, too much water can erode the watering basin and allow water to escape before it can soak down into the soil. If this occurs, the basin should be repaired before the next watering.

WATERING TABLE (662.03-1)

Shrubs	12 - 36 inches (300 - 900 mm), height	4 gallons (15 L)
Shrubs	36 in - 5 feet (900 mm - 1.5 m), height	7 gallons (25 L)
Trees	5 - 8 feet (1.5 - 2.5 m), height	15 gallons (55 L)
Trees	2 - 3 inches (50 - 75 mm), caliper	25 gallons (95 L))
Trees	3 - 4 inches (75 - 100 mm), caliper	30 gallons (115L)
Trees	Greater than 4 inches (100 mm), caliper	35 gallons (115 L)

WATER-RELATED STRESS SYMPTOMS

Symptoms	Soil Condition	Problem	Action to be Taken
Leaves are slightly dropping. Soft, hazy-green color.	Dry	Lack of water	Apply water as soon as possible.
Leaves are dropped and wrinkled.	Dry	Severe lack of water	Apply water immediately
Leaves are dropping, brown and falling from the plant.	Very dry, look for cracking.	Severe lack of water	Water immediately. Plant is near shedding leaves is to compensate for lack of water.
Leaves are brown along margins but not drooping. Some leaves are falling from the tree.	Wet	Over-watering	Stop watering. Allow soil to dry

Documentation Requirements - 662 Landscape Watering

1. Document watering method
2. Determine gallons of water used for payment (weigh slips or measure tank)

666 Pruning Existing Trees

Documentation Requirements - 666 Pruning Existing Trees

1. Pruning and payment method outlined in item 666.03 thru 666.08.

670 Erosion Protection

Documentation Requirements - 670 Erosion Protection

1. Document and measure the erosion control items installed and maintained in accordance with the plans. Note: Use form CA-EC-1.

671 Temporary Erosion Control Mats

Documentation Requirements - 671 Temporary Erosion Control Mats

1. Document type of erosion control mats (type A thru type I 670.03), seeding, and mulching installed and maintained. Materials outlined in 671.02
2. Measure areas for payment

SS-840 Mechanically Stabilized Earth (MSE) Walls

Introduction

MSE Walls have been constructed in the State of Ohio for over 20 years. In previous years, there were special provisions in the contract that detailed the construction and design requirements. In the old special provisions each wall supplier had a unique special provision. The new supplemental specification (SS-840) combines all of the special provisions into one document.

SS-840 is being updated frequently. Check the plans and addenda to see which version is included in the contract. If a more recent version is available, consider adopting the new version by a change order. There may be a cost or savings involved with adopting the new version, depending on what has changed.

Below is a detail of a typical MSE Wall application. This is an elevation view of a MSE Wall and bridge.

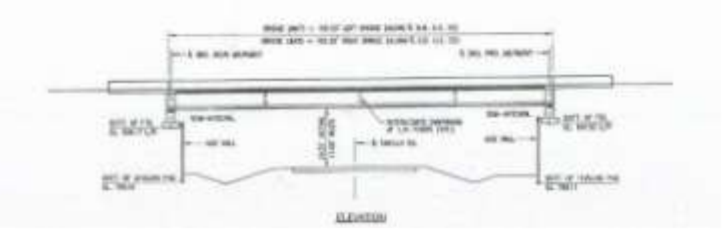


Figure 840.01.A MSE Wall Elevation View

For the same bridge a plan view is shown below.

Figure 840.01.B Plan View of the MSE Wall and Bridge

MSE wall specifications are different than the normal construction specifications. There are both design and construction criteria in the specifications. The plans will detail a three line diagram of the MSE wall structure. The internal details and the construction shop drawings are submitted later after the sale of the project.

This detail shows the reinforcing mesh in general form and the undercut.

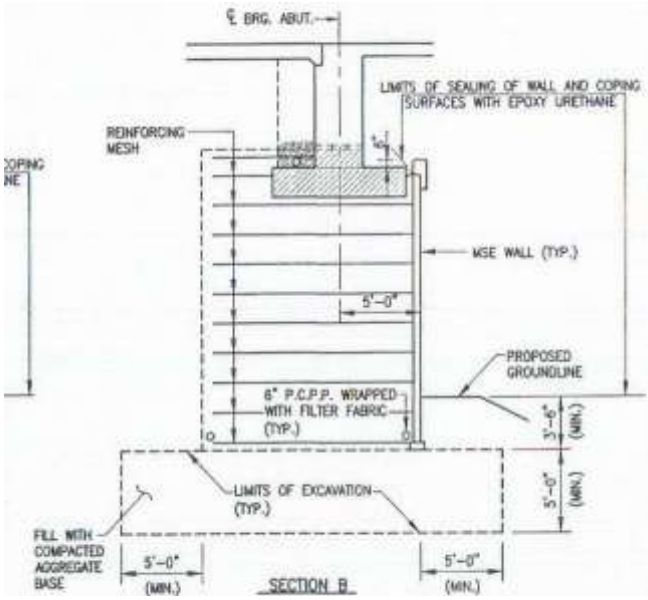


Figure 840.01.C Typical Plan Cross Section of a MSE Wall

In the detail below the Designer has laid out the select granular backfill and 203 embankment.

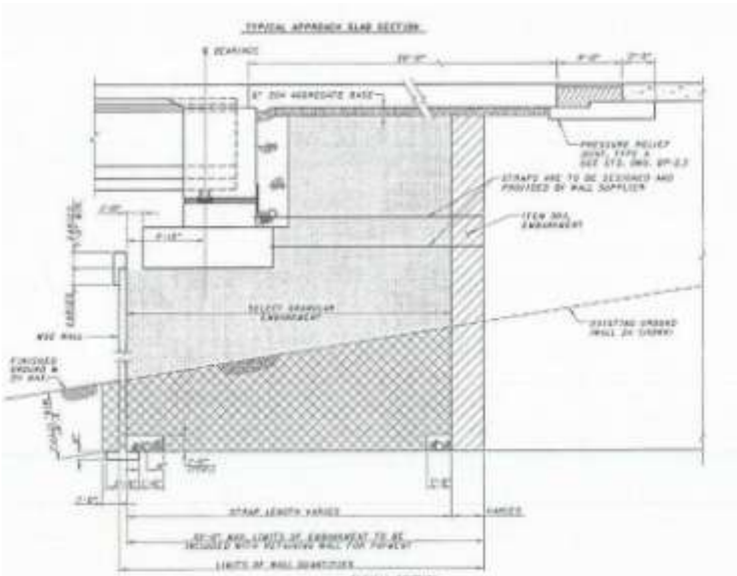


Figure 840.01.D Layout of the Select Granular Backfill and 203 Embankment

There are applications where the designer may choose to place a wall on both sides of an embankment as detailed below.

Figure 840.01.E MSE Walls on Both Sides

Specification Changes

Some of the major changes are detailed below:

1. The separate special provisions for individual wall manufactures were converted into one supplemental specification.
2. More construction details were added to control the work in the field better.
3. Step by step construction process is detailed.
    a. Foundation compaction improved.
    b. Undercut and drainage details were added.
    c. Leveling pad width increase to 24 inches.

d. Horizontal and vertical alignment and joint spacing details were added. The flashlight test was added.
e. Fabric gluing method is detailed.
f. Step ups overhangs were addressed.
g. Granular backfill placement and compaction requirements were modified.
h. Reinforcing steel connections details were added.
i. Pile sleeve backfill material changed from bentonite-cement slurry to sand.

4. The design requirements were expanded upon.
5. Added the requirement for the Office of Structural Engineering to review the shop drawing.

General Information

The following figure details the general configuration of the MSE Wall system.

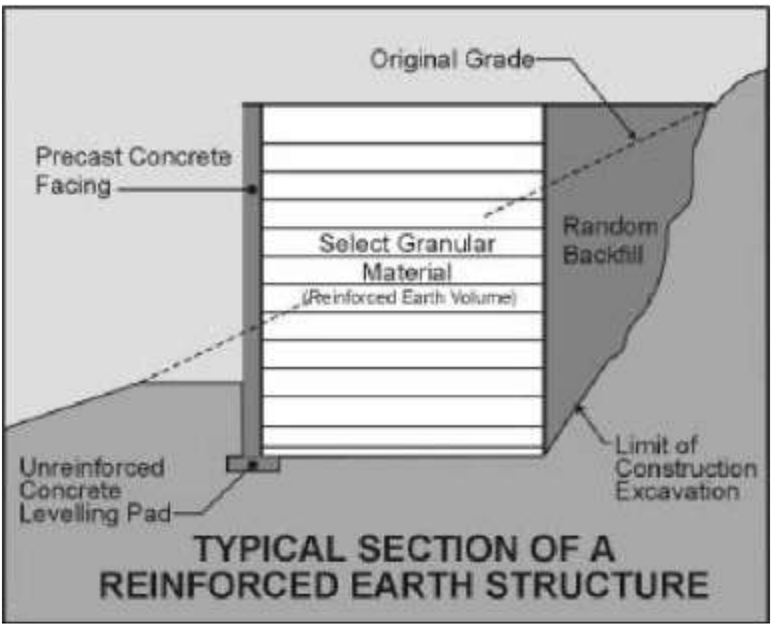


Figure 840.01.F Typical Section of an MSE Wall Structure

Terms

The following are standard terms that will be used throughout this text.

Coping - The coping is used to tie in the top of the wall panels and to provide a pleasing finish to the wall top. It is cast in place.

Filter Fabric - A geotextile filter fabric is used to cover the joint between panels. It is placed on the backside of the panel joints. This keeps the soil from piping through the joints and allows excess water to flow out.

Concrete Leveling Pad - The leveling pad is unreinforced cast-in-place concrete. The concrete is 24 inches wide, 6 inches thick and has a minimum compressive strength of 2500 psi. Cure the cast-in-place concrete for a minimum of 12 hours prior to placing the first row of facing panels.

Original Ground - The existing ground surface at the site.

Random Backfill - Random backfill is the backfill that is allowed in normal embankment construction.

Select Granular Backfill - Select granular backfill is the granular backfill that meets the gradation, corrosion, unit weight, internal friction angle and any other requirements.

Soil Reinforcement - Soil reinforcement holds the wall facing panels in position and provides reinforcement for the soil. The soil reinforcement can be strips, grids, or mesh. The reinforcement can be made of steel (inextensible materials) or polymers (extensible materials).

Spacers - Wall panel spacers are typically ribbed elastomeric or polymeric pads. They are inserted between panels to help provide the proper spacing. Proper spacing keeps the panels from having point contact and spalling the concrete.

Wall Facing Panel - Wall Facing panels or panels are used to hold the soil in position at the face of the wall. The panels are made of precast concrete.

Wall/Reinforcement Connection - This is where the connection is made between the wall facing panel and the soil reinforcing.

Wood Clamps – Wood clamps are pieces of wood with a steel bolt. It is used to hold the panel in place once the panel is set. The panel is not released from the crane until the wood clams are in place and tight.

Wooden Spacers - Wooden spacers are used to space the panels at the ¾” vertical spacing. The spacer is held between the panels as they are set to ensure the joints are not too close or far away.

The wooden wedges should be made from any hard wood.

Wooden Wedges - Wooden wedges are used to help hold the panels at the correct batter during the filling operation. The wooden wedges should be made from hard wood (such as oak, maple or ash).

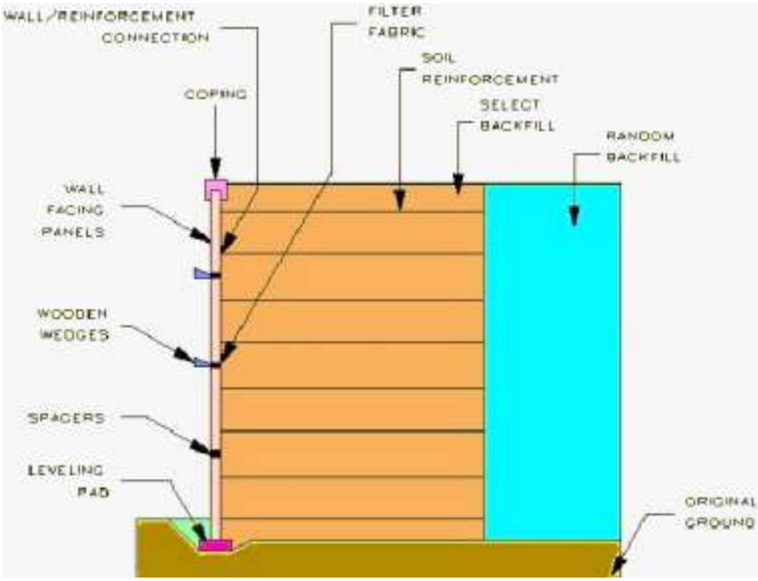


Figure 840.01.G MSE Wall Parts

MSE Wall Construction

The wall system consists of the original ground, concrete leveling pad, wall facing panels, coping, soil reinforcement, select backfill and any loads and surcharges. All of these items have an affect on the performance of the MSE wall and are taken into account in the stability analysis. A change in any of these items could have a detrimental effect on the wall. The construction sequence follows:

Wall Excavation (840.06.C)

There are many instances that the MSE wall is constructed in a cut section. This means that the excavation behind the wall needs to be supported temporarily in order to construct the wall. A pay item for Cofferdams Cribs and Sheeting will be included in all MSE Wall plans, but if it is missing, the specification states that the cost for cofferdams, cribs and sheeting are included with the MSE wall pay item. The Contractor is responsible for supporting the wall excavation. A cut slope will be shown in the plans which will be filled with select granular backfill. The select granular backfill will be a separate pay item. All other work to support the excavation or to fill the void behind the wall will be the responsibility of the Contractor.

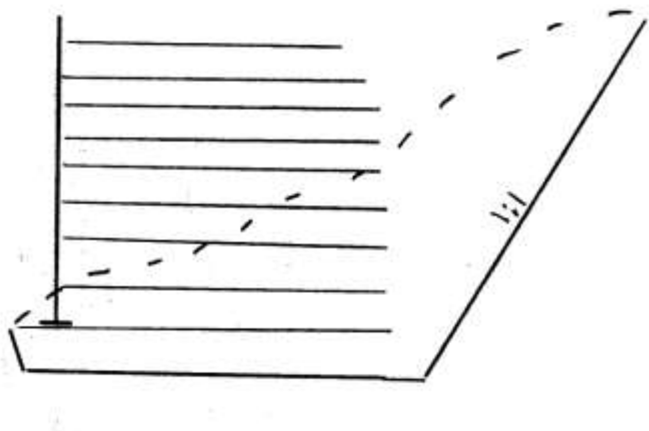


Figure 840.06.C.1 Excavation and Select Granular Backfill Areas

Figure 840.06.C.1 shows the wall excavation and embankment areas. All of the area below the dotted line is paid for under wall excavation. All the area between the wall and the 1 to 1 slope is filled with select granular backfill. The area below the leveling pad is filled with undercut material. Below is a field view of the same situation.

Figure 840.06.C.2 Area Behind the Wall

Foundation (840.06.D)

Preparation and Compaction

The MSE wall footprint area needs to be prepared in the leveling pad, soil reinforcement and select granular backfill areas.

Figure 840.06.D.1 Foundation Preparation

Figure 840.06.D.1 above shows a track hoe excavating down to the MSE wall foundation. All organic matter, vegetation, slide debris and other unstable materials detailed as unsuitable in 703.16 needs to be removed. Once the unsuitable soil is removed, one foot outside of the foot print formed by the leveling pad and soil reinforcement needs to be compacted. The foundation needs to be compacted to meet the requirements of 203.07. If the foundation material is granular then the material needs to be compacted by one of the test section methods detailed in S-1015.

Once the foundation is compacted, then the foundation for the wall needs to be graded level for the full length and width of the leveling pad and the soil reinforcement.

Foundation Evaluation

Once the foundation is compacted the Department needs to evaluate the foundation. The plan design soils consultant needs to be contacted to evaluate the foundation. This can be paid for through continuing services during construction through the project design coordinator. The soils consultant will evaluate the soil conditions. In the design phase a bearing capacity and stability analysis was performed for the MSE wall based on the plan borings. This needs to be reevaluated based on the existing soil conditions during construction. The soils consultant will make a field visit to the site to determine if the foundation soils found during construction meet the soil conditions designed for in the plans. They will then write a report to the Department to give us there results. The Contractors pay depends on receiving this report so the Contractor will prompt the Department to make this evaluation.

The project should review the soils consultant report. The project should ensure that the excavated soils match the soil borings performed to design the wall. If the existing conditions do not match plan soil borings or there are any unusual problems with the report then contact the State Construction Geotechnical Engineer.

Undercut and Drainage

Drainage and the foundation conditions are important parameters of the MSE Wall system. Therefore many contracts will detail an undercut. If an undercut is in the plans then the foundation work detailed above should be performed on the foundation of the undercut.

Below is a sketch that details a standard undercut.

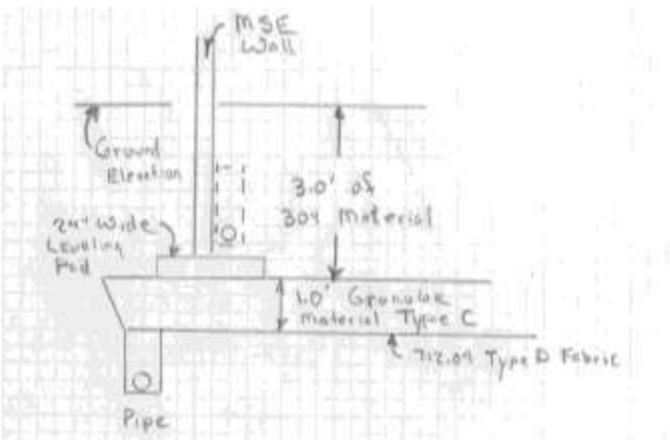


Figure 840.06.D.2 Standard Foundation Undercut

Once the foundation of the undercut is compacted then the drainage pipe is constructed. The plans will detail the pipe with a pay item. The pipe must be outletted. There will be at least 50 feet of outlet pipe in the plans to outlet the pipe. The project will have to look for an outlet if it is not detailed in the plans. Pipe, manholes and other items can be used as a drainage outlet.

If the pipe cannot be drained then move the pipe up to the outside of the wall until it can be drained. The dotted pipe in Figure 840.06.D.2 above the leveling pad represents this pipe. It is shown on the inside of the wall, But there is no need to put the drain on the inside of the wall. It can go on the outside of the wall also. The sand on the inside is free draining.

If the foundation or the foundation of the undercut cannot be compacted then an undercut depth may need to be determined. The following general procedure can be used to estimate the required depth of undercut.

Test pits can be used to further evaluate the foundation. For details on how to construct a test pit see Section 204. Construct two test pits, one on each side of the foundation of the wall or in the area of suspect soil conditions. Dig the test pit at least 3 feet deep. Take three penetrometer readings in each type of soil. If less than three soil types exists in the test pit then take readings in at least three different locations along the side walls of the test pits. Take a reading in the bottom of the test pit also. Use form CA-EW-3 to record the readings. All four sections on the form need to be filled out.

Once the readings are completed, average the values for each type of soil then average all four averaged values for the soil types. Once the average is obtained record the information on the Critical Layer or Design Layer on the bottom of the CA-EW-3.

The undercut depth can be obtained by using Subgrade Treatment Chart in section 204. Use the new construction line on the chart and the Critical Layer or Design Layer value previously calculated for the test pit. The determined undercut depth will result in a firm construction foundation.

Do not partially undercut the foundation. This would lead to differential settlement. If an undercut is required, then undercut the entire foundation.

Figure 840.06.D.3 below shows a five foot undercut operation. The replacement material in this case was a well graded blast rock. The material of choice for foundation replacement should be Item 203 Granular Material Type C. The upper portion should be chocked off with at least one foot of Item 203 Granular Material Type B. Geotextile Fabric Type D should be placed below the Granular Material Type C. This will prevent the piping of fines from the top and the bottom of the Granular Material Type C.

Figure 840.06.D.3 Replacing the Foundation

Leveling Pad Construction (840.06.E)

Once the foundation is compacted and prepared, a 2-foot wide and 6-inch thick un-reinforced concrete pad is constructed. The purpose of this pad is to serve as a guide for the wall panel erection. This leveling pad is not intended to provide significant structural foundation support in the final configuration of the wall. But there is significant construction panel loading on the leveling pad. Therefore it must be properly constructed and on a firm foundation in order to minimize potential wall movements during the construction of the wall.

Figure 840.06.E.1 Leveling Pad Construction

The leveling pad is important to the construction of the wall because the leveling pad sets the horizontal and vertical alignment of the wall. It must be in the correct horizontal position, level and at the correct grade.

Figure 840.06.E.2 Accurate Leveling Pad Construction is Important

If the final wall is not level, the panels will bind against each other causing spalling of the edges and corners. If the wall is not started correctly, the finished product is seldom satisfactory.

No more than 2 shims (each 3/16 inch thick) should be required to level the panels on the leveling pad. If level cannot be obtained with two shims then the leveling pad and the bottom of the panels needs to be checked.

Figure 840.06.E.3 Improper Shimming

Under no circumstances are bearing pads allowed on the leveling pad. Using bearing pads can create point loads on the panels and allow for movement of the panels during construction.

Figure 840.06.E.4 Bearing Pads are Not Allowed on the Leveling Pad

Care must be taken to ensure the leaving pad is correctly aligned. The leveling pad is 24 inches wide to allow for some alignment errors and inconsistencies such as happens when going around corners and curves. In addition, the wider leveling pad will supply more support during construction.

Do not allow any overhanging of the panels off the leveling pad. If this happens, stop the construction and investigate the problem. If needed, reconstruct the leveling pad.

Figure 840.06.E.5 Improper Overhang

Leveling pads that change in elevation have special challenges in design and construction. Figure 840.06.E.6 below details this challenge. This figure is a general step up figure with some of the dimensions changing in the new SS-840.

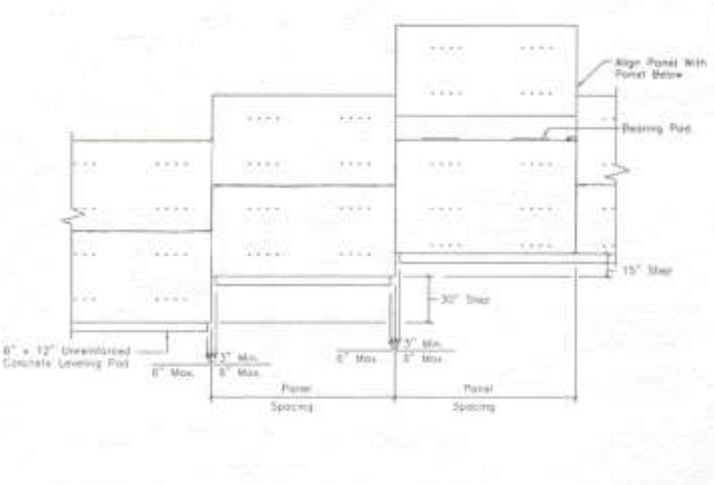


Figure 840.06.E.6 Change in Leveling Pad Elevation

The challenge is to arrange the leveling pad and panels so that when this elevation change occurs the panel is almost fully supported by the leveling pads. Multiple elevation changes are even more difficult to construct. In all cases, a six inch maximum overhang along the wall is allowed. The minimum distance being around 3 inches.

Figure 840.06.E.7 Acceptable if Less than 6 inch Overhang

The concrete leveling pad must cure for at least 12 hours before wall panels can be placed.

Figure 840.06.E.8 Finished Concrete Leveling Pad

Wall Panels Types and Parts (840.04)

Wall panels come in many shapes and sizes. The most common are the square, rectangular or cruciform. They can be custom built into any configuration that will fit together. The front face can have any type of finish, shape, texture or other surface treatments that can be formed.

Figure 840.04.A Reinforced Earth Panels

Figure 840.04.B Rectangular Panels

Figure 840.04.C Textured Finish Panels

Corner Panels

Corner panels provide a good connection between the two walls and act like slip joints for the wall allowing differential movement between the two walls.

Figure 840.04.D Corner Panels

Slip Joints

Typical a slip joint is used to handle large differential vertical movement of the wall. There are two in the figure below one on each side of the corner section.

Figure 840.04.E Corner (front) and Slip Joints (One on Each Side)

Panel Storage (840.05)

Panels should be stored flat and on spacers or dunnage. Spacers are typically sent by supplier on pallets of panels. Spacers protect the galvanized soil reinforcement connections from being bent or damaged by other panels. Panel faces should be kept away from areas that are muddy to prevent staining of the face of the panel. The project should ensure that panels don't have spalling or cracking upon delivery to the site.

Correct storage is shown in Figure 840.05.A. Note that the dunnage height is more than the soil reinforcement connections to minimize damage.

Figure 840.05.A Proper Panel Storage with Dunnage

Figure 840.05.B is an example of improperly stored panels. The panels in this case can get chipped or cracked.

Figure 840.05.B Improper Panel Storage

The soil reinforcement connections can get bent also.

Figure 840.05.C Damaged Tabs

Panel Inspection (840.05)

Panel Dimensions

When the panels first arrive at the project, the panel documentation needs to be checked. The panels come in with a TE-24. The documentation required with this TE-24 are a record of final inspection of all precast components and the measurements of the tolerances, strength and dimensions of all panels. As one final check the dimensions need to be randomly checked at the project. The shipment paperwork, shop drawings and the actual panel dimensions need to be compared to ensure that issues are found in a timely manner. The earlier in the process that these problems are found the better off we are in terms of correcting the issues. Some of the panel items to pay particular attention to are:

1. Length, Width and Thickness
2. Squareness
3. Finish

Physical measurements of the panels are required. The project should use a tape and carpenters square to check the above. All of these dimensions have an effect on the Contractor's ability to construct the wall within the specification tolerances.

Figure 840.05.D Checking the Squareness of the Panel

Damage to the Galvanized Soil Reinforcement Connections

If the soil reinforcement connections are damaged to the point that it inhibits the soil reinforcement from being attached then the panel needs to be rejected. Many times the connection is filled with residual cement or concrete that does not allow the soil reinforcement to be connected. If this is the case then have the Contractor clean out the connections. Do not cut the soil reinforcements.

If the connections are bent more than 15 degrees from perpendicular then the panel needs to be rejected. When bent beyond 15 degrees, the galvanizing is compromised and cannot be repaired.

Damage to the Panels

The panels also need to be inspected for damage. Panels can be damaged almost anywhere in the manufacturing or construction process. Many of the chips and cracks are caused by poor handling. Chips or spalls can be prevented by using nylon straps in the handling process. Cracks can be avoided by using care in the handling process. There is a list of defects and damages in 840.05.H that are sufficient reason for rejecting a panel. Depending on the severity of the damage, the Contractor may propose a repair.

Figure 840.05.E Rejected Cracked Panel

Figure 840.05.F Rejected Lifting Spall

Figure 840.05.G Repairable Lifting Strap Spalling

Figure 840.05.H Repairable Handling Spalls

Wall Construction (840.06.G)

Panel Identification

At this point, we have constructed the foundation, added drainage, checked the materials and constructed the leveling pad.

There is one last step we need to perform before we construct the wall; the wall and shop drawings must be checked to ensure that the correct panels are being used in the correct location along the wall. Depending on the wall height, the panel shape or design, the number of soil reinforcement connections on the back of the panel may vary. The panels with the most connections will typically be in the lower panels of the wall. In the upper portions of the wall, the number of connections may be less. It is important that the panels are used in their proper position. Below is a typical shop drawing showing the panel organization.

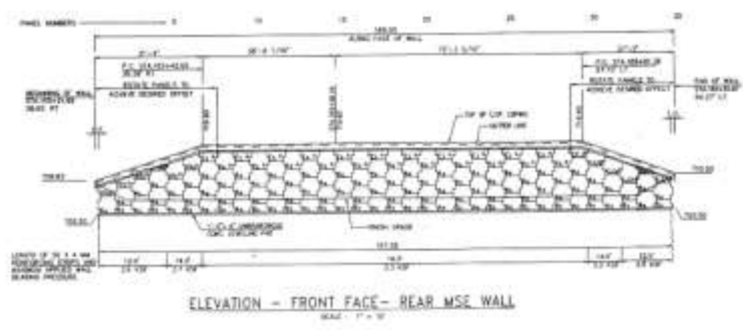


Figure 840.06.G.1 Typical Panel Erection Shop Drawing

The erection drawings have a numerical code on each panel that depicts its position in the wall. In the above shop drawing, the letter “A” denotes full height panels in the first row and the subsequent rows until the shape changes as the panel is just below the coping. The letter “B” denotes half height panels in the first row. The codes HX, F11, L11, KX, K, E, EX, HJJ, KJJ, LJJ, DJJ and EJJ denote panels just below the coping. (Note combination of letters) R or L will be used to denote the right or left side of the wall. A number that follows the letters denotes the number of tie strips required for the panels. Below is a code that details the panel letter and numerical system.

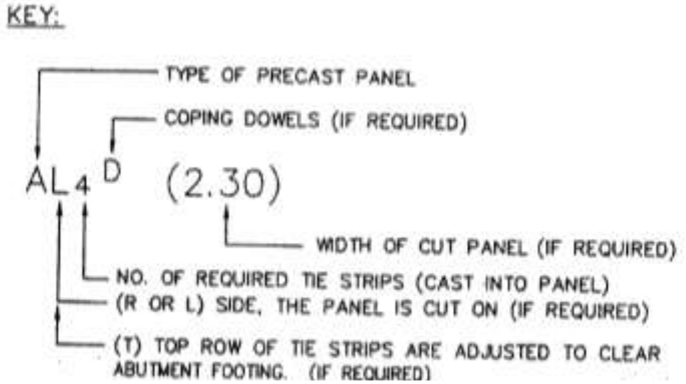


Figure 840.06.G.2 Code for Panel Placement (Reinforced Earth)

The code that is detailed above is for Reinforced Earth walls. The code for other wall systems will be different, and the code for a particular wall system may change at any time. The codes are marked on the back of the panels for easy reference during construction. Below is a photo of the marking on the back of a panel.

Figure 840.06.G.3 Actual Panel Markings

The above markings show piece A has 3 tie strips and is on the right side of the wall. Other required markings include date of manufacturing, production lot number and the precaster's and accredited manufacturer's inspection and acceptance marks.

Placing the Panels

Picking up the panels is an important aspect of the construction procedure. If the panels are not properly picked up spalling or cracking can occur. The figure below shows the correct method of picking up the panels. The crane lifts the panel such that no concrete to concrete contact occurs.

Figure 840.06.G.4 Picking up the Panels

The correct placement of the first row or two of panels is very important. When the panel construction is not started correctly the finished product is rarely satisfactory.

In the figure below, a chalk line is placed on the leveling pad to properly align the panels along the leveling pad. Sometimes a 2×4 is used to align the panels. Adjust the alignment using a crowbar as shown below. At this point the panel is still supported by the crane.

Figure 840.06.G.5 Proper Placement

As one last check of the horizontal alignment, the panel to panel horizontal offset needs to be checked. Use a straight edge across the panel horizontal joints to ensure that the panel to panel horizontal offset does not exceed a ½ inch.

The first row may be composed of both half and full height panels. A photo of full and half height panels is shown below. The panels need to be in proper alignment and level.

Figure 840.06.G.6 Half Height Panels

Horizontal Leveling

Once the panel is placed on the leveling pad the panel needs to be leveled horizontally. A 6-foot level rod is placed on the top surface of the panel to determine if it is level.

Figure 840.06.G.7 Proper Horizontal Leveling

If it is not, shims are placed under the panel in order to make the panel level. Galvanized metal washers or rubber shims are allowed. A maximum 3/8 of an inch in total shim height at any location is allowed. If more shims are required then the leveling pad is not level or the panel bottoms are not flat. In either case, the issue is the Contractor's responsibility to resolve.

Figure 840.06.G.8 Metal Shims to Level the Panels

Horizontal Joint Spacing

Without the correct joint spacing, panel corners will crack and spall with the wall settlement. Spacing blocks must be used. As the panels are placed together, the ¾ inch spacers are placed in the joints. The panels are maneuvered so that there is contact between both panels and the joint spacer. The required joint spacing is ¾ of an inch plus or minus ¼ of an inch. If this spacing cannot be achieved, the Contractor is required to submit an action plan to correct the problem. The spacer is shown in the figure below. If the panel is moved during the joint spacing adjustment then the horizontal leveling should be checked again.

Leave the horizontal spacers in until ½ panel height is filled with backfill.

Figure 840.06.G.9 Wooden Joint Spacers

Vertical Alignment

The panels need to be set with a backward batter toward the inside of the wall. The typical batter is about 1/8 inch per foot of panel height or about ½ to 1 inch per panel. The act of compacting the backfill behind the wall pushes the panel outward so the panel will be vertical once the fill is placed against it. The amount of batter is adjusted for the site conditions such as backfill properties; the finer sand may require a more batter. If a fine graded material, such as foundry sand, is used then it may require a one inch batter. A well-graded crushed limestone may require a half an inch batter.

Figure 840.06.G.10 Batter Check

A level with a batter spacer is placed on the outside or inside of the wall. Use the outside of the wall unless textured. The batter spacer can be used on the top or bottom of the level. If the level is used on the outside of the wall, the batter spacer is used on the top of the level. If the level is used on the inside of the wall the spacer is used on the bottom of the level. The spacer is usually duct taped on to the level at a thickness of the batter. In the figure below, it shows the batter spacer being used on the inside of the wall.

Figure 840.06.G.11 Vertical Leveling Spacer on the Inside of the Wall

The level can also be used on the outside of the wall as shown below.

Figure 840.06.G.12 Vertical Batter on the Outside of the Wall

Vertical and horizontal alignments and joint spacing needs to be checked one last time prior to temporarily locking the panel in place. For the entire time the horizontal leveling, joint spacing and vertical alignment is being adjusted, the panel is still suspended from the crane so that the panel is not damaged.

Triangular Wedges and Wood Blocks

Wooden triangular wedges are used to lock the panel into vertical alignment once the wall is battered with the level. The wedges are shown below on the leveling pad.

Figure 840.06.G.13 Wooden Wedges for Vertical Alignment

No more than three levels or rows of the wooden wedges should be placed in the wall without removing the lower row. If more than three levels of wedges are used they may become bound in the wall making them very difficult to remove and can cause the panel to spall.

Wooden clamps are then used to hold the panels together. Wooden clamps are two pieces of wood held together with a long bolt. The bolt is tightened to hold the panels together.

Figure 840.06.G.14 Wooden Clamps

Triangular wedges are also used in combination with the clamps to secure the panels as shown in the figure below.

Figure 840.06.G.15 Triangular Wedges and Wooden Clamps

External bracing is required for the first row of panels to maintain stability and alignment. Typical bracing is shown below.

Figure 840.06.G.16 Proper Bracing

At this point the geotextile fabric and the select granular backfill is placed to the height of the wooden clamps. These steps will be described in detail later.

When panels are placed on one another, a horizontal bearing pad is used to separate the panels. A minimum of two bearing pads are used. The horizontal joint should be ¾ inch at this point. Some Accredited Wall Systems may supply thicker bearing pads. This is anticipation of the bearing pads deflecting under the load of the wall. Check the accepted wall shop drawings to ensure that the thicker pads are allowed.

Figure 840.06.G.17 Bearing Pads on the Second Row

Subsequent panel rows are placed betweens panels that were previously placed. The ability to properly space and align these rows relies on the proper placement of the lower rows. All of the error produced by the lower rows is propagated upward and is difficult to correct. The same leveling, joint spacing, vertical and horizontal alignment also applies to all the rows.

Figure 840.06.G.18 Panel Placement

Panel to panel vertical offset needs to be checked as soon as the next row of panels is placed. Use a straight edge across the vertical joints to ensure that the offset between panels is less than a ½ inch.

Figure 840.06.G.19 Second Row of Panels Placed

The process starts all over again as crow bars are used to align the next row of panels.

Figure 840.06.G.20 An Existing Joint Offset Problem

Alignments need to be checked periodically to ensure proper alignment. This will ensure that problems are spotted early and corrections can be made before the panels get too far out of alignment.

Figure 840.06.G.21 Wall Alignment

As stated before, the panels are battered back so that the fill placement can move them forward into a vertical position. After the fill is placed, check the vertical position of the wall. After the third row of panels are placed, use a plumb bob to check the vertical alignment. Hold the plumb bob at the top of the panel and measure the out of plumbness as shown below.

Figure 840.06.G.22 Checking Vertical Alignment with a Plumb Bob

The tolerance is ½ of an inch in 10 feet. By using a 10-foot straight edge and a level or a plumb bob this tolerance can be measured. At no point along the straight edge can any portion of the panels be more than an inch away from the string or straight edge.

Figure 840.06.G.23 Measure from the Wall to the String (Out of Plumb Here)

A summary of the wall erection tolerances are listed below:

1. Vertical Tolerance: ½ inch overall and 1 inch at any point
   Use a 10-foot straight edge
2. Horizontal Tolerance: ½ inch overall and ½ inch at any point
   Use a 10-foot straight edge
3. Panel to Panel Tolerance: ½ inch horizontal and vertical
   Use a 6-foot straight edge

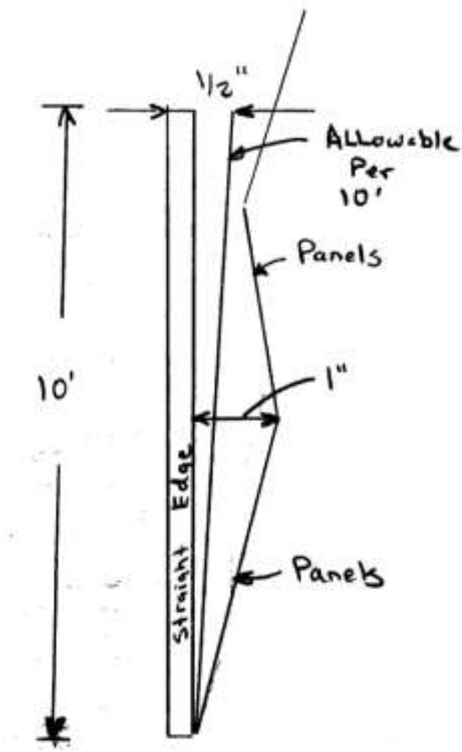


Figure 840.06.G.24 Panel Tolerances

Filter Fabric Placement and Inspection

Filter fabric is placed across the joints so that the granular backfill does not leak through the joints to the outside of the wall. The minimum lap on each side of the joint is one foot on each side of the joint and one foot along any cut piece of fabric along the joint. These requirements apply to horizontal and vertical joints.

The fabric is cut in lengths to cover the horizontal and vertical joints. Once the fabric is cut, the fabric is laid on a flat surface. An adhesive is used to hold the filter fabric in place until the select granular backfill is placed over the joints. A thick bead of the adhesive approximately ½ an inch in diameter is applied around the entire perimeter of the fabric about two inches from the edges of the fabric. See the figure below.

Figure 840.06.G.25 Correct Application of the Adhesive

Figure 840.06.G.26 Fabric Completely Covering the Joints

Once adhesive is applied to the fabric it is immediately placed on the wall. Ensure that the fabric is placed on the wall before the adhesive dries. The fabric needs to fully engage the wall at all locations to ensure that the sand does not leak through the joints.

Figure 840.06.G.27 Wrong Application of the Adhesive on the Wall

A shown above, randomly placing adhesive on the wall does not ensure that the joint is properly sealed. More adhesive is not necessarily good. Correctly applied adhesive and the appropriate placement of the fabric is the solution.

In the past, some projects have only glued the top portion of the fabric applied to a horizontal joint. This method should be discontinued and not be allowed.

Figure 840.06.G.28 Partial Gluing (Do not allow this)

Small tears or wrinkles in the fabric can cause leaking of the sand. Any leaking of the sand through the joints is not tolerable. Leaking sand is like a leaky water pipe; it never gets better with time, it only gets worse.

Once the fabric and the backfill are placed, the project should go around to the front of the wall to inspect the joint spacing and the fabric's ability to hold the sand behind the wall. Take a flash light and inspect the joints. Look to see if the fabric is in place and holding the sand back.

Look for deposits of sand in the horizontal and vertical joints as shown below.

Figure 840.06.G.29 Sand in the Joints on the Outside of the Panels

Sand deposits may be caused by sand falling over the wall during construction or the sand is leaking through the joints. By carefully inspecting the joints, the source of the sand deposit will be found. In the figure below, the sand is leaking out of the joints and being deposited on the ground.

Figure 840.06.G.30 Sand Falling from Several Joints

After further inspection of the wall from behind, it was found that the fabric was not placed in the upper portion of the MSE Wall. This project was about three years old at the time of the inspection. A thorough inspection during the construction of the wall would have prevented this maintenance problem.

Figure 840.06.G.31 No Fabric Placed Behind the Wall

Below is a photo of a wall taken shortly after construction. As you can see there are sand deposits at the bottom of the slip joints. In this case, the fabric was either not placed or improperly placed.

Figure 840.06.G.32 Sand Piles around Slip Joints

In the figure below, looking behind the wall at a typical slip joint during construction, you can see that the fabric has to go around a bend. Careful construction in this location is required. When placing fabric around corners or obstructions leave the fabric loose so that it does not tear during the placement of the backfill in the corner.

Figure 840.06.G.33 Fabric Placement around a Slip Joint

There are a lot of other items of work that obstruct the proper placement of the fabric in this situation. In the figure below, there are the reinforcing steel, wooden clamps, and a settlement plate that the fabric needs to go around. There is ample opportunity for sand to leak around the fabric if we are not careful.

Figure 840.06.G.34 Obstructions near a Slip Joint

The joint spacing needs to be reexamined in the front of the wall. We have previously checked and recorded the joint spacing when the panels were constructed. There may be cases where after the wall is constructed the joint spacing is wider than the allowable ¾ of an inch plus ¼ of an inch.

Figure 840.06.G.35 Wide Joint and Exposed Fabric

The joint gap in the above figure is almost 1¾ of an inch. The gap is wider than the panel's ship lap, thereby exposing the fabric. The width of the ship lap is about 1½ inches. In the above case, the Contractor needs to be instructed to place expansive foam and caulk to the joint to prevent the fabric being exposed to sunlight.

Sunlight can cause the fabric to deteriorate with time, whether it is direct or indirect. Therefore, a flashlight is used to ensure that sunlight exposure to the fabric is minimized. A flashlight is held perpendicular to the joints about six inches away from the joint. Such a flashlight test is shown in the figure below.

Figure 840.06.G.36 Flashlight Test

If the light from the flashlight can be seen on the fabric, then the joint needs to be sealed. Expanding foam and caulk is used to cover the fabric.

There have been instances where, after the wall has been constructed, the fabric is being destroyed during the water jetting operation. The water jetting is used to clean the panels prior to sealing. Therefore, examine the joints after the sealing operation.

As a final note on the wall construction, continue to monitor the wall throughout the duration of the project. The wall is designed and constructed to tolerate movement. But too much movement is detrimental to the wall and the structural items around the wall.

Select Granular Backfill Material and Placement (840.06.I)

Material

The granular backfill materials have special requirements that are not normally associated with granular material in other items of work. There are material requirements such as pH, resistivity, chloride and sulfate levels. These requirements minimize the corrosion of the metal soil reinforcement. The project and district test lab need to review and evaluate the test data for these requirements. Ensure that the test results meet the specification requirements and that the correct tests were taken on the materials. If the backfill material does not meet these requirements then there is a high probability that the metal soil reinforcement will prematurely corrode and the life of the MSE Wall will be shortened.

Another requirement is the internal angle of friction. The internal angle of friction is critical to the design of the wall. The wall design and the factor of safety are sensitive to numerical value of the friction angle. The factor of safety can change dramatically with only a few degree friction angle change. The design friction angle is 34 degrees. The test ensures that the design assumption is valid.

The specification allows the use of granular material type 2 which is old Item 310 material. It can be a very fine sand or a coarse 304 type material. Since economics drives the material choice, the vast majority of the time sand is used.

The specification also allows the use of Item 304 material. This material is a well graded and very stable material.

It is a requirement to use the Item 304 material for the first 3 feet of backfill behind the wall. This is a stronger material and is more resistant to the influences of water. After the first 3 feet are placed, the sand or the 304 may be used.

Select Granular Backfill Placement and Compaction

The below placement and compaction procedures were developed to produce uniform compaction of the select granular backfill (SGB). Uniform placement and compaction of this material is essential in order to keep uniform pressure against wall as it is constructed. Unnecessary compaction or non-uniform compaction of this material can create bulges in the wall or loose areas in the backfill behind the wall. This procedure is to be followed all the way to the top of the wall.

On the initial row of panels (and only the initial row of panels) the backfill is not placed against the panel until the first layer of soil reinforcement has been connected and the initial layer of backfill is placed and compacted on top of the soil reinforcement. This is to keep the bottom of the panels from “kicking out”. If the SGB cannot be compacted effectively below the first row of soil reinforcement (because some manufacturers may have mesh that we cannot compact through) then the wall supplier will need to design a kicker to prevent the wall from kicking out at the bottom.

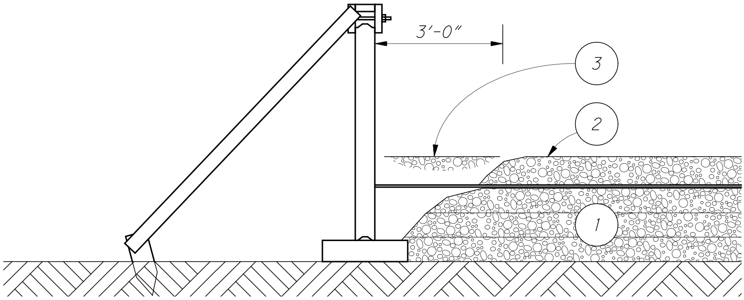


Figure 840.06.I.1 Backfilling for the First Panel Only

Once the backfill is placed and compacted to the elevation of the first layer of soil reinforcement as shown in Figure 840.06.I.1, the soil reinforcement is connected. Then the next loose lift is placed on top of the soil reinforcement 3 feet away from the wall. The material is then leveled by moving it parallel to the wall and windrowing the material toward the soil reinforcement ends and away from the wall. See Figure 840.06.I.2 for the spreading operation details. This SGB material 3 feet away from the wall is then compacted in the same way as it was placed.

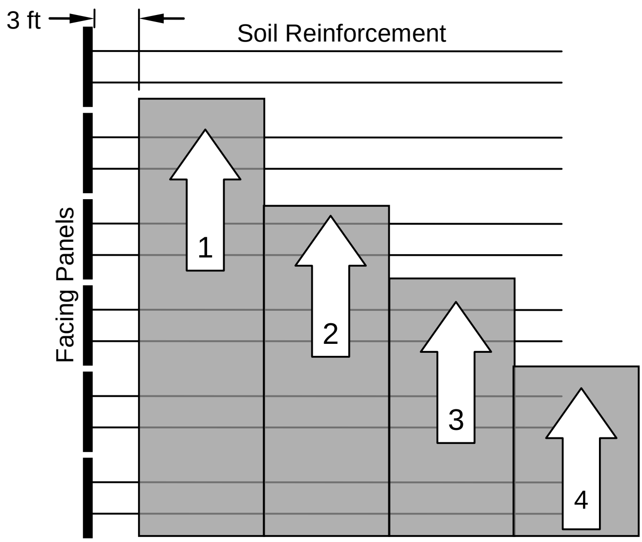


Figure 840.06.I.2 Procedure for SGB Placement and Compaction

Once this is completed, then the void is filled and compacted next to the wall to the elevation of the soil reinforcement. The material void left above the soil reinforcement is then placed and compacted. Place and compact this inner most 3 feet as detailed in Figure 840.06.I.3. Within three feet of the wall, the SGB is compacted with six passes of a mechanical tamper or vibratory plate compactor. The compaction equipment should have a centrifugal force between ½ and 2 tons.

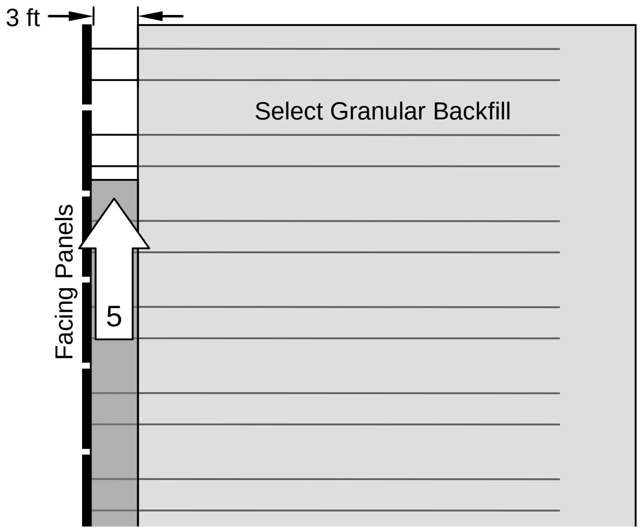


Figure 840.06.I.3 Place and Compact the SGB Next to the Facing Panels

Use the procedure detailed in Figures 840.06.I.2 and 840.06.I.3 for the SGB placement and compaction procedure for the remaining sections of wall.

The SGB is placed in maximum 8-inch loose lifts. It may be helpful to mark the lift thicknesses on the back side of the wall panels. The action of moving the SGB parallel to the wall and windrowing or compacting the material toward the reinforcement ends and away from the wall takes out the slack in the reinforcement and locks the reinforcement and the panels in position.

Figure 840.06.I.4 Improper Spreading Technique
(From back to front is improper)

Any slack in the reinforcement should be removed to avoid excessive panel movement. With geogrid soil reinforcement some tension needs to be applied to the reinforcement by means of a kicker tension device or a rod during this backfill placement.

Figure 840.06.I.5 Final Compaction Operation Next to the Wall

Consistent placement and compaction of SGB are one of the keys to a good performing MSE Wall.

Compaction Testing of the Select Granular Backfill

No compaction testing is performed on the SGB within three feet of the wall. For the SGB more than three feet from the wall facing panels, smooth-drum vibratory rollers weighting between 6 and 10 tons are required to compact the material. The compaction testing is performed according to Supplements 1015 and 878.

Supplement 878 details the general inspection and compaction testing requirements when these services are hired through the Contractor. All of the inspection and compaction procedures that are required for ODOT inspection personnel are required for the Contractor's personnel under S-878. A trained compaction and inspection person is required under this specification. All of the Department inspection and compaction forms are to be used.

Supplement 1015 details the inspection and compaction procedures to be employed during the work.

At the beginning of the work, a test section is constructed to determine the density requirements for the select granular backfill. The moisture requirements are determined by using the moisture density curve for the Method A test section. For a Method B test section, the moisture requirements are determined by constructing several test sections at different moisture contents. For determining which test section that is used see section S-1015.

The select granular material is compacted between three percent below and optimum moisture content. If additional water is required after spreading the material then water must be added to meet these requirements. The moisture content of the select granular backfill material prior to and during compaction is to be uniformly distributed throughout each layer of material. If watering is required after spreading then the project should dig up the material to ensure that this requirement is met.

Figure 840.06.I.6 Taking a Compaction Tests

Once the moisture content is correct, the test section is constructed to determine the density requirements for the remaining areas of the select granular backfill. This test section is approximately 40 square yards. This test section is compacted until a maximum density is achieved. The number of passes and the maximum density is used in the remainder of the work. A minimum of 98 percent of the maximum density is required. A new test section should be constructed if the compaction tests are not close to the maximum value by using the same number of passes, if the material or foundation conditions change.

In the figure below, the compaction started from 3 away from the wall and is proceeding to the back of the soil reinforcement. In the background, the area within three feet from the wall is compacted after the roller compaction is complete. This procedure was detailed in the previous section.

Figure 840.06.I.7 Smooth-drum Vibratory Compaction Equipment

Maintenance and Drainage (840.06.F)

At the end of each day's operation, the Contractor is to shape the last layer of backfill to allow rainwater to runoff away from the wall face. The drainage system is under or in front of the wall. This will permit the water to dissipate from the system. The SGB of the wall can be drained laterally to dissipate out to the sides. Drainage problems can develop similar to the figure below.

Figure 840.06.F.1 Washout around the Soil Reinforcement

Water ponding in front of the wall has been a problem is the past. In the figure below, you can see the ponding of the water in front of the wall. This is not acceptable.

Figure 840.06.F.2 Water Ponding in Front of the Wall

It is required to pump the water out of this area immediately after the water is ponded. In addition, once the wall is erected up to the ground elevation, this void is filled with embankment material. This will further stabilize the wall.

If water is ponding behind the wall during construction as shown below:

Figure 840.06.F.3 Water Ponding Behind the Wall

Then collect the water by using a drainage curtain as detailed below:

Figure 840.06.F.4 Drainage Blanket

Side slope erosion has been a problem in the past. One solution has been to construct 2 feet of embankment on the side slopes. This will bury the highly erosive select granular material and erosion can be minimized.

Figure 840.06.F.5 Protection of the Erosive Side Slopes with Embankment

Soil Reinforcement Placement (840.06.H)

Soil Reinforcement Storage

The soil reinforcement is used to tie the wall to the soil. Like the panels, the soil reinforcement should be stored on dunnage and carefully handled to prevent damage. Damage may include bending of the metallic reinforcement and damaging the galvanization. The geogrid soil reinforcement should not be torn, cut, left in the sun or otherwise damaged.

No equipment should be allowed to run directly on the reinforcement.

Figure 840.06.H.1 Reinforcement Storage on Dunnage

The project should check for required length and gauge of steel reinforcement. Check the condition of steel reinforcement upon delivery to the site. Below is a typical plan view of the soil reinforcement on a project. The length of the reinforcement from the wall is directly proportionate to the height of the wall. The wall height below is the highest in the center and the length of the reinforcing is the longest. The length of the reinforcing cannot change from the bottom to the top of the wall. It can only change along the wall due to changes in the height or design changes.

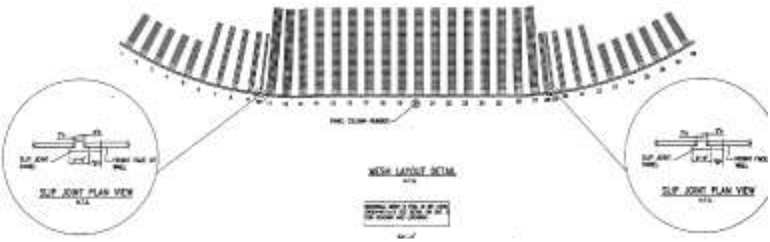


Figure 840.06.H.2 Typical Reinforcement Layout

Below is a detail of a cross sectional view of the soil reinforcement in the same wall. Notice the soil reinforcement connection to the wall and regular intervals.

The length of the reinforcing is the same from the bottom of the wall to the top of the wall. Many of these walls are placed below an abutment as detailed below.

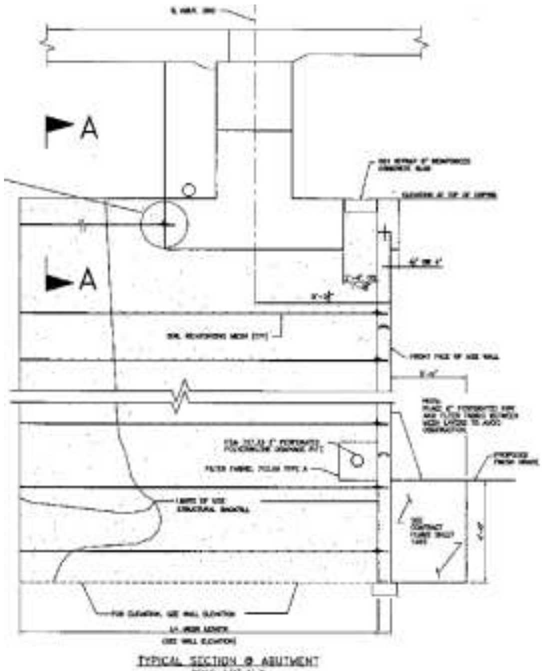


Figure 840.06.H.3 Cross Section of the Soil Reinforcement Layout

Below in the following details are the reinforcing mesh codes for a Foster wall. These are the codes that were used on past projects. For Foster walls, the reinforcing mesh will change frequently. The project should familiarize themselves with the codes on the shop drawings and ensure that the correct mesh types are placed in the proper location.

In the figure below, it details the wire mesh codes. Careful review of these keys is required by the project.

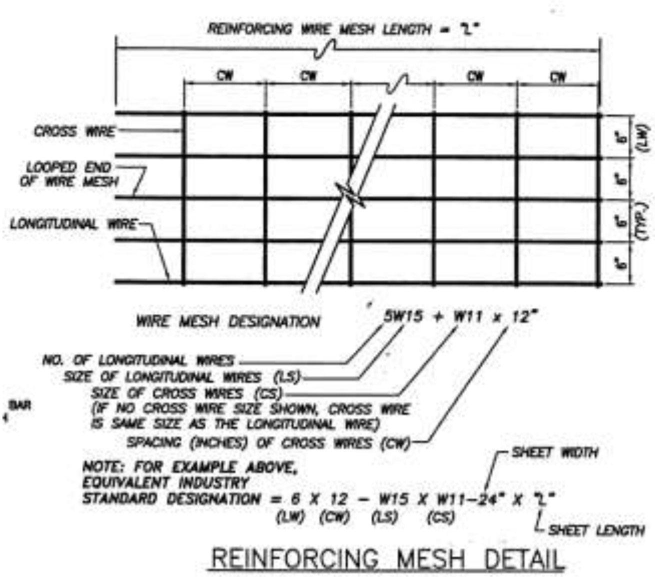


Figure 840.06.H.4 Reinforcing Mesh Details

In the detail below, it shows a sample of how the reinforcing mesh is laid out as it relates to the panels. The panels are numbered in the example and the type of reinforcing mesh is detailed beside the panel type.

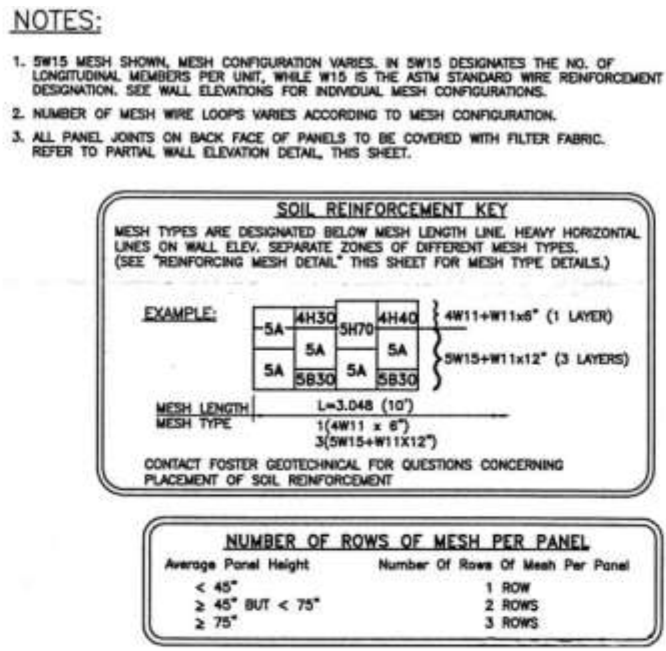


Figure 840.06.H.5 Reinforcing Panel and Reinforcing Key

Typically, the reinforcement is placed perpendicular to the wall face. Any slack in the reinforcement should be removed. The geogrid soil reinforcement should have some tension placed in the reinforcement. By using the placement and compaction procedure detailed in the previous section it will keep the tension in the soil reinforcement.

Once the fill is compacted to the elevation of the soil reinforcement, the soil reinforcement can be attached to the facing panels and placed perpendicular to the face of the wall on top of the compacted material.

Connections

Connecting the soil reinforcing to the wall is relatively simple operation. There are three connections that will be detailed below.

Reinforced Earth Connection

A Reinforced Earth Wall's connections and soil reinforcement consist of galvanized strips, tabs manufactured in the wall and nuts and bolts to connect them. There are tabs with holes that stick out of the wall about 3 inches. The tabs have a top and bottom and go around the strips when they are connected.

Figure 840.06.H.6 Reinforced Earth Connections and Strips

At times there is concrete inside the tabs that makes it difficult to place the strips inside the tabs. The concrete needs to be cleaned out to line up the holes. Many times the Contractor will cut the strips instead of cleaning out the concrete. Do not allow the strips to be cut in the field. This can reduce the strength of the connection. Also, the galvanizing of the strip will be compromised and the strip will prematurely rust.

Figure 840.06.H.7 Tabs for Reinforced Earth Connections

Once the holes are lined up, the bolt is inserted from the bottom up and the nut is tightened. By placing the bolt from the bottom, it is easy to see if the nut has been placed on the connection.

Figure 840.06.H.8 Bolted Reinforced Earth Connection

Below are multiple strips connected to the wall for a Reinforced Earth Wall. Leaving the select granular backfill lower at the tabs is acceptable. The select granular backfill needs to be as close to the strips as possible for all wall types.

Figure 840.06.H.9 Reinforced Earth Multiple Connections to the Wall

<u>Wire Mesh Connection</u>

The connection for steel wire mesh soil reinforcement consists of hooked eyelets in the panels and reinforcing mesh with two transverse bars at the end. The end of the wire mesh is laid with the two transverse bars resting on top of the hooked eyelets. A rod is inserted through the eyelets, locking the mesh into place, as shown below. Wooden wedges are then hammered between the wall and the mesh to put the eyelets in full contact with the mesh and the soil reinforcement in tension.

Figure 840.06.H.10 Wire Mesh Type Connection

Below is a typical layout of the soil reinforcement of a wire mesh wall.

Figure 840.06.H.11 Mesh Steel Laid Out

Geogrid Soil Reinforcement Connection

The connection for geogrid soil reinforcement consists of short sections of geogrid cast into the panels and a plastic bodkin bar. The ribs of the geogrid soil reinforcement are meshed with the short sections of geogrid that are cast into the panels. Then the plastic bodkin is weaved between the two sets of ribs and the soil reinforcement is pulled tight. The completed connection is shown below.

Figure 840.06.H.12 Geogrid Soil Reinforcement Connection

Figure 840.06.H.13 Overview of Geogrid Soil Reinforcement

Obstructions

There are times when the soil reinforcements have to go around obstructions. It is not acceptable to just simply leave out the reinforcement at that location. This would create a weak location along the wall.

At horizontal obstructions, such as pipes, the reinforcement should not be angled more than 15 degrees up or down. All situations that exceed 15 degrees must be detailed on the accepted shop drawings or acceptable to the Office of Structural Engineering. The soil reinforcement must have a four inch clearance above or below the obstruction. Also, when clearing horizontal obstructions, the reinforcement should be smoothly curved around the obstruction. The reinforcement should not be kinked at any time.

The detail below shows a horizontal obstruction lower than the soil reinforcing and connection.

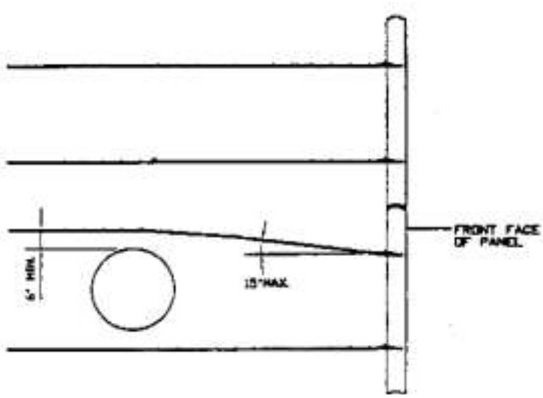


Figure 840.06.H.14 Soil Reinforcement going over a Horizontal Obstruction

The detail below shows a horizontal obstruction higher than the soil reinforcing and connection.

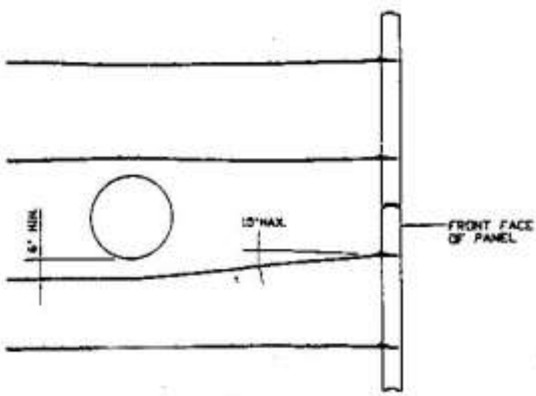


Figure 840.06.H.15 Soil Reinforcement going under a Horizontal Obstruction

The photo below shows the soil reinforcement going under a storm sewer line.

Figure 840.06.H.16 Soil Reinforcement going under a Storm Sewer Line

At vertical obstructions, such as piles or catch basins, if the reinforcement must be splayed more than 15 degrees from horizontal the accepted shop drawings should detail a modification. All situations that exceed 15 degrees must be detailed on the accepted shop drawings or acceptable to the Office of Structural Engineering. It may require additional reinforcement length to meet design.

Figure 840.06.H.17 Soil Reinforcement Splayed Around Piles

In the detail below, the soil reinforcement was designed around the inlet by using a galvanized angle in front of the inlet and keeping the reinforcing steel perpendicular to the wall. Again this would have to be detailed on the acceptable shop drawings.

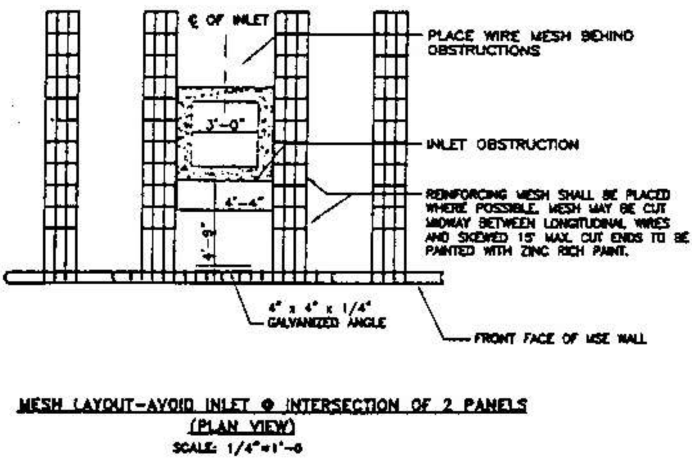


Figure 840.06.H.18 Typical Details for Obstructions

Below is a photo of the galvanized angle in front of the catch basin to allow the soil reinforcement to be placed around the catch basin.

Figure 840.06.H.19 Field Example of the Reinforcing Around an Obstruction

In the detail below, the reinforcing mesh is cut and splayed around the inlet. No angle is required in front of the inlet.

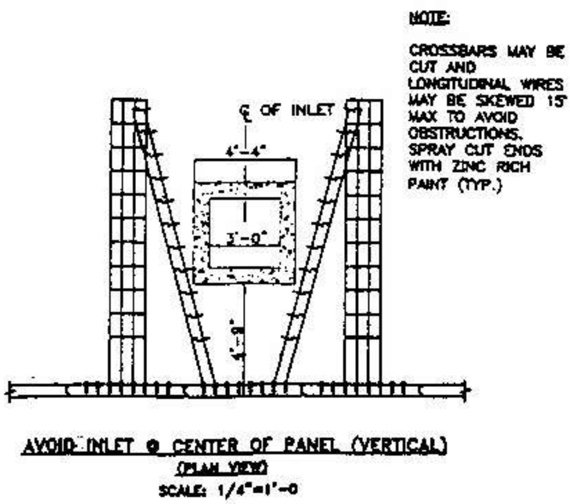


Figure 840.06.H.20 Cutting the Mesh to go around the Obstruction

Coping (840.06.K)

The coping is then placed on the top of the wall. It is used to smooth out the appearance of the top of the wall and to connect adjacent panels at the top of the wall. The wall is completed when the coping is properly installed on top of the wall. The coping has to be cast in place on the top of the wall.

Here is the typical form and reinforcing steel for the coping.

Figure 840.06.K.1 Forming the Coping

Moment Slab

The moment slab is put on the top of the wall to prevent vehicles from going off the roadway. It has to have a large support system to resist these loads. The reinforcing steel is shown below.

Figure 840.06.K.2 Moment Slab Reinforcing Steel

The finished moment slab is shown below.

Figure 840.06.K.3 Completed Moment Slab

If your project has a concrete pavement on top of the wall there may be a problem with crack propagation of the barrier joints on to the pavement. Review these details carefully and make adjustments as required.

Figure 840.06.K.4 Align the Joints of the Barrier and the Concrete Pavement

Design Conflicts, Design and Construction Loads

Before the actual start of construction of the wall, the various parts of the plans (shop drawings, drainage, lighting, etc.) need to be compared to the contract wall plans to check for conflicts. A conflict may not have been noticed in the design stage. If the plans show heavy loads on the wall and the shop drawings do not indicate it, the Office of Structural Engineering should be contacted. The Designer may have missed loadings from various types of structures. If they did not take these loads into consideration, the wall could bow or even fail. This also can happen for temporary loads that the Contractor may impose such as pile driving.

Final Checks

There are various items that need to be evaluated at the end of the project such as sand leaking out of the joints, open joints, exposed fabric settlement and more.

There are multiple power point presentations on the Office of Constructions web site under Training. The Web site is as following

http://www.dot.state.oh.us/construction/OCA/training/training.htm

Check Lists

The following is a general checklist to follow when constructing a Mechanically Stabilized Earth wall (MSE wall). The answer to each of these should be yes unless the plans, specifications or specific approval has been given otherwise.

YES NO

☐ ☐ 1. Has the contractor submitted wall shop drawings?

☐ ☐ 2. Has the contractor submitted select granular backfill certified test data?

☐ ☐ 3. Has the contractor supplied a the wall suppliers construction manual?

☐ ☐ 4. Have the shop drawings been accepted?

☐ ☐ 5 Do we have the correct panels (shape, size and soil reinforcement connection layout) per the accepted shop drawings?

☐ ☐ 6. Do we have the correct reinforcement (proper length and size)?

☐ ☐ 7. Have the panels and the reinforcement been inspected for damage as outlined in the specifications?

☐ ☐ 8. If any panels or soil reinforcement were found damaged have they been rejected or repaired in accordance with the specifications?

☐ ☐ 9. Are the panels and the soil reinforcement properly stored to prevent damage?

☐ ☐ 10. Has the MSE wall area been excavated to the proper elevation?

☐ ☐ 11. Has the foundation been properly evaluated?

☐ ☐ 12. Has the drainage for the wall been installed ?

☐ ☐ 13. Has the leveling pad area been properly excavated?

☐ ☐ 14. Has the leveling pad been set to the proper vertical and horizontal alignment?

☐ ☐ 15. Has the leveling pad cured for a minimum of 12 hours before any panels are set?

☐ ☐ 16. Is the first row of panels properly placed? Do they have proper spacing, bracing, tilt and where required, do they have the spacers installed?

☐ ☐ 17. Has the proper filter fabric and adhesive been supplied?

☐ ☐ 18. Is the filter fabric being properly placed over the joints?

☐ ☐ 19. Is the adhesive being applied to the fabric then on to the wall?

YES NO

☐ ☐ 20. Is the filter fabric being stored properly (stored out of the sunlight and protected from UV radiation)?

☐ ☐ 21. Is the contractor using the correct panels (correct size, shape and with the proper number of connections) for that panel's wall location and elevation?

☐ ☐ 22. Is the fill being placed and compacted in 8 inch loose lifts?

☐ ☐ 23. Is the equipment being kept off of the soil reinforcement until a minimum of 8 inches of fill is placed?

☐ ☐ 24. Are the lifts being placed by the proper method and sequence?

☐ ☐ 25. Is the fill being compacted by the correct equipment and in the correct pattern?

☐ ☐ 26. Is the proper compaction being met?

☐ ☐ 27. Is the soil reinforcement being properly connected (connections tight and all of the slack in the soil reinforcement removed)?

☐ ☐ 28. Is the soil reinforcement in the proper alignment?

☐ ☐ 29. Is the vertical and horizontal alignment being checked periodically and adjusted as needed?

☐ ☐ 30. Is the contractor removing the wooden wedges as per the specifications? (The wooden wedges shall be removed as soon as the panel above the wedged panel is completely erected and backfilled.)

☐ ☐ 31. At the end of each day's operation is the contractor shaping the last layer of backfill to permit runoff of rainwater away from the wall face or providing a positive means of controlling runoff away from the wall such as temporary pipe, etc?

☐ ☐ 32. Has the contractor backfilled the front of the wall?

☐ ☐ 33. Is the coping being installed correctly?

MSE Wall Construction Do's and Don'ts

1. Review approved shop drawings.
2. Review the Section 840 in the MOP for Mechanically Stabilized Earth (MSE) Walls.
3. Verify leveling pad elevations.
4. Confirm fill material has been tested and approved before it is brought to the job site.
5. Inspect panels.
6. Inspect soil reinforcement for damage.
7. Reject all panels that are not in compliance with the plans and specifications.
8. Ensure panels, soil reinforcement and filter fabrics are properly stored to prevent damage.
9. Ensure the reinforcing can go around all obstructions with less than 15 degrees of splay.
10. Install panels in accordance with the plans and specifications.
11. Place and properly compact fill in accordance with plans and specifications.
12. DO NOT use thick fill lifts. Fill lifts thicker than 8-inch loose lifts require more energy to compact and may move the panels out of alignment.
13. Use corner panels at all corners. If corner panels are not indicated on the plans, the designer should be notified.
14. Soil reinforcement should not be splayed more than 15 degrees from normal. If reinforcement needs to be splayed more than 15 degrees, notify the designer.
15. Check the batter of the panels often. Adjust accordingly. The vertical alignment of the panels below the panels being installed may be affected by the compaction of the soil behind the panels being installed.
16. Check overall batter regularly.
17. When attaching filter fabric to the back of the panels, the adhesive shall be applied to the fabric then attached to the panel.

Out of Tolerances Conditions and Possible Causes Criteria

The following is taken out of FHWA's Publication "Mechanically Stabilized Earth Walls And Reinforced Soil Slopes Design & Construction Guidelines" NHI Course No. 132042.

Table 16. Out-of-Tolerance Conditions and Possible Causes

MSE structures are to be erected in strict compliance with the structural and aesthetic requirements of the plans, specifications, and contract documents. The desired results can generally be achieved through the use of quality materials, correct construction/erection procedures, and proper inspection. However, there may be occasions when dimensional tolerances and/or aesthetic limits are exceeded. Corrective measures should quickly be taken to bring the work within acceptable limits. Presented below are several out-of-tolerance conditions and their possible causes.

Distress	Possible Causes
1. Distress in wall: Differential settlement or low spot in wall. Overall wall leaning beyond vertical alignment tolerance. Panel contact, resulting in spalling/chipping	Foundation (subgrade) material too soft or wet for proper bearing. Fill material of poor quality or not properly compacted.
2. First panel course difficult (impossible) to set and/or maintain level. Panel-to-panel contact resulting in spalling and/or chipping.	Leveling pad not within tolerance.
3. Wall out of vertical alignment tolerance (plumbness), or leaning out.	Panel not battered sufficiently. Oversized backfill placing and/or compaction equipment working within 3-foot zone of back of wall facing panels. Backfill material placed wet of optimum moisture content. Backfill contains excessive fine materials (beyond the specifications for percent of materials passing a No. 200 sieve). Backfill material pushed against back of facing panel before being compacted above reinforcing elements. Excessive or vibratory compaction of uniform, medium-fine sand (more than 60 percent passing a No. 40 sieve). Backfill material dumped to close to free end of reinforcing elements, then spread toward back of wall, causing displacement of reinforcements and pushing panel out. Shoulder wedges not seated properly. Shoulder clamps not tight. Slack in reinforcement to facing connections. Inconsistent tensioning of the geosynthetic reinforcement. Localized over compaction

Distress	Possible Causes
4. Wall out of vertical alignment tolerance (plumbness) or leaning in.	Excessive batter set in panels for select granular backfill material being used. Inadequate compaction of the backfill. Possible bearing capacity failure.
5. Wall out of horizontal alignment tolerance, or bulging.	Backfill material placed wet of optimum moisture content. Backfill contains excessive fine materials (beyond the specifications for percent of materials passing a No. 200 sieve). Backfill material pushed against back of facing panel before being compacted above reinforcing elements. Excessive or vibratory compaction of uniform, medium-fine sand (more than 60 percent passing a No. 40 sieve). Inconsistent tensioning of the geosynthetic reinforcement. Localized over compaction Backfill saturated by heavy rain or improper grading of backfill after each day's operations.
6. Panels do not fit properly in their intended locations.	Panels are not level. Differential settlement (see Cause 1). Panel cast beyond tolerances. Failure to use spacer bar.
7. Large variations in movement of adjacent panels.	Backfill material not uniform. Backfill compaction not uniform. Inconsistent setting of facing panels.

Documentation Requirements – 840 MSE Walls

1. Did the panels arrive with a TE-24?
2. Were the panels rejected or repaired as per the specifications?
3. Was the select granular material approved?
4. If the wall was in a cut were the sidewalls properly protected?
5. Was the foundation properly prepared?
6. Was the drainage properly constructed?
7. Was the filter fabric properly placed?
8. Was the foundation undercut properly constructed?
9. Was the leveling pad placed as specified?
10. Were the wall panels placed according to the plan and markings on the back of the panels?
11. Was external bracing used for the first lift of panels?
12. Were the horizontal and vertical tolerances met?
13. Was the soil reinforcement placed perpendicular to the wall face?
14. Was the SGB placed in 8-inch lifts?
15. Was the backfill compacted to the specification requirements?
16. Was the backfill within 3 feet of the wall compacted to the specification requirements?
17. Did a manufacturer's representative inspect the site during the wall construction?
18. Did the soils consultant properly take the compaction tests?
19. Was the coping and traffic barrier constructed properly?
20. Were the pile sleeves constructed properly?
21. Perform all the compaction tests according to S-1015 or SS-878.

22. Document on the CA-EW-1,CA-EW-3, CA-EW-8, CA-EW-12 and CA-D-3. Do not duplicate the information on all forms unless necessary

850 Cement Treated Free Draining Base

Materials (850.02)

The cement treated free draining base (CTFDB) is to be a mixture of coarse aggregate, Portland cement and water.

Cement used must be Type 1A (701.01) or Type I (701.04) conforming to ASTM C 150.

The coarse aggregate used can be either No. 57 or No. 67 size per Table 703.01-1.

Proportioning, Mixing and Transporting (850.03)

The Contractor must proportion, mix and transport the CTFDB according to Item 499.

The mix is to be prepared as follows:

Use a minimum cement content of 250 pounds per cubic yard (148 kg/m^3) when using No. 57 size coarse aggregate and it must be 220 pounds per cubic yard (130 kg/m^3) when using No. 67 size.

The water-cement ratio is to be 0.36.

A water- reducing admixture meeting 705.12 can be used.

Verification of Design (850.04)

The Contractor must submit a mix design for the proposed CTFDB 30 days prior to the start of production. This mix design must describe the proposed aggregate size, the cement content and the water content by weight. A private laboratory must perform tests on the proposed mix to verify the yield of the mix design.

Inspection should include random sampling of the CTFDB material delivered to the project to ensure conformance to the mix design. The unit weight of the mix must be determined and the yield checked.

Equipment (850.05)

The Contractor must provide all equipment necessary to mix, transport, place, compact and finish the CTFDB. Equipment must be approved before the work begins.

A spreader must be used if the width being placed is more than 12 feet (3.6 m) or the total area of any given width exceeds 5000 square yards (4000 m^2) of area. The spreader could be a concrete spreader or an asphalt paving machine.

Initial compaction may be done by using a steel wheel roller, a modified slip-form paving machine with vibratory plates or high-density screed pavers. Compaction must not crush aggregate particles or cause segregation. Final compaction must be done with steel wheel rollers weighing 6 to 10 tons (5 to 9 metric tons). If vibratory rollers are used, do not use them in vibratory mode.

Spreading with an Asphalt Paving Machine

Spreading CTFDB with a Concrete Spreader

Placing and Spreading (850.06)

The Contractor must thoroughly moisten the base if there is no prime coat specified in the contract, prior to placing the CTFDB. Workers must not contaminate the CTFDB by walking through it with mud other foreign material on their work shoes.

The CTFDB must be spread in a smooth uniform layer prior to compacting it.

Inspection should include sampling the CTFDB mixture and testing for in place gradation after it is spread and before compaction. This testing is to be done in accordance with Supplement 1090.

Limitations on Placing Operations (850.07)

Minimum temperature is required to be 35 ºF (2 ºC) and rising.

The material is not placed on frozen material or on rain softened subgrade or base.

Vibrating Plate behind Concrete Spreader

Steel Wheel Roller Compact the CTFDB

Compaction and Shaping (850.08)

The CTFDB is to be shaped to produce a uniform density and cross-section. Compaction must not cause crushing of the aggregate particles.

The Contractor must make a minimum of two passes over any given area with the required steel wheel rollers.

Construction joints between each day's work must be made by cutting transversely across the hardened CTFDB with diamond saws or the contractor is permitted to use forms to form the construction joints.

Curing CTFDB with 6-mil White Opaque Polyethylene Sheeting

Curing (850.09)

Curing of CTFDB is to be done by placing 6-mil (150 µm) white opaque polyethylene sheets over the completed work. These coverings must be left in place for a minimum of three days. A cure day is defined as 24 consecutive hours of time in which the temperature is above 40 ºF (5 ºC). Add a cure day for each day the temperature falls below 40 ºF (5 ºC). Do not allow the use of liquid concrete curing membranes for curing.

Protection of Underdrains (850.10)

Care must be exercised by the contractor so as to not damage any installed underdrains during placing or compacting of the CTFDB. The Contractor must ensure positive connection between the underdrain backfill and the CTFDB at all times during construction.

Protection of Cement Treated Free Draining Base (850.11)

The Contractor is permitted to haul materials or operate equipment on completed CTFDB provided there is no significant displacement, breakup or contamination. If any of this occurs, the Contractor must stop using the completed CTFDB for such purposes until the Contractor can demonstrate to the Department that it will not happen again in the future. Any damage to the CTFDB must be corrected by the contractor at no cost to the State.

The Contractor must protect the completed CTFDB from contamination from fine material at all times.

The Contractor must use track mounted asphalt paving machines for placing the first lift of asphalt concrete on top of completed CTFDB. This first course must cure at a minimum over-night before placing succeeding lifts of asphalt concrete.

Thickness Tolerances (850.12)

The compacted depth of the CTFDB is to be 4 inches (100 mm) with a tolerance of ±½ inch (13 mm). Depth checks must be made every 2000 square yards (1650 m^2). Areas found to be out of this tolerance must be removed and replaced at no cost to the Department and retested for proper thickness.

Surface Tolerance (850.13)

The CTFDB must be constructed to the proper elevation and have the plan specified cross-slope. Checks should be made periodically to verify these parameters. The surface tolerance of the finished surface must not vary more than ½ inch from a 10 foot (13 mm from a 3 m) straightedge. Any irregularities exceeding this amount must be corrected by the Contractor.

Exposure to the Elements (850.14)

The Contractor is required to place the next pavement layer on top of the CTFDB within 40 days from the end of the curing period. In addition, the Contractor must plan the work such that the CTFDB is completely covered with the next pavement layer and have the underdrain system in place and functioning by the end of the construction season in any calendar year.

Method of Measurement and Basis of Payment (850.15 & 850.16)

The project will measure and calculate the area in square yards (square meters) based on the typical sections shown on the plans. Payment will be made at the contract bid price for work that is accepted in place.

Documentation Requirements - 850 Cement Treated Free Draining Base

1. Materials
2. Verify design
3. Proportioning and mixing as per 850.03.
4. Prime base or sprinkle base with water
5. Temperature must be above 35 °F (1.6 °C)

6. Use a spreader, if project quantity exceeds 5,000 square yards (4,000 square meters)
7. Compact and cure in accordance with 850.08, and 850.09
8. Check segregation and thickness.
9. Curing and protection.
10. Pay and measure according to 850.15 and 850.16.
11. Document on CA-EW-12 and CA-D-1 and CA-D-2.Do not duplicate the information on these forms unless necessary.

851 Asphalt Treated Free Draining Base

Description (851.01)

This work consists of constructing asphalt treated free draining base (ATFDB) course, mixed in a central plant and spread and compacted on a prepared surface. The (ATFDB) drainage layer is immediately beneath the pavement and is made of graded aggregate, asphalt-treated permeable material. Construction of this drainage layers will serve satisfactorily as drains and as structural support for the surfacing materials.

The requirements of Item 401 apply, except as modified by Supplemental Specification 851.

Materials & Composition (851.02 & 851.03)

The aggregate gradation should conform to Table 703.01-1 and 703.04 with the exceptions detailed in 851.02 and the binder should be PG 64-22 conforming to the requirements of 702.01. The contractor is not allowed to use reclaimed asphalt concrete pavement in the mix.

The binder amount should be 1.5 to 3.5 percent by weight of the mix with the aggregate. Ensure that the aggregate does not show excess drainage at 250 °F (120 °C) and is coated with shiny black coating of asphalt binder.

Brown or dull mix appearance is not acceptable and is a sign of excess aggregate absorption of the asphalt binder or low asphalt binder content. Minor bare aggregate exposure is acceptable.

Design Verification (851.04)

A minimum of 3 weeks before the production of the ATFDB, the contractor should submit a computed blend of aggregate and asphalt binder, using standard JMF submittal forms, and production temperature range to the Laboratory for initial design verification. The contractor should notify the Laboratory before the delivery of any material.

Final design verification is subject to field verification and actual performance. Field verification may include additional testing by the Laboratory.

Rollers (851.06)

The contractor should use only tandem steel wheel rollers weighing 6 to 10 tons (5.5 to 9 metric tons) for compaction.

Weather Limitations (851.07)

The contractor should spread the ATFDB mix only when the atmospheric temperature is above 45 °F (7 °C).

Cease all operations if rain occurs during placement of the ATFDB, or when rain is imminent. Do not spread on frozen material.

Spreading and Compacting (851.08)

The contractor should spread the ATFDB material in a method that produces a smooth, uniform layer before compacting. Cease all operations when signs of degradation, segregation, or contamination are evident. Communicate with the contractor and the material monitor to resolve the problem before resuming placement.

The contractor should compact the ATFDB sufficiently, by compacting the layer at least two roller passes over any given point, unless otherwise directed by the engineer for more passes. Do not over compact the ATFDB to the extent where the aggregate particles are crushed or broken. Complete rolling before the mix temperature has dropped to less than 100 °F (38 °C).

Do not cool ATFDB with water.

Form transverse construction joints by cutting back into the completed work to form a vertical face.

If significant breakup of the ATFDB occurs at or near the outer portion of a lift during the compaction operation, provide lateral support using forms or other methods approved by the Engineer at no additional cost to the Department. Do not contaminate the ATFDB with this lateral support.

When the ATFDB is placed in areas inaccessible to rollers, compact it using a method approved by the Engineer.

After compaction has been completed, do not place the next layer of pavement on the ATFDB until the next day.

Thickness Tolerances (851.09)

The compacted thickness of the ATFDB layer should be 4 inches (100 mm). Ensure the placed ATFDB conforms to the specified thickness by randomly checking the thickness during construction. The district could run a dry-rodded unit weight to establish a conversion factor that could be used to establish the required placement rate as per 401. Also, since the loose layer does not compact much a check using a prod should be used frequently to check the layer thickness. Remove all sections found to be ±½ inch (±13 mm) from the specified thickness and replace them with ATFDB at no additional expense to the Department.

Surface Tolerance (851.10)

Ensure that the finished surface is uniform and varies no more than ½ inch (13 mm) from a 10-foot (3 m) straightedge applied to the surface parallel to the centerline of the pavement. Remove any section found to be out of tolerance and replace it with ATFDB within the specified tolerance at no additional expense to the Department.

Quality Control and Acceptance (851.11)

The quality control and acceptance requirements of Item 403 apply, except as detailed in 851.11. Project administrators should check with the district lab to ensure material conformance to the specifications.

The ATFDB should be coated with shiny black coating of asphalt binder and not be brown or dull in appearance. Minor inconsistent bare aggregate exposure is acceptable. If the delivered mix is brown or dull in appearance, immediately inform the district lab and the contractor to adjust the asphalt binder content.

Underdrains (851.12)

Ensure that the underdrain system is functional before placing the ATFDB. Do not allow construction equipment to crush the underdrain pipe or system as a result of the placement or compaction of the ATFDB. Ensure a positive connection between the underdrain system and the ATFDB regardless of the sequence of operations in the Contract Documents.

Protection of the ATFDB (851.13)

The ATFDB is not designed to carry construction traffic. The Engineer will allow hauling units and other construction vehicles to operate on the ATFDB provided no significant displacement, breakup, or contamination occurs. If the Engineer determines significant displacement, breakup, or contamination of the ATFDB is occurring, the Contractor shall stop operating hauling units and construction vehicles on the ATFDB. The contractor should repair or replace all damage to the ATFDB, subbase, subgrade, or underdrains caused by the hauling units or construction vehicles at no additional expense to the Department.

The ATFDB layer should be protected from fine material contamination. Adequate surface and subsurface drainage for the ATFDB, subbase, and subgrade should be provided at all times.

The Contractor may use a rubber tire paver if it does not damage the ATFDB, subbase, subgrade, or underdrains. If damage occurs, cease paving and switch the rubber tire paver with a track mounted paver before restarting the paving.

When constructing asphalt concrete pavement on the ATFDB, allow the first course to cure overnight before placing the succeeding pavement courses.

Exposure to the Elements (851.14)

The ATFDB layer should be covered by constructing the pavement within 40 days, and before the atmospheric temperature falls below 35 °F (2 °C) for any period of time

The contractor should remove and replace all damage caused to the ATFDB, subbase, subgrade, or underdrains by the exposure to temperatures below 35 °F (2 °C) at no additional expense to the Department.

Method of Measurement and Basis of Payment (851.15 & 851.16)

The Department will measure the accepted quantities of Asphalt Treated Free Draining Base by the number of square yards (square meters). The Department will measure the width as the width of the asphalt treated free draining base shown on the typical sections of the plans and additional widening where called for, or otherwise directed in writing by the Engineer. The Department will measure the length horizontally along the centerline of each roadway or ramp. Payment will be made at the contract bid price for work that is accepted in place.

Documentation Requirements - 851 Asphalt Treated Free Draining Base

1. State condition of base (example: primed 304, clean and dry concrete, etc.)
2. Write location on tickets where material is placed
3. Mark on ticket the time unloaded
4. Obtain temperature of the mix at project site and place this information on ticket of load checked. This should be done a minimum of four times daily or any time temperature is in question.
5. State kind of rolling equipment.
6. Calculate and document the required placement rate (Tons/Station)
7. Document on form CA-FP-4 Project documents compliance with Item 851 on Form CA-D-3A and measurements on CA-D-1 and 2
8. Document lift thickness
9. Tickets should be totaled with initialed and dated tape attached

S-1015 Compaction Testing for Unbound Materials

General

Supplement 1015 details the compaction testing requirements for all ODOT projects. ODOT technicians and testing personnel provided by the Contractor must follow the testing procedures described in S-1015.

When the Contractor will provide the compaction testing, one of two possible supplemental specifications will be included in the contract documents. The two supplemental specifications, SS-878 and SS-879, are similar, but SS-878 pays for the inspection and testing as a lump sum pay item, while SS-879 pays for the work by providing incentive pay to the contractor.

There is one compaction and inspection table for S-1015, SS-878 and SS-879. Table 1015.10-1 in Section 1015.10 includes columns for the materials, test or method, maximum lot size and minimum number of test. The same number and type of inspections and compaction tests are taken regardless of which specification is used in the contract.

SS-878 Inspection and Compaction Testing of Unbound Materials

This note is used when construction personnel are limited and the District wants full time inspection and compaction testing for the work.

SS-878 pays for the inspection and compaction testing as a lump sum pay item and covers Items 203, 204, 205, 206, 304, 307, 411, 503, 603 and MSE wall select granular backfill.

The major aspects of the specification are as follows:

1. The Contractor is to supply full time qualified inspection and compaction testing for all specified items.
2. The compaction tests are performed according to S-1015.
3. The documentation is performed on Department forms.
4. The documentation is presented to the Engineer daily and a summary report is required every two weeks.
5. There are qualifications requirements for the inspection and compaction personnel.
6. The Department will perform QA compaction tests.
7. There is a lump sum payment for this work.
8. Several Districts are using their own notes that require the Contractor to supply the compaction testing for a project. This supplemental specification requires comprehensive inspection and compaction testing for the work.

SS-879 QC/QA for Embankment Construction

The major aspects of the specification are as detailed below:

1. Several of the sections in this specification refer to SS-878 because they are basically the same work with the payment mechanism being different.
2. The Contractor supplies full time qualified inspection and compaction testing for Items 203 and 204.
3. The compaction tests are performed according to S-1015.
4. The documentation is performed on Department forms.
5. There are qualifications requirements for the inspection and compaction personnel.
6. The Department will perform QA compaction tests.

This supplemental specification is very similar to SS-878, except there is a pay adjustment plus or minus 4 percent to the amount bid for Items 203 and 204. This specification allows for more Contractor responsibility for the work with an appropriate incentive. It also allows the Department to reduce the amount of full time inspection of the work.

Metrication and Rounding

Most of the tables, forms, graphs, curves and tests in this section are in English and Metric units. The units are labeled with the English units first and the Metric units are in parenthesis, i.e., English (metric). All forms ending with an M are metric. (For example, CA-EW-5 is the English compaction form and CA-EW-5-M is the Metric form).

Weight measurements should be measured to the nearest 0.01 of a pound or kilogram. All calculations are normally recorded to the nearest 0.1 or 4 significant digits. Normally the final compaction results are recorded to the nearest percentage of compaction and acceptance is based on rounding. The rounding of 97.6 percent compaction is rounded up to 98 percent compaction, while 97.5 is rounded down to 97 percent compaction. The rounding of other calculations and measurements are done in a similar manner.

Importance of Proper Inspection and Compaction Testing

The Contractor constructs the embankment. As the representatives of the Department, our Inspectors and Engineers observe the work to ensure compliance with the specifications. As the Department inspects the work, we give instructions to the Contractor, such as the material is too dry, too wet, not enough stability or density.

What happens when an embankment fails and we determine that one of the following has occurred?

1. The instructions to the Contractor were in error.

2. Compaction tests were performed incorrectly.
3. Compaction forms were incomplete.
4. No inspection or part-time inspection occurred during the construction.

All of the above reasons are arguments that are issues during a claim. Valid or not, these are reasons that will be debated when responsibility is discussed. Considerable financial loss to the Department could result during these negotiations or in court because of any one of the above reasons.

Our goal with this section is to minimize the Department liability in the above claim situations.

In addition, compaction testing is an important evaluation tool that measures the quality of the earthwork construction work. Therefore, this entire section is dedicated to obtaining correct and accurate results.

Compaction of Soils (1015.01)

Moisture-Density Relationship (1015.01.A)

In order to understand compaction testing, the project personnel must first understand the moisture-density relationship and some of the variables associated with this relationship.

A relationship exists between the density of a soil and the moisture content of a soil as the moisture content is varied while the compactive effort remains constant. A standard force is used in the test that closely approximates the densities that can be readily obtained in the field with sheepsfoot rollers and other types of common compaction equipment. The greatest density obtained in the test is termed "maximum density" and the corresponding moisture content is termed "optimum moisture." This moisture-density relationship is shown in Figure 1015.01.A.

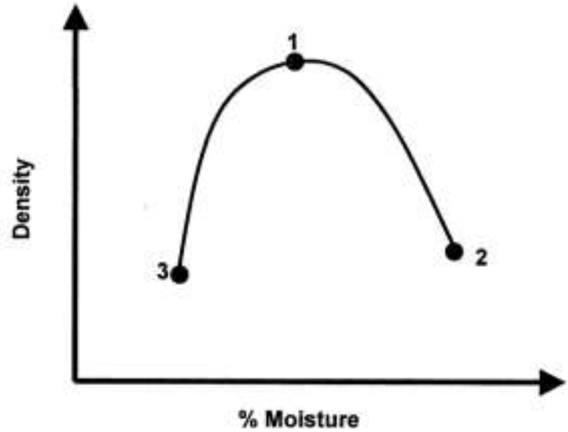


Figure 1015.01.A - Typical Moisture-Density Curve

The test used by the Department to determine the moisture-density relations of soil is AASHTO T-99, Method C. The basic principle involved in the moisture-density relationship is an important tool when evaluating a soil.

For a given force of compaction and given moisture content, a soil will have a corresponding density. Additionally, there is a particular moisture content for each soil at which a given compaction requirement can be obtained with less compaction effort than at any other moisture content. This moisture content is the optimum moisture content.

Structural properties of a soil vary with moisture content and density. For example, a clay soil at a low density will have very high load-supporting strength when dry, but when it is saturated at this same density it will have a very low load-supporting strength. Hence, when the structural properties of the soil are being determined, its moisture content and density must be defined and controlled to permit accurate evaluation of the soil in that particular condition.

Refer to Figure 1015.01.A to understand the influence of moisture on the compaction of soils. At point 3, the soil is compacted at a moisture content where the compactive effort cannot overcome the friction or resistance of the soil to achieve a maximum density. As the water content increases, the particles develop larger and larger water films around them, which tend to “lubricate” the particles and makes them easier to move about and reorient into a denser configuration.

However, as the moisture content is increased, we eventually reach point 1, where the density does not increase any further with water content. At point 1, the soil has just enough moisture to overcome most of the friction and not too much to have excess pore pressure to displace the soil.

As the moisture is increased from point 1 to 2, the density decreases as the water starts to displace and replace soil particles because of the excess pore pressure.

Making a Moisture-Density Curve (1015.01.B)

This section outlines procedures to determine the optimum moisture, maximum wet weight, and maximum dry weight of a soil, shale or granular materials. This data is used to determine the suitability of soil for use in embankment and subgrade and to establish a standard for field compaction control if needed.

The procedures outlined in this section follow AASHTO T-99, Method C with some minor modifications.

Equipment (1015.01.B.1)

The equipment needed to make a moisture-density curve is as follows:

1. Proctor Mold
    a. Cylindrical brass or cadmium-plated steel mold approximately 4 inches (102 mm) in diameter, 4.5 inches (114 mm) in height and having a capacity of 1/30 ft^3 ($9.43 \times 10\text{-}4\ m^3$).
    b. The cylinder is mounted on a removable base plate and fitted with a detachable collar approximately 2.5 inches (63 mm) in height.
2. Proctor Hammer
    a. Brass or cadmium-plated steel sleeve rammer having:
        i. A striking face 2 inches (50 mm) in diameter.
        ii. Weighing 5.5 lbs (2.5 kg).
        iii. Equipped to control the height of drop to 12 inches (305 mm).
3. Steel straightedge 12 inches (305 mm) long.
4. Scale of 25 lb (12 kg) capacity sensitive to 0.01 lbs (1 gram).
5. A 3/4-inch (19 mm) sieve.
6. Oil or gas stove or portable oven unless dried by other methods.
7. Baking pans, approximately 12 × 8.5 × 2.5 inches (300 × 200 × 63 mm).
8. Masonry trowel and putty knife.
9. If the test is performed in the field, use a large concrete block or piece of concrete beam.
    a. Minimum size is a 12 × 6 inch (300 × 150 mm) cinder block.
    b. Or a 4 × 12 inch (100 × 305 mm) solid concrete block.
    c. Do not use wood or asphalt.

Procedure (1015.01.B.2)

Use the form in Figure 1015.01.B to record test data as obtained by the procedure outlined in this section. This form shows an example of recorded test data. Each column is lettered and used throughout this section to facilitate referring to the explanation.

1. Secure a representative sample of soil of about 40 lbs (20 kg).
2. Pass the sample through a 3/4-inch (19 mm) sieve.
3. Wet or dry the sample.
    a. Change the moisture content to 4 to 6 percent below optimum.

   b. See 1015.01.F, "Estimating Optimum Moisture" in this section for more information.
4. Make a proctor.
   a. Make a specimen by compacting the prepared soil in the proctor mold.
      i. Make three equal layers to give a total compacted depth of about 5 inches (130 mm).
   b. Compact each layer by applying 25 uniformly distributed drops from the 5.5 lb (2.5 kg) rammer dropping from a height of 12 inches (305 mm) above the elevation of the soil.
   c. See Figure 1015.01.D for recommended Loose and Compacted Soil Lifts.
      i. Loose Lifts will change depending on the consistency of the soil.
   d. Ensure that the cylinder is resting on a uniformly rigid foundation during the compaction.
      i. Use a large concrete block or piece of concrete beam.
      ii. The minimum size is a 12 × 6 inch (300 × 150 mm) cinder block.
      iii. Or a 4 × 12 inch (100 × 305 mm) solid concrete block.
      iv. Do not use wood or asphalt.
5. Remove the extension collar.
   a. The soil should be less than ½ inch (13 mm) above the mold.
   b. If the soil is lower than the top of the mold, repeat the test.
   c. Carefully trim the compacted soil even with the top of the mold using the straightedge.
   d. Add fine material to fill any voids if necessary.
      i. Use the fines from the tested soil.
6. Weigh the cylinder and sample. Input this information in Column 'A'
   a. Calculate the density of the specimen by subtracting the weight of the mold from the weight of the specimen and mold, and multiply the difference by 30 for English units and 1060 for metric units.
      i. Column A – 9.81 lbs = Column B
         13.34 - 9.81 = 3.53
         9.81 is the weight of the mold
      ii. Column B × 30 = Column C
         3.53 × 30 = 105.9
      iii. Column C is the wet density of the proctor soil.
7. Remove the material from the mold and slice vertically through the center.
   a. Take a representative sample of the material from one of the cut faces and determine the moisture content by a method outlined in section 1015.02.H "Alternate Tests for Moisture".
   b. If the only available scales are those included in the compaction control kit, a 1 lb (0.5 kg) sample is required for the moisture determination. However, if a more sensitive scale

is available use a 0.22 lb (100 gram) sample. The smaller sample will dry faster.

i. The scales need to be leveled with a carpenter's level. Put the scale on a piece of flat plywood then level the board. You may elect to level the weighting plate.

ii. The older scales must also be balanced once it is leveled. The weighting mechanism should float between the top and bottom bar. If it does not then sand or pebbles can be added to the lever arm to make it balance.

c. Calculate the dry weight and the moisture content as follows:

i. Column D…Weight of the dish and the wet soil. 96.2

ii. Column E…. Weight of the dish and soil after drying. 93.4

iii. Column F…Column D - E = Weight of Water 96.2 - 93.4 = 2.8

iv. Column H…Column E - G= Dry Soil Weight 93.4 – 40.0 = 53.4

v. Column I…F/H × 100 = Percent Moisture Water Content = Weight of Water /Dry Weight (2.8/53.4) × 100 = 5.2%

vi. Column J…C/(1+ I) = Dry Weight of the Soil Dry Weight =Wet Weight/ (1 + Wc) In the Example:
WD= 105.9/(1+0.052) = 100.5

8. Thoroughly break up the remainder of the material until inspection shows that it will pass a ¾ inch (19 mm) sieve. It is not necessary to pass all of the material through the sieve.
9. Add water in sufficient amount to increase the moisture content of the soil sample by 2 or 3 percent, and repeat the procedure outlined in D through H.
10. Repeat D through H, each time adding water until you obtain at least 4 readings for the wet weight, dry weight and moisture content.

a. Continue the process until a minimum of two points are plotted on the wet and dry side of the dry weight curve and there is a decrease in the wet weight.

11. Use Figure 1015.01.C (1015.01.C-M) as an example and plot test data as follows:

a. Plot wet weight, 'Column C' versus moisture content, 'Column I' of the successive tests on linear graph paper.

i. Draw a smooth curve between the successive points.

ii. The peak of this curve is the maximum wet weight of the material being tested.

iii. This maximum weight is not used for compaction acceptance.

b. Plot dry weight, 'Column J', versus moisture content, 'Column I', of the successive tests on linear graph paper.

i. Draw a smooth curve between the successive points.
ii. The peak of this curve is the maximum dry weight of the soil.
iii. The moisture content at this point is the optimum moisture.
iv. This curve can be used for compaction acceptance.

Figure 1015.01.C (1015.01.C-M) shows curves plotted from the test data in Figure 1015.01.B.

CA-EW-4
03/03/03

STATE OF OHIO
DEPARTMENT OF TRANSPORTATION
WORKSHEET FOR
MOISTURE-DENSITY TEST

Project No. 722 (68) Date: 5-30-99

County: Ashland Tare: 9.81(Mold Weight) Operator: Dave Johnson

Sample: 1

A Weight of Compacted Sample + Container lbs. (kg.)	B Weight of Sample lbs. (kg.)	C Weight of Sample lbs/ft³ (kg/m³)	Penetration and Resistance: Size in² (mm²)	Reading lbs. (N)	Pressure lbs/in² (mPa)	Moisture Determination: Dish No.	D Wet Wt. + Dish grams	E Dry Wt. + Dish grams	F Water Wt. grams	G Dish Wt. grams	H Soil Wt. grams	I % Water (Dry)	J Dry Weight of Soil lbs/ft³ (kg/m³)
13.34 (6.05)	3.53 (1.60)	105.9 (1696)				1	86.2	83.4	2.8	40.0	53.4	5.2	100.5 (1614)
13.63 (6.18)	3.83 (1.73)	114.9 (1837)				2	98.6	93.7	4.9	38.0	55.7	8.8	105.2 (1686)
13.87 (6.28)	4.06 (1.84)	121.8 (1953)				3	97.1	90.9	6.2	39.0	61.9	11.9	108.8 (1745)
14.13 (6.41)	4.32 (1.96)	129.6 (2076)	1/20 (32.3)	60 (267)	1200 (8.27)	4	99.6	91.7	7.9	41.0	50.7	15.6	112.1 (1796)
14.16 (6.42)	4.35 (1.97)	130.5 (2092)	1/10 (64.5)	40 (178)	400 (2.76)	5	94.8	86.2	8.6	40.0	46.2	18.6	110.1 (1764)
14.04 (6.37)	4.23 (1.92)	126.8 (2035)	1/5 (129)	50 (222)	150 (1.03)	6	95.2	84.5	10.7	38.0	46.5	23.0	103.2 (1654)

Max. Dry Weight: 112.5 (1802) lbs./ft³ (kg/m³)
Optimum Moisture: 15.5 %

Remarks:

Curve: Project Curve
DOT - 1838

Figure 1015.01.B – Moisture-Density Calculation Form

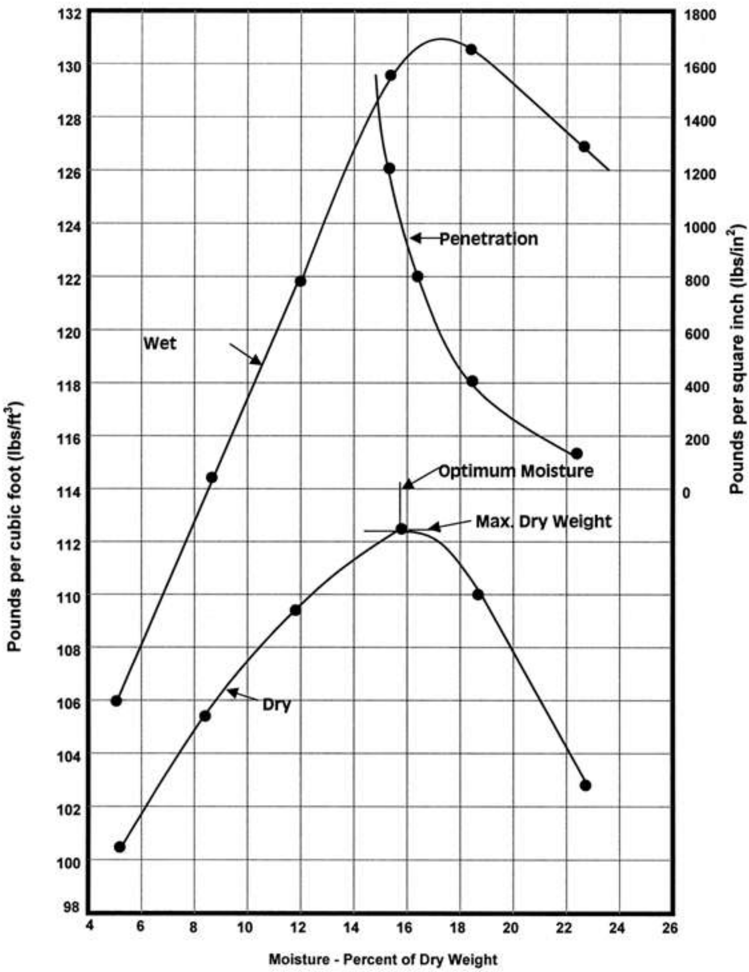


Figure 1015.01.C – Moisture-Density Curve Plot

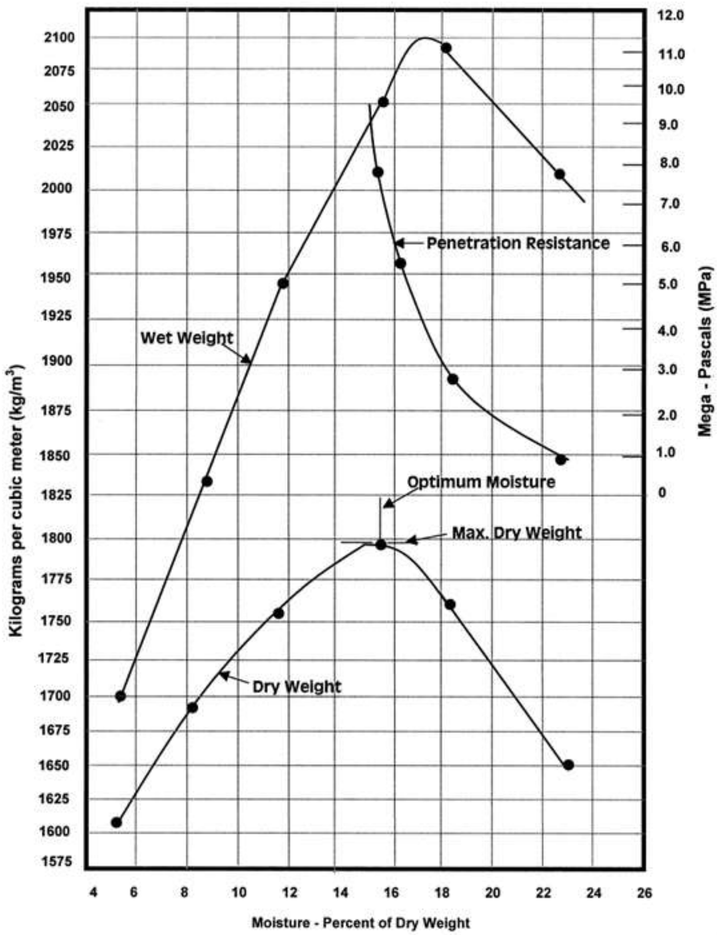


Figure 1015.01.C-M – Moisture-Density Curve Plot (metric)

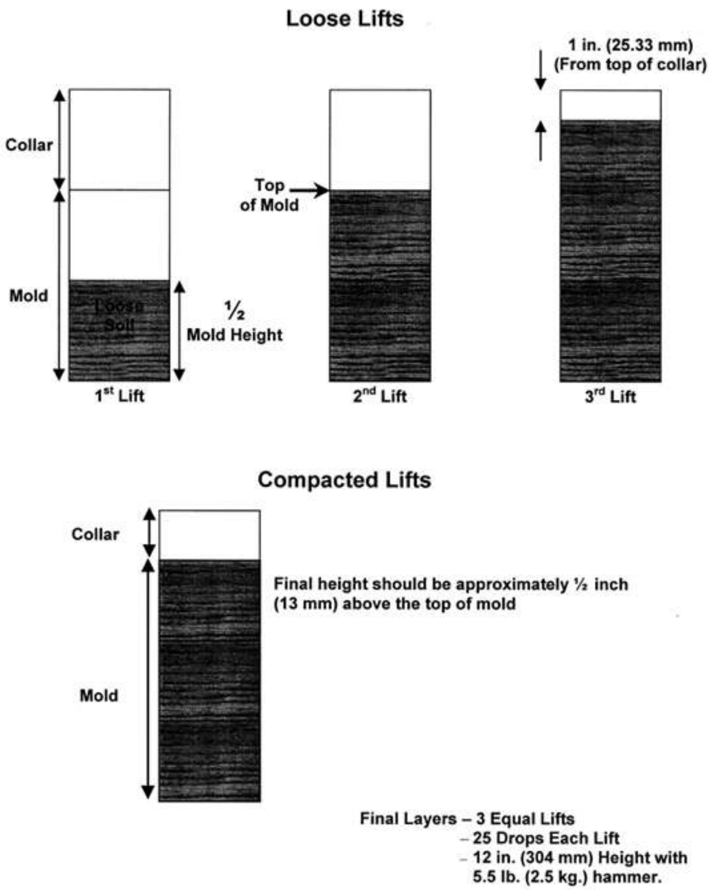


Figure 1015.01.D - Loose and Compacted Lifts for the Proctor Test

Ohio Typical Density Curves (1015.01.C)

The Ohio Typical Density Curves are a set of soil curves originally developed in the 1930's and 1940's to represent all the soils in Ohio. They were developed in the laboratory using the standard proctor test. They started with an original set of nine curves that represented over 1,000 samples. Additional curves were added that represent over 10,000 lab samples. These curves are plotted in Figure 1015.01.E. These curves are still used today to represent all the soils in Ohio. Using these curves minimizes the need to make moisture-density curves for each type of soil encountered in the field.

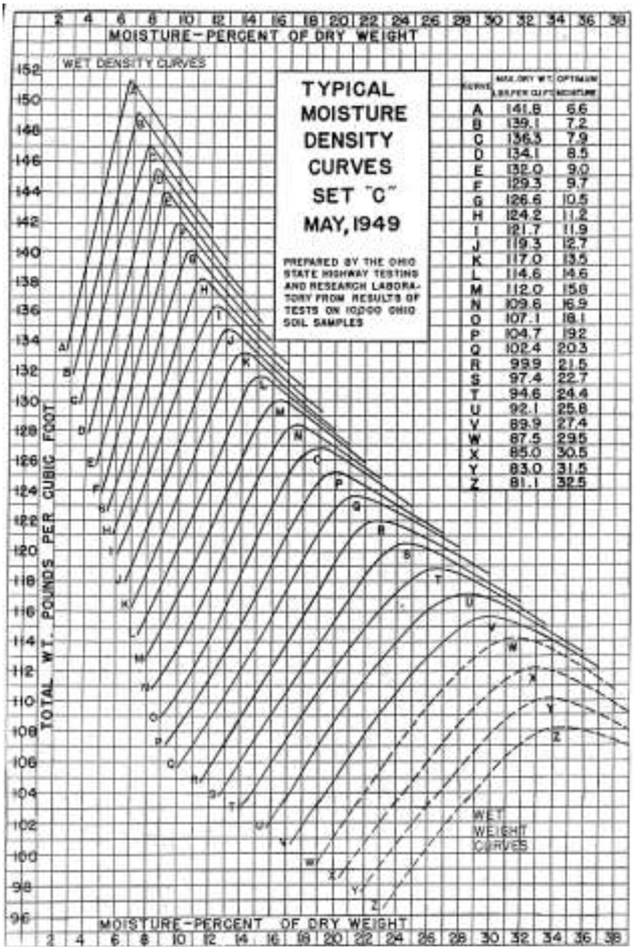


Figure 1015.01.E - Ohio Typical Density Curves

A one-point proctor test is used to choose the curve that represents the soil under consideration. The procedure is similar to the AASHTO T 272 test and is detailed in Supplement 1015.02.A in section 1015.02.F of this manual.

Usefulness of the Moisture-Density & the Ohio Typical Density Curves (1015.01.D)

By examining the moisture-density or the Ohio typical density curves, one can gain general information on the load-carrying capacity and other information about the soil properties.

The optimum moisture and maximum density of the moisture-density relationship are comparative factors. A high maximum density ranges from 125 to 140 lbs/ft^3 (2000 to 2250 kg/m^3) dry weight. A low maximum density ranges from 100 to 85 lbs/ft^3 (1600 to 1350 kg/m^3) dry weight. A low optimum moisture coincides with a high maximum density and will be on the order of 7 percent. A high optimum moisture coincides with a low maximum density and may be on the order of 25 percent.

The maximum density of a soil gives approximate information on its gradation and soil type. The approximate range of the maximum dry density for particular soils are as follows:

Soil Type	Typical Maximum Dry Density Pounds per Cubic Feet (Kilograms per Cubic Meter)
A-1 & A-2	120 to 135 (1922 to 2163) Granular Soils
A-2	120 to 130 (1922 to 2082) Granular Soils
A-3	110-to 120 (1762 to 1922) Granular Soils
A-4	105 to 120 (1682 to 1922) Silty Soils
A-6 & A-7	90 to 110 (1442 to 1762) Clayey Soils

The optimum moisture gives approximate information on the clay and silt content of the soil. The shape of the moisture-density curve varies from a sharply peaked parabolic curve to a flat one or to one sloping irregularly downward as the moisture content increases. This shape gives additional valuable information showing the influence of moisture on the load-supporting value of the soil. For example, a flat moisture-density curve indicates a soil that will have about the same load-supporting strength over a wide range in moisture contents, while a moisture-density curve with a sharp peak indicates a soil that is sensitive to changes in moisture content.

Variations in the Moisture-Density Relationship (1015.01.E)

To truly understand the moisture and density relationship as it relates to soil compaction, the project personnel should understand what items affect this relationship. This section briefly addresses these issues.

This moisture-density relationship is affected by, but not limited to, the following conditions:

1. A change in the laboratory compactive effort, or a field compactive effort that is different from the laboratory testing compactive effort.
2. A temperature of the compacted soil that is near or below freezing temperature.
3. Coarse aggregate that is added or subtracted from the soil.

Changing the Compactive Effort (1015.01.E.1)

The AASHTO T 99 proctor test used to make the Department's moisture-density curves was originally made to simulate field compaction conditions. It uses a standard compactive effort that allows us to evaluate and compare the compaction and densities of different soils. What happens to this moisture-density relationship as you increase or decrease this compactive effort?

In Figure 1015.01.F, the compactive effort may be increased or decreased to change the maximum density as much as 10 to 15 lbs/ft^3 (160 to 240 kg/m^3). As the compactive effort increases, the curve shifts to the left and up along the same line of optimum. If the compactive effort is lowered, the compaction curve shifts to the right and down.

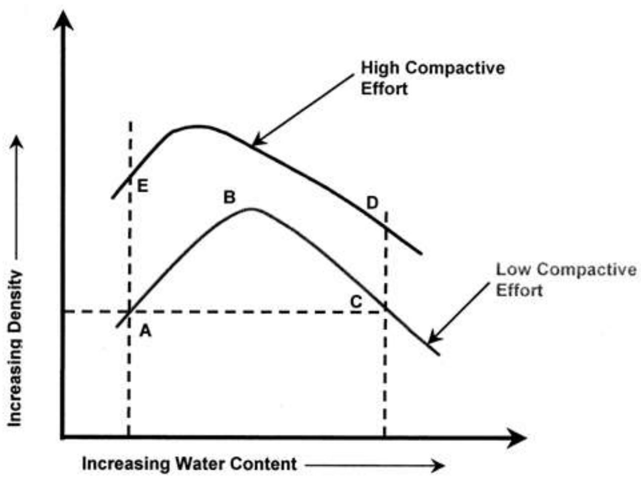


Figure 1015.01.F - Changing the Compactive Effort

Temperature Effects on Soil (1015.01.E.2)

If a soil is compacted at low temperatures, the maximum density cannot be achieved in the field. The specifications do not allow soil to be compacted that is frozen. In Figure 1015.01.G shows why this is the case. The maximum density can change as much as 10 lbs/ft^3 (160 kg/m^3) for soils compacted at temperature differences of 40º F (20º C). But, there may not be any difference in maximum density at all. Temperatures affect some soils but not others. There is not a formula that takes this temperature difference into consideration.

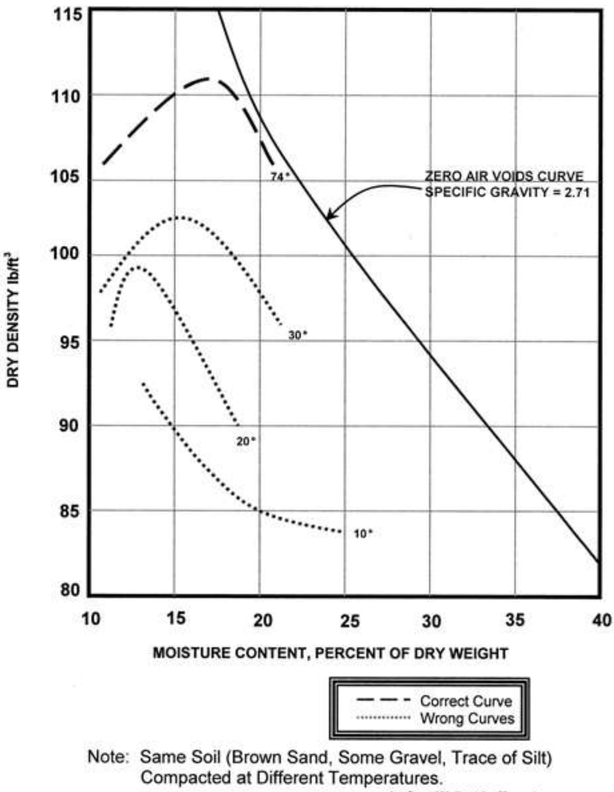


Figure 1015.01.G - Temperature Effects on the M-D Curve

Compaction procedures must be altered to check for this difference. Use the following procedure when the Contractor is compacting the soil at temperatures lower than 45º F (7º C) or when the site conditions warrant:

1. Take the normal proctor test during the compaction testing. Choose the curve associated with this compaction test.
2. Take enough soil from the same hole to make another proctor later. After the soil is warmed to approximately 70º F (21º C) make an additional proctor. Pick an additional curve using the wet weight of the second proctor and moisture content from a drying method.
3. Compare the two results and use the higher curve if there is a difference. Use this procedure at any time the material is suspect in the field.

Coarse Aggregate Problem (1015.01.E.3)

The moisture-density relationship is very good for soils passing the ¾ inch (19 mm) sieve as it relates to the field compaction of soils. There are problems when this relationship is extrapolated to soils larger than the ¾ inch (19 mm) sieve material or for granular soils. Corrections must be made to account for these materials. In certain circumstances, field densities do not correspond to the laboratory results. These will be pointed out in later sections.

Figure 1015.01.H details a plot of adding or subtracting coarse aggregate to a soil and the resulting change in the moisture-density curves.

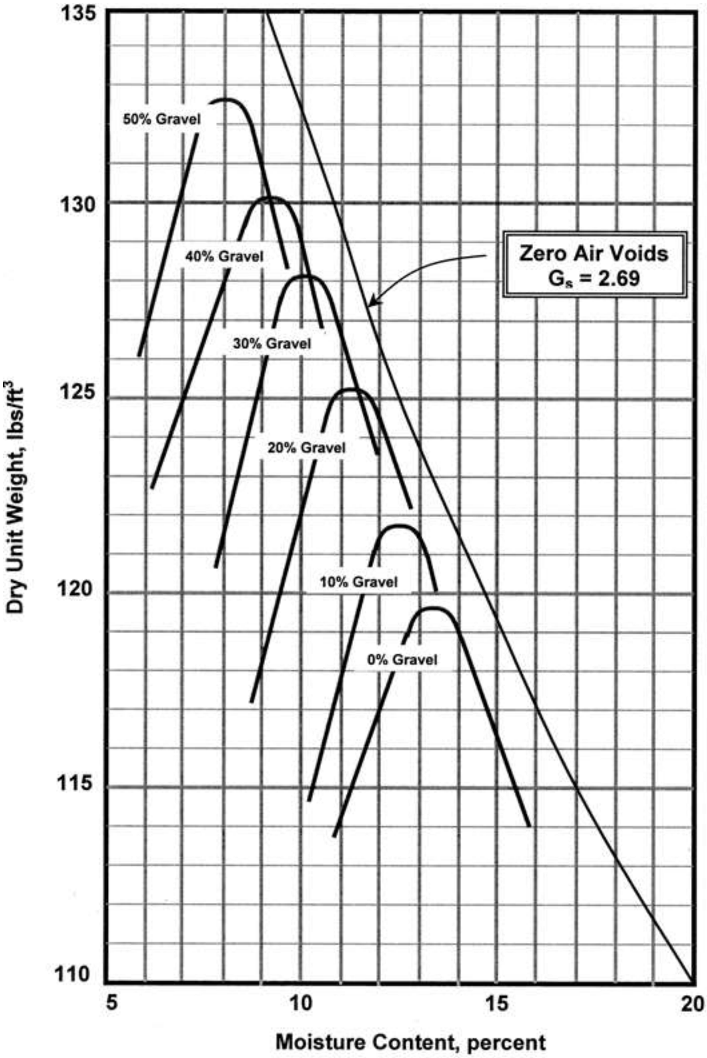


Figure 1015.01.H - Coarse Aggregate Effects on Soil M-D Curve

As you add gravel or plus ¾ inch (19 mm) material to the soil, the optimum moisture shifts to the left and the maximum density increases. The average increase in density is approximately 1 percent per 10 percent of material retained on the ¾ inch (19 mm) sieve. This effect is taken care of on the compaction form CA-EW-6 and is fully explained in Section 1015.03 in this manual.

If you sieve the material through the ¾ inch sieve, remove 20 percent coarse aggregate, and do not consider this, you could easily be one or two curves lower than intended.

Use the correction on the CA-EW-6 compaction form where more than 10 percent of the material is retained on the ¾ inch (19 mm) sieve. This correction usually increases the maximum density and also an optimum moisture correction is made.

Importance of Temperature and Coarse Aggregate Corrections (1015.01.E.4)

The accuracy of all compaction testing is important. But, the importance of making temperature and coarse aggregate corrections in the compaction testing are less obvious to the project personnel. Without these corrections the compaction testing could easily be off by more than 2 lbs/ft^3 (32 kg/m^3) without the project personnel being aware of a problem.

If the compaction testing is off by 2 lbs/ft^3 (32 kg/m^3), or approximately one Ohio Typical Density Curve, this may result in a loss of 15 percent of the soil strength. If the testing is off by two curves, the potential loss could be 30 percent, and so on. The strength may not be apparent in construction, but in the long term it may have devastating effects on the performance of the embankment.

Estimating Optimum Moisture (1015.01.F)

Soil Boring Interpretation Method

All cohesive soils are compacted at water contents less than the plastic limit of the material. For A-7-6 soils, the optimum moisture content is around the plastic limit minus 3. For A-4 and A-6 soils, the optimum is around the plastic limit minus 5. The optimum moisture content of granular materials ranges between 5 and 10, and for non-plastic silts is around 11.

You can obtain an estimate of the consistency of the material by using the above information and looking at the soil's water content from the soil borings before the work begins. Keep in mind the water content on the soil borings is the water content at the time the borings were drilled. They should be considered an estimate of the present field conditions.

You can approximate the optimum moisture of a material by the feel of the material in the field, using one of the following methods.

Hand Squeeze Method

Take a sample of the material in question in your hand.
Squeeze the material together and let go.

Consult the following table:

If the material…	Then material is…
Falls apart in small pieces	Dry of optimum
Stays together	At or above optimum
Breaks into two or three large pieces	At optimum
Stays together and there is excess water on hands	Above optimum

Ball Method

Roll the material into a one-inch ball.
Place it between your thumb and index finger and squeeze the material.
Consult the following table:

If the material…	Then material is…
Ball cannot be formed	Below optimum
Becomes oval	Above optimum
Breaks apart into uniform pieces (Some clays will have larger pieces than silts)	At optimum

Spit Method

Spit on the material.
Consult the following table:

If the saliva…	Then material is…
Beads up	Above optimum
Slowly sinks in	At optimum

Use these methods as estimates; they do not replace compaction testing. These estimates are different for each type of soil (clay, silt, granular).

Compaction Testing of Soils (1015.02)

General (1015.02.A)

Proper compaction at the proper moisture is the most effective and most economical way to improve the stability of soils. Satisfactory performance of pavement and embankment depends on the good compaction of the embankment and subgrade materials. Careful control is necessary to ensure compliance with the specification compaction requirements for embankments and subgrades.

The density test is the principal means by which the Engineer determines whether or not the specified compaction requirements have been met. The number of tests to be made for a given quantity of embankment material placed is set by Supplement 1015.10. The Engineer has broad powers to increase or decrease this testing depending on the field conditions. The Engineer may use his or her judgment to make tests at locations where the information is most needed for proper control.

For example, consider an area of embankment under construction where the soil and moisture conditions are uniform and ideal for good compaction, and where previous compaction tests have shown that the specification requirements are being met consistently under the same number of roller passes. As long as inspections show that the uniform conditions of soil, moisture, lift thickness, and roller pass continue for this area, only occasional check tests for compaction are required.

Where relatively few tests are made because materials and conditions are uniform, document this by describing conditions on the Compaction Forms or other appropriate project records. Avoiding a large number of tests in areas of uniform condition where specified compaction is consistently obtained allows the project personnel to concentrate their effort on other areas of the project where conditions are less uniform or suspect.

Tests must be made in areas where inspection indicates that the material is questionable even if specified compaction is being obtained. Evidences of questionable compaction, which can be determined by inspection, include the following:

1. Low number of roller passes to obtain compaction.
2. Excessive deflection under heavy construction equipment.
3. Using lightweight rollers.
4. Very wet or dry soil.
5. Areas compacted without full time inspection.
6. Inconsistent materials, such as shale and rock mixtures, or recycled concrete mixed with soil.

The observation that a sheepsfoot roller will “walk out” or “ride high” on a layer of hard, dry soil is not evidence of satisfactory compaction. This soil may be stable when dry but weak when wet.

Areas where it has been determined that compaction or moisture does not meet specification requirements must be corrected before the next lift of embankment is placed.

The Engineer must give specific directions to the inspectors. These directions must cover the inspector’s responsibility and authority given to them by the Engineer. This ensures that timely decisions are made in the field and that full compliance with the contract requirements is obtained on the project.

Control of compaction includes making moisture and density determinations for establishing whether the compaction meets the requirements prescribed in the specifications.

A sufficient number of tests must be made to ensure that construction complies with the specifications. The nuclear gauge method is the only method used for compaction testing. The sand-cone, rubber-balloon, and cylinder density tests have been eliminated.

Regardless of the method chosen, a one-point proctor test is used to identify the curve that represents the soil in question for each compaction test, except for materials requiring a test section.

Equipment (1015.02.B)

1. Equipment listed in Section 1015.01.B.1.
2. A 3-inch (75 mm) or 4-inch (100 mm) post-hole auger.
3. A container with a 4.5-inch (114 mm) hole cut in the bottom.
4. Troxler 3440 Nuclear Gauge.
5. 25 to 50 lbs (12 to 23 kg) of dry uniform natural sand passing the No. 10 (2 mm) sieve.
6. Form CA-EW-5, "Nuclear Gauge Compaction Form" and Form CA-EW-6 Nuclear Gauge Compaction with an Aggregate Correction.

Preparation of Test Site (1015.02.C)

Select a location for the density test that is representative of a rolled area of the embankment layer being constructed. If loose, uncompacted material, such as results from sheepsfoot rolling, exists on the surface, remove the loose material to expose the compacted material underneath. Carefully level the test area by any convenient means, such as a dozer, grader, hand shovel, straightedge, etc.

Compaction Testing of Soil Using a Nuclear Gauge (1015.02.D)

The Department uses nuclear equipment manufactured by Troxler Laboratories. Presently the Department uses the 3440 series gauges. The operator should have a Manual of Operation for the gauge.

There is no radiological danger for the operation of a nuclear gauge so long as the correct operating and safety rules are followed. Each operator is issued a specific set of instructions governing safety when the gauge is assigned to him or her. For more information about the safety requirements see the following link to the Nuclear Labs Web site:

www.dot.state.oh.us/Divisions/ConstructionMgt/Materials/Pages/Radiation-Safety.aspx

In addition, contact the Nuclear Lab at (614)275-1375 for more information.

For nuclear measurement of density, gamma rays emitted into the soil from a gamma source are scattered by the electrons in the soil and lose energy in the process. The number of scattered rays returned and counted in the gauge depends on the average length of the path of the ray between the detector and source. The electron density increases proportionally with the density of the soil and causes greater scattering and energy loss. Therefore, the chances that scattered gamma rays returning to the detector with sufficient energy to be counted become smaller with increased soil density, and the count rate drops. In common types of soils, a low gamma ray count indicates a high density, and a high count indicates a low density.

For nuclear measurements of moisture, the neutron energy absorption technique measures the moisture content of rock or soil materials. The nuclear method for measuring the moisture content of soil and rock materials is based on the principle of measuring the slowing of neutrons emitted into the soil from a fast-neutron source. The energy loss is much greater in neutron collisions with atoms of low atomic weight, and is directly proportional to the number of such atoms present in the soil. The effect of such a collision is to change a fast neutron to a slow neutron. Hydrogen, which is the principal element of low atomic weight found in soils, is contained largely in the molecules of water in an inorganic soil. The number of slow neutrons detected by the gauge, after an emission of fast neutrons from a radioactive source, is counted electronically in the gauge. The count obtained by the gauge is proportional to the amount of water in the soil or rock.

Density and moisture determinations can be made in any of the following two positions relative to the material being tested:

1. Backscatter - Source and detector in the gauge are resting on the surface of the material being tested.
2. Direct Transmission - Source in the rod is extended below the gauge into the material being tested, and the detector in the gauge is on the surface of the material being tested.

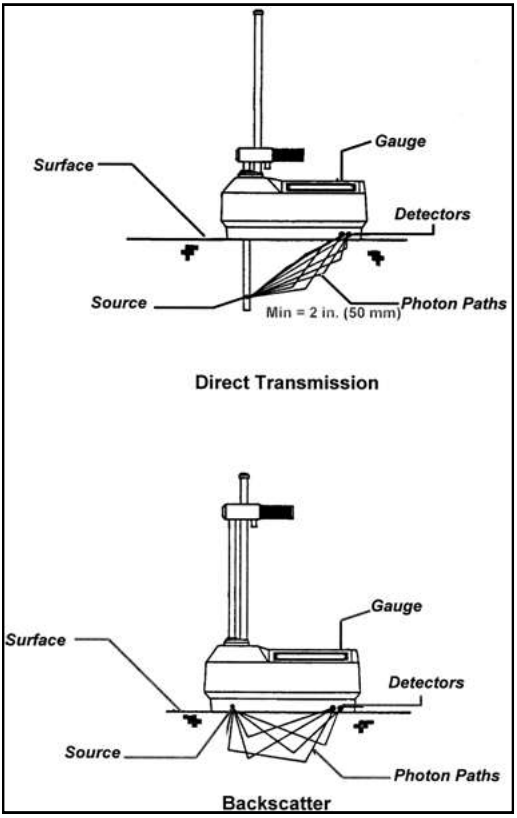


Figure 1015.02.A - Nuclear Gauge Direct and Backscatter Positions

Moisture-Density Testing (1015.02.D.1)

Use form CA-EW-5 or CA-EW-6 for moisture-density testing when using a nuclear gauge. The following is a summary of the gauge operations when testing soils. Consult the owner's manual of procedures more detailed explanation. The gauge is self-driven throughout the process. The operator pushes a button and the gauge asks a question or gives an answer.

1. Determine the standard count
    a. Perform at least every week or when the test location changes.
    b. Put the gauge on the standard block with the handle opposite the metal plate. See Figure 1015.02.B.

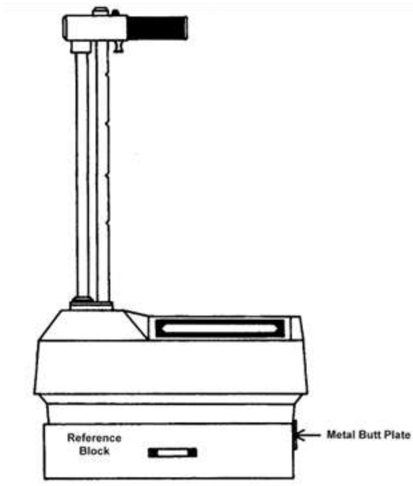


Figure 1015.02.B - Nuclear Gauge on the Standard Block

    c. Make sure the standard block is resting on material which weighs more than 100 lbs/ft3 (1600 kg/m3).
    d. Press the "ON" button on the gauge panel (see Figure 1015.02.C).
        i. Wait approximately 4 minutes for the gauge to "warm up."
        ii. Gauge may already be on prior to placing it on the block.
        iii. The gauge will beep when ready.

YES EXIT	NO/CE C/CE	STATUS 7	MODE 8	SPECIAL 9
STORE MS	OFFSET MR	PROJECT 4	PRINT 5	ERASE 6
PROCTOR/ MARSHALL +	TIME -	COUNTS 1	DEPTH 2	CALC. 3
SHIFT X	STANDARD +	RECALL 0	.	START/ ENTER =

Figure 1015.02.C - Nuclear Gauge Keypad

iv. Readout:
1. Depth: Safe Position
2. Time: 1 min. (possibly a longer duration)
3. Battery: Volts

e. Press the Standard Button:

i. Readout
1. Do you want to take a new standard?
2. Press "YES"
3. Is the gauge in the safe position?
4. Press "YES"

ii. Readout:
1. Taking a standard count.
2. Takes 240 seconds.
3. Gauge will beep when complete.

iii. Readout when standard count is complete:
1. MS XXXX X.X%P
2. DS XXXX X.X%P
3. P-Pass, F-Fail
4. If reading is within 1% for density or 2% for moisture, the standard passed.

f. Record standard count on lines 4 and 7 on the CA-EW-5 and lines 1 and 2 on the CA-EW-6.

g. Do you want to accept the new standard?

i. Press "YES" if acceptable.

ii. Readout
1. Ready
2. Depth
3. Volts
4. Ready to take the readings.

2. Taking Nuclear Gauge Readings

a. Clear away all loose material or dried crust.

i. Obtain a level area with sufficient size to accommodate the gauge.

ii. Use the scraper plate to help smooth out the surface.
iii. See Figure 1015.02.D

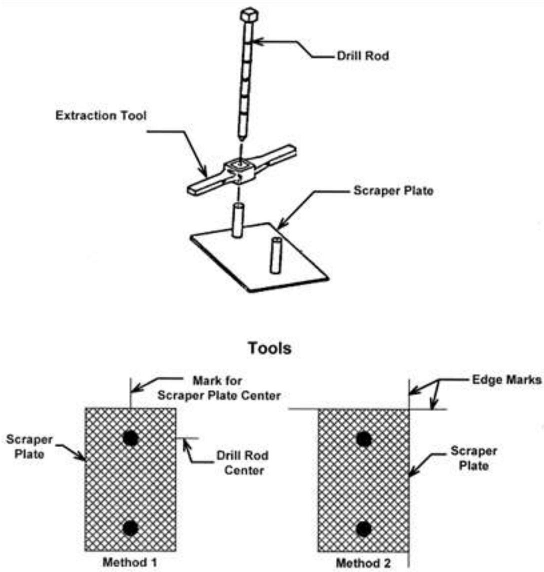


Figure 1015.02.D - Scraper Plate and Use

b. Use the native fines or fine sand to fill the voids to finish smoothing out the surface.
    i. The maximum void beneath the gauge should not exceed 1/8 inch (3 mm).
c. Make a hole perpendicular to the prepared surface by using the pin (drill rod) provided by the manufacturer.
    i. Drive 2 inches (50 mm) further than the depth of the reading.
d. Mark the outside of the scraper plate.
e. Remove the scraper plate and position the nuclear gauge on the prepared location.
    i. Raise the gauge up on one side and extend the rod out about 2 inches (50 mm).
    ii. Place the rod over the hole and extend the rod the rest of the way.
f. Extend the rod to the required depth. See Figure 1015.02.E.

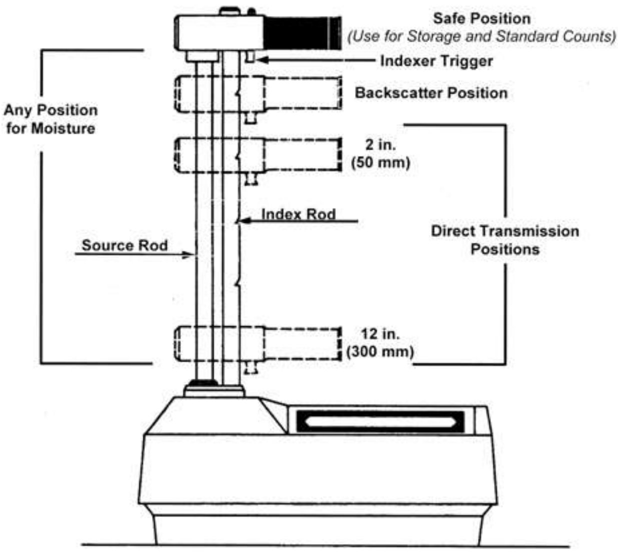


Figure 1015.02.E - Positions of the Nuclear Gauge

- i. Backscatter Position is used for:
  1. Bases.
  2. Granular Materials.
  3. Materials requiring a Test Section.
- ii. 8-inch (200 mm) depth used for Embankment.
- iii. 12-inch (300 mm) depth used for Subgrade.
- iv. The gauge gives the depth.
- v. The deepest depth is the most accurate.

g. Pull the gauge toward the detector end or away from handle to seat the gauge into position (see Figure 1015.02.A).
- i. Eliminates the air gap between the source rod and the hole.

h. Press "START/ENTER".

i. After one minute:
- i. Readout
  1. DD = Dry Density = Line 6= 133.0 lbs/ft3
  2. WD = Wet Density = Line 5 =144.4 lbs/ft3
  3. % M = % moisture = Line 8 = 8.3%

j. Record information on Lines 5, 6, and 8 of the CA-EW-5 Form and on lines 3, 4, and 5 on the CA-EW-6 Form.

k. See Figure 1015.02.F
- i. DD = Dry Density = Line 6= 133.0 lbs/ft3
- ii. WD = Wet Density = Line 5 =144.4 lbs/ft3
- iii. % M = % Moisture = Line 8 = 8.3%

Using the Ohio Typical Curves (1015.02.E)

Optimum moisture and maximum dry weight can be determined from the proctor test results, nuclear gauge results, and the Ohio Typical Density Curves as described in Section 1015.01.C and 1015.01.D. Use the Plotted Ohio Typical Density Curves for the compaction testing, that are in the Forms section of this manual.

Once the wet weight and percent moisture is obtained from the proctor test, it can be used to find the curve that represents the soil being tested. Use nuclear method or drying method to determine percent moisture in lieu of the penetration resistance method; do not use the penetration resistance method.

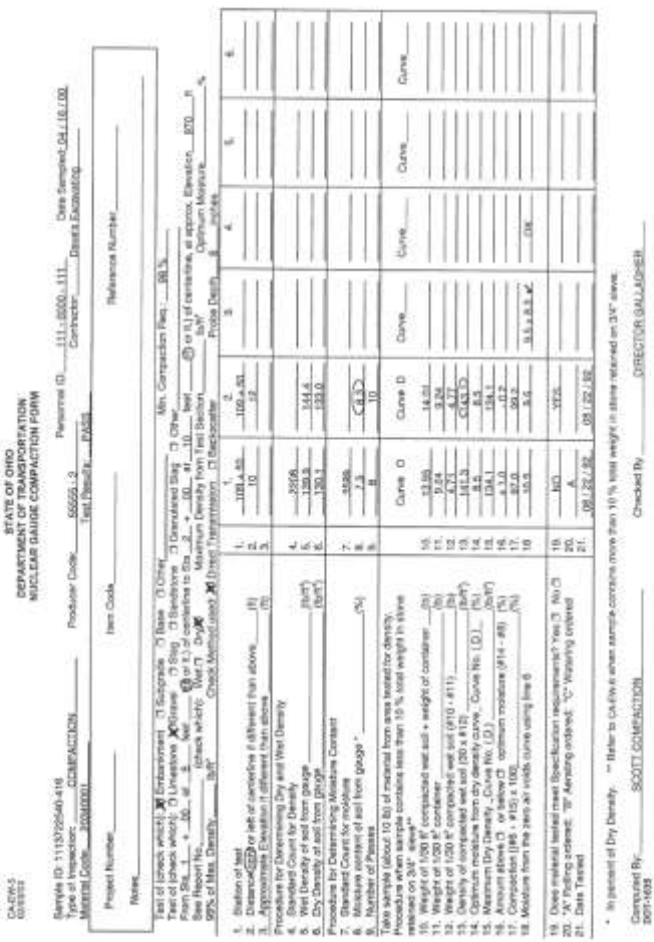


Figure 1015.02.F - Completed CA-EW-5 Compaction Form

Selecting a Typical Curve Using the Nuclear Gauge Results (1015.02.F)

1. Secure a representative soil sample of about 10 lbs (5 kg).
   a. Use the soil between the end of the probe and the back of the gauge (see Figure 1015.02.A).
2. Sieve the material through a 3/4 inch (19 mm) sieve.
   a. Use Form CA-EW-5 if less than 10% of the soil is retained.
   b. Use Form CA-EW-6 if more than 10% of the soil retained.
   c. Use a Test Section Method if more than 25% is retained.
3. Thoroughly mix the material passing the 3/4 inch (19 mm) sieve.
4. Make a Proctor using section 1015.01.B.2 of this manual.
   a. Make a proctor test for every compaction test (a soil cannot be correctly identified without this test).
   b. When weighing the proctor mold and soil, the scales must be level and balanced.
      i. The scales need to be leveled with a carpenter's level. Put the scale on a piece of flat plywood then level the board. You may elect to level the weighting plate.
      ii. The older scales must also be balanced once it is leveled. The weighting mechanism should float between the top and bottom bar. If it does not then sand or pebbles can be added to the lever arm to make it balance.
5. Record and calculate the 'Proctor' results on Lines 10 through 13 on the CA-EW-5 and lines 11-14 on the CA-EW-6.
   a. Use Figure 1015.02.F
   b. Line 10 (14.01 lbs) – Line 11(9.24 lbs) = Line 12 (4.77 lbs)
   c. Line 12 (4.77 lbs) × 30 = Line 13 (143.1 lbs/ft3)
6. Pick the Wet Weight Curve Using
   a. The proctor wet density.
   b. Line 13 = 143.1lbs/ft3
   c. Moisture from gauge readings or by another drying method.
   d. Line 8= 8.3%
7. Use the printed Ohio Typical Density or Project Curves (see Figure 1015.02.G).
   a. Draw a horizontal line through the wet weight per cubic foot (cubic meter) on the Ohio Typical Density Curves from the proctor weight on Line 13 on the CA-EW-5 or Line 14 on the CA-EW-6 Form.
      i. Line 13 = 143.1 lbs/ft3
   b. Extend a vertical line from the percent moisture shown on Line 8 on the CA-EW-5 or Line 5 on the CA-EW-6 Form, to intersect the horizontal line.
      i. Line 8 = 8.3%

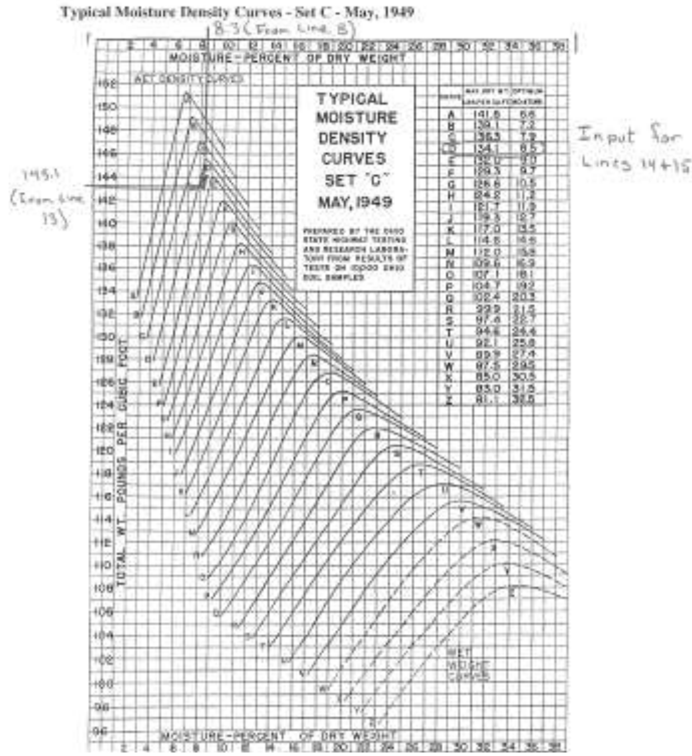


Figure 1015.02.G - Example of Using the Ohio Typical Density Curves

c. If the intersection falls on a curve, choose the curve.

d. If the intersection falls between two curves, choose the next highest curve.

8. Use the Maximum Dry Weight and Optimum Moisture data in the upper right hand corner of Figure 1015.02.G from the curve that is chosen.
   a. In this example curve 'D' is the correct curve.
9. After the curve is selected, record optimum moisture on Line 14 and the maximum dry density on Line 15 of Form CA-EW-For the CA-EW-6 record the optimum moisture on Line 15 and the maximum dry density on Line 18.
   a. Line 15 = Maximum Density = 134.1 lbs/ft3
   b. Line 14 = Optimum Moisture = 8.5%

Calculating Compaction and Zero Air Voids (1015.02.G)

Use Figure 1015.02.F

1. Use line 16 to calculate the difference in moisture contents.

   a. Line 14 = 8.5% - Line 8 (8.3%) = - 0.2% (below optimum)
2. Use line 17 to Calculate Compaction.
   a. (Line 6/ Line 15) × 100 = (133.0 lbs/ft3/ 134.1 lbs/ft3) × 100 = 99.2%.
3. Compare to the allowable in the specifications shown in Table 203.07-1.

Table 203.07-1 Embankment Compaction Requirements

Maximum Laboratory Dry Weight (lb/ft^3)	Minimum Compaction (percent)
90 to 104.9	102
105 to 119.9	100
120 and more	98

   a. Since Line 15 = 134.1 lb/ft3 > 120 the minimum required compaction is 98%.
   b. Line 17 = 99.2% > 98
   c. The test passes.
4. If density and stability are achieved, then moisture passed.
   a. See Procedures Manual Section 203.07.
5. Check zero air voids.
   a. Use Figure 1015.01.02.H.
   b. Use line 6 = 133.0
      i. Get 9.5
   c. 9.5% > Line 8 = 8.3%
   d. Good (Line 8 may be a maximum of 1% above the Figure 1015.02.H value.)

Can calculate the percentage by using the formula in Figure 1015.02.H

      i. Where G=2.67 and D = line 6
      ii. The formula is much easier to use than the graph if you are good with math.
6. The check on the zero air voids is a check on the nuclear gauge readings. The moisture obtained from the curve or graph is the maximum moisture that can exist in the soil being tested. If the gauge moisture readings are larger than the ones obtained from the graph then an error may exist in the test.

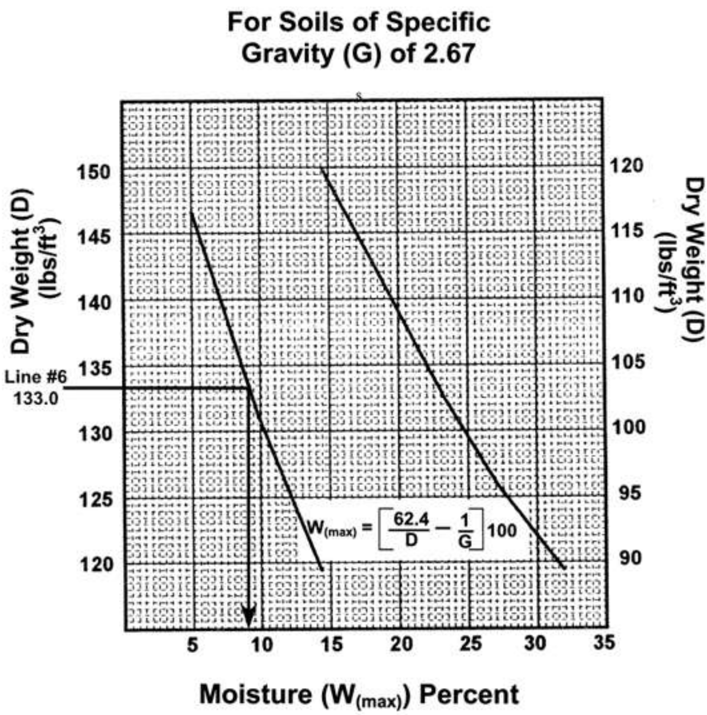


Figure 1015.02.H - Zero Air Voids Curve

Moisture Controls (1015.02.H)

Moisture Control of Soil Embankments during Construction (1015.02.H.1)

This section discusses moisture controls during construction, details some of the variables in the moisture controls, and discusses alternate methods used to verify or modify the moisture readings from the nuclear gauge.

Experience has shown that to obtain the specification density, the moisture content must be at or near optimum. Some soils, particularly silty soils with low plasticity, may meet the moisture (± 3 percent from optimum) and the compaction requirements but have unsatisfactory stability.

Some soils compact better and meet the density and stability requirements at minimum moisture of -3 or more below optimum. The reason for limiting the moisture contents for soil embankment this way is to ensure stable embankments.

The “Elasticity and Deformation of Soils” is discussed in Section 203.02 and “Moisture Controls” are discussed in Section 203.07.A of this manual.

There is not a numerical moisture requirement in the specifications. The Contractor must compact the material at a moisture content to obtain the density and stability of the material. Moisture and compaction controls are necessary to secure the quality of embankments and subgrades that are essential for the long life and performance.

Alternate Tests for Moisture (1015.01.H.2)

The specifications do not numerically limit the moisture content of embankment or subgrade soils. Moisture determinations must be made in the field to pick the required moisture-density curve and to control the Contractor's compaction operations. The following sections deal with various methods of determining moisture contents of soils.

For engineering purposes, the moisture of soil is expressed in percent of dry weight.

$$\text{Percent Moisture} = \frac{\text{Weight of water in soil}}{\text{Weight of dry soil}} \times 100$$

Most of the time, the moisture of a soil should be obtained by using the nuclear gauge readings. However, there are situations where drying methods can and should be used. Moisture content is the most variable reading from the nuclear gauge. There are varieties of chemicals in the soils that can minimize the moisture content reading reliability. This is particularly true for recycled materials such as fly ash, bottom ash, foundry sand, or asphalt.

Use the moisture estimating principles detailed in section 203.02, "Estimating Optimum Moisture." This section guides the determination of an alternate moisture measurement.

For each drying method the soil to be tested should be a representative sample of at least 1 pound (0.5 kilograms). The soil should be placed in a small, clean can or jar and covered with a tight lid at the construction site, to prevent evaporation of moisture while moving to the location of the test. The test should be conducted as soon as possible after taking the sample. Location where sample is taken must be noted.

All the moisture tests should be checked against each other to ensure accuracy of the moisture testing. To record the moisture results use Figure 1015.01.B, "Moisture-Density Calculation Form" and read the appropriate sections.

Oven-Drying Method (1015.02.H.3)

This method of determining moisture content is applicable to all types of soils. The time required to dry the sample depends on the size and moisture content of the sample and the type of soil.

This method should be used for any recycled material. This can be used to apply a moisture correction to the nuclear gauge readings when the material is uniform. This is particularly true for fly ash.

Equipment

1. Two-burner stove. Either oil stove or a camp stove using white gasoline.
2. "Boss 75" portable oven, or equivalent.
    a. This oven measures approximately 20 inches (0.5 meters) high, 20 inches (0.5 meters) wide and 13 inches (0.3 meters) deep.
    b. It sets on and is heated by the stove.
3. Several baking pans approximately 12 × 8.5 × 2.5 inches (300 × 200 × 63 mm).
4. Masonry trowel or putty knife.
5. Can of fuel. Can has tight stoppers and is painted red if used for gasoline.
6. Scale of 25-pound (12-kilogram) capacity sensitive to 0.01 pound (1 gram).
7. Piece of flat glass or pieces of bond paper with texture similar to the compaction forms.

Procedure

1. Weigh the pan to the nearest 0.01 pound (1 gram). Record the weight.
2. Place approximately 1 pound (0.5 kilograms) of representative sample of wet soil in the pan on the scale.
    a. Record the combined weight.
3. Break up all lumps of soil with the putty knife or trowel and avoid any loss of the sample.
4. Place the pan with the sample in the oven with the stove on. Stir the soil every 3 to 5 minutes.
5. After the soil has changed to a lighter color and appears to be dry, remove the soil sample from the oven and test to determine if it is completely dry by using one of the following methods:
    a. Lay a piece of bond paper approximately 2 × 3 inches (50 × 75 mm) on the sample.
        i. If the paper curls immediately when laid on the sample, the soil contains moisture.
        ii. The paper used for this test must be bond of hard surface texture like the paper used for the compaction forms.
    b. Hold a piece of clean glass or a mirror in a horizontal position about 1 inch (25 mm) above the soil sample.
        i. If the glass steams up, this is an indication of further moisture in the sample.
    c. Keep the glass away from the heat of the stove or direct rays of hot sun prior to the test since this test depends upon condensation of moisture in the hot air onto the cooler glass.
6. If the test indicates further moisture is in the sample, stir the sample and continue drying.
    a. Test the soil every 3 to 5 minutes until the test indicates the soil is dry.

7. Weigh the dried sample and pan to the nearest 0.01 pound (1 gram). Record this weight.
8. Subtract the weight of the pan from the weight of the pan and the dry sample to obtain the weight of the dried sample.
9. Subtract the weight of the dried sample from the weight of the wet sample. This is the weight of water in the original sample.
10. Divide the weight of the water by the weight of the dried sample. Multiply this result by 100. This gives the percentage of moisture in the sample. The equation is:

$$\text{Percent Moisture} = \frac{\text{Weight of wet soil} - \text{Weight of dry soil}}{\text{Weight of dry soil}} \times 100$$

Open-Pan Drying Method (1015.02.H.4)

This method is quick, simple, and obtains accurate results for granular material. This method should not be used for fine-grained soils (silts or clays) because the high temperatures may burn away the organic material if it happens to be present. This method can be used for fine-grained soils where limited accuracy is satisfactory and approximate moisture results are acceptable.

This method should not be used for any recycled material. It has been found to give lower moisture contents than is really in the material. This is particularly true for fly ash.

Equipment

1. Scale of 25 lb (12 kg) capacity sensitive of 0.01 lb (1 gram).
2. Several baking pans approximately 12 × 8.5 × 2.5 inches (300 × 200 × 63 mm).
3. Putty knife or other device for breaking up and stirring the soil.
4. Two-burner stove burning white gasoline.
5. Piece of flat glass or pieces of hard surface bond paper with texture similar to the compaction forms.

Procedure

Follow steps outlined in Section 1015.02.H.3 Oven-Drying Method Steps A thru L, except place the pan directly over the burner instead of in the oven.

Precautions

The following cautions should be taken to avoid introducing errors into the test.

1. Avoid overheating the soil.
    a. Use two pans, one inside the other, to avoid hot spots that may occur when a single pan is used.
2. Avoid baking the soil.

   a. Baking can be prevented by testing the material with a paper or glass test at sufficiently close intervals, so that further heating can be discontinued after all the moisture has been evaporated.
3. Ensure that no soil is lost during the test.

Alcohol-Burning Drying Method (1015.02.H.5)

This method is quick and simple. The alcohol burns at a low enough temperature 286º F to 320º F (140º C to 160º C) so that it can be used with accuracy for most soil types.

This method should be done outside or in a well-ventilated area.

Equipment

1. Scale of 25 lb (12 kg) capacity sensitive of 0.01 lb (1 gram).
2. 12 × 8.5 × 2.5 inches (300 × 200 × 63 mm) baking pan.
3. Pan or can with perforated bottom and filter paper to fit bottom.
   a. A 10 oz (300 mL) round sample can is suitable for this purpose.
4. Glass stirring rod.
5. Supply of alcohol in tightly sealed can.

Procedure

1. Weigh perforated pan or can with filter paper in the bottom. Record weight.
2. Place sample of wet soil in perforated pan or can; weigh and record weight.
3. Place perforated pan or can in larger pan and stir alcohol into the soil sample with a glass rod until the mixture has the consistency of a thin mud or slurry.
   a. When stirring, do not disturb the filter paper on the bottom.
   b. Clean the rod.
4. Ignite the alcohol in the other pan and in the sample and burn off all alcohol.
5. Repeat the process three times, or until successive weighings indicate no reduction in weight, after each time burning.
6. After final burning, weigh perforated can or pan and dry soil, and record weight.
7. The weight of dry soil equals the weight minus weight of perforated pan or can and filter.
8. Calculate moisture content as shown in Section J though L of Section 1015.02.H.3.

Gasoline-Burning Drying Method (1015.02.H.6)

Application

This is a quick and simple method of drying. However, the gasoline burns at such a high temperature that it should be used only to dry granular materials. This method should only be conducted outside.

Equipment and Procedures

This method of drying is similar to the alcohol-drying method with the exception that the perforated pan and filter are not used. The gasoline can be mixed with the sample in the baking pan and burned in the pan. Except for this, the test is run exactly the same as the alcohol-burning method, described in Section 1015.02.H.5.

Compaction Testing Requiring an Aggregate Correction (1015.03)

The Aggregate Correction Problem (1015.03.A)

As detailed in Section 1015.01.E.3 “Coarse Aggregate Problem” the moisture-density relationship is very good for soils passing the ¾ inch (19 mm) sieve as it relates to the field compaction of soils. There are problems when this relationship is extrapolated to soils larger than the ¾ inch (19 mm) sieve material or for granular soils. Corrections must be made to account for these materials. In certain circumstances, field densities do not correspond to the laboratory results.

Figure 1015.03.A details a plot of adding or subtracting coarse aggregate to a soil and the resulting change in the moisture-density curves.

As you add gravel or plus ¾ inch (19 mm) material to the soil, the optimum moisture shifts to the left and the maximum density increases. The average increase in density is approximately about 1 percent per 10 percent of material retained on the ¾ inch (19 mm) sieve.

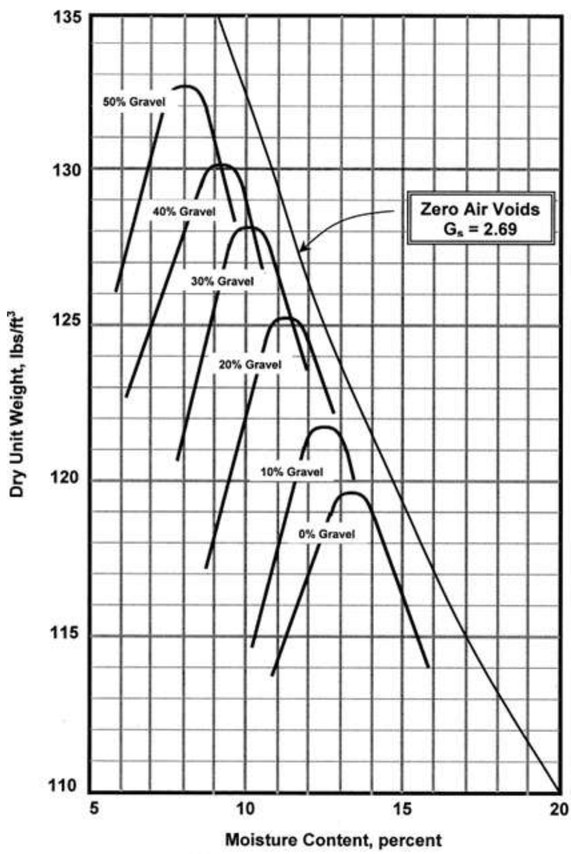


Figure 1015.03.A - Coarse Aggregate Effects

If you sieve the material through the ¾ inch sieve, remove 20 percent coarse aggregate, and do not consider this, you could easily be one or two curves lower than intended.

This correction usually increases the maximum density and an optimum moisture correction is made. This effect is taken care of on the compaction form CA-EW-6.

Use the correction on the CA-EW-6 compaction form where more than 10 percent but less than 25 percent of the material is retained on the ¾ inch (19 mm) sieve. See Figure 1015.03.B, Aggregate Correction Method.

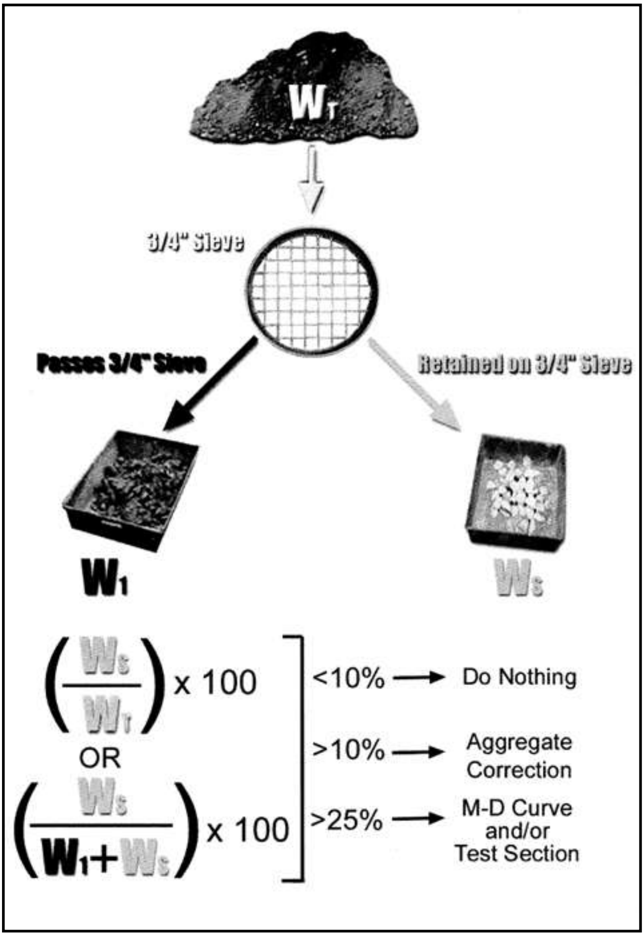


Figure 1015.03.B - Aggregate Correction Method

Caution: An, 'almost' pure sand may have between 10 and 25 percent retained on the ¾ inch sieve. A test section method would be used in this case. This method is to be used with 'Fine Grained Materials' with significant granular material retained not granular materials.

Using Form CA-EW-6 Nuclear Gauge Compaction with an Aggregate Correction (1015.03.B)

A completed Form is detailed in Figure 1015.03.C. The general sections of this form are as follows:

CA-EW-6

STATE OF OHIO
DEPARTMENT OF TRANSPORTATION
NUCLEAR GAUGE COMPACTION WITH AN AGGREGATE CORRECTION

Sample ID: ______ Date Sampled: ______
Type of Inspection: ______ Producer Code: ______ Contractor: ______
Material Code: ______ Test Results: ______

Project Number ______ Item Code ______ Ref. Number ______
Notes ______

Test of (check which): ☐ Embankment ☐ Subgrade ☐ Base ☐ Other ______ Min. Compaction Req. ______ %
From Sta ______ + ______ at ______ feet ______ (rt. or lt.) of centerline, at approx. Elevation ______ ft.

I. Nuclear Gauge Readings
1. Standard Count for Density 1.= 2208
2. Standard Count for Moisture 2.= 3500
3. Wet Density of the Soil from the Gauge 3.= 129.1 lb/ft³
4. Dry Density of the Soil from the Gauge 4.= 111.1 lb/ft³
5. Percent Moisture from the Gauge 5.= 16.2 %

II. Remove the Soil from Under the Gauge and Sieve the Soil Through a 3/4" Sieve
6. Weight of wet soil (& stone if any) from hole + weight of pan 6.= 14.0 lb
7. Weight of Pan or Container 7.= 2.0 lb
8. Weight of wet soil (& stone if any) from under the nuclear gauge (#6 less #7) 8.= 12.0 lb
9. Weight of stone & Sieve or Pan 9.= 3.4 lb
9a. Weight of Sieve or Pan 9a.= 1.0 lb
9b. Weight of stone removed from sample and retained on 3/4" Sieve (#9 less 9a) 9b.= 2.4 lb
10. Percent stone in sample (9b ÷ #8 x 100) 10.= 20.0 %

III. Proctor Test Using the Soil Passing the 3/4" Sieve
11. Weight of 1/30 ft³ compacted wet soil + weight of container 11.= 13.40 lb
12. Weight of 1/30 ft³ container 12.= 9.24 lb
13. Weight of 1/30 ft³ compacted wet soil (#11 less #12) 13.= 4.16 lb
14. Density of compacted wet soil (30 x #13) 14.= 124.8 lb/ft³

IV. Pick the Correct Curve from the Ohio Typical Density Curves Using #14 and (#5 or #16)
15. Optimum moisture from Dry Weight Curve (Curve N) 15.= 16.9 %
16. Moisture from Line 5 or Corrected moisture by Drying if required 16.= 16.2 %
17. Amount above ☐ or below ☒ optimum moisture (#16 - #15) 17.= -0.7 %
18. Maximum Dry Density (From Curve No. N) 18.= 109.8 lb/ft³

V. Compaction Calculation Procedure When Line 10 is less than 10%
19. Compaction (#4 ÷ #18 x 100) 19.= Use 10 > 10% Go to line 20

VI. Compaction Calculation When Line 10 is greater than 10% and less than 25%**
20. Corrected Maximum Dry Density using Graph A and Lines (#10 & 18) 20.= 116.5 lb
21. Corrected Optimum Moisture using line 20 and Typical Density Curves 21.= 13.5 %
Use Graph "A"
22. Compaction (#4 ÷ #20 x 100) 22.= 95.4 %
23. Amount above ☒ or below ☐ optimum moisture (#5 - #21) 23.= + 2.7 %
24. Moisture from zero air voids curve using (#4) 24.= 18.0 % > 16.2 O.K.

*Average Specific Gravity Values: Limestone = 2.6 Gravel = 2.5 Sandstone & Sandy Shale = 2.2
**If line 10 is greater than 25%, make a Granular Moisture Density Curve and use the Test Section Method

Does material tested meet specification requirements for: (write YES or NO on each of the following)
Max. dry weight: Yes ; Moisture: Yes ; Compaction: No ;
Does test check zero air voids curve (check which): YES X NO
Action taken by (check which): Inspector ______ Project Engineer ______
If material tested does not meet specification requirements:
Additional rolling ordered ____ Aerating ordered ____ Watering ordered ____ Other
Computed By: ______ Checked By: ______

Figure 1015.03.C - Completed CA-EW-6 Compaction Form (pictures added for clarity)

I. Nuclear Gauge Readings

Lines 1 thru 5 are explained in Section 1015.02.D.

II. Remove the Soil from under the Gauge and Sieve thru a ¾ inch Sieve

This section is straightforward calculation of the stone retained on the ¾ inch sieve. Calculate through lines 6 through 10.

The percentage on line 10 is represented by the following equation:

$$\text{Percent of Stone in Sample} = \frac{\text{Weight of stone retained}}{\text{Weight of total soil sample}} \times 100$$

III. Proctor Test Using the Soil passing the ¾ inch Sieve

See Sections 1015.02.F section 'D' & 1015.01.B.2 for an explanation of Lines 11 thru 14.

IV. Pick the Curve for the Ohio Density Curves Using # 14 and (#5 or 16)

See Section 1015.02.F for an explanation of Lines 15 through 18.

V. Compaction Calculation When Line 10 is less than 10%

Line 19 is explained in Section 1015.02.G.

VI. Compaction Calculation When Line 10 is greater than 10% and less than 25%

This section uses Figure 1015.03.D Aggregate Correction Graph A and Figure 1015.03.E Moisture Correction with an Aggregate Correction to find a new Maximum Dry Density and Optimum Moisture.

The Nuclear Gauge Testing is almost the same as detailed in Section 1015.02 with the exceptions being the calculation of the Percent retained on the ¾ inch sieve in on line 10 in Section II and Section VI is new.

<u>Calculate a New Maximum Dry Density</u>

This section details Figure 1015.03.D Aggregate Correction Graph A:

The instructions are on the graph.

1. The inputs needed are:
   a. The Specific Gravity of the Stone Retained on the ¾" sieve.
      i. The typical values are listed on the graph.
   b. The Maximum Density Found on Line 18: 109.6 lb/ft3
   c. The Percent retained on the ¾ inch sieve on Line 10: 20%
2. Draw a line between the specific gravity and the Line 18 value.
3. Input Line 10 value on the bottom of the graph and draw a vertical to the previously line drawn.
4. Continue the line to the left on a right angle to the Corrected Maximum Dry Density.
5. Input this value found on line 20 on the CA-EW-6.

This is the corrected Maximum Dry Density: 116.5 lb/ft^3

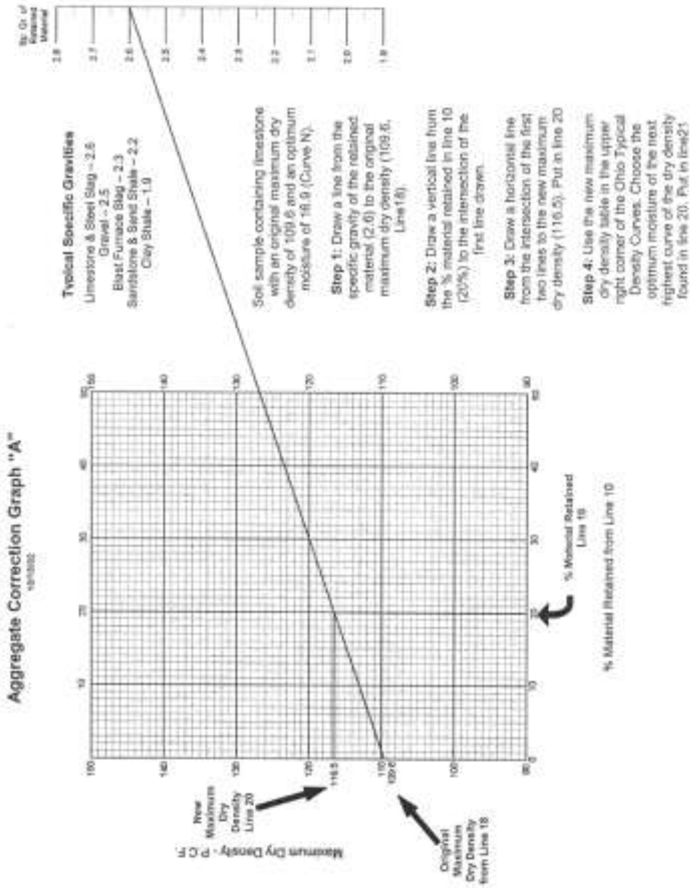


Figure 1015.03.D - Aggregate Correction Graph A

<u>Determine a New Optimum Moisture</u>

New optimum moisture is found by inputting the New Maximum Dry Density into the maximum Density Values in the upper right hand corner on Figure 1015.03.E.

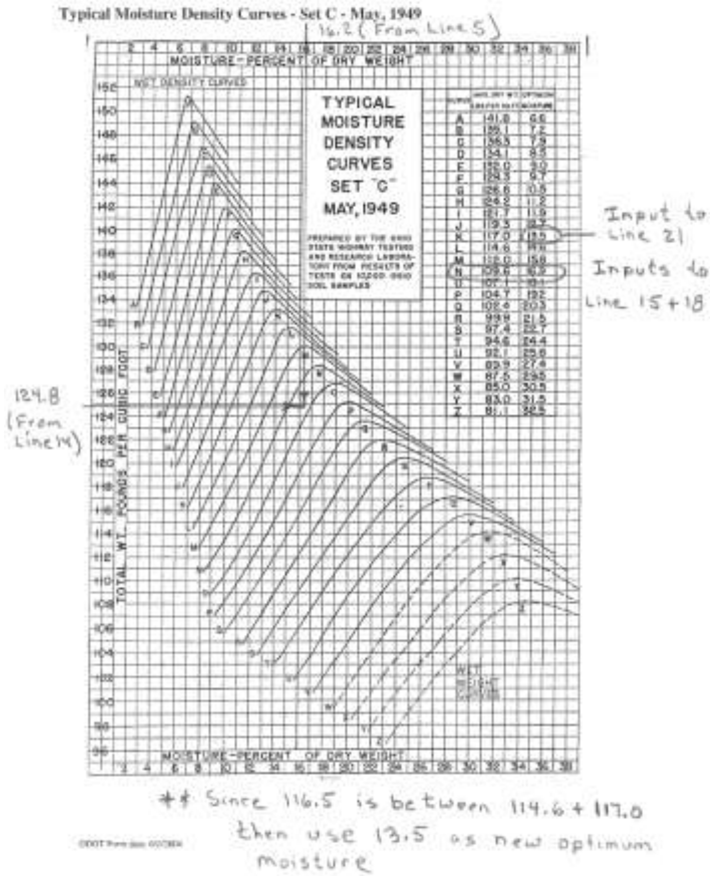


Figure 1015.03.E - Moisture Correction for an Aggregate Correction

For Example, the Maximum Dry Density on Line 20 is 116.5 lbs/ft^3. This value is between curve K (117) and L (114.5). New optimum value is 13.5% which is the moisture corresponding to the next highest curve which is Curve K.

<u>Compaction, Difference in Optimum Moisture and Zero Air Voids</u>

The compaction, difference in optimum moisture, and the zero air voids are calculated on lines 22 to 24. The calculation is the same as before.

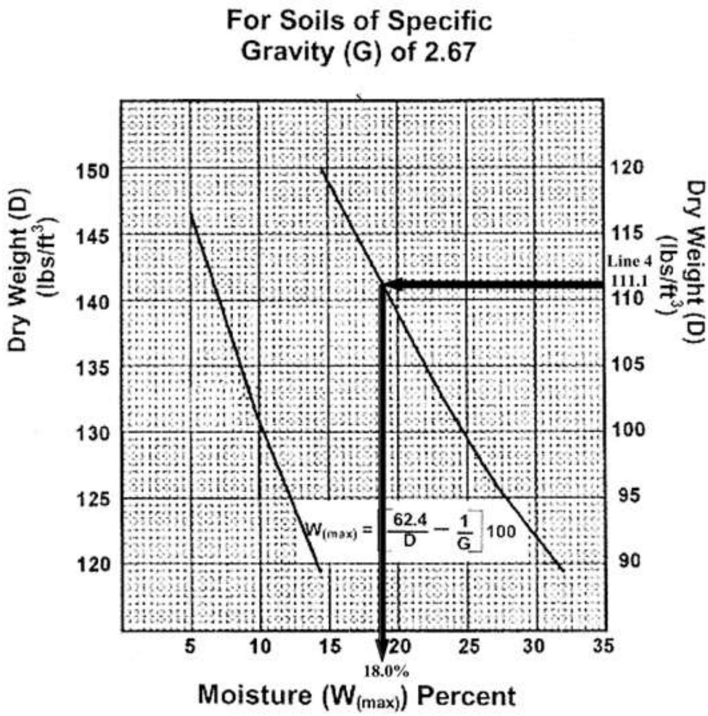


Figure 1015.03.F - Zero Air Voids curve

Form CA-EW-5 Line #	Form CA-EW-6 Line #	Step	
4 &7	1 & 2	Step 1 Standard Count Section 1015.02.D.1	
5, 6 & 8	3 - 5	Step 2 In Place Readings Section 1015.02.D.1	
		Step 3 Dig Hole Under Gauge Obtain a 10 lb Sample Section 1015.02.F Step A	

Figure 1015.03.G - Outline for Using Forms CA-EW-5 and CA-EW-6 (1 of 2)

Figure 1015.03.H - Outline for Using Forms CA-EW-5 and CA-EW-6 (2 of 2)

1	Soil (8" lifts)	Sieve 3/4"	<10% Retained	A. One Point	
	Defined at >35% P-200		>10% Retained	B. Aggregate Correction	
			>25% Retained	C. Granular Material	See Granular
2	Granular Material < 35% P-200	8" Lifts	Moisture Density Curve	Test Section	Method A With Curve
	Examples: 304	Method A			Method B No Curve
	307	Method C			Method C Variable Material
3	Rock	3' Lifts or Largest Particle	18" Lifts near Bridges	Track and Fill Voids	Compact & Use Roller Passes
4	Rock & Shale Mixtures	8" Lifts		Compact like Shale	
5	Shale (8" Lifts)	Bucket Durability Test	< 25 % Retained In 3/4" Sieve	One Point	
			25-75 % Retained	Test Section	
			> 75 % Retained	Roller Passes	
				> 40 % Breaks Down	Test Section
				< 40 % Breaks Down	Roller Passes

Figure 1015.03.I - Compaction and Testing Guide

Compaction Testing for Granular Materials (1015.04)

General Explanation (1015.04.A)

This section describes how to perform compaction testing for materials used as granular soil, sand, structural backfill type 1 or 2, 304, 411, select granular backfill for MSE walls, granular material type A, B, C, D or F, or any materials that requires a test section.

The dry weight of the material is used for compaction control. The wet weight method is no longer used.

Moisture-Density proctor curves were originally developed for use on cohesive (clays and silts) soils. Errors or complications arise when trying to extrapolate these principles to other materials. This is the reason the Engineer or Inspector is given the latitude to choose density requirements that are based on the test section results.

A one-point proctor method using the typical density curves may be used for granular soils. The top curves of the Ohio Typical Density Curves A through E are usually chosen in this case. These curves will only work in a very limited number of cases. This method should only be used as a last resort.

These materials must have a moisture-density curve made a few weeks before the Contractor proposes to use the material. Curves may be made in the field or by the Laboratory.

Making a moisture-density curve for these materials is the same procedure explained in Section 1015.01.B. A typical moisture-density curve for a granular material is shown in Figure 1015.04.A.

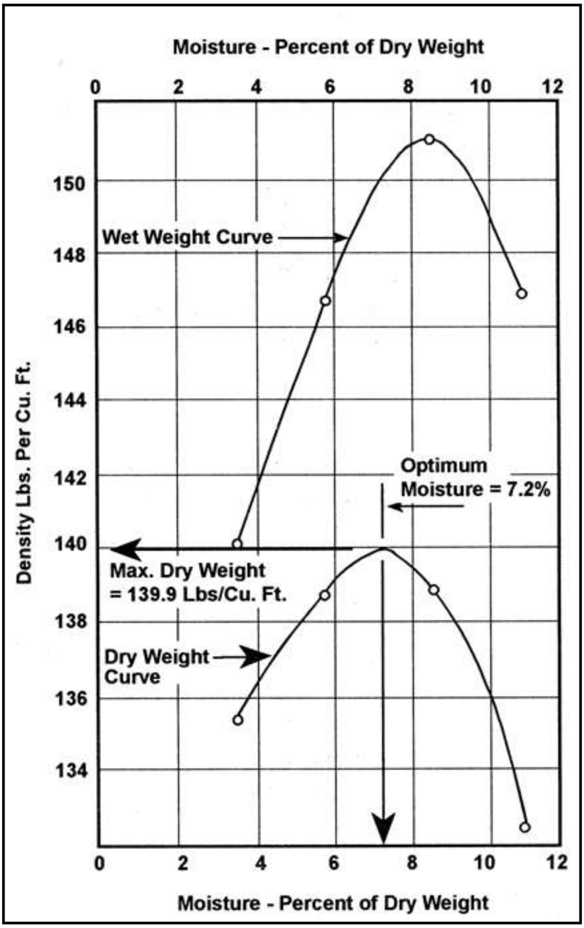


Figure 1015.04.A - Typical Granular Moisture-Density Curve

The district should contact the Office of Geotechnical Engineering at the following link to have a moisture-density curve made:

www.dot.state.oh.us/Divisions/ProdMgt/Geotechnical

The maximum density and optimum moisture data obtained from this curve may or may not work in the field. The following are examples and further explanation of some of the problems associated with the density control of these materials.

Examples of Density Problems (1015.04.B)

Using a Sandy Material (1015.04.B.1)

It may not be possible to obtain the maximum density of the curve no matter how or with what equipment the Contractor uses to compact the material. This is particularly true for sandy material with silt fines.

Reason

The proctor mold used to produce the moisture-density curve confines the sand in all directions. In the field, since sand doesn't interlock or knit together well without being confined, the roller will squeeze the material laterally. The proctor maximum densities may not be obtained in the field.

The sand may not even support the weight of the roller. The lab and field confining pressures and compactive effort are not compatible in this case.

This is shown in Figure 1015.04.B

Solution

Use the test section maximum density.

1015.04.B.2 Using a Well Graded Granular Material like 304

In this case, the maximum dry densities obtained in the field using the test section method often exceed the maximum dry density of the moisture-density curve.

Reason

The 304-type material is well interlocked and allows the roller to transfer more energy, compactive effort, or load to the material.

This roller load or energy is much larger than the proctor hammer load of 5.5 lbs. (2.5 kg) dropped 12 inches (305 mm) in three lifts.

This is shown in Figure 1015.04.B

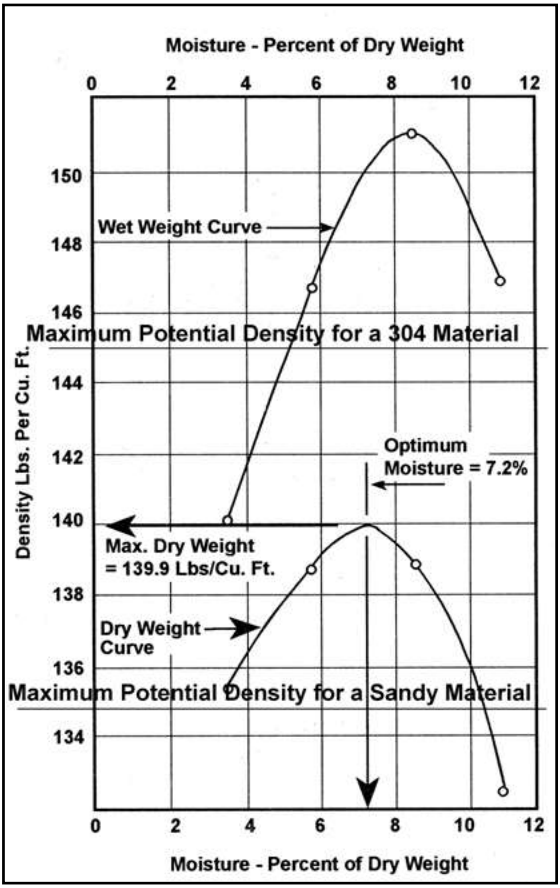


Figure 1015.04.B - Maximum Density Problems

Solution

Use the test section maximum density.

Compacting on a Soft Foundation (1015.04.B.3)

If the material is being compacted on a soft foundation, then the maximum density cannot be achieved. Excessive rolling will only result in pumping and creating an unstable foundation.

This applies to all types of materials. You cannot compact good material over bad material and expect to achieve a maximum density. You cannot compact material on jello-type material to a maximum density either. The maximum test section densities, if taken at all, would be less than the maximum curve value.

Compacting in Confined Spaces (1015.04.B.4)

There are a variety of locations where light equipment is used to compact material. Some examples are for:

1. Pipe backfill.
2. Manhole backfill.
3. Around abutments.
4. MSE walls.

The potential maximum density is limited to the type of equipment used to compact this material in these confined spaces.

Throughout the specifications for these items, ODOT requires minimum compaction equipment weight for these areas where a test section is used for compaction acceptance.

The maximum density that can be achieved is proportional to the heaviest equipment that can be used in these locations. The maximum density that can be achieved in these locations is usually less than the moisture-density curve value.

Moisture Problems (1015.04.C)

The granular material should be brought on site at or near optimum moisture. When this is not the case, moisture should be added before rolling occurs. This is particularly important for 304 gradation materials since this material cannot readily absorb water.

In 304.03, it is required that the stockpile of 304 material have a moisture content of at least 2 percent below optimum.

Optimum moisture from the proctor moisture-density curve of granular materials is not always correct. Sometimes the granular material begins to roll or pump when the material is compacted at or near optimum moisture obtained from the moisture-density curve. This is caused by excess water in the material and the difference between the field and curve confining forces. In this case, dry the material until stability is achieved; usually 1 to 3 percent below optimum will work.

Summary of the Moisture-Density Problems (1015.04.D)

A granular moisture-density curve should always be used to estimate the maximum density and optimum moisture. When using these materials, the proctor moisture-density curve is used as a guide; the exact maximum density and optimum moisture can only be found in the field.

The test section method of compaction acceptance compensates for:

1. Material Differences.
2. Moisture-Density Curve and Potential Field Density Differences.
3. Moisture Problems.
4. Soft Foundations.
5. Confined Construction.

The maximum density determined in the field is relative to all of the above.

Equipment and Compaction Testing (1015.04.E)

The equipment used for compaction testing is the same equipment listed in 1015.02.B.

The compaction testing is the same as in section 1015.02.D, except for the following:

1. A proctor is not taken for every test.
    a. Only used to obtain the moisture-density curve.
2. The ‘Backscatter Mode’ on the gauge is used.
    a. Ensure that the surface voids are all filled or the surface texture is the same.
    b. Variation in the measurements will result.
3. Use Form CA-EW-5.

Minimum Roller Weights for Test Sections (1015.04.F)

Throughout the specifications, you will find minimum roller weight requirements when a test section method is used for acceptance.

The following is from C&MS 203.06.A, page 92.

> *“For soil or granular material, when a test section is used, use a minimum compactive effort of eight passes with a steel wheel roller having a minimum weight of 10 tons (9 metric tons).”*

The following is from C&MS 603.11.E, page 440.

> *“At the beginning of the work, construct a test section in the conduit trench. The Engineer will use at least 96 percent of the test section maximum dry density for acceptance of the production areas. Use at least the same number of passes or compactive effort used to construct the test section to compact the production areas. Use compaction equipment with a total weight or centrifugal force of at least 1/2 ton (0.5 metric tons). Supply the manufacture’s specification for the compaction equipment. Except when using a hoe pack, use at least six passes with the compaction equipment in the production areas.”*

The maximum potential obtained in the field is relative to the roller weight used in the test section. Therefore, minimums were established to fit the field conditions. You will notice that the confined areas have a much lower minimum weight and less maximum acceptance value.

Do not be confused by the word centrifugal force. It is only the effective weight when including the vibration of the equipment.

Procedure for Constructing a Test Section Method A (1015.05)

Method A is used when the moisture-density curve can be established to estimate the maximum density and optimum moisture.

The following is an outline of the procedure:

1. Test section size is 400 square yards.
2. Spread the material at the correct lift thickness.
    a. Usually 6 to 8 inches.
3. Moisture content at - 2 to + 2 of optimum.
    a. Water or dry throughout the lift.
    b. Reduce moisture if unstable.
4. Compact with two passes.
5. Take a compaction test.
    a. Mark the location with paint.
    b. Record on Line 6 of Form CA-EW-5.
6. Compact with one more pass and continue testing until:
    a. No further increase in density.
    b. Or the density decreases.
7. Once a maximum is obtained.
    a. Make two additional passes and take one additional test.
    b. Verifies the maximum value.(Verification Test).
8. Record the total number of passes.
    a. Use Line 9 of CA-EW-5.
9. Use this number of passes or the specification minimum in the production area.
10. Compact the production area to at least 98% of the test section maximum.

There are statements throughout the specifications that require a minimum number of passes. Experience has shown that these minimum passes for the different materials result in more uniform compaction in the production areas.

If the specification calls for 8 passes, use the 8 passes even though the test section may show that 6 passes are needed to obtain a maximum. More production area tests will pass by using these minimum passes.

There are also statements throughout the specifications that allow a decrease in minimum number of passes such as:

> *"The Engineer may reduce the minimum passes if the passes are detrimental to compaction".*

There are also statements about making a new test section when conditions change.

> *"Construct a new test section if the pipe type, bedding material, backfill material, or trench conditions change."*

All of these statements allow the Engineer to control the work to meet the field conditions and to obtain maximum densities.

Test Section Value Examples ('X' denotes Maximum Used)

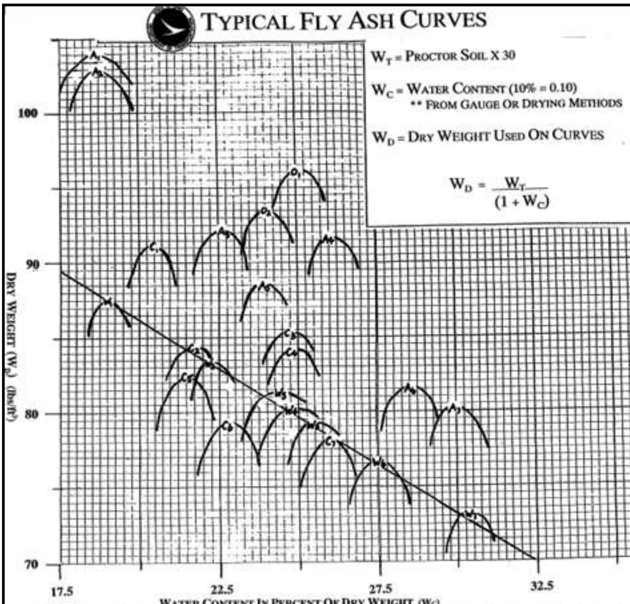
Passes	2	3	4	5	6	Verification Passes (2)
Density	126	134	135	140X	122	125
	110	108	112	116	116X	109
	120	129	132	130		145 (Take more Tests)

Test Section Method B (1015.06)

This type of test section is used when a moisture-density curve cannot be made or is not available at the time of construction. Recycled materials such as some foundry sands or fly ash can be tested this way. Since the maximum density or optimum moisture are unknown, we have to create the field curve.

Use the same procedure as in Section 1015.05 except for the following.

1. Place the material in the required lifts.
   a. Bone dry (0 to 3%).
2. Compact and test until:
   a. A maximum value is reached.
   b. Record the density on Line 6 on the CA-EW-5.
   c. Record the number of passes on line 9.
3. Place new material.
   a. At a new location.
   b. At a moisture content 2% higher.
4. Compact and test to a maximum value.
5. Repeat the procedure.
   a. At higher moisture until.
      i. Maximum value is achieved.
      ii. Two test sections have the same or lower densities.
      iii. Material becomes unstable.
6. Use this maximum density, optimum moisture and number of passes in the production areas.



American Electric Power	WD_{MAX}	WC_{OPT}
A_1	103.4	18.9*
A_2	103.4	18.5
A_3	103.0	19.0*
A_4	103.0	18.5*
A_5	102.9	18.7
A_6	102.9	18.5*
A_7	102.8	19.0*
A_8	102.8	18.0*
A_9	102.6	18.0*
A_{10}	102.5	18.5*
A_{11}	92.1	22.6
A_{12}	91.9	26.0
A_{13}	88.6	23.8
A_{14}	81.5	28.4
A_{15}	80.1	29.9

Cincinnati Gas & Electric	WD_{MAX}	WC_{OPT}
C_1	91.3	20.5
C_2	85.4	24.7
C_3	84.3	21.8
C_4	84.1	24.9
C_5	82.4	24.4*
C_6	82.3	21.5
C_7	81.7	22.8*
C_8	80.1	25.8*
C_9	79.3	22.9
C_{10}	79.2	25.6*
C_{11}	78.5	24.8*
C_{12}	78.2	26.0

West Virginia Power Plant	WD_{MAX}	WC_{OPT}
W_1	87.5	19.0
W_2	83.4	22.3
W_3	83.2	22.2*
W_4	81.3	23.6*
W_5	81.0	23.9
W_6	80.6	23.8*
W_7	80.0	24.6
W_8	79.3	25.3
W_9	78.3	26.3*
W_{10}	76.6	27.5
W_{11}	73.0	30.2

ODOT Test Laboratory	WD_{MAX}	WC_{OPT}
O_1	96.0	25.0
O_2	93.5	24.0

(*) Curve Not Plotted

Figure 1015.06.A - Typical Fly Ash Curves

Test Section Method C (1015.07)

This test section is used for open graded material such as non-stabilized drainage base. It also can be used for open graded aggregate bases where the surface texture is very open and or non-uniform.

The test section procedure is the same as detailed in 1015.05 except for the following:

1. Use the CA-EW-7 compaction form.
2. Place the material at 3% above saturated surface dry (SSD).
3. Compact at 1.5% above SSD.
4. Construct a Test Section.
    a. 400 square yards.
    b. Take 3 tests.
    c. Then average them.

   d. Compare the averages.
   e. See Section 2 of the CA-EW-7 Form.
5. The maximum is reached when:
   a. A maximum density average is achieved.
   b. Or the aggregate breaks.
   c. Whichever is first.
6. Take 10 tests in the control section.
   a. See Section 3 on the CA-EW-7.
   b. Use 95% of this density as the control section maximum.
7. For acceptance.
   a. Take 5 tests in a 5000 square yard lot.
   b. This average must be greater than 95% of the control section maximum.

Compaction Testing for Shale (1015.08)

Compaction testing for shale will depend on the durability of the shale. Perform the durability test ("bucket test") outlined in Section 203.02.P under Shale Identification (703.16.D). The compaction testing is directly associated with the results. It provides a ready means to determine what test method to use for compaction acceptance. The following is a summary:

1. If less than 25% of the shale is retained on the ¾ inch (19 mm) sieve.
   a. Then test and break down like soil.
   b. Use the one-point proctor method.
2. If 25 to 75% of the shale is retained on the ¾ inch (19 mm) sieve.
   a. Break down to granular material size.
   b. Test for compaction test using the test section method.
3. When greater than 75% of the shale is retained on ¾ inch (19 mm) sieve, use roller method in 703.16.D.4 for durability.
   a. If more than 40% breaks down.
      i. Break down to granular size.
      ii. Use the test section method.
   b. If less than 40% breaks down.
      i. Hard Durable Shale.
      ii. Use roller passes in 203.06.
      iii. No testing is required.

In practice, different materials will always be mixed together in a fill situation. However, this hardness or durability test gives a good indication of how the material should break down during compaction, and is an excellent means to determine compaction acceptance.

Compaction Acceptance (1015.09)

This section divides up the work into lots. It allows the project to accept material based on a lot size. The lot size is denoted in section 1015.10.

Minimum Number of Tests (1015.10)

Use Forms CA-EW-5, CA-EW-6 and CA-EW-7 for recording and reporting results of compaction tests. Retain these tests in the project files. Keep these tests in the folders of the items of work.

This section outlines the lot size and number of tests that are used on each lot for acceptance.

Under normal field conditions, the number of density and moisture checks required should not be great after the initial period of adjustment, assuming that the work is proceeding smoothly and materials being compacted are uniform.

The Engineer and inspector will learn to judge the moisture content of the material quickly by appearance and feel. If adequate densities are being obtained and the proper moisture content is being maintained, the job of inspection may then become one of deciding on the number of passes of the roller required for satisfactory test section density and seeing that this number of passes is actually made.

Under such conditions, only one or two density checks per day may be required. Where conditions are more variable, density and moisture checks may be needed as often as once an hour. The Engineer and Inspector can determine the exact number of checks required.

Sample problems for forms CA-EW-5 and CA-EW-6

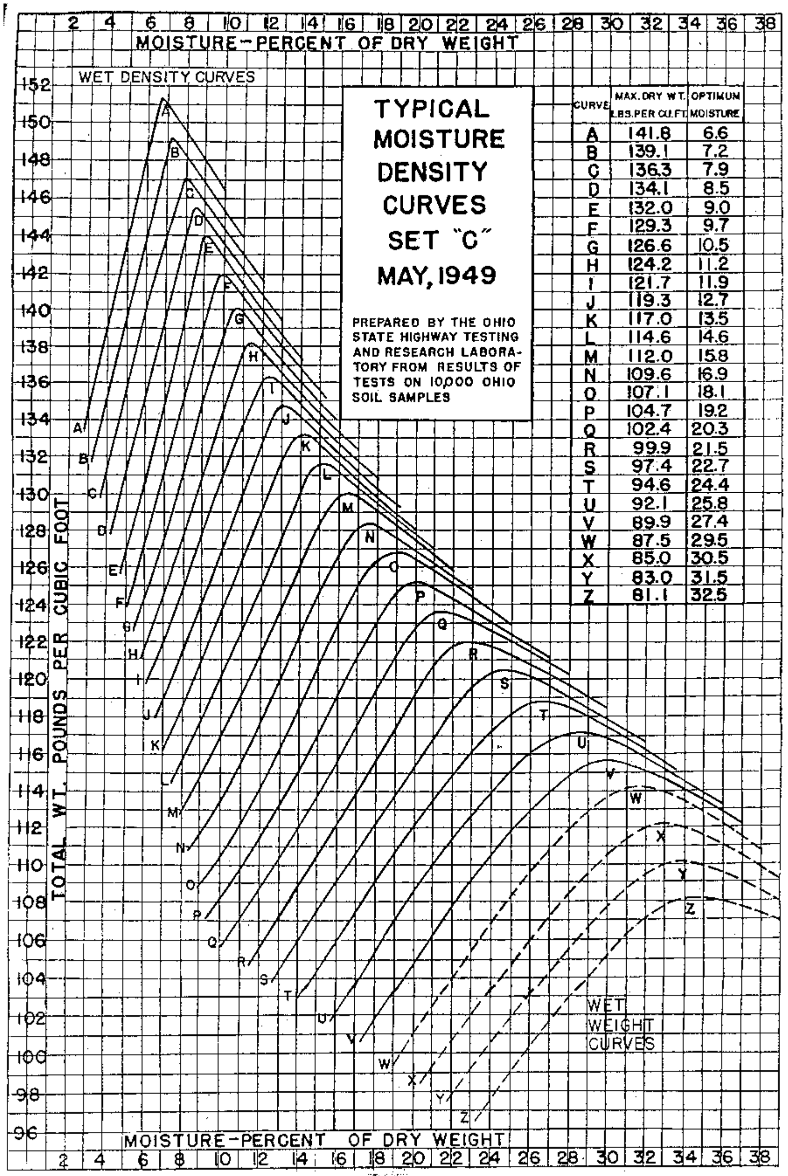
1	Soil (8" lifts)	Sieve 3/4"	<10% Retained	A. One Point	
	Defined at >35% P-200		>10% Retained	B. Aggregate Correction	
			>25% Retained	C. Granular Material	See Granular
2	Granular Material < 35% P-200	8" Lifts	Moisture Density Curve	Test Section	Method A With Curve
	Examples: 304	Method A			Method B No Curve
	307	Method C			Method C Variable Material
3	Rock	3' Lifts or Largest Particle	18" Lifts near Bridges	Track and Fill Voids	Compact & Use Roller Passes
4	Rock & Shale Mixtures	8" Lifts		Compact like Shale	
5	Shale (8" Lifts)	Bucket Durability Test	< 25 % Retained In 3/4" Sieve	One Point	
			25-75 % Retained	Test Section	
			> 75 % Retained	Roller Passes	
				> 40 % Breaks Down	Test Section
				< 40 % Breaks Down	Roller Passes

Compaction and Testing Guide

Form C-135 Line #	Form C-173 Line #		
4 & 7	1 & 2	Step 1 Standard Count Volume 3 Section 1015.02.D.1 Step 1	
5, 6 & 8	3 - 5	Step 2 In Place Readings Volume 3 Section 1015.02.D.1 Step 2	
		Step 3 Dig Hole Under Gauge Obtain a 10 lb Sample Volume 3 Section 1015.02.F Step A	

Page 1 of the Compaction Testing Outline

Page 2 of the Compaction Testing Outline



Ohio Typical Density Curves

CA-EW-5
03/03/03

STATE OF OHIO
DEPARTMENT OF TRANSPORTATION
NUCLEAR GAUGE COMPACTION FORM

Sample ID: 1113722540-416 Personnel ID: 111 - 0000 - 111 Date Sampled: 04 / 16 / 00
Type of Inspection: COMPACTION Producer Code: 55555 - 2 Contractor: Dave's Excavating
Material Code: 20340001 Test Results: PASS

Project Number: ____ Item Code ____ Reference Number ____

Notes ____

Test of (check which): ☒ Embankment ☐ Subgrade ☐ Base ☐ Other ____ Min. Compaction Req.: 98 %
Test of (check which): ☐ Limestone ☒ Gravel ☐ Slag ☐ Sandstone ☐ Granulated Slag ☐ Other ____
From Sta. 1 + 00 at 5 feet (rt. or lt.) of centerline to Sta. 2 + 00 at 10 feet (rt. or lt.) of centerline, at approx. Elevation 970 ft
See Report No. ____ (check which): Wet ☐ Dry ☒ Maximum Density from Test Section ____ lb/ft³ Optimum Moisture ____ %
98% of Max. Density ____ lb/ft³ Check Method used: ☒ Direct Transmission ☐ Backscatter Probe Depth 6 inches

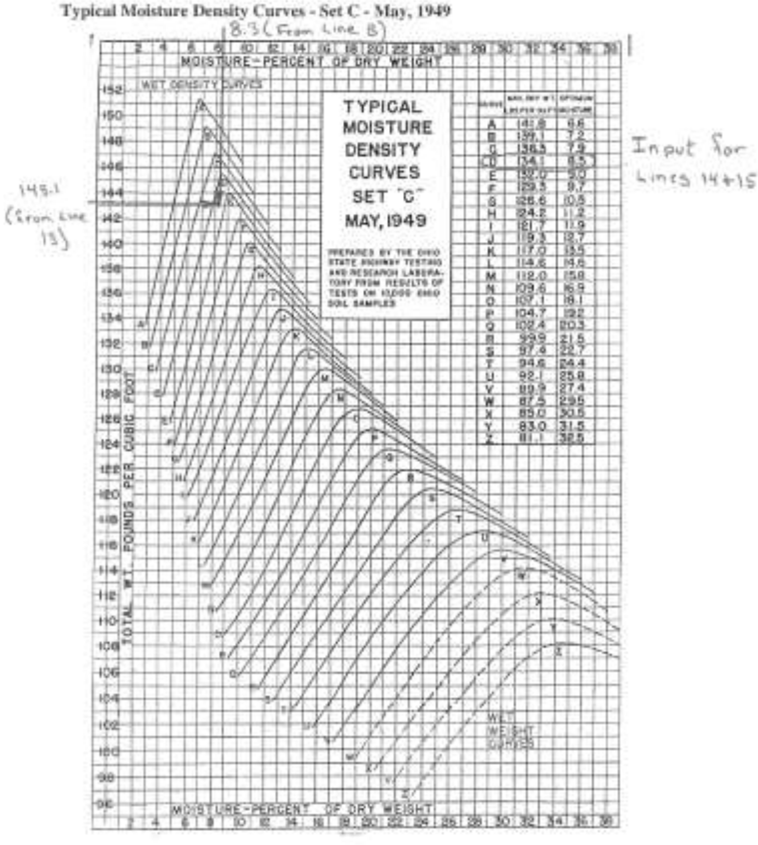
		1.	2.	3.	4.	5.	6.
1. Station of test	1.	109 + 50	109 + 50				
2. Distance right or left of centerline if different than above (ft)	2.	10	12				
3. Approximate Elevation if different than above (ft)	3.						
Procedure for Determining Dry and Wet Density							
4. Standard Count for Density	4.	2208					
5. Wet Density of soil from gauge (lb/ft³)	5.	139.9	144.4				
6. Dry Density of soil from gauge (lb/ft³)	6.	130.1	133.0				
Procedure for Determining Moisture Content							
7. Standard Count for moisture	7.	3599					
8. Moisture content of soil from gauge * (%)	8.	7.5	8.3				
9. Number of Passes	9.	8	10				
Take sample (about 10 lb) of material from area tested for density. Procedure when sample contains less than 10 % total weight in stone retained on 3/4" sieve**		Curve D	Curve D	Curve ____	Curve ____	Curve ____	Curve ____
10. Weight of 1/30 ft³ compacted wet soil + weight of container (lb)	10.	13.95	14.01				
11. Weight of 1/30 ft³ container (lb)	11.	9.24	9.24				
12. Weight of 1/30 ft³ compacted wet soil (#10 - #11) (lb)	12.	4.71	4.77				
13. Density of compacted wet soil (30 x #12) (lb/ft³)	13.	141.3	143.1				
14. Optimum moisture from dry density curve, Curve No. (D) (%)	14.	8.5	8.5				
15. Maximum Dry Density, Curve No. (D) (lb/ft³)	15.	134.1	134.1				
16. Amount above ☐ or below ☐ optimum moisture (#14 - #8) (%)	16.	+ 1.0	- 0.2				
17. Compaction [(#6 - #15) x 100] (%)	17.	97.0	99.2				
18. Moisture from the zero air voids curve using line 6	18	10.5	9.5	9.5 > 8.3 ✓	OK		
19. Does material tested meet Specification requirements? Yes ☐ No ☐	19.	NO	YES				
20. "A" Rolling ordered; "B" Aerating ordered; "C" Watering ordered	20.	A					
21. Date Tested	21.	08 / 22 / 92	08 / 22 / 92				

* In percent of Dry Density. ** Refer to C-173 when sample contains more than 10 % total weight in stone retained on 3/4" sieve;

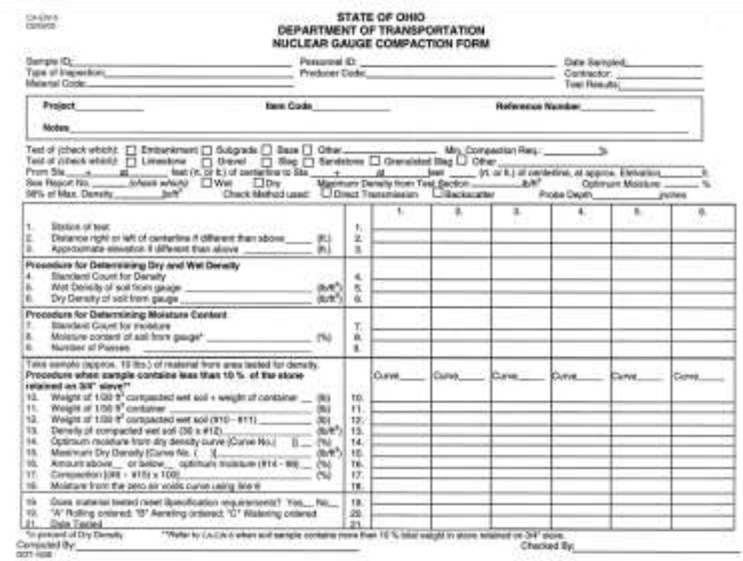
Computed By: SCOTT COMPACTION Checked By: DIRECTOR GALLAGHER
BDT-1635

Filled Out CA-EW-5

Typical Moisture Density Curves - Set C - May, 1949



Ohio Typical Density Curves for the CA-EW-5 Example


STATE OF OHIO
DEPARTMENT OF TRANSPORTATION
NUCLEAR GAUGE COMPACTION FORM

Sample ID:______ Personnel ID:______ Date Sampled______
Type of Inspection:______ Producer Code:______ Contractor:______
Material Code:______ Test Results:______

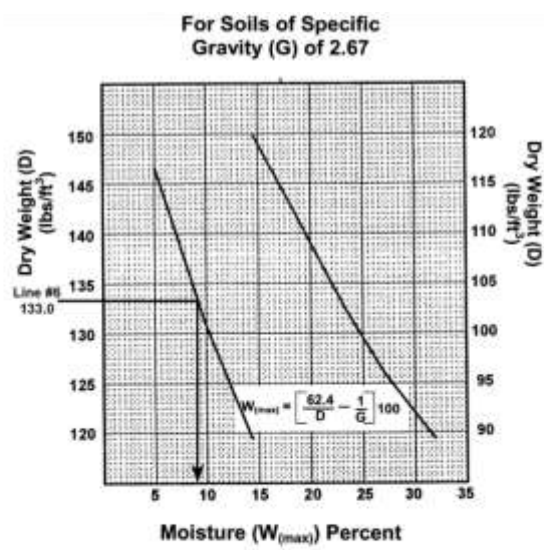
Project______ Item Code______ Reference Number______
Notes______

Test of (check which): ☐ Embankment ☐ Subgrade ☐ Base ☐ Other______ Min. Compaction Req.:______%
Test of (check which): ☐ Limestone ☐ Gravel ☐ Slag ☐ Sandstone ☐ Granulated Slag ☐ Other______
From Sta.____+____at______feet (rt. or lt.) of centerline to Sta.____+____at______feet ____ (rt. or lt.) of centerline, at approx. Elevation______ft.
See Report No.______(check which) ☐ Wet ☐ Dry Maximum Density from Test Section______lb/ft³ Optimum Moisture______%
98% of Max. Density______lb/ft³ Check Method used: ☐ Direct Transmission ☐ Backscatter Probe Depth______inches

		1	2	3	4	5	6
1. Station of test	1.						
2. Distance right or left of centerline if different than above ____ (ft.)	2.						
3. Approximate elevation if different than above ____ (ft.)	3.						
Procedure for Determining Dry and Wet Density							
4. Standard Count for Density	4.						
5. Wet Density of soil from gauge ____ (lb/ft³)	5.						
6. Dry Density of soil from gauge ____ (lb/ft³)	6.						
Procedure for Determining Moisture Content							
7. Standard Count for moisture	7.						
8. Moisture content of soil from gauge* ____ (%)	8.						
9. Number of Passes	9.						
Take sample (approx. 10 lbs.) of material from area tested for density. **Procedure when sample contains less than 10 % of the stone retained on 3/4" sieve****		Curve____	Curve____	Curve____	Curve____	Curve____	Curve____
10. Weight of 1/30 ft³ compacted wet soil + weight of container ____ (lb)	10.						
11. Weight of 1/30 ft³ container ____ (lb)	11.						
12. Weight of 1/30 ft³ compacted wet soil (#10 − #11) ____ (lb)	12.						
13. Density of compacted wet soil (30 x #12) ____ (lb/ft³)	13.						
14. Optimum moisture from dry density curve (Curve No.) ( ) ____ (%)	14.						
15. Maximum Dry Density (Curve No. ( )) ____ (lb/ft³)	15.						
16. Amount above__ or below__ optimum moisture (#14 − #8) ____ (%)	16.						
17. Compaction (#6 ÷ #15) x 100 ____ (%)	17.						
18. Moisture from the zero air voids curve using line 6	18.						
19. Does material tested meet Specification requirements? Yes__ No__	19.						
20. "A" Rolling ordered; "B" Aerating ordered; "C" Watering ordered	20.						
21. Date Tested	21.						

*In percent of Dry Density **Refer to CA-EW-6 when soil sample contains more than 10 % total weight in stone retained on 3/4" sieve.
Computed By:______ Checked By:______
DOT-1008

Blank CA-EW-5



Zero Air Voids Curve for the CA-EW-5 Example

Aggregate Correction Method

CA-EW-6
02/03/03

STATE OF OHIO
DEPARTMENT OF TRANSPORTATION
NUCLEAR GAUGE COMPACTION WITH AN AGGREGATE CORRECTION

Sample ID: ______ **Date Sampled:** ______
Type of Inspection: ______ **Producer Code:** ______ **Contractor:** ______
Material Code: ______ **Test Results:** ______

Project Number ______ **Item Code** ______ **Ref. Number** ______

Notes ______

Test of *(check which)*: ☐ Embankment ☐ Subgrade ☐ Base ☐ Other ______ Min. Compaction Req.: ______ %
From Sta ______ + ______ at ______ feet ______ (rt. or lt.) of centerline, at approx. Elevation ______ ft.

I. Nuclear Gauge Readings

1. Standard Count for Density ______ 1.= 2208
2. Standard Count for Moisture ______ 2.= 3509
3. Wet Density of the Soil from the Gauge ______ 3.= 129.1 lb/ft³
4. Dry Density of the Soil from the Gauge ______ 4.= 111.1 lb/ft³
5. Percent Moisture from the Gauge ______ 5.= 16.2 %

II. Remove the Soil from Under the Gauge and Sieve the Soil Through a 3/4" Sieve

6. Weight of wet soil (& stone if any) from hole + weight of pan ______ 6.= 14.0 lb
7. Weight of Pan or Container ______ 7.= 2.0 lb
8. Weight of wet soil (& stone if any) from under the nuclear gauge (#6 less #7) ______ 8.= 12.0 lb
9. Weight of stone & Sieve or Pan ______ 9.= 3.4 lb

9a. Weight of Sieve or Pan ______ 9a.= 1.0 lb
9b. Weight of stone removed from sample and retained on 3/4" Sieve (#9 less 9a) 9b.= 2.4 lb
10. Percent stone in sample (9b ÷ #8 x 100) ______ 10.= 20.0 %

III. Proctor Test Using the Soil Passing the 3/4" Sieve

11. Weight of 1/30 ft³ compacted wet soil + weight of container ______ 11.= 13.40 lb
12. Weight of 1/30 ft³ container ______ 12.= 9.24 lb
13. Weight of 1/30 ft³ compacted wet soil (#11 less #12) ______ 13.= 4.16 lb
14. Density of compacted wet soil (30 x #13) ______ 14.= 124.8 lb/ft³

IV. Pick the Correct Curve from the Ohio Typical Density Curves Using #14 and (#5 or #16)

15. Optimum moisture from Dry Weight Curve (Curve N) ______ 15.= 16.9 %
16. Moisture from Line 5 or Corrected moisture by Drying if required ______ 16.= 16.2 %
17. Amount above ☐ or below ☒ optimum moisture (#16 - #15) ______ 17.= -0.7 %
18. Maximum Dry Density (From Curve No. N) ______ 18.= 109.6 lb/ft³

V. Compaction Calculation Procedure When Line 10 is less than 10%

19. Compaction (#4 ÷ #18 x 100) ______ 19.= line 10 > 10% **Go to line 20**

VI. Compaction Calculation When Line 10 is greater than 10% and less than 25%**

20. Corrected Maximum Dry Density using Graph A and Lines (#10 & 18) ______ 20.= 116.5 lb
21. Corrected Optimum Moisture using line 20 and Typical Density Curves ______ 21.= 13.5 %

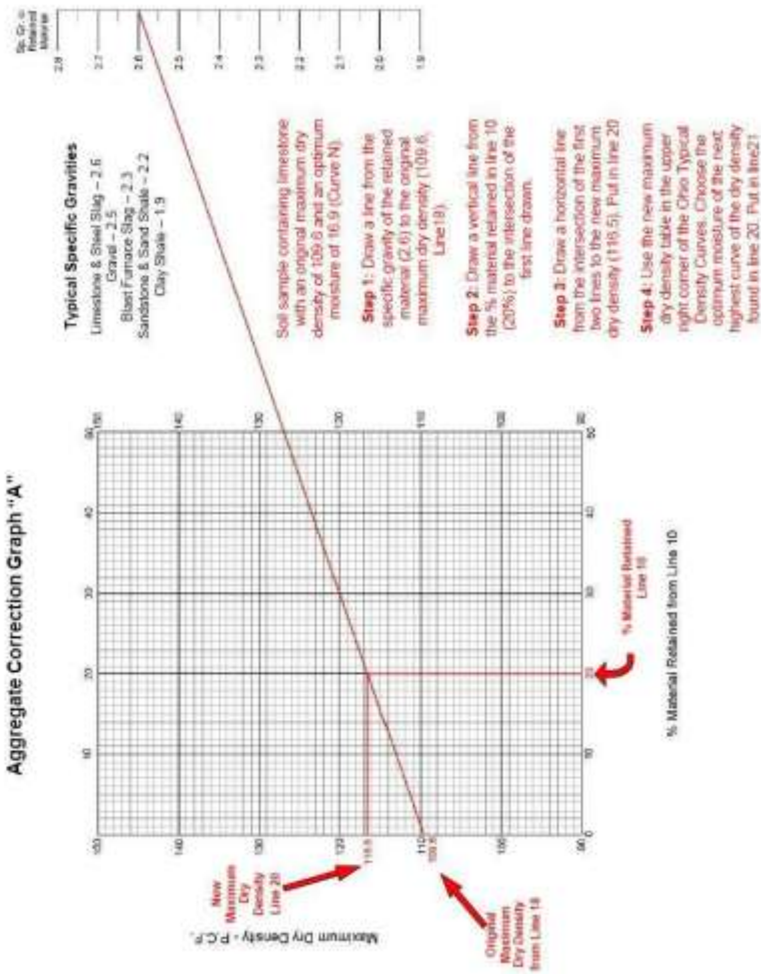
$\left.\begin{array}{l}20.\\21.\end{array}\right\}$ **Use Graph "A"**

22. Compaction (#4 ÷ #20 x 100) ______ 22.= 95.4 %
23. Amount above ☒ or below ☐ optimum moisture (#5 - #21) ______ 23.= + 2.7 %
24. Moisture from zero air voids curve using (#4) ______ 24.= 18.0 % **> 16.2 O.K.**

*Average Specific Gravity Values: Limestone = 2.6; Gravel = 2.5; Sandstone & Sandy Shale = 2.2
**If line 10 is greater than 25%, make a Granular Moisture Density Curve and use the Test Section Method.

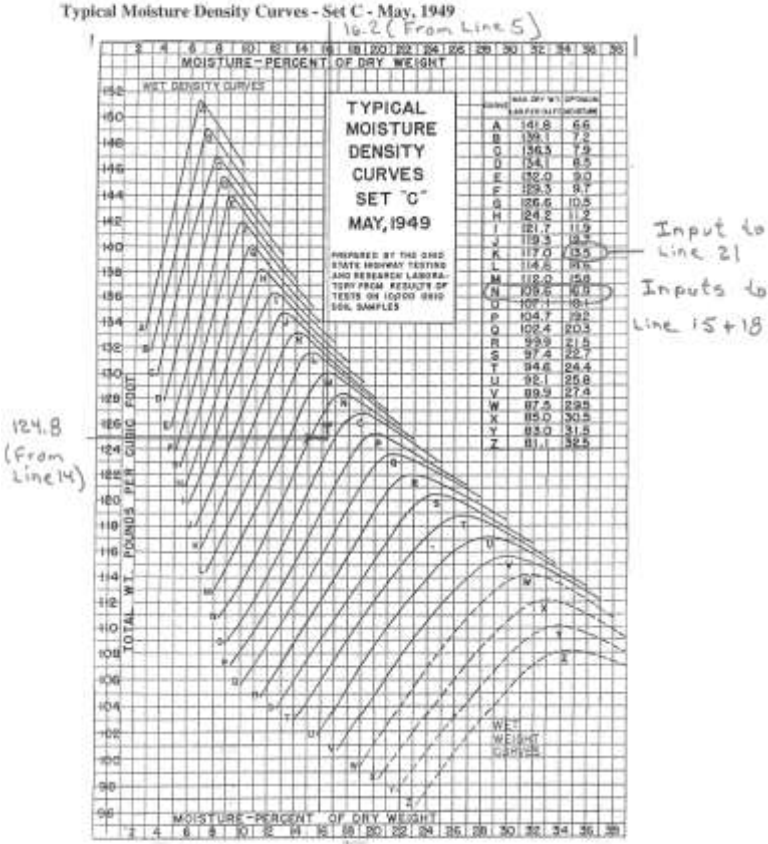
Does material tested meet specification requirements for: (write YES or NO on each of the following)
Max. dry weight: Yes ; Moisture: Yes ; Compaction: No ;
Does test check zero air voids curve *(check which)*: YES X NO
Action taken by *(check which)*: Inspector ______ Project Engineer ______
If material tested does not meet specification requirements:
Additional rolling ordered ______ Aerating ordered ______ Watering ordered ______ Other
Computed By: ______ Checked By: ______
DOT-1646

CA-EW-6 Example



Aggregate Correction Graph A

Typical Moisture Density Curves - Set C - May, 1949



** Since 116.5 is between 114.6 + 117.0 then use 13.5 as new optimum moisture

ODOT Form date 6/1/2004

Ohio Typical Density Curve for CA-EW-5 Example

CA-EW-6
03/03/03

STATE OF OHIO
DEPARTMENT OF TRANSPORTATION
NUCLEAR GAUGE COMPACTION WITH AN AGGREGATE CORRECTION

Sample ID: ☐ **Date Sampled:** ________
Type of Inspection: ________ **Producer Code:** ________ **Contractor:** ________
Material Code: ________ **Test Results:** ________

Project Number ________ **Item Code** ________ **Reference Number** ________

Notes ________

Test of *(check which)*: ☐ Embankment ☐ Subgrade ☐ Base ☐ Other ________ Min. Compaction Req.: ______ %
From Sta ______ + ______ at ______ feet ______ (rt. or lt.) of centerline, at approx. Elevation ________ ft.

I.	**Nuclear Gauge Readings**		
1.	Standard Count for Density	1.= ______	1.= ______
2.	Standard Count for Moisture	2.= ______	2.= ______
3.	Wet Density of the Soil from the Gauge	3.= ______ lb/ft³	3.= ______ lb/ft³
4.	Dry Density of the Soil from the Gauge	4.= ______ lb/ft³	4.= ______ lb/ft³
5.	Percent Moisture from the Gauge	5.= ______ %	5.= ______ %
II.	**Remove the Soil from Under the Gauge and Sieve the Soil Through a 3/4" Sieve**		
6.	Weight of wet soil (& stone if any) from hole + weight of pan	6.= ______ lb	6.= ______ lb
7.	Weight of Pan or Container	7.= ______ lb	7.= ______ lb
8.	Weight of wet soil (& stone if any) from under the nuclear gauge (#6 less #7)	8.= ______ lb	8.= ______ lb
9.	Weight of stone & Sieve or Pan	9.= ______ lb	9.= ______ lb
9a.	Weight of Sieve or Pan	9a.= ______ lb	9a.= ______ lb
9b.	Weight of stone removed from sample and retained on 3/4" Sieve (#9 less 9a)	9b.= ______ lb	9b.= ______ lb
10.	Percent stone in sample (9b ÷ #8 x 100)	10.= ______ %	10.= ______ %
III.	**Proctor Test Using the Soil Passing the 3/4" Sieve**		
11.	Weight of 1/30 ft³ compacted wet soil + weight of container	11.= ______ lb	11.= ______ lb
12.	Weight of 1/30 ft³ container	12.= ______ lb	12.= ______ lb
13.	Weight of 1/30 ft³ compacted wet soil (#11 less #12)	13.= ______ lb	13.= ______ lb
14.	Density of compacted wet soil (30 x #13)	14.= ______ lb/ft³	14.= ______ lb/ft³
IV.	**Pick the Correct Curve from the Ohio Typical Density Curves Using #14 and (#5 or #16)**		
15.	Optimum moisture from Dry Weight Curve (Curve ___)	15.= ______ %	15.= ______ %
16.	Moisture from Line 5 or Corrected moisture by Drying if required	16.= ______ %	16.= ______ %
17.	Amount above ☐ or below ☐ optimum moisture (#16 - #15)	17.= ______ %	17.= ______ %
18.	Maximum Dry Density (From Curve No. ___)	18.= ______ lb/ft³	18.= ______ lb/ft³
V.	**Compaction Calculation Procedure When Line 10 is less than 10%**		
19.	Compaction (#4 ÷ #18 x 100)	19.= ______ %	19.= ______ %
VI.	**Compaction Calculation When Line 10 is greater than 10% and less than 25%****		
20.	Corrected Maximum Dry Density using Graph A and Lines (#10 & 18)	20.= ______ lb/ft³	20.= ______ lb/ft³
21.	Corrected Optimum Moisture using line 20 and Typical Density Curves	21.= ______ %	21.= ______ %
22.	Compaction (#4 ÷ #20 x 100)	22.= ______ %	22.= ______ %
23.	Amount above ☐ or below ☐ optimum moisture (#5 - #21)	23.= ______ %	23.= ______ %
24.	Moisture from zero air voids curve using (#4)	24.= ______ %	24.= ______ %

*Average Specific Gravity Values: Limestone = 2.6; Gravel = 2.5; Sandstone & Sandy Shale = 2.2
**If line 10 is greater than 25%, make a Granular Moisture Density Curve and use the Test Section Method.

Does material tested meet specification requirements for: (write YES or NO on each of the following)
Max. dry weight: ______ ; Moisture: ______ ; Compaction: ______ ;
Does test check zero air voids curve *(check which)*: YES ______ NO ______
Action taken by *(check which)*: Inspector ______ Project Engineer ______
If material tested does not meet specification requirements:
Additional rolling ordered ______ Aerating ordered ______ Watering ordered ______ Other ______
Computed By: ________ Checked By: ________
DOT-1646

Blank CA-EW-6

Documentation Requirements - Supplement 1015 Compaction Testing of Unbound Materials

1. Document all materials, inspection and compaction information on Form CA-EW-12.
2. For Items 203, 204, 205, 206, 840, 503, 603 Soil Embankment and all Items where 203 Embankment is specified
    a. If less than 10 percent of material passes the ¾ inch sieve, document on form CA-EW-5
    b. If more than 10 percent but less than 25 percent of the material passes the ¾ inch sieve, document on form CA-EW-6
    c. If more than 25 percent of the material passes the ¾ inch sieve, document on form CA-EW-5
3. Items 203 Granular Embankment, 203 Granular Material Types A, B, C, D or F, Item 304, 411, 503, Select Granular Backfill for MSE walls and 603 Structural Backfill and Granular Embankment, document on form CA-EW-5
4. Non-stabilized drainage base, Document on CA-EW-7