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Field Reference Manual for Quality Concrete Pavements

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16. Abstract
This Field Reference Manual for Quality Concrete Pavements was developed as part of an effort sponsored by FHWA to develop the "state-of-the-practice" for Quality Assurance (QA) of concrete pavements. This goal has been achieved through the development of this document and workshop training materials that provide engineers, inspectors, technicians and constructors a more thorough understanding of QA as it relates to the long-term performance of concrete pavements.

Although excellent training courses and workshops are offered by National Highway Institute (NHI) and others, obtaining training through conventional training courses is becoming increasingly difficult because of time and budget constraints. The training materials developed as part of this effort aim at addressing these needs and at providing a link between construction operations and QA.

Development of these deliverables required synthesizing existing reference documents and formatting the deliverables in a manner which is easy to understand and clearly communicates the importance of QA activities on the long-term performance of concrete pavements. The resulting workshop materials and Quality Field Reference for Concrete Pavements were designed to provide the end user with the knowledge of why QA is critical to the construction process and also provide the confidence and ability to implement improved QA processes through "real-world" case study examples that were designed to be interactive.

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1. Quality Assurance Concepts

INTRODUCTION

The intent of this field reference for ensuring the quality of concrete pavements is to provide the practitioner in the field with a clear and concise document that will give them guidance on steps that they can take to construct a smooth and durable concrete pavement. In keeping with this objective, the recommendations provided in this document are brief in nature. There are four key references from which this document was developed; these should be consulted whenever greater detail is needed to resolve an issue or question. These four references listed here are provided on a CD contained in a pocket of the front cover of this document:

- Integrated Materials and Construction Practices for Concrete Pavement: A State-of-the-Practice Manual, FHWA
- Testing Guide for Implementing Concrete Paving Quality Control Procedures, National Concrete Pavement Technology Center
- Concrete Pavement Field Reference Pre-Paving, American Concrete Pavement Association
- Concrete Pavement Field Reference Paving, American Concrete Pavement Association

References to Quality Assurance (QA) in the construction of transportation facilities can be found as far back as the 1960s.[(1)] The accepted definition of QA related to transportation infrastructure construction found in TRB Circular E-137 (May 2009) is as follows:

> Quality Assurance - "All those planned and systematic actions necessary to provide confidence that a product or facility will perform satisfactorily in service."

A comprehensive QA training resource developed by the Federal Highway Administration (NHI Course No. 134064, *Transportation Construction Quality Assurance*), defines QA in simpler terms:[(1)]

> "Making sure the quality of a product is what it should be."

Publicly funded construction of transportation facilities in the U.S. is a multi-billion dollar industry; which entrusts taxpayer funds to state transportation agencies (STAs) and private contractors to provide a safe and long lasting network of surface transportation facilities. Federal regulations require STAs to have an approved QA program.

A note of clarification:

> In the past, the term Quality Control/Quality Assurance (QC/QA) has incorrectly been used synonymously with QA. Early implementation of QA concepts in the transportation arena viewed quality control as a contractor responsibility and quality assurance as an agency responsibility. A more comprehensive approach is to consider QC as an element of QA. Figure 1 illustrates this approach where QA is the umbrella which covers all of the core elements for the construction of safe and long lasting transportation facilities. **Thus, the term QC/QA should no longer be used.**

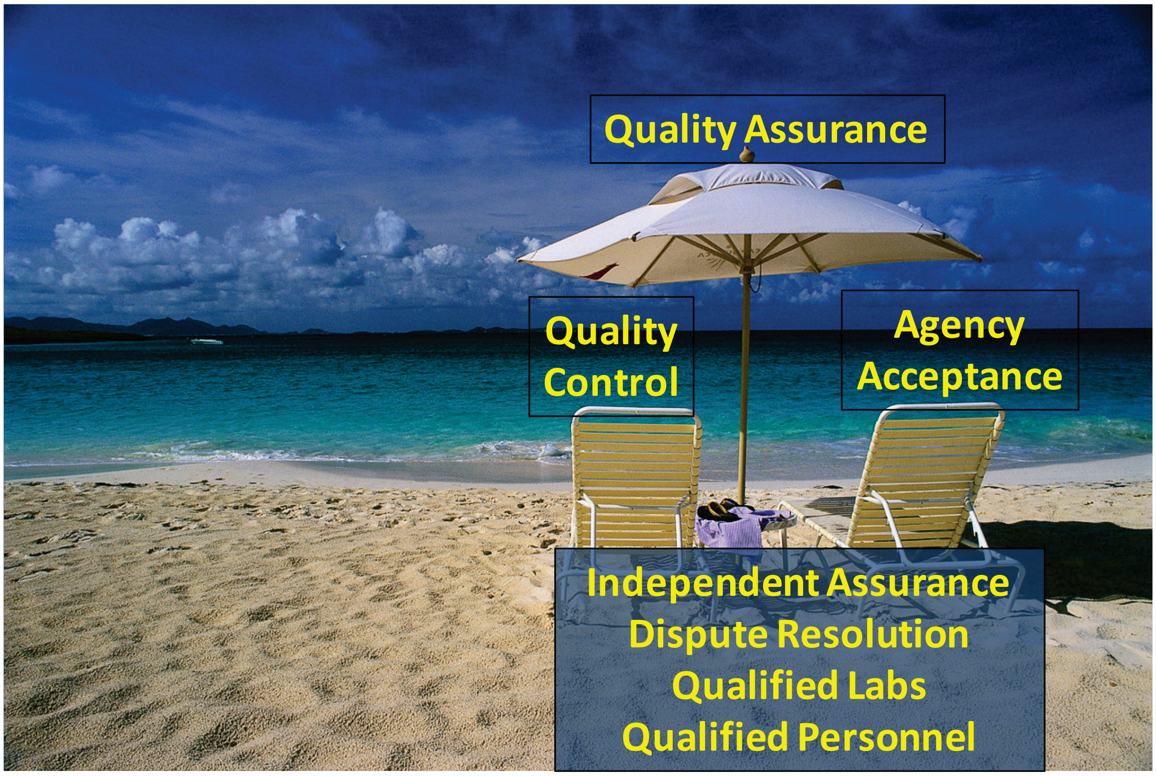

Figure 1 – Core Elements of a Quality Assurance Program

For an in-depth discussion of the items presented in this introduction to quality assurance concepts, refer to: Publication No. FHWA-NHI-08-067, June 2008, U.S. Department of Transportation, Federal Highway Administration, NHI Course No. 134064, *Transportation Construction Quality Assurance*.

The primary purpose of this field reference is to provide STA and contractor personnel with guidance aimed at improving and ensuring the quality of concrete pavements that are constructed. Another good source of information is ACPA's online application library which includes several applications to assist in the design, construction, and analysis of concrete pavements (http://apps.acpa.org/apps/).

WHY SHOULD I CARE?

Regardless of one's role (agency or contractor) in the construction of transportation facilities, a safe surface transportation system appeals to the universal motivation for self-preservation. Also, as taxpayers we expect our investment to yield a long lasting transportation system. More specifically, improved quality reduces the costs associated with re-work. These cost savings from improved quality have benefits for contractors and agencies as shown in Figure 2.

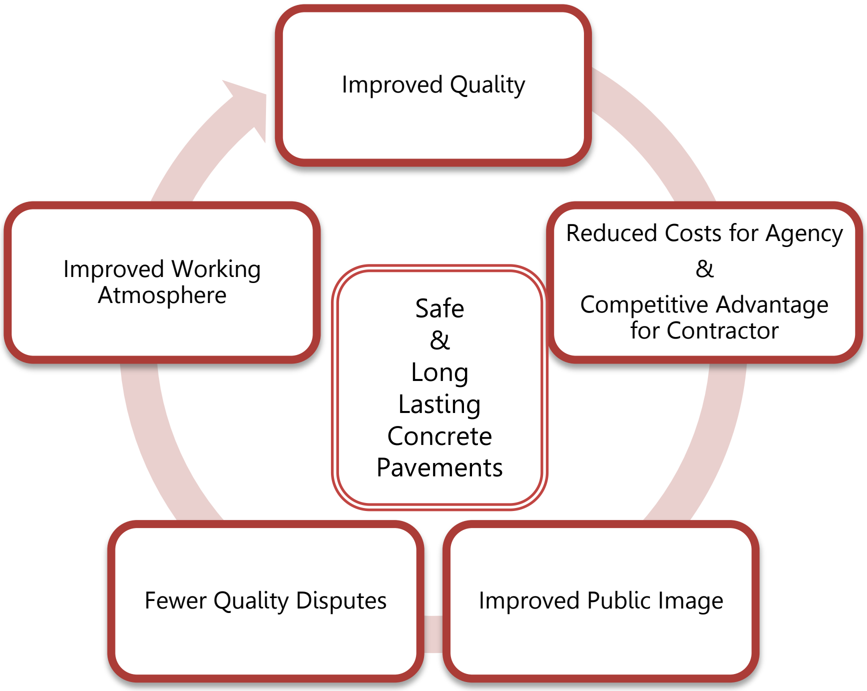

Figure 2 – Benefits of Improved Quality for Transportation Facilities

A comprehensive QA approach is the path to improved construction quality which benefits all parties. This makes for a true win-win proposition.

Roles, Responsibilities and Communication

Quality is enhanced when the agency and contractor can agree that the common objective of constructing a safe and long lasting concrete pavement will at the same time satisfy each entity's individual objectives. It is important to understand each other's perspectives, roles and responsibilities as they relate to quality assurance and the construction of a concrete pavement.

Contractor

Although QC functions are commonly contractually delegated to subcontractors, producers, fabricators and manufacturers, the prime contractor must take the lead role in monitoring the effectiveness of quality control at all levels during the construction process. Quality control must be integrated throughout the contractor's operation. Both management and production personnel must be focused on quality to achieve the desired results. Quality control consists of more than a skeleton staff performing tests and submitting forms to the STA. True quality can only be achieved by a trained labor force utilizing materials that conform to specifications, and which are supported by a QC staff and program that provide timely feedback. This document and the associated workshop materials present contractor QC functions for specific steps in the concrete paving process in the following manner:

- Details of successful practices as a means to understand how quality impacts performance.
- Pre-production checklists to ensure that critical items have been reviewed.
- Key inspection items that should be observed during construction.
- Testing and measurements.

- Appropriate actions when quality deficiencies are observed.

Continuous process improvement and prevention of defects should be the aim of the entire contractor organization and material supply chain. It is far better to prevent defects rather than become proficient at finding the cause of defects after the fact. Open and timely communication between all parties is vital to an effective QC program.

Agency

The agency's primary responsibility under a QA program is acceptance. The agency should respect the contractor's QC function. This means that production and placement activities should not be controlled by the agency, but by the contractor. That is not to say that the agency should take a "hands-off" approach, rather the agency should be proactive in monitoring the contractor's QC activities and insisting on conformance to the contractor's QC plan. Acceptance therefore consists of the following:

- Monitoring contractor QC activities.
- Measure and evaluate the quality of the final product.
- Determine the final payment value of the completed work.

Perhaps one of the most important concepts to understand regarding QA is the distinction between contractor QC testing and acceptance testing performed by the agency or agency's representative. The agency should encourage the contractor to perform QC testing, and the agency should also expect that the contractor's QC testing will identify some materials that are not in conformity to specifications. Contractor QC test results are necessary to help the contractor adjust their process. These test results are not acceptance tests nor should they lead to punitive measures. Punishing a contractor who identifies and corrects quality deficiencies discourages QC testing, because the contractor ultimately concludes that they would be better off avoiding the punishment by not knowing about quality deficiencies. Quality control testing allows for timely corrections which will minimize quality deficiencies. Acceptance testing based on random samples will accurately reflect the overall quality of the product.

Sampling

Acceptance testing should be based upon samples which have been obtained in a random manner to remove any potential bias. Random sampling is also applicable to contractor testing which will be evaluated using statistical process control (SPC) techniques. Random samples should be obtained in accordance with ASTM D 3665 or other state approved procedures such as a spreadsheet, software, calculator or random number tables. Another sampling method which has been commonly used in the past is selective sampling.

Selective sampling may be used in certain circumstances.(1) When a contractor makes process adjustments or is starting production, it is desirable to take samples at non-random intervals. For example, when random testing reveals that the air content of the concrete mixture is trending lower, a process adjustment is made to increase the air content. At this time, it is advisable to intentionally test the next two or more batches of concrete to monitor and validate the effectiveness of the process change. Selective sampling may also be appropriate to identify the limits of out of specification materials and/or workmanship. However, these samples should not be included in an acceptance pay factor calculation. Rather, additional random samples should be obtained within the limits of the "out of specification" area to evaluate the quality of that discrete population.

Appendix C provides a detailed field inspection checklist for concrete pavement construction used by the Iowa Department of Transportation.

Communication and Meetings

The impact of communication between the contractor and the agency on quality cannot be over emphasized. An effective QA program promotes communication and information flow that is:

1. Open,
2. Two-way,
3. Transparent, and
4. Timely.

Project meetings can be an effective means of communicating expectations, identifying potential conflicts and clarifying plan and specification details. Appendix D includes concrete pavement specific checklists that can be used as a guideline for conducting effective pre-bid, pre-work and pre-placement meetings.

Variability

The variability observed in concrete paving projects is attributable to four sources: material, process, sampling, and testing (Figure 3).[1] It is important to note that every test result we examine includes these sources of variability.

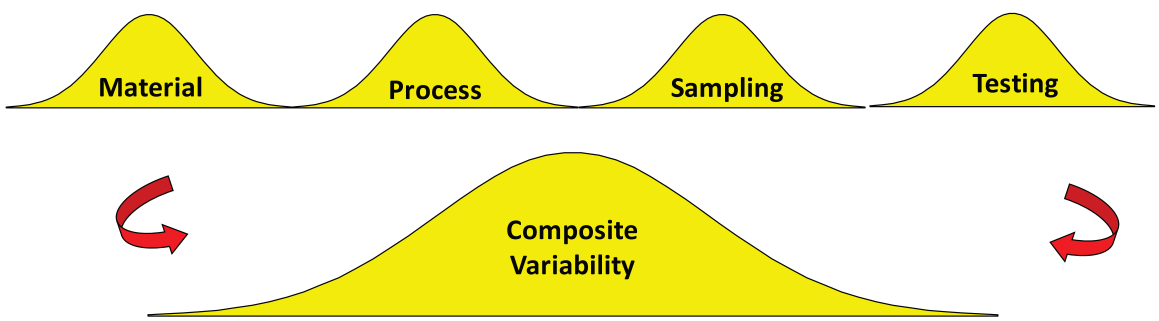

Figure 3 – Sources of Construction Variability

Understanding the materials and the precision and bias of each test procedure is critical to proper interpretation of QC testing and acceptance testing (Figure 4). For example, two technicians may test the air content of a sample of concrete using properly calibrated test equipment. It is likely that their test results will be "different". Some of this "difference" is attributable solely to the inherent variability in the test procedure. Because of this, test results which are very near or outside of specification limits should be interpreted with care and repeated whenever possible. Some concrete tests are simply too imprecise to be used as acceptance tests.

Figure 4 – Test Results Must Be Interpreted Properly

The term process control is often used synonymously with quality control. Reducing variability in our materials and our processes is a focus of quality control efforts. Reduced variability indicates a higher level of control. The same is true in our sampling and testing activities. We should strive to reduce the variability of our QC testing activities. Some recommendations for doing so are:

- Utilizing the same technician, especially within payment lots.
- All technicians should be properly trained and certified.
- Follow strict adherence to testing procedures.
- Testing equipment should be calibrated and certified as necessary.

Statistical Process Control

Control charts (Figure 5) are useful tools which when combined with some well proven rules can assist contractors in identifying changes in their materials and processes. The primary purpose of using Statistical Process Control (SPC), specifically control charts, is to identify change. **Their function is not to indicate whether a test result passes or fails acceptance criteria, but rather to indicate if a test result was unusual.**[2]

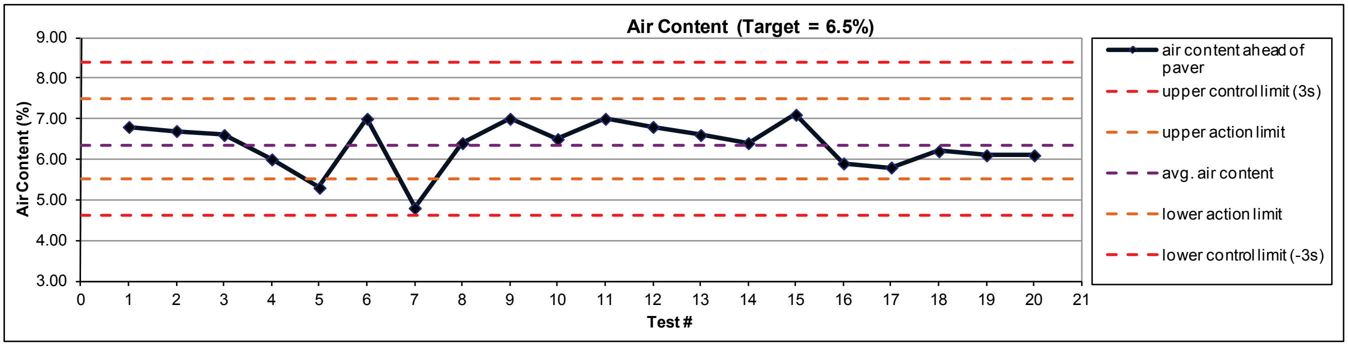

Figure 5 – Example Control Chart

Control charts are an effective means for identifying the impact of assignable causes on the materials and/or construction processes. Some agencies/contractors use moving average instead of individual test results as a tool for trend evaluation. Once identified, the materials and/or processes can be adjusted to account for the influence of the assignable cause. For example, a sharp reduction in air content may indicate that the carbon content of the fly ash has changed, requiring an increased dosage of air entraining admixture. Simply put, a control chart provides a visual indication of whether a process is in control.

Detailed guidance regarding the implementation of control charts and SPC for contractor QC organizations can be found in the *Testing Guide for Implementing Concrete Paving Quality Control Procedures*, which is included on the data CD provided during the workshops associated with this document.[3] It is also available for free at: http://www.cptechcenter.org/technical-library/documents/mco/testing_guide.pdf.

Quality Control Plan

A quality control plan is a document prepared by the prime contractor and subcontractors which serves as the roadmap for constructing the project within specification requirements. A QC plan is formally defined as "A project-specific document prepared by the contractor which identifies all QC personnel and procedures that will be used to maintain all production and placement processes "in control" and meet the agency specification requirements."[1]

A proper QC plan should identify the personnel, procedures and materials that will be used on the project. Additionally, the plan should address the following for each item of work covered by the QC plan:

1. Reference the applicable specifications for each item of work.
2. Provide action limits (not specification limits) that dictate when the process should be adjusted.
3. Provide suspension limits that define when the process should be stopped and adjusted before resuming production.
4. Describe what corrective actions will be taken when the process is deemed to be out of control.

A template QC plan for concrete paving is provided in Appendix A of this document. Additional guidance can also be found in *Transportation Construction Quality Assurance*.[1]

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2. Factors Influencing Long-Life Concrete Pavements

INTRODUCTION

This section discusses the decisions made in the design office and at the construction site that can affect the life of concrete pavements. By knowing these, we can better keep an eye on what is going on and make better decisions leading to improved longevity of the pavement.

There are a number of important parameters discussed; some of them are only relevant at specific times. For instance, selection of pavement type occurs at the design stage, and is not considered again during construction or testing. On the other hand, smoothness may be specified during design, but activities that affect the final product are only relevant during construction and testing.

STRUCTURAL DESIGN

The DARWIN M-E™ mechanistic empirical pavement design method was developed in an effort to improve the basic pavement design process. M-E design combines mechanistic principles (stress/strain/deflection analysis and resulting damage accumulation) with local field verification and calibration. The M-E procedure is considered to be a more scientifically based approach than the 1993 AASHTO procedure, incorporating new aspects of pavement design and performance prediction, and generally resulting in less conservative designs.

A benefit of M-E analysis is that it predicts specific distress types as a function of time or traffic. Cracking, faulting, and changes in smoothness (based on the International Roughness Index) are predicted based on calibrated distress models.

The M-E procedure is based on the accumulation of incremental damage, in which a load is placed on the pavement at a critical location, the resulting stresses, strains and deflections are calculated to estimate the damage resulting from the load. The distresses that accumulate in the pavement as a function of time or traffic are then summed over the life of the pavement. The main questions addressed in the process are discussed below.

What do we want?

All of the following are modeled to predict their state at the end of the selected design life. If the results are unacceptable, then the variables that can be changed are adjusted and the analysis is repeated until acceptable outputs in the following are achieved:

- Surface roughness, IRI.
- Cracking.
- Faulting.

What do we have to accommodate?

There are parameters that vary from location to location and cannot be changed due to their nature, but must be addressed in the modeling:

- Expected traffic loading.
  - Type of traffic (classes).
  - Growth of traffic density with time.
- The climate in which the pavement is built.
- Water table depth.

What can we adjust?

These are some of the parameters that can be adjusted in the design process in order to achieve the properties and performance required:

- Pavement type (JPCP or CRCP).
- Joint details (load transfer, spacing, sealant).
- Edge support (if any).
- Drainage.
- Layer properties.
  - Concrete.
  - Base layers.
  - Subgrade.

The following sections discuss how each of these parameters will affect longevity and how they can be addressed at the design, construction and testing stages, where relevant.

PAVEMENT TYPE

Two different concrete pavement design types are commonly used: jointed plain concrete pavements (JPCP) or jointed reinforced concrete pavements (JRCP), and continuously reinforced concrete pavements (CRCP).

Each of these design types can provide long-lasting pavements that meet or exceed specific project requirements. Each type is suitable for new construction, reconstruction, and overlays (resurfacing) of existing roads. The selection of which type is to be used is made at the design stage.

JPCP

Because of their cost-effectiveness and reliability, the vast majority of concrete pavements constructed today are JPCP designs (Figure 6). They do not contain reinforcement. They have transverse joints spaced less than 15 to 20 ft apart. They may contain dowel bars across the transverse joints to transfer traffic loads across slabs and may contain tiebars across longitudinal contraction joints to promote aggregate interlock between slabs.

Figure 6 – Jointed Plain Concrete Pavement Before Paving

CRCP

CRCP designs have no transverse joints, but contain a significant amount of longitudinal reinforcement, typically 0.6 to 0.8 percent of the cross-sectional area. Transverse reinforcement is often used. The high content of reinforcement both influences the development of transverse cracks within an acceptable spacing (3 to 8 ft apart) and serves to hold cracks tightly together. Some agencies use CRCP designs for high-traffic, urban routes because of their suitability for high-traffic loads.

FOUNDATION SYSTEM

Subgrade

The subgrade is the natural ground, graded and compacted, on which the pavement is built. The quality of the subgrade will influence some of the design decisions, and if it is to be modified by some treatment approach, then it is important that the modifications achieve the intended purpose.

Due to its rigid nature, a concrete pavement distributes the pressure from applied loads over a larger area of the supporting material. As a result, deflections are small and pressures on the subgrade are low. Concrete pavements, therefore, do not require especially strong foundation support. However, subgrade uniformity and stability affect both the long-term performance of the pavement and the construction process. The subgrade should have a uniform condition, with no abrupt changes in the degree of support and there should be no hard or soft spots. Non-uniform support increases localized deflections and causes stress concentrations in the pavement. Localized deflections and concentrated stresses can lead to premature failures, fatigue cracking, faulting, pumping, rutting, and other types of pavement distress.

Requirements for subgrade preparation may vary considerably, depending on soil type, environmental conditions, and amount of heavy traffic. Providing reasonably uniform support conditions beneath the concrete slab requires controlling three major causes of subgrade non-uniformity:

- Expansive soils,
- Frost action, and
- Pumping.

Preparation of the subgrade includes the following activities:

- Compacting soils at moisture contents and densities that will ensure uniform and stable pavement support.
- Whenever possible, setting grade lines high enough and making side ditches deep enough to increase the distance between the water table and the pavement. This will include providing sufficient drainage to the system so that the concrete slab does not become saturated.
- Cross-hauling and mixing soils to achieve uniform conditions in areas where there are abrupt horizontal changes in soil types.
- Using selective grading in cut and fill areas to place the better soils nearer to the top of the final subgrade elevation.
- Improving extremely poor soils by treating them with lime, cement, cement kiln dust, or fly ash, or by importing better soils, whichever is more economical.

Base

A base layer may be needed on top of the prepared subgrade and immediately below the concrete pavement to accommodate heavy traffic or poor-quality subgrades. The material quality requirements for a base under concrete pavement are not as strict as those for a base under asphalt pavement because the pressures imposed on a base under concrete are much lower than those under asphalt.

For light traffic pavements, such as residential streets, secondary roads, parking lots, and light-duty airports, the use of a base layer may not be required, and the desired results can be obtained with proper subgrade preparation. Bases may be constructed of granular materials, cement-treated materials, lean concrete, hot-mixed asphalt, or open-graded, highly-permeable materials, which may be stabilized or unstabilized.

When the use of a base is considered appropriate, the best results are obtained by following these guidelines:[4]

- Selecting base materials that meet minimum requirements for preventing pumping of subgrade soils.
- Specifying grading controls that will ensure a reasonably constant base grading for individual projects.
- Specifying a minimum base depth of 100 mm (4 in.).
- Specifying a minimum density for untreated bases of 105 percent of ASTM D 698 / AASHTO T 99 for heavily traveled projects.

A cement-treated or lean concrete base provides a strong and uniform support for the pavement and joints, provides an all-weather working platform, and contributes to smoother pavements by giving firm support to the forms or paver during construction. However, this system imposes added restraint to the concrete thus increasing the stresses due to thermal and drying shrinkage, meaning that greater care has to be taken to prevent early age cracking. Highly permeable bases may be unstable, but some ability to drain water penetrating the joints is desirable.

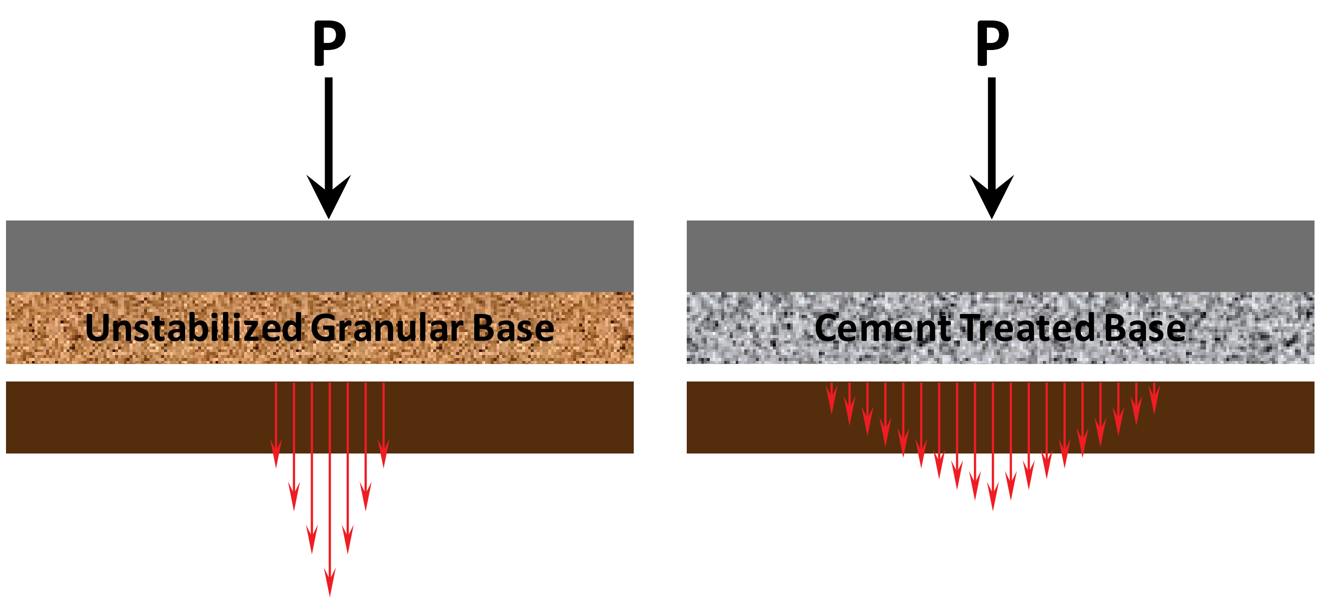

Figure 7 – Load Distribution of Unstabilized and Stabilized Bases

JOINTING

Concrete shrinks with decreasing temperature and moisture loss as it ages, stresses set up by restraint of this movement will cause random cracking unless joints are cut in the concrete at the appropriate time and spacing. Such cracking can lead to faulting and reduced durability of the system.

In addition, curling and warping are vertical deflections in the slab due to differential temperatures and moisture contents. The combination of traffic loading and slab weight on curled and warped pavements will result in cracking, faulting, and reduced smoothness. The magnitude of deflections and stresses are decreased with reduced panel size (e.g. joint spacing).

Detailing joint layout is important in reducing the risk of random cracking. Mismatched joints, slabs with a width / length ratio greater than 1.5, and embedded objects (manholes, inlets, utility service accesses, etc.) without isolation joints should be avoided.[5]

Figure 8 – Example of Poor Joint Detailing

Joint Spacing

When transverse joints are too far apart, the concrete may still crack randomly at locations other than the joints. The M-E design indicates that shorter joint spacing increases the predicted life of a pavement, however there are increased costs associated with constructing and maintaining more joints. An optimal joint spacing therefore exists for each specific project, depending on the slab thickness, base stiffness, and concrete strength. Most state agencies specify transverse contraction joints in plain (unreinforced) pavement at intervals between 15 and 20 ft.

Joint Depth

The design depth of saw cuts is the minimum depth required to create a properly functioning joint to control cracking.[6] Cuts that are too shallow may not create an adequately weakened plane, thereby allowing random cracks to occur. Cuts that are unnecessarily deep require additional time and cost and reduce aggregate interlock.

In general, the depth of conventional saw cuts is one third to one quarter of the pavement thickness. However, unless a State specifies otherwise, early-entry cuts can generally be approximately 25 mm (1 in.) deep, regardless of pavement thickness. Because early-entry saw cuts are made before the concrete has developed significant strength or stresses, this shallower cut will generally create an effective plane of weakness where a crack should form.

Saw Timing

There is an optimum time to saw contraction joints in new concrete pavements. That time occurs within the sawing window. The window is a short period after placement when the concrete pavement can be cut to successfully control crack formation. The window begins when concrete strength is sufficient for sawing without excessive raveling along the cut. The sawing window ends just before random cracking starts to occur.

Sawing too early causes the saw blade to break or pull aggregate particles free from the pavement surfaces along the cut. The resulting jagged, rough edges are termed raveling (Figure 9). Some raveling is acceptable where a second saw cut would be made for a joint sealant. If the raveling is too severe, it will affect the appearance and/or the ability to maintain the joint.

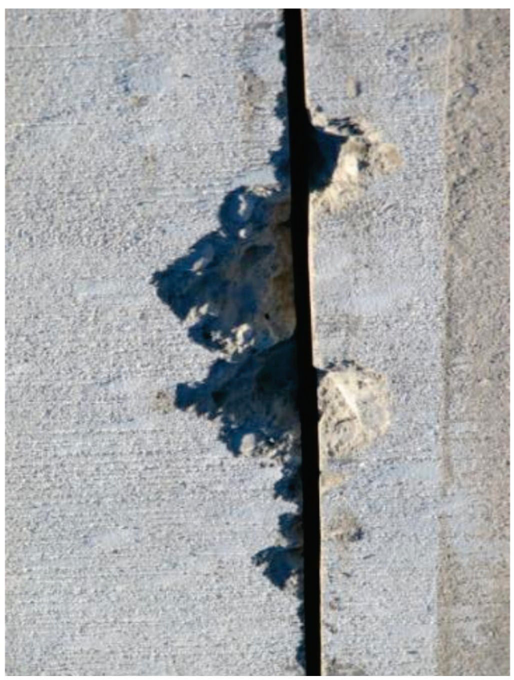

Figure 9 – Excessive Joint Raveling

HIPERPAV® is a free software tool that can be used to assess the early age behavior of concrete pavement. The software models early stress and early strength of the concrete pavement, making it useful to evaluate the potential for uncontrolled cracking.

SMOOTHNESS

The smoothness of a concrete pavement is impacted by design, construction practice, concrete materials, and environment. Pavement smoothness is the users' primary measure of a pavement's performance, and it is therefore an important aspect in terms of quality. M-E analysis estimates changes in smoothness as a function of time and traffic.

Several factors influence the smoothness of a pavement:(7)

- Specification
  - Base should be wider (6′) than the pavement to allow for a stable paver trackline.
  - Horizontal alignment, cross-slope and super-elevated curves can add to roughness.
  - Accurate grade and staking calculations are essential.
  - Embedded reinforcement and fixtures negatively impact smoothness.
  - Concrete mixture should slipform easily.
  - Block-outs or leave-outs will add to roughness.
- Construction(4, 8)
  - Base and trackline need to be stable and constructed to a tolerance (1/2″ in 10′).
  - Concrete uniformity from batch to batch.
  - Keep the paver moving to minimize bumps.
  - Set up fixed forms accurately (where relevant).
  - Set and maintain the stringline so that it is taut and accurate.
  - Keep a proper amount of concrete consistently in front of paver.
  - Monitor vibrators.
  - Adjust the paver's profile pan and adjust staking interval for grades and curves.
  - Securely anchor and place concrete on dowel assemblies in front of the paver or use properly maintained and adjusted automatic dowel bar inserters (DBI).
  - Check the surface behind the paver with the longest straightedge possible.
  - Use cut-back headers.
  - Educate and motivate the crew.

MIXTURE

Decisions regarding the mixture are made at all stages.

Mixture components

At its simplest, concrete is a mixture of glue (cement, water, and air) binding together fillers (aggregate). However other materials, like supplementary cementitious materials (SCMs) and chemical admixtures, are added to the mixture. All these materials affect the way concrete behaves in both its fresh and hardened states.

Cementitious Materials

Cementitious materials include portland cement and supplementary cementitious materials such as fly ash and slag cement. SCMs contribute to the fresh and hardened properties of concrete. Blended cements are a manufactured blend of portland cement and one or more supplementary cementitious materials (SCMs).

It is important to test mixtures containing SCMs to ensure they are achieving the desired results, to verify the correct dosage, and to detect any unintended effects. Changing an SCM source, type, or even dosage will require new trial batches.

Aggregates

In general it is desirable that the aggregates have the following qualities:

- Well-graded mixtures require less water than mixtures with gap-graded aggregates, have less shrinkage, are easier to handle and finish, and are usually more economical.
- Rough surface texture (for bond and interlock).
- Low absorption (reduces water requirement variability).
- Low alkali-aggregate reactivity (for reduced risk of deleterious alkali-silica reactivity and alkali-carbonate reactivity).
- Frost resistant (for durability associated with D-cracking and popouts).
- Low coefficient of thermal expansion (for reduced cracking from volume change due to changing temperatures).
- Abrasion resistant (for durability and skid resistance).
- Free of dust and clay contaminants.

Water

Mixing water can consist of batch water, ice, free moisture on aggregates, water in admixtures, and water added after initial mixing. Some water recycled from returned concrete and plant washing may be allowed by specification.

Potable water is generally acceptable for use in concrete but questionable mixing water from untreated sources should be tested for its effect on concrete strength and setting time.

Chemical Admixtures

Admixtures are materials added to concrete mixtures to modify concrete properties such as air content, water requirement, workability and setting time. Admixtures should complement, not substitute for, good concrete proportioning and practice. Admixtures may have unintended side effects. Therefore, run trial batches with job materials and under job conditions to verify admixture compatibility. Dosages of admixture will likely have to be varied through the day as moisture content of the aggregates varies and the weather changes.

Properties

There are a number of critical properties of concrete that impact pavement longevity. Some properties, like workability, are manifested only in the fresh or plastic stage of concrete. Others, like frost resistance, are most important in the hardened concrete. Still others, like strength gain, begin early in the hydration process, remain critical during the first few days, and play a role in concrete for many months or even years. In general, the contractor is concerned about the fresh properties (how easy it is to get the concrete in place), and the owner is concerned about the long-term hardened properties (how long it will last).

Uniformity

The goal is to make uniform concrete, in order to prevent problems at the paver (Figure 10) and in the final pavement, this is necessary even though the materials used to make the concrete may be variable. Material properties must be monitored regularly and proportions adjusted accordingly. A non-uniform concrete mixture causes frequent adjustments in the construction process and leads to variable pavement performance. **Providing a uniform concrete mixture is critical to constructing a quality concrete pavement.**

Figure 10 – Non-uniform Concrete Leads to Paving Issues

Workability

Workability is an indication of the ease with which concrete can be constructed. Good workability means that the concrete mixture can be readily consolidated and finished. Workability requirements vary by placement method (e.g. machine or hand). Therefore the concrete mixture should be proportioned and produced with workability properties that accommodate the method of placement.

Changes in workability indicate that the raw materials, proportions, or the environment are changing. If workability changes, the causes should be investigated early, as it is likely that this is a symptom of a significant change in the mixture that will affect other properties directly related to pavement longevity.

Water should not be added to a concrete mixture to adjust workability or finishing properties unless this can be done without exceeding the water-cementitious materials ratio of the mixture design.

Strength development

Concrete strength is often used to measure concrete quality, although this can be a false assumption as other properties such as: low air content, poor consolidation, random cracking, high permeability, etc. may not be directly related to strength.

Sufficient concrete strength is needed to carry the loads and many specifications will limit the minimum strength required based on the design. The primary factor controlling strength is the w/cm ratio, although strength increases with a decreasing w/cm ratio. Strength gain is accelerated at higher temperatures and decelerated at lower temperatures, and strength decreases as air content increases.

Strength is measured in compression or in flexure (bending). Early strength can also be assessed in the field using maturity (time and temperature) measurements. For more information on implementing maturity measurements for concrete paving, consult the following FHWA Tech Brief - *Maturity Testing for Concrete Pavement Applications*, November 2005; available for download at:
http://www.fhwa.dot.gov/pavement/pccp/pubs/06004/06004.pdf

Shrinkage

Concrete shrinkage occurs due mainly to cooling and drying, although three other shrinkage mechanisms also play a role. It starts soon after mixing and continues for a number of days and can contribute to random cracking in slabs. Shrinkage primarily increases with increasing water (paste) content in the concrete, meaning that increasing amounts of cementitious materials and water in the mixture may increase cracking risk.

Shrinkage cracking is also tied to the weather at the time of placement:

- Placing concrete in the morning so that the temperature at time of setting is high, increases the potential stresses due to large reductions in ambient temperature at night.
- Cooling the concrete at the time of placement will reduce the peak temperature.
- Covering the concrete when cold fronts are approaching will protect the concrete from large differentials.
- Providing adequate curing early on will reduce the effects of drying shrinkage.
- Use of an evaporation retarder may help in reducing the risk of plastic shrinkage cracking (NOTE:, evaporation retarders are not to be used as finishing aids).
- Use of SCMs in hot weather to both reduce and delay the early age peak temperature.

Permeability

Concrete durability is enhanced by improving concrete's ability to prevent aggressive fluids from penetrating the concrete, that is, by reducing concrete permeability as discussed below. Permeability is reduced by:

- Reducing cracking.
- Reducing the number of connected pores in the paste system by:
  - Reducing the w/cm.
  - Use of appropriate amounts of supplementary cementitious materials.
  - Allowing hydration to continue for as long as possible, i.e. curing.

Permeability and strength are not synonymous.

Potential Durability
Durability is the ability of the concrete to survive the environment to which it is exposed, which will vary from region to region depending on weather and soils, among other things. Potential durability of the concrete is implicit in the DARWIN M-E™ design method, but few details are provided on how to achieve it. Some decisions that will impact durability have to be made at the design stage such as requiring measures to address local materials or weather related factors. Likewise the quality of the concrete mixture in terms of the ingredients, proportions and workmanship will have a strong influence on the lifetime of the pavement. The most common issues to be addressed are:

- Cold weather.
- Alkali silica reaction.

Cold Weather
Frost resistance is a concrete's ability to resist damage during winter weather conditions. Concrete that is exposed to cold weather can experience several kinds of damage including:

- Freeze-thaw damage,
- Salt scaling,
- D-cracking, and
- Popouts.

Freeze-thaw damage is due to the expansion of water in the capillaries as it freezes, causing cracking that can be as deep as several inches into the concrete. Cycles of freezing and thawing can eventually cause severe surface loss. Deicing salts can aggravate freeze-thaw damage and cause cracking, scaling, and disintegration.

Concrete's ability to resist freeze-thaw damage may be enhanced by entraining a number of small, closely spaced air bubbles in the paste. The air voids provide space for freezing, expanding water in the pores to move into, thus relieving the pressure. It is generally accepted that a spacing factor of 0.008 in. or less will be adequate to protect concrete. Increasing the total air content will reduce the spacing factor, which is why many specifications place a limit on the minimum amount of air in a mixture. For a given air content, small, closely spaced air voids provide better protection than larger, more distant voids. For equal protection, larger bubbles would require a larger volume of air. This is undesirable, since an increase in air content can result in a decrease in strength.

Over-finishing should be avoided because it may cause loss of air at the surface. In addition, working bleed water or evaporation retarders (which contain a high amount of water) into concrete weakens the top surface and can cause a crust to form with water accumulation underneath, which could easily scale off.

When aggregates with a critical pore size are saturated, they expand and fracture when the water freezes, causing D-cracking and/or popouts. In areas where D-cracking in pavements is known to be a problem, a smaller maximum size aggregate may help mitigate the problem. Testing at the reduced maximum size is advisable.

Alkali-Silica Reaction

Alkali-silica reaction (ASR) is a harmful condition in concrete resulting from a chemical reaction between some aggregate minerals and the high alkaline (pH) pore solutions found in concrete. Over time, the product of these chemical reactions, ASR gel, can absorb water and expand, leading to concrete cracking and reduced service life. The amount of gel formed in the concrete depends on the amount and type of silica in the aggregate and the alkali hydroxide concentration in the concrete pore solution.

For ASR to occur, three conditions must be present:

- Reactive forms of silica in the aggregate,
- High-alkali (pH) pore solution (water in the paste pores), and
- Sufficient moisture.

If any one of these conditions is absent, ASR gel cannot form and deleterious expansion from ASR cannot occur. Therefore, the best way to avoid ASR is through good mixture design and materials selection.

It is important to design mixtures specifically to control ASR, preferably using locally available materials. Use nonreactive aggregates, if possible, or a combination of nonreactive and reactive aggregate. If reactive aggregate is unavoidable, use supplementary cementitious materials or blended cements proven by testing to control ASR or limit the alkali content of the concrete. When applicable, different amounts of pozzolan or slag should be tested to determine the optimum dosage. Too low a dosage of fly ash may exacerbate the problem. Low-calcium (typically Class F) fly ashes are generally better at mitigating ASR than high-calcium (typically Class C) fly ashes. Ground, granulated blast-furnace slag and natural pozzolans are also effective in mitigating ASR when used in the proper dosages.

Lithium compounds may also be useful in reducing or preventing expansion. Typically, a solution of lithium-bearing compound (usually lithium nitrate) is added when batching concrete.

Mixture Design and Proportioning

Mixture design is the process of determining required and specifiable properties of a concrete mixture, normally conducted by the designer / specifier to allow for local conditions. Factors considered will include the intended use, geometry, and exposure conditions. The following are three factors to be addressed in concrete mixture design:

- Strength,
- Durability, and
- Economy.

Some aspects of the design may belong with the contractor, such as choosing workability for the placing equipment to be used, and the placement conditions.

Mixture proportioning considers how the desired and specified properties of the concrete can be achieved by optimized selection of concrete ingredients. Proportioning may be initially determined using numerical approaches, but it is critical that trial batches be made using job-specific materials. It is advisable that trials also be conducted at the likely placement temperatures to ensure that the mixture is likely to perform satisfactorily at construction stage, and that potential problems are flagged early on. At this stage, the mixture can be assessed for compliance with all requirements of the specification. It is also advisable that alternate mixtures be assessed, such as with alternate supplies of materials, so that delays are not incurred if problems arise during construction requiring a change in proportions.

Critical parameters to observe in mixture proportions are:

- w/cm should be between 0.38 and 0.42 for slipform pavements as this is the primary parameter that controls hardened mixture performance.
- Combined aggregate gradation should fall within Zone 2 of the Coarseness Factor and Workability Chart (Refer to ACI 302.1R-04 for detailed guidance)(Figure 11 from COMPASS Software).

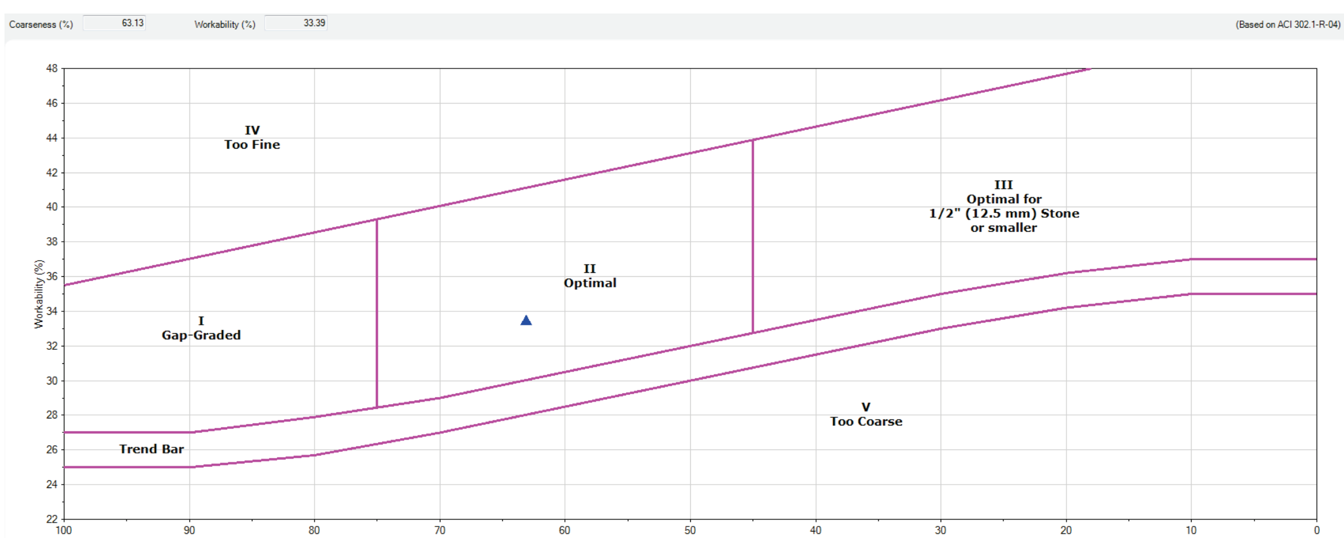

Figure 11 – Example Coarseness and Workability Factor Chart

- SCM dosage should be high enough to address durability concerns but not so high to cause setting and cracking problems.
- Paste content should be sufficient to fill all the voids between the aggregate particles and to provide adequate workability to the mixture.

Trials using the full-scale batch and handling plant are recommended because mixtures will perform differently depending on the size and type of mixing in the batch. However some contractors use a small trial batcher (9 ft^3) to perform mix trials (especially for mobile projects). If done properly they can be an effective way to perform trials. If trials are performed with small trial mixers a trial run of the plant prior to the start of operations should be performed to make sure the plant is operating properly.

Mixture Verification

Just before paving, the mixture designs should be verified in the field (unless there is experience with a similar mixture). This process is necessary to ensure that the materials and the final mixture are substantially the same as those that were used during the laboratory trials.

The following questions should be considered when verifying laboratory mixtures in the field:

- Are the fresh properties acceptable for the type of equipment and systems being used?
- Are there signs of incompatibilities?
- Are the flexural or compressive strengths from the field mixture comparable to those from the laboratory mixture (±250 lb/in^2)?

Field trials are also a preferred practice when portable plants are used. The batching process, including mix time, should be the same as that to be used during paving operations.

Workability of the field trial batches should be tested immediately after batching and at a later time to simulate the transportation time. Field trial batches should be repeated until the desired workability after the estimated time in transport is achieved and then tested.

Workability and air content can be manipulated during the batching process in the field by varying chemical admixture dosages.

ACCEPTANCE TESTING

Acceptance is based on testing. When any result is reported, the following need to be considered:

- Is the right method being used?
- Was the test conducted properly?
- Are specification tolerances realistic with respect to inherent testing variability?
- What are the consequences of failure?
- What is the potential error in the test?
- What actions are required?

TEST METHODS

Not every parameter can be examined by a standardized test. For instance timing of saw cutting is as much of an art as anything else – it depends on the weather, the mixture and the experience of the saw operator. However, failure is readily observed in random cracking.

Following is a listing of appropriate test methods and suggested acceptance limits.

Foundations - Subgrade/Subbase Construction

Subgrade Soils

- Procedures such as ASTM D 1883, ASTM D 3152, ASTM D 4546, ASTM D 4829, and CALTRANS Test 354 are suitable for evaluating the volume change of subgrade soils (Figure 12).[9]

	Data from Index Tests *			
Degree of Expansion	**Plasticity Index (%) (ASTM D 4318)**	**Shrinkage Limit (%) (ASTM D 427)**	**Colloid Content (% finer than 0.001 mm) (ASTM D 422)**	**Estimate of Probable Expansion ** (% total vol. change) (dry to sat. condition)**
Very High	>35	<11	>28	>30
High	25 to 41	7 to 12	20 to 31	20 to 30
Medium	15 to 28	10 to 16	13 to 23	10 to 20
Low	<18	>15	<15	<10
* All three index tests should be considered in estimating expansive properties				
** Based on a vertical loading of 1 lb/in^2, for higher loadings the amount of expansion is reduced, depending on the load and the clay characteristics				

Figure 12 – Tests for Expansive Soils

Unstabilized Bases

- Limit the amount of fines passing a 75-µm (#200) sieve.
- Aggregates having less than 50 percent loss in the Los Angeles abrasion test (ASTM C 131 / AASHTO T 96) are satisfactory.
- Minimum of 100 percent of ASTM D 698 / AASHTO T 99 density. For projects that will carry large volumes of heavy traffic, the specified density should not be less than 105 percent of standard density or 98 to 100 percent of ASTM D 1557 / AASHTO T 180 density.
- To permit accurate grading of the base, the maximum size of material is usually limited to 1" and preferably to ¾".

Stabilized Bases

- Granular materials in AASHTO Soil Classification Groups A-1, A-2-4, A-2-5, and A-3 are used for cement-treated bases. They should:
    - Contain no more than 35 percent passing the 75-µm (#200) sieve.
    - Have a PI of 10 or less.
    - May be either pit-run or manufactured.
- Cement-treated bases have been built with A-4 and A-5 soils in some non-frost areas and are performing satisfactorily. Generally such soils are not recommended for bases in frost areas or where large volumes of heavy truck traffic are expected.
- Use of A-6 and A-7 soils is not recommended.

Concrete Materials

Cementitious Materials

- Cements should comply with ASTM C 150 / AASHTO M 85 Type I, II or V, ASTM C 595 / AASHTO M 240, or ASTM C 1157 Type GU, HE, MS or MH.
- Fly ash and slag cement are specified in ASTM C 618 / AASHTO M 295 and ASTM C 989 / AASHTO M 302 respectively.

Aggregates

- Individual aggregate gradation should comply with ASTM C 33/ AASHTO M 6 at a minimum.
- Combined gradation of the system should be in Zone II of the coarseness factor and workability chart.
- Aggregate moisture content should be regularly tested in accordance with ASTM C 566. Mixture proportions should be adjusted at the plant for the actual aggregate moisture content.
- Other requirements of the aggregate are addressed in ASTM C 33/ AASHTO M 6
- ASR reactivity is addressed in AASHTO PP 65.
- Abrasion resistance is usually measured using the Los Angeles (LA) abrasion test method (ASTM C 535 and ASTM C 131).
- D-Cracking potential can be assessed by conducting the procedure in ASTM C 1646.

Water

- If the quality of water is a concern, it can be assessed by evaluating it using the method in ASTM C 1602.

Chemical Admixtures

- Air entraining admixtures must comply with the requirements of ASTM C 260.
- All other admixtures are specified by ASTM C 494 / AASHTO M 194.

Mixture

Uniformity

- ASTM C 94 / AASHTO M 157 set out the requirements for monitoring and accepting the uniformity of concrete.
- Unit weight testing (ASTM C 138) is likely the best method for monitoring batch-to-batch uniformity.
- Microwave water content testing (AASHTO T 318) is also an excellent indicator of batch-to-batch uniformity.

Workability

- Slump: ASTM C 143 / AASHTO T 119 is the most commonly specified measure of workability. Typically, a range between 1 and 2 inches is satisfactory for slipform paving.
- Consideration may be given to allowing the contractor to select the slump required for their equipment, then using the test as a uniformity measure. This may be preferable to specifying a fixed range that may not be appropriate for the circumstances.

Strength

- Strength is normally specified in terms of flexural or compressive requirements.
- The value specified will depend on the design, but typical minimum values are about 650 psi flexural and 4000 psi compressive.
- Statistical approaches are often used for acceptance and PWL calculations.
- Before the pavement is opened to traffic, a minimum flexural strength of 450 psi is recommended.
- Testing should be in accordance with the following specifications:
    - ASTM C 39 / AASHTO T 22 for compressive strength.
    - ASTM C 78 / AASHTO T 97 for flexural strength using third-point loading.
    - ASTM C 293 / AASHTO T 177 for flexural strength using center-point loading.
    - ASTM C 496 / AASHTO T 198 for splitting tensile strength.
- Maturity approaches may be used in accordance with ASTM C 918 or 1074.

Shrinkage

- ASTM C 157 / AASHTO T 160 are commonly used to determine length change in unrestrained concrete due to drying shrinkage.
- Any specification based on ASTM C 157 must include the specimen size.
- The standard procedure is to take an initial length measurement at 24 hours. The specimens are then stored in lime-saturated water for 27 days, when another length

measurement is taken. All specimens are then stored in air at a constant temperature until 64 weeks.

- Since most projects cannot wait 64 weeks, an alternative set of initial reading, drying age, and final reading age are sometimes specified.
- This test should only be applied at the mixture design stage and not used as a regular acceptance tool.

Permeability

- The so-called "rapid chloride" test (ASTM C 1202 / AASHTO T 277) is currently the most commonly used "permeability" measurement. The test does not measure permeability directly but measures conductivity, which is a surrogate test for permeability. It is primarily intended for use in reinforced elements. The data can be used for comparison purposes between concrete mixtures.
    - While intended for use at the design stage, numerous authorities are using the test for acceptance purposes.
    - A minimum value of 1500 coulombs at 56 days is considered an indicator of more than adequate performance for pavements.
    - The Wenner resistivity device (Figure 13) is rapidly growing in acceptance as an alternative to ASTM C 1202/AASHTO T 277 for quality control and acceptance purposes.
- ASTM C 1585 determines the capillary absorption of concrete and offers a useful tool for assessing the relative performance of different concrete systems.

Figure 13 – Wenner Probe for Testing Surface Resistivity

Frost Resistance

- Air content is measured using:
    - ASTM C 231 / AASHTO T 152 pressure method in fresh concrete (Figure 14).
    - ASTM C 173 / AASHTO T 196 volumetric method in fresh concrete used for absorptive aggregates.

Figure 14 – Pressure Air Content Testing Device

- Air-void system can be assessed using:
    - ASTM C 457 for hardened concrete.
    - A minimum of 5% air behind the paver, or a spacing factor less than 0.008 in. is strongly recommended.
- Freeze-thaw resistance is assessed using ASTM C 666 during design stage.
    - Acceptance values typically range between a minimum relative dynamic modulus of elasticity of 70% and 90%.
- Salt scaling is assessed using ASTM C 672 at design stage.
    - A minimum visual rating of 3 or 4 is recommended.
    - Some states also monitor the mass loss of the samples and require a value of less than 0.3 lb/ft^2 after 50 cycles.

Thickness

Pavement thickness can be assessed using the following techniques:

- Probing behind the paver is a useful means of quality control (Figure 15).
- Coring the hardened concrete is often used for acceptance purposes. It is recommended that close attention be paid to ensuring that the pavement is not too thin because this will significantly reduce the life of the concrete.
- Non-destructive approaches are available. One such device requires that a steel plate be anchored on the base in front of the paver leading to good a correlation with core data.

Figure 15 – Thickness Probing Behind the Paver

Smoothness

The hardened pavement surface should be tested with a lightweight profiler (Figure 16), high speed inertial profiler, California Profilograph, or a straightedge for hand placements.

Figure 16 – Lightweight Inertial Profiler for Smoothness Testing

Tolerances and Action Limits

All test methods have some variability, meaning that the probability of accepting bad pavement and rejecting good pavement is unavoidable. This risk can be reduced if the testing is conducted by trained and certified staff (ASTM C 1077) operating calibrated equipment in compliance with the method.

Interpretation of the data may take engineering judgment. If a failure is reported, decisions need to be made regarding:

- Should a truck be rejected?
- Should the job be stopped until the cause is determined?
- Should there be a financial penalty imposed?
- Should the pavement be removed?

Answers to these will depend on:

- The reliability of the data,
- The consequences of the failure, and
- The amount of pavement affected.

Many states impose "Action" and "Stop" limits. If a result crosses an action limit, work is allowed to proceed but the cause of the variation must be determined and corrected. If the trend continues and the "Stop" limit is crossed, then the pavement is rejected and work must stop until corrective actions are implemented.

Incentives / Disincentives

Many specifications use incentives and disincentives to reward good work and to provide a financial edge to quality contractors. The subtlety behind this approach is that with any incentive scheme, there is a high probability that there will be unintended consequences. It is important that when this approach is adopted, the parameters that are indeed critical to the owner are those that are incentivized.

PUTTING IT ALL TOGETHER

Critical parameters for concrete longevity are:

- Thickness.
- Durability.
- Smoothness.
- Strength.

These apply at every point on the pavement, and this is what we are trying to achieve. No one factor is more important than another.

Inspection involves a thorough understanding of the system, what really affects it and how much. This must be combined with a large dose of common sense and engineering judgment, gained through training and experience.

3. Quality Assurance for Concrete Pavements

The recommendations given in this document regarding the construction of a high quality concrete pavement are based on the premise that quality assurance is the umbrella covering all aspects of the construction process. Therefore, the steps (processes) involved in the construction of a concrete pavement are presented in a uniform format that provides both contractor and agency guidelines for constructing, inspecting and measuring (testing) the construction process. The construction steps are presented in temporal order and include the following information:

- Description,
- Key inspection items to encourage successful practices and to identify deficiencies,
- Quality control measurements, and
- Checklists.

Note: QC measurements are listed for each construction process. For detailed guidance regarding what test procedures should be applied and how results should be interpreted, refer to the *Testing Guide for Implementing Concrete Paving Quality Control Procedures*.

These recommendations for quality assurance are intended to supplement contractual specifications, not replace them. When conflicts occur between these suggested practices and the specifications, the contract provisions should be followed. Roles and responsibilities have been intentionally omitted from these recommendations for the following reasons:

- Quality assurance should not be viewed as an “Us vs. Them” scenario; rather all parties should be working together towards a common goal.
- The term inspection is generic. Both the contractor and agency should be performing visual “inspections” of key items that influence performance, yet these are not easily measured.
- These roles are defined by contract, and change depending upon contract terms (i.e. some states allow acceptance testing by the contractor).

Following are the construction steps included in this field guide:

Section 4. Pre-Paving

A. Subgrade/Subbase Construction.
B. Staking and Stringline.
C. Fine Grading.
D. Dowel Basket Placement.
E. Reinforcing Steel Placement (CRCP).
F. Paver Preparation.

Section 5. Plant Site and Mixture Production

A. Aggregate Stockpile Management.
B. Plant Set-Up and Calibration.
C. Mixture Production.
D. Transporting Concrete.

Section 6. Placement, Finishing, Texturing, Curing and Sawing

A. Spreading Concrete.
B. Slipforming.
C. Insertion of Dowels and/or Tie Bars.
D. Hand Finishing.
E. Texturing.
F. Curing.
G. Sawing.
H. Weather Adjustments.

4. Pre-Paving

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SUBGRADE/SUBBASE CONSTRUCTION

Description:
Subgrade is the soil prepared and compacted to support a pavement system. Subgrades soils may be chemically modified to control expansion and/or improve strength.

A subbase is a layer in the pavement system which lies above the subgrade and below the portland cement concrete pavement (Figure 17). Categories of subbase layers include:

- Granular – compacted crushed aggregate or gravel.
- Stabilized – portland cement or bituminous stabilized aggregate.
- Drainable – unbound aggregate and portland cement or bituminous bound aggregate.

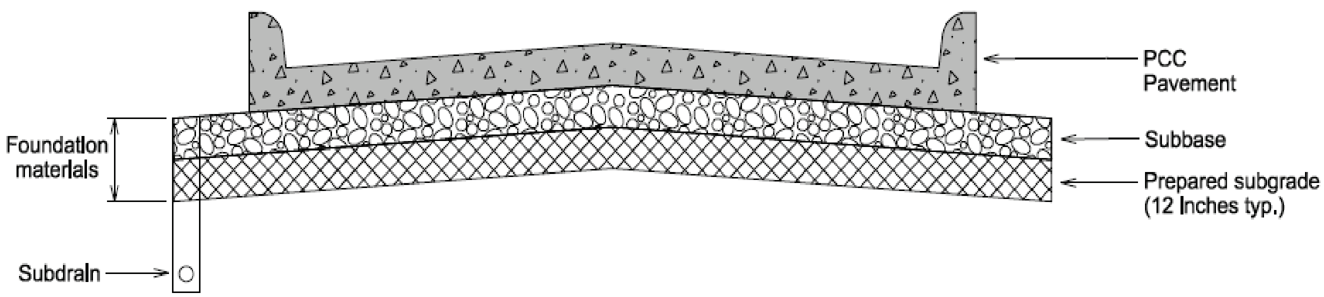

Figure 17 – Illustration of Subgrade, Subbase and Pavement Layers

The subgrade and subbase system should provide uniform support and drainage (where required) for the PCCP and serve as a working platform for placing the PCCP (Figure 18). Non-uniformity can lead to stress concentrations in the PCCP, which may lead to premature failure.

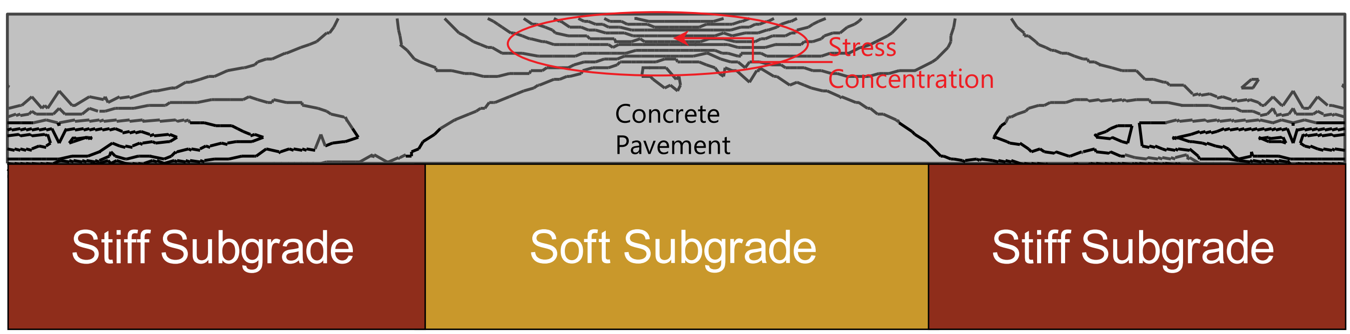

Figure 18 – Non-uniform Subgrade Leads to Stress Concentrations in the Concrete Pavement

Subgrade Key Inspection Items:

- Visually monitor for changes in soil type and moisture content.
- Identify non-uniformity and instability – repair subgrade/subbase failures before paving (Figures 19 and 20).

Figure 19 – Identify Subgrade/Subbase Failures

Figure 20 – Subgrade/Subbase Failures Must Be Repaired to Achieve Uniform Support

Subgrade Quality Control Measurements:

- Moisture and density – AASHTO T 310; recommended frequency of 1 test per 2,000 SY.
- Intelligent compaction systems – continuous measurement.

Checklist

Natural Subgrade

No.	Item	✓ When Complete
1.	Proctor densities and optimum moisture contents correspond to soil type(s) found in the field	☐
2.	Establish a rolling pattern and verify desired objectives are achieved with QC measurements (moisture and density)	☐
3.	Proof roll or use intelligent compaction methods to identify non-uniformity	☐
4.	Remediate areas identified by proof rolling or intelligent compaction	☐

Chemically Modified Subgrade

No.	Item	✓ When Complete
1.	Proctor densities and optimum moisture contents correspond to soil type(s) found in the field	☐
2.	Calculate spread rate (lb/sy) for modifying material	☐
3.	Verify spread rate for each truckload of modifying material	☐
4.	Establish a rolling pattern and verify desired objectives are achieved with QC measurements (moisture and density)	☐
5.	Verify thickness	☐
6.	Proof roll or use intelligent compaction methods to identify non-uniformity	☐
7.	Remediate areas identified by proof rolling or intelligent compaction	☐

Subbase Key Inspection Items

- Visually monitor for segregation and changes in moisture content (Figure 21).
- Monitor lift thickness when appropriate.
- Drainable subbases should be protected from infiltration of fines which can reduce drainage capacity.
- Identify non-uniformity and instability.

Figure 21 – Visually Inspect Granular Subbase for Segregation

Subbase Quality Control Measurements:

- Moisture and density – AASHTO T 310; recommended frequency of 1 test per 2,000 SY
- Intelligent compaction systems – continuous measurement.
- Gradation – AASHTO T 27; recommended frequency of 1 test per 8,000 SY.
- Thickness – Rod/Level/Grade Stake for unstabilized and coring for stabilized; recommended frequency of 1 test per 8,000 SY.
- Strength for lean concrete subbase – AASHTO T 22; recommended frequency of 1 test per 4,000 SY.
- Grade tolerance – verify during production with respect to grade stakes; recommended frequency of 1 check per 100 lineal foot.
- On projects using automatic machine controls (e.g. gps, laser, etc.), grade tolerance should be checked at least every 100 lineal foot.

Checklist

Granular Subbase

No.	Item	✓ When Complete
1.	Proctor densities and optimum moisture contents correspond to delivered aggregate materials	☐
2.	Establish a rolling pattern and verify desired objectives are achieved with QC measurements (moisture and density)	☐
3.	Verify spreading techniques do not contribute to segregation	☐
4.	Proof roll or use intelligent compaction methods to identify non-uniformity	☐
5.	Remediate areas identified by proof rolling or intelligent compaction	☐

Stabilized Subbase (Cement Treated Aggregate or Asphalt)

No.	Item	✓ When Complete
1.	Mixtures conform to JMF	☐
2.	Placement, consolidation and finishing operations produce a uniform non-segregated product	☐
3.	Controls in place to meet minimum thickness and smoothness tolerances	☐
4.	Establish a rolling pattern and verify desired objectives are achieved with QC measurements (moisture and density)	☐
5.	Verify thickness	☐
6.	Proof roll or use intelligent compaction methods to identify non-uniformity	☐
7.	Remediate areas identified by proof rolling or intelligent compaction	☐

Drainable Subbase

No.	Item	✓ When Complete
1.	Mixtures conform to JMF	☐
2.	Placement, consolidation and finishing operations produce a uniform non-segregated product	☐
3.	Controls in place to meet minimum thickness and smoothness tolerances	☐
4.	Protection from infiltration of fine materials	☐
5.	Verify thickness	☐

Lean Concrete – refer to checklists for concrete paving

STAKING AND STRINGLINE OR STRINGLESS

Description

Construction staking is the process of placing reference hubs for alignment and elevation of the finished pavement (Figure 22). Stringline set from these reference hubs controls the steering and elevation of fine grade trimmers and pavers. These processes have a direct impact on the thickness and smoothness of the subbase and concrete pavement.

Figure 22 – Surveyed Reference Hub and Stringline

It is critical that the contractor and surveyor clearly communicate, agree and verify that the offset and grade will achieve the desired result. Paving hubs should be set at an offset that will minimize disturbance from and to the construction processes. The contractor should specify whether grades are to be flat or projected. A projected grade corresponds to a theoretical elevation extended (projected) from the pavement grade, to the paving hub.

Stringless controls (GPS, laser or combinations) are available for fine grading and paving equipment (Figure 23). The models (data) used for stringless machine control should be prepared in accordance with the manufacturer's recommendations and independently checked for accuracy.

Figure 23 – Stringless Paving Using a Robotic Laser and Radio Communication

Key Inspection Items

- Spot check paving hubs and grades for accuracy by checking against a known benchmark.
- Visually inspect stringline for abrupt changes and/or discontinuities.
- Check that pins and wands are solid and resistant to moving.
- Depending upon the offset used, subgrade and subbase that has pumped may move the paving hub from its surveyed elevation and alignment. Correct the subgrade/subbase and re-survey.

Quality Control Measurements

- Random survey check of paving hubs.
- Random check of stringline elevation and alignment relative to paving hub information (not applicable to string which has been eyeball adjusted for smoothness).

Checklist

No.	Item	✓ When Complete
1.	Verify that the surveyor has provided the correct grades for the requested offset and grade type (projected or level)	☐
2.	Pins are placed at appropriate intervals (25'or less in tangent sections, closer spacing through tight curves)	☐
3.	Wands are adjusted for alignment (stringline should be directly above the hub)	☐
4.	Stringline is set to the correct elevation with respect to the hub	☐
5.	Stringline is uniformly taut	☐
6.	Stringline is marked for visibility to prevent accidental bumping	☐

FINE GRADING

Description

Finishing the subgrade and subbase to their final shape (cross-slope) and elevation is critical to obtaining the desired thickness and smoothness in the concrete pavement. Fine grading can be performed with trimmers (Figure 24) and/or motor graders. Automatic machine control (stringline or stringless) is necessary to fine grade subgrade/subbase layers to tolerances which will allow for construction of smooth concrete pavements with uniform thickness.

Figure 24 – Fine Grading with a Trimmer

Fine grading subgrade and subbase(s) literally sets the foundation for controlling the thickness and smoothness of the concrete pavement. While smooth pavements can be constructed on subbases that are not fine graded to tight tolerances, doing so will result in non-uniform thickness of the concrete pavement. This will result in a pavement that is thinner than desired (reduced performance) or thicker than desired (contractor profits are diminished) or most likely a combination of both scenarios.

Key Inspection Items

- Check the finished grade – subgrade or subbase should be ±0.02′ from plan elevation.
- Blend and compact trimmed material into low spots uniformly – fine materials that are trimmed from high spots should be re-used in a manner which does not result in segregated pockets of granular materials.

- Visually identify areas of segregation in granular subbases – re-blend materials and re-compact.

Quality Control Measurements

- Measure, log and analyze grade tolerance at 50′ intervals (3 to 5 places across the width of the roadway) – correct highs and lows.
- Check subbase thickness at 50′ intervals in three locations across the width of the layer.

Checklist

No.	Item	✓ When Complete
1.	Maintain the moisture in subgrade and subbase during fine grade operations and until the next layer is placed	☐
2.	Re-use trimmings in a manner which does not result in segregated pockets of granular material	☐
3.	Stringline or stringless model is set to correct alignment and elevation	☐

DOWEL BASKET PLACEMENT

Description

Dowels are placed in concrete pavements when truck traffic is anticipated. The purpose of the dowels is to transfer loads between slabs, thus reducing the maximum stress induced by truck loading. In order for dowels to efficiently transfer the loads, they must be:

- Aligned perpendicular to the transverse joint (*).
- Aligned parallel to the pavement surface (*).
- Embedded on both sides of the joint (minimum 3" embedment)(**).
- Placed vertically within tolerance (minimum 2" cover)(**).

(*) Rotational misalignment less than 3% of dowel length, NCHRP Synthesis 56 and ACPA 1998.
(**) Guide to Dowel Load Transfer Systems for Jointed Concrete Roadway Pavements, Snyder, 2011.

Dowel baskets are anchored in subgrade or untreated subbases using stakes. Anchoring in treated subbases is accomplished using clips which are held in place using nails that are installed using a powder actuated charge. Proper anchoring is just one consideration. For dowels to be effective, the sawed joints must be placed over the pre-placed bars. Therefore, the dowel basket location needs to be adequately marked on both sides of the pavement to ensure sawing the joint in the correct place (Figure 25). Dowel baskets must also be placed at the correct offset from the edge of the pavement. Baskets that are located too near the edge of the pavement are prone to be hit by spreading and paving equipment.

Figure 25 – Positive Marking of Dowel Basket Location for Sawing Joints

Key Inspection Items

- Check transverse spacing and offset from the edge of pavement.
- Visually inspect for alignment – correct misaligned bars.
- Verify that basket locations are marked on both sides of the pavement.
- Baskets should be anchored so that the stake is on the downstream side of the basket frame.
- Check the stability of the baskets – are they anchored adequately to withstand the force of a slipform paver pushing concrete over them?

Quality Control Measurements

- None during pre-paving, however the embedment and cover of bars should be verified by probing behind the paver at 300′ intervals (at least 1 bar for each basket across the width of the slab should be located)(Figure 26).

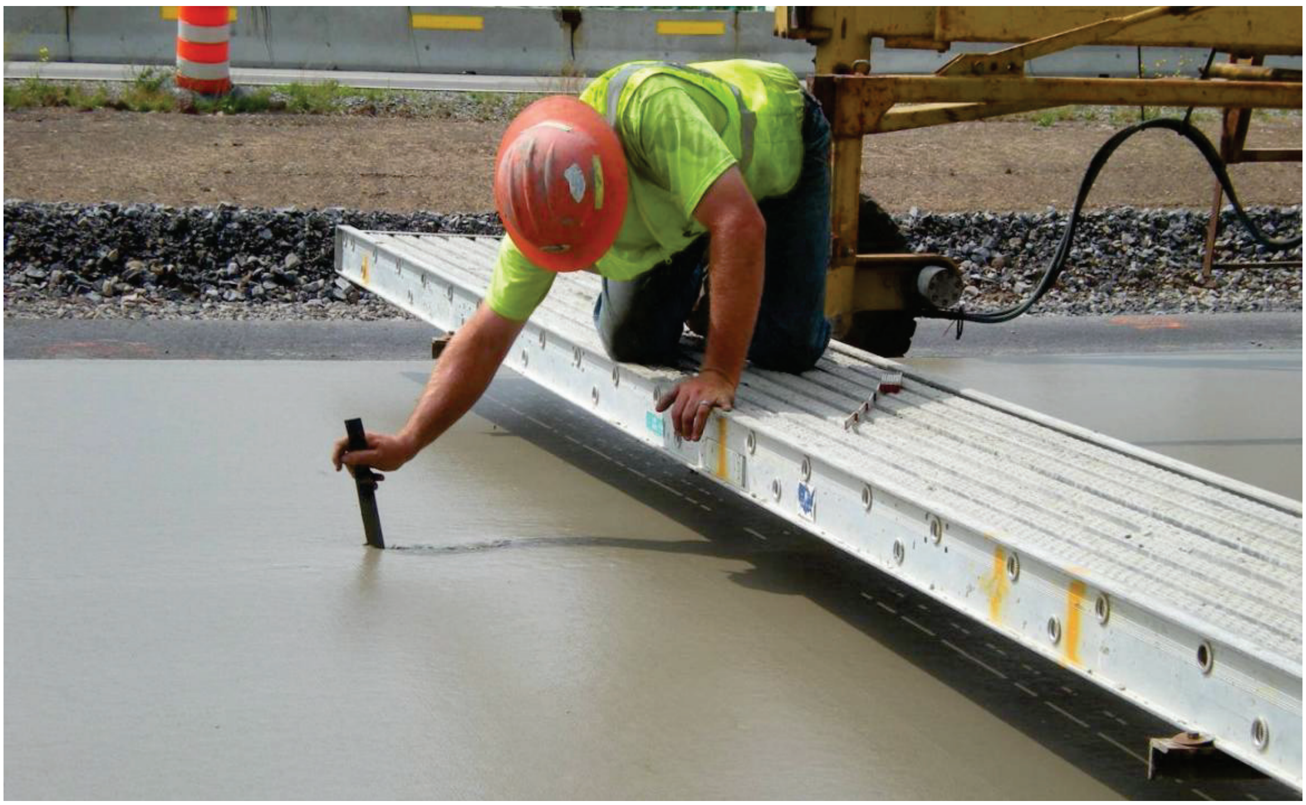

Figure 26 – Probing for Dowel Locations

- Non-destructive devices such as ground penetrating radar, MIT Scan (Figure 27) or pachometer (cover meter) can be used to evaluate dowel/joint placement. It should be noted that the MIT Scan device will not operate properly unless the shipping wires on the baskets are cut.

Figure 27 – MIT Scan used to Locate Dowels

Checklist

No.	Item	✓ When Complete
1.	Correct dowel dimensions (diameter and length)	☐
2.	Basket height is appropriate for the pavement thickness	☐
3.	Bar spacing is as specified	☐
4.	Bar coating is as specified and not unduly damaged	☐
5.	Bond breaker is adequate	☐
6.	Verify that the dowel location is marked adequately on both sides of the slab to ensure proper joint sawing	☐

STEEL PLACEMENT (CRCP)

Description

Continuously reinforced concrete pavements use steel reinforcing bars throughout the length of the pavement. Transverse joints are not necessary for CRCPs, the steel is designed to hold the cracks tight and promote aggregate interlock across the crack. The bar size and spacing is determined through the design process, bars should be placed within the specified tolerances.

In the past, some CRCPs have been constructed using tube feeders for the longitudinal steel; this practice is no longer recommended or allowed in most states because the steel was not maintained at mid-slab depth. Bars should be placed on supports which hold the steel at the correct height (Figure 28). Attention should be paid to the offset between the outside bars and the edge of pavement, spreading and concrete equipment can hit bars which are placed too close to the edge of pavement.

Figure 28 – Properly Supported Reinforcing Steel

Key Inspection Items

- Check bar spacing and offset from the edge of pavement.
- Laps should be staggered (Figure 29).

Figure 29 – Staggered Laps for Longitudinal Reinforcing Bars

- Periodically anchor the mat using a bar driven into the subgrade, this will help to prevent the entire mat falling off the supports if the outside bars are caught by the spreader or paver.
- Check the stability of the bar mat – is it tied and supported adequately to withstand the force of concrete spreader dumping concrete on it and a slipform paver pushing concrete over it?
- Transverse construction joints are heavily reinforced. Ensure that the concrete is adequately consolidated.

Quality Control Measurements

- None during pre-paving, however the steel location should be verified by probing behind the paver at 300′ intervals.

Checklist

No.	Item	✓ When Complete
1.	Correct steel diameter and grade	☐
2.	Correct bar support height for the thickness of concrete pavement	☐
3.	Adequate supply of bar supports and tie wire	☐
4.	Proper consolidation at headers	☐

PAVER PREPARATION

Description

Slipform pavers are complex machines (Figure 30). Each paver should be maintained and adjusted according to the manufacturer's recommendations.

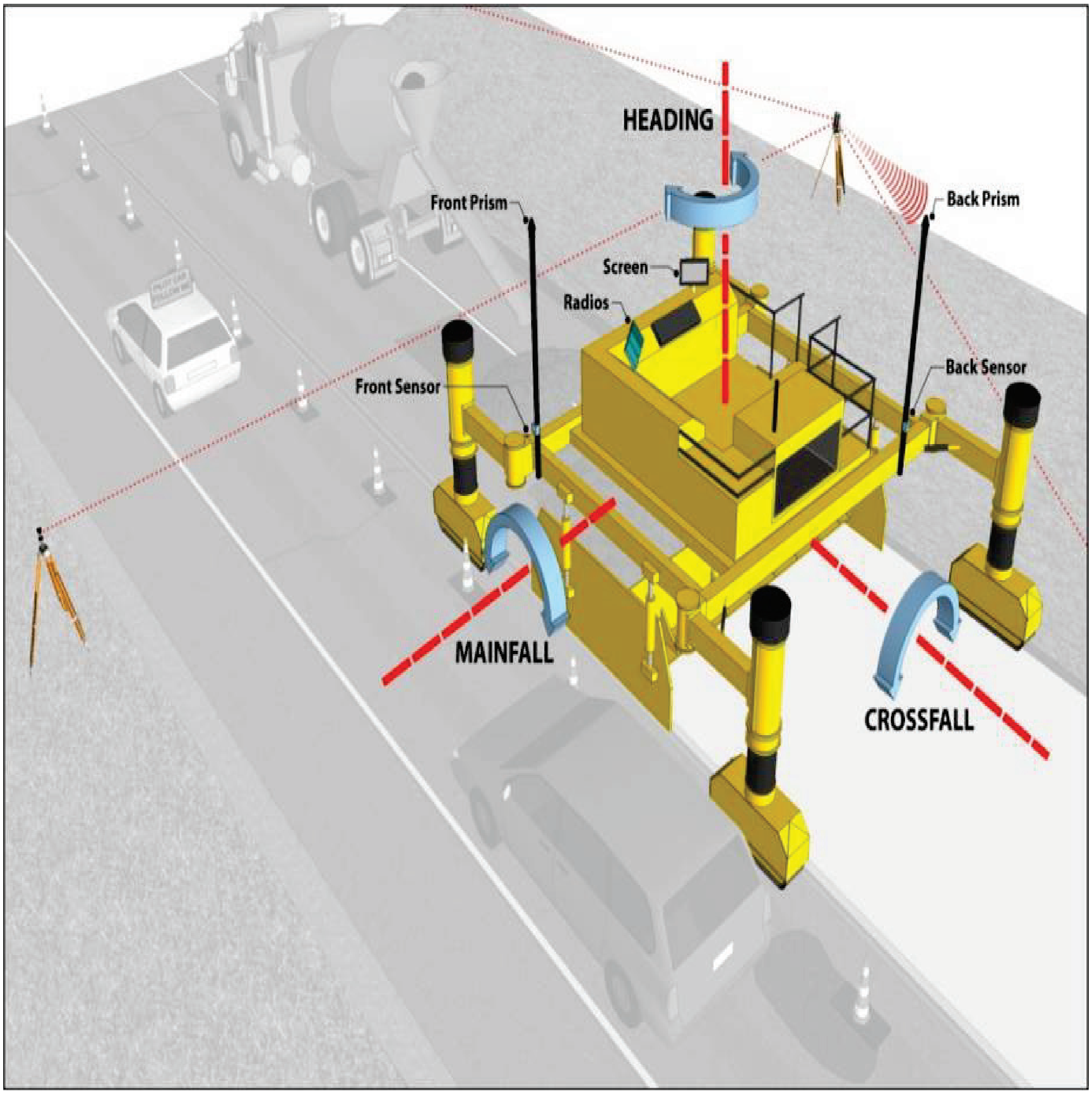

Figure 30 – Schematic of a Slipform Paver

There are a few basic guidelines which are applicable to all pavers, these include:

- Clean the paver – remove dried concrete that could come loose during paving.
- Fix hydraulic leaks – **hydraulic fluid is not a concrete admixture.**
- Check vibrator spacing, operation and frequency.
- Adjust the extrusion pan to the correct width and shape (cross-slope and crown).
- Set the paver parallel to the stringline.
- Set the height relative to the string to provide the correct pavement thickness.
- Run the paver on the string or with the correct stringless model for approximately 50' and re-check alignment, elevation and crown/cross-slope.

- Check that the tie bar inserter(s) are set to insure that the tie bars are located correctly in the pavement.
- If integral curb is being placed, confirm that the curb mold matches the curb design.

Key Inspection Items

- Paver width – the paver should be set slightly narrower than the design width because the concrete will expand in width behind the paver.
- Crown and cross-slope.
- Vibrators are operable.

Quality Control Measurements

- Vibrator frequency – constant data collection with monitors or manually at least twice daily.

Checklist

No.	Item	✓ When Complete
1.	Paver is clean	☐
2.	Vibrators are working	☐
3.	Vibrator spacing, height and orientation is correct	☐
4.	No leaks	☐
5.	Width, crown and cross-slope is correct	☐
6.	Dry run on string	☐
7.	Double check crown, cross-slope and thickness after dry run	☐

5. Plant Site and Mixture Production

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AGGREGATE STOCKPILE MANAGEMENT

Description

Proper stockpiling techniques can contribute to concrete pavement quality by minimizing the effects of:

- Mud balls – stockpile foundations should be firm and well drained to resist pumping of mud balls into the bottom layer(s) of the aggregate stockpile.
- Segregation – stockpiles constructed in layers will minimize segregation.
- Variable moisture content – while it may be impossible to maintain uniform moisture content, a well thought out plan and proper testing can accommodate changing moisture contents (Figure 31).

Figure 31 – Plan for Changes; Different Colors Indicate Variable Aggregate Moisture Content

It is critical that the loader operators, concrete plant operator, and quality control staff communicate clearly regarding which part of the stockpiles are being used to produce concrete. Aggregate moisture testing representative of those areas of the stockpiles is necessary to accurately compensate for the free moisture found in the aggregate during mixture production. Sensors at the aggregate bin may be used if previous experience shows satisfactory results. Caution should be exercised when using aggregate from the bottom 1′ of stockpiles which have been placed on unstabilized ground.

Key Inspection Items

- Visually inspect the stockpile for segregation.
- Rutting and pumping at the edges of the stockpile suggests that mud balls may be a concern.

Quality Control Measurements

- Sieve analysis during stockpiling – out of tolerance aggregates should be rejected.
- Aggregate moisture content.

Checklist

No.	Item	✓ When Complete
1.	Stockpile foundations have been stabilized	☐
2.	Aggregate sources match the approved mixture design	☐
3.	Aggregate gradation is within JMF tolerances	☐

PLANT SET-UP AND CALIBRATION

Description

Proper plant set-up occurs far before the plant is mobilized on site. From the onset, the logistics of raw material deliveries, stockpiling and batch truck traffic need to be considered. This is important for safety, productivity and quality. Batch plants are complex machines. Maintenance and set-up should conform to the manufacturer's recommendations (Figure 32). Once the plant is erected and functional, the scales should be calibrated and certified. This should be done each time the plant is relocated on the project.

Figure 32 – Proper Plant Set-up and Maintenance is Critical to Providing Uniform Concrete

A trial batch should be performed prior to production to confirm that the plant is working properly. Uniformity testing should be performed on the trial batch to confirm that the plant is capable of thorough mixing.

Key Inspection Items

- Check for scale calibration and certification.
- Review the trial batch ticket for the proper proportions.
- Check admixture and cementitious delivery tickets to assure that they match the approved mixture design.

Quality Control Measurements

- Mixer uniformity testing.

Checklist

No.	Item	✓ When Complete
1.	Check all bins and belts to prevent intermingling of aggregates	☐
2.	Scales calibrated and certified	☐
3.	Water meter calibrated	☐
4.	Admixture dispensing system is calibrated	☐
5.	Mixing blades are not worn out	☐
6.	Proper mixture proportions are programmed into the plant control system	☐

MIXTURE PRODUCTION

Description

A uniform concrete mixture is critical to the construction of a high quality concrete pavement. Specifications require that each individual material meet certain criteria. It would be incorrect to assume that combining these individual components which have already been tested and/or certified to meet specification will result in a quality concrete mixture. In fact, great care must be taken to produce a concrete mixture which will be both workable for placement and durable.

Key Inspection Items

- Review aggregate moisture testing and moisture compensation on the batch tickets.
- Periodically monitor mixing time.
- Check that the aggregate moisture contents used for adjusting batch proportions is representative of the material being taken from the stockpiles.

Quality Control Measurements

- Sieve analysis and combined gradation
- Aggregate moisture content
- Concrete temperature (*)
- Unit weight (*)
- Air content (*)

(*) Each of these quality measurements should be checked at least once per day at the plant site and compared to samples obtained at the point of delivery.

Checklist

No.	Item	✓ When Complete
1.	Batch proportions match the approved mixture design (daily)	☐
2.	Moisture compensation is representative of the aggregates being batched (at least 2 times per day, more if necessary)	☐
3.	Material inventories are adequate	☐
4.	Mixing drum is clean of dried materials which could break loose	☐
5.	Mixing blades are not overly worn	☐

TRANSPORTING CONCRETE

Description

There are numerous ways to transport concrete; the primary objective of this step in the construction process is to deliver the concrete in a timely manner without causing it to segregate. Obviously, mixer trucks can mitigate potential segregation, however most central mixed concrete delivered to concrete paving projects is transported in non-agitating trucks (Figures 33 and 34). Therefore, the haul route must be maintained in a manner that will minimize segregation and air loss caused by rough haul roads.

Figure 33 – Transporting Concrete in a Dump Truck

Figure 34 – Transporting Concrete in a Live Bottom Trailer

Haul units must also be cleaned to prevent clumps of dried concrete from contaminating the pavement. The plant site should provide an ample wash-out area that can accommodate multiple trucks. Having enough trucks to deliver concrete is a key factor for allowing the paver to maintain a steady pace.

Key Inspection Items

- Look for segregation in the mixture; this could be wet spots, dry clumps, areas of paste concentration, etc.
- Check the haul road for smoothness.
- Watch for dried concrete in the haul units.
- Ensure an adequate number of haul units are on the project.

Quality Control Measurements

- None

Checklist

No.	Item	✓ When Complete
1.	Haul route is maintained	☐
2.	Wash-out area is adequate	☐
3.	Adequate number of trucks on-site	☐
4.	Vibrators on truck beds are operational	☐

6. Placement, Finishing, Texturing, Curing and Sawing

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SPREADING CONCRETE

Description

Concrete can be discharged from a truck directly in front of a paver or a placer/spreader may be used (Figure 35). In either case, the objective is to maintain a uniform head of concrete at the front of the paver. Adjustments in this process are constant. When the elevation of the subbase deviates from plan, the volume of concrete required also varies, causing the spreading operation to react to the demands of the paver. When the head in front of the paver becomes too large, a front end loader must redistribute the concrete (Figure 36); this should be avoided. If the paver becomes starved for concrete, the grout box empties. Again, this is a situation that should be avoided. When the head varies from one extreme to the other, pavement smoothness suffers.

Figure 35 – Concrete Belt Placer/Spreader

Figure 36 – Adjusting Paver Head with an End Loader

Key Inspection Items

- Subgrade/Subbase should be sprinkled with water and remain damp before concrete spreading occurs.
- Reject pavement in areas where the grout box empties.
- Monitor the amount of concrete in front of the paver; note the time and location of extremes and correlate these events to the smoothness profiles.
- Visually inspect for non-uniformity before the concrete is extruded through the paver (segregation, unmixed materials, etc.).
- Visually inspect for areas of segregation where belt placers are used; excessive belt speed and excessive vertical drop can cause segregation (gap graded mixtures are prone to segregation).

Quality Control Measurements

QC and acceptance samples are taken at the point of delivery:

- Concrete temperature.
- Subbase temperature.
- Slump.
- Unit weight.
- Air content.
- Strength.

Checklist

No.	Item	✓ When Complete
1.	Spreader, if used, is set narrower than the paver	☐
2.	Spreader, if used, has automatic control for steering and elevation (stringline or stringless)	☐
3.	Water truck is available for sprinkling grade	☐

SLIPFORMING (extrusion)

Description

After the concrete is spread, it is extruded through the paver. Some pavers use an auger while others use a paddle to move the concrete from side to side. If the spreading operation is efficient, this side to side movement is minimized. Vibrators are used to consolidate the mixture and help extrude the concrete through the paver's mold (Figure 37).

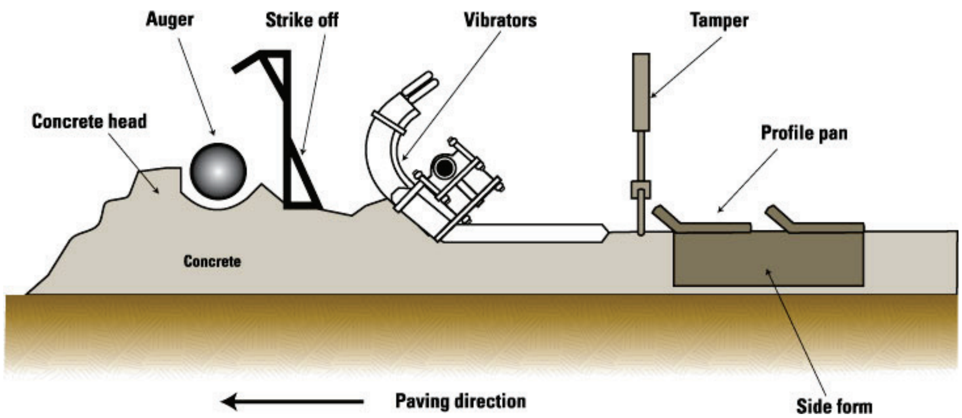

Figure 37 – Section View of A Slipform Paver

Ideally, the paver should move at a uniform speed. It is the paver operator's responsibility to adjust the paver speed to match the delivery rate of concrete. Vibrator frequency should also be adjusted with the paver speed. There are many adjustments that can be made to a slipform paver. These adjustments should be made by experienced personnel.

Key Inspection Items

- Visually inspect the edge for stability. Continued edge problems should not be tolerated. They are an indication of a non-uniform mixture, improper consolidation, or an out of adjustment paver.
- Visually inspect the pavement for surface tears directly behind the paver before any hand finishing has occurred. Tears in the surface may indicate that the paver needs adjustment and/or the mixture needs to be modified.
- Look for concrete build-up in the grout box – clean out hardened concrete from the grout box.
- Adjust vibrator frequency for paver speed; vibrators should stop whenever the paver stops.

Quality Control Measurements

- Vibrator frequency (automatic with monitors or manually at least twice per day).
- Paver speed – maintain a log of paver speed, noting start and stop locations.
- Smoothness profiles – correlate roughness to any events noted during paving.

Checklist

No.	Item	✓ When Complete
1.	Vibrators operable before starting	☐
2.	Monitor vibrator operation at least hourly	☐
3.	Stringline or stringless models have been checked for accuracy	☐
4.	Paver and all associated equipment are fueled and ready for uninterrupted operation	☐

INSERTION OF DOWELS AND/OR TIE BARS

Description

Dowels may be inserted instead of placed using a wire dowel basket (Figure 38). The same tolerances and concerns apply to inserted dowels as to those placed in a basket.

Figure 38 – Automatic Dowel Bar Inserter (DBI)

In order for dowels to efficiently transfer the loads, they must be:

- Aligned perpendicular to the transverse joint (*)
- Aligned parallel to the pavement surface (*)
- Embedded on both sides of the joint (minimum 3″ embedment) (**)
- Placed vertically within tolerance (minimum 2″ cover) (**)

(*) Rotational misalignment less than 3% of dowel length, NCHRP Synthesis 56 and ACPA 1998.
(**) Guide to Dowel Load Transfer Systems for Jointed Concrete Roadway Pavements, Snyder, 2011.

The sawed joints must be placed over the inserted bars. Therefore, the dowel location needs to be adequately marked on both sides of the pavement to ensure sawing the joint in the correct place (Figure 39).

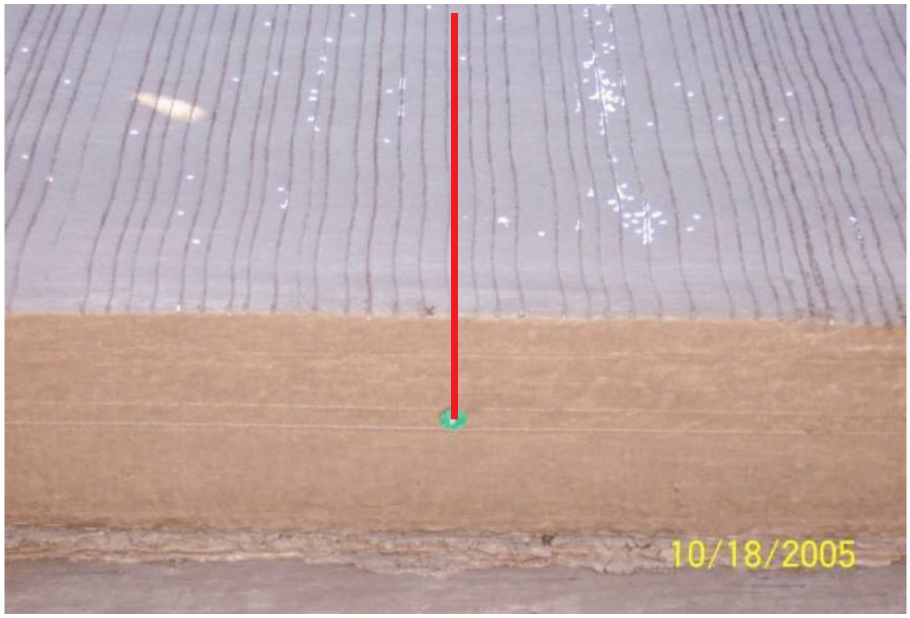

Figure 39 – Marking the Location of Inserted Dowels

Key Inspection Items

- Check transverse spacing and offset from the edge of pavement.
- Verify that dowel locations are marked on both sides of the pavement.
- Monitor consolidation above and around the dowels by coring after each day of paving.

Quality Control Measurements

- None during pre-paving, however the embedment and cover of bars should be verified by probing behind the paver at 300′ intervals (at least 1 bar for each basket across the width of the slab should be located).

Non-destructive devices such as ground penetrating radar, MIT Scan or pachometer (cover meter) can be used to evaluate dowel/joint placement.

Checklist

No.	Item	✓ When Complete
1.	Correct dowel dimensions (diameter and length)	☐
2.	Bar spacing is as specified	☐
3.	Equipment is set-up to place the dowels at approximately mid-depth of the pavement	☐
4.	Bar coating is as specified and not unduly damaged	☐
5.	Bond breaker is adequate	☐
6.	Verify that the dowel location is marked adequately on both sides of the slab to ensure proper joint sawing	☐

HAND FINISHING

Description

Hand finishing a slipformed concrete pavement should be kept to a minimum. The objective is to finish the surface so that only minor imperfections remain. Over-finishing brings excess paste to the surface. This excess paste leads to a non-durable surface which further exposes the pavement to infiltration of moisture and deicing chemicals. Adding water to the surface is an indication that the mixture and/or the paver need adjustment. Additional water (or evaporation retardant) that is finished into the pavement surface results in the same durability issues as over-finishing.

A straightedge should be used to identify bumps and dips. Once identified by the straightedge, they should be corrected by an experienced concrete finisher (Figure 40).

Figure 40 – Using a Straightedge to Identify Dips and Bumps

Edges occasionally fall and need to be repaired by finishers. A board is typically placed to reinforce the edge and the concrete is reconsolidated and finished. The mixture and/or the paver should be adjusted when edges continue to fall.

Key Inspection Items

- Do not allow the addition of water to the pavement surface – adjust the mixture and/or paver.
- Note locations where finishers cut bumps/fill dips.
- Monitor wetting/re-wetting of the burlap – overspray may "accidentally" add water to the pavement surface.
- Consolidation at end-of-day headers.

Quality Control Measurements

- Smoothness profiles – correlate to events noted during paving.

Checklist

No.	Item	✓ When Complete
1.	Finishing tools are straight and true	☐
2.	Header supplies and tools are on hand	☐

TEXTURING

Description

Detailed guidelines for texturing can be found in *HOW TO REDUCE TIRE-PAVEMENT NOISE INTERIM BETTER PRACTICES FOR CONSTRUCTING AND TEXTURING CONCRETE PAVEMENT SURFACES*, which is available from the CP Tech Center at: http://www.cptechcenter.org/technical-library/documents/How_to_Reduce_Tire-Pavement_Noise_final.pdf

A brief summary of texturing guidelines includes the following items:

- Operate the texture machine at a consistent speed.
- Use stringline to control the steering and elevation of the texture machine.
- Use clean and straight tines (Figure 41).
- Adjust tine length and angle to control texture depth.

Texturing is typically performed with the same piece of equipment as curing. **In no case should curing be delayed by the texturing process.**

Figure 41 – Clean and Straight Tines Minimizes Positive Texture

Key Inspection Items

- Tine spacing should be checked.
- Observe nominal texture depth – it is impractical to measure texture depth, look for texture that is obviously too deep or too shallow.

Quality Control Measurements

- None.

Checklist

No.	Item	✓ When Complete
1.	Tine spacing as specified	☐
2.	Broken tines replaced	☐
3.	Cleaned tines	☐

CURING

Description

Curing compound is applied to a concrete pavement to create a membrane which prevents evaporation of water from the pavement. The intent is to maintain the moisture in the concrete mixture during the hydration process. If moisture is allowed to evaporate from the surface, capillary voids are created which later allow moisture and deicing chemicals to enter the pavement structure. Plastic shrinkage cracks can also occur when curing practices are ineffective. Curing compounds used for paving include white pigment to reduce heat at the surface from solar radiation.

Timely application of an adequate quantity of curing compound is the objective.

Key Inspection Items

- Visually inspect for complete and uniform coverage; the surface should be similar in appearance to a white sheet of paper (no gray streaks)(Figure 42).
- Curing should be applied before any surface drying can occur.
- Curing should not be applied until bleed water is gone.

Figure 42 – Complete and Uniform Coverage of Curing Compound

Quality Control Measurements

- Record start and stop locations and times.
- Calculate an average coverage rate each time cure is added to the tank.

Checklist

No.	Item	✓ When Complete
1.	Curing materials are on the job and meet specification	☐
2.	Curing tanks are full and material has been agitated	☐
3.	Pump for re-filling is operable	☐
4.	Nozzles are clean and functioning	☐
5.	Wind screen is adjusted	☐

SAWING

Description

Joints are created in concrete pavements to promote cracking. The sawcut creates a weakened plane which if placed early enough in the life of the pavement induces a crack where we would like it to occur (at the joint). Late sawing can result in random cracking.

There are many factors which influence when and where cracking will occur. Joint sawing requires well maintained equipment and experienced personnel (Figure 43).

Figure 43 – Sawing Joints Requires Well Maintained Equipment and Experienced Personnel

Key Inspection Items

- Saw depth – check for compliance at mid-slab locations.
- Visually inspect for cracks.
- Raveling – is it excessive (sawing too early) or is it minimal (sawing too late)?

Quality Control Measurements

- Log time of paving, time of sawing and slab temperature.
- Install temperature sensors in the pavement every hour – monitor and correlate temperature with the time of sawing relative to the time of placement.
- HIPERPAV® can be used to assess the early age behavior of concrete pavement. The software models early stress and early strength of the concrete pavement, making it useful to evaluate the potential for uncontrolled cracking and the effectiveness of sawing operations.

Checklist

No.	Item	✓ When Complete
1.	Adequate number of saws and blades on the project	☐
2.	Saw blades are the correct diameter for the required saw depth	☐
3.	Water trucks are available to support the saw crew	☐
4.	Lights if necessary are available and operable for the saw crew	☐

WEATHER ADJUSTMENTS

Description

The construction of concrete pavements is influenced by changes in the weather. Contractors should monitor concrete/pavement temperature and be prepared to make the appropriate adjustments in their processes and materials if necessary.

Appendix B contains an example weather management plan which should be prepared by contractors to demonstrate their readiness to adjust to variable conditions.

The following items provide a brief summary of appropriate actions for rain, hot and cold weather.

Rain

Sudden rain showers can occur without warning. The contractor should have an adequate supply of plastic sheeting to cover the fresh concrete and protect it from the rain. When the forecast predicts rain, it may be prudent to adjust the schedule and place small hand pours, ramps or shoulders which may be smaller in size and easier to cover. Unprotected pavement that is rained on should not be “re-finished”. The texture may be restored by sawcut grooving.

Hot Weather

Increased temperature speeds up the hydration process. If possible, the temperature of the mixture should be kept below 90°F by adjusting the placement time (night paving), using chilled mixing water, or other means. Class C fly ash and some admixtures may cause early stiffening of the mixture at higher temperatures. Again, the preferred method of mitigation is to reduce the temperature of the mixture.

Cold Weather

The first consideration for cold weather is to protect the concrete form freezing for a minimum of 48 hours. Secondly, is coordinating the sawing of joints. When the pavement is covered to protect it from freezing, it must be uncovered to saw and recovered again. Uncover the slab directly ahead of the sawing operation to prevent rapid cooling of the pavement which may induce a crack. Supplementary cementitious materials may retard strength gain in cooler temperatures; sawing operations will need to be adjusted for this.

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10. ACPA Application Library http://apps.acpa.org/apps/

Appendix A: Template Quality Control Plan

This appendix is provided as an example of a "Quality Control Plan" (QCP) that is applicable to portland cement concrete pavement. It follows the format recommended by *Transportation Construction Quality Assurance* (1) and may be used as a guide when preparing a project specific QCP. Each QCP should document the QC activities necessary to produce a product the meets the specification. "Boilerplate" documents are not acceptable; each QCP should be thoughtfully prepared to fit the specific needs of that project. Blindly copying and recycling QCP documents for use on multiple projects diminishes the value of the QCP. The process of developing a project specific QCP provides valuable insight into project details and opportunities for quality improvements.

Portland Cement Concrete Pavement Quality Control Plan (QCP)

1.0 Scope and Applicable Specifications

Cite all applicable standard specifications, special provisions and drawings.

1.1 Standard specifications
1.2 Special provisions
1.3 Drawings

2.0 Quality Control Organization

Identify all QC personnel, list appropriate certifications and describe their responsibilities.

2.1 QC Plan Manager
2.2 Off-Site QC Personnel (e.g. aggregate suppliers)
2.3 QC Laboratory Personnel – Supervisor and technicians
2.4 On-Site QC Personnel – inspector(s) and technician(s)

3.0 Quality Control Laboratories

List all QC labs with their location, contact information, and relevant accreditations, certifications and qualifications.

3.1 QC lab information
3.2 Test procedures performed at the laboratory (e.g. ASTM C 39 Compressive Strength of Cylindrical Concrete Specimens)

4.0 Materials Control

List all materials used in the construction of PCCP.

4.1 Example materials control table

Material	Specification(s)	Source	Shipper	Storage Location	On-Site Processing
Coarse Aggregate	ASTM C33 Size #67 DOT 700.11	Rock Crushers, DOT Approved Pit #3033 (555) 555.5551 Red Bird	Rock Haulers, (555) 555.5552 Burt Semis	Plant Site	Concrete plant
Dowel Baskets	DOT 700.25	Bar Busters, Birmingham, OK (555) 555.5553 Nathan Steele	Iron Freight, (555) 555.5554 Calvin Tiress	Exit #17 Storage Yard	N/A
---Additional Materials---	----------	----------	----------	----------	----------

Appendix A – Table 1: Example Materials Control Table

5.0 Quality Control Sampling and Testing

Provide details on sampling, testing and reporting for all QC activities.

5.1 Random sampling plan
5.2 Sample identification and storage system
5.3 Example QC sampling and testing table
5.4

Material	Test Method	Lot Size	No. of Sublots	Testing Frequency	Sampling Location	Sampling Method	Report Type
Coarse Aggregate	Gradation ASTM C 136	5,000 yd^2	5	1 per sublot and/or minimum 1 per day	Stockpile	Random "Power Pile" GTM #207	Tabular and Graphical: % retained CF/WF 0.45 Power
Concrete	Air Content ASTM C 231	N/A	N/A	First 3 loads per day and repeat for 3 loads whenever admixture dosages are adjusted	Plant Grade Behind Paver	Biased Start of day	Tabular and Control Chart

Fresh Concrete	Temperature Air Content ASTM C 231 Unit Weight ASTM C 138 Water Content AASHTO T 318	5,000 yd^2	5	1 per sublot	Grade	Random	Tabular and Control Chart
Concrete Pavement	Thickness Probe GTM #215	5,000 yd^2	5	1 per sublot	Grade	Random	Tabular and Control Chart
Hardened Concrete	Thickness ASTM C 174 Compressive Strength ASTM C 39	5,000 yd^2	5	1 per sublot	Pavement Cores	Random	Tabular and Control Chart

Appendix A – Table 2: Example QC Sampling and Testing Table

6.0 Production Facilities

Include details for the concrete plant and relevant QC activities.

6.1 Stockpile management plan
6.2 Truck washout procedures
6.3 Pre-production QC activities
- 6.3.1 Sieve analysis of aggregates
  - 6.3.1.1 Sample and test for every 500 tons delivered
  - 6.3.1.2 Compare to JMF tolerances established by the approved mixture design
  - 6.3.1.3 Reject all nonconforming material

- 6.3.2 Verification batch
  - 6.3.2.1 Check mixer uniformity
  - 6.3.2.2 Compare mixture verification batch to mixture design properties
    - 6.3.2.2.1 Slump at 5, 10 and 15 min.
    - 6.3.2.2.2 Unit weight
    - 6.3.2.2.3 Air content
    - 6.3.2.2.4 Microwave water content
    - 6.3.2.2.5 Heat signature
  - 6.3.2.3 Repeat verification batch until uniformity and properties are acceptable

6.4 Production QC activities

- 6.4.1 Sieve analysis of aggregates
  - 6.4.1.1 Sample and test for every 500 tons delivered
  - 6.4.1.2 Compare to JMF tolerances established by the approved mixture design
  - 6.4.1.3 Reject all nonconforming material
- 6.4.2 Air content of fresh concrete
  - 6.4.2.1 Sample the first 3 loads of each day
  - 6.4.2.2 Sample the first 3 loads after AEA admixture dosage is adjusted
  - 6.4.2.3 Reject any concrete sampled at the plant with an air content less than 5%
- **6.4.3 Additional tests as necessary – include frequency and procedures for corrective actions**

7.0 Field Operations

Describe in detail each step of the concrete paving process and the associated QC activities.

7.1 Pre-paving

- 7.1.1 Staking and setting stringline
  - 7.1.1.1 Inspection items
    - 7.1.1.1.1 Visual inspection of stringline for abrupt changes/discontinuities
    - 7.1.1.1.2 Spot check that pins are not loose
  - 7.1.1.2 QC measurements (include action and suspension limits, when appropriate)
    - 7.1.1.2.1 Random check of paving hub elevation – 1 per 1,000'
  - 7.1.1.3 Checklist items to be completed daily by the stringline foreman and submitted to the QC Manager before paving commences
  - 7.1.1.4 Corrective actions
    - 7.1.1.4.1 Re-survey and reset stringline where errors are identified
- 7.1.2 Dowel basket placement
  - 7.1.2.1 Inspection items
    - 7.1.2.1.1 Transverse spacing
    - 7.1.2.1.2 Offset from edge of pavement
    - 7.1.2.1.3 Joint markings on both sides of the pavement
    - 7.1.2.1.4 Anchored firmly on the downstream side of the wire frame
  - 7.1.2.2 QC measurements (include action and suspension limits, when appropriate)
    - 7.1.2.2.1 Check location by probing at 300' intervals – record longitudinal and vertical shift and submit to the QC Manager daily
  - 7.1.2.3 Checklist items to be completed daily by the concrete paving foreman and submitted to the QC Manager before paving commences

7.1.2.4 Corrective actions
7.1.2.4.1 Replace misaligned or damaged baskets
7.1.2.4.2 Stop paving if the baskets are shifting more than 3" longitudinally. Re-anchor all baskets to prevent movement
7.1.2.4.3 If baskets have moved, use a non-destructive device to locate bars in all joints previously placed; develop a mitigation plan for all joints that have load transfer issues and submit to the Engineer for approval

7.2 Paving
7.2.1 Continue with each step of the paving process using the same format
7.2.1.1 Inspection items
7.2.1.2 QC measurements (include action and suspension limits, when appropriate)
7.2.1.3 Checklist items – note who is responsible, when it is to be performed and who it is submitted to
7.2.1.4 Corrective actions

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Appendix B: Weather Management Plan

The following is an example of an acceptable weather management plan. This plan may be used with edits, and expanded as necessary, by the contractor to meet the needs of his concrete mixtures, haul units, evaporation modeling method or software, paving hours and other items that are project specific.

CONTRACTOR XYZ WEATHER MANAGEMENT PLAN

Project: XYZ
Location: XYZ
Submitted By and Title: XYZ
Date: XYZ

The following project specific plan details actions that will be taken during concrete placement in hot weather, cold weather and times when a rainstorm is imminent.

1.0 Hot Weather Paving

Hot weather paving is defined as paving when the concrete temperature is greater than 85˚F or the moisture evaporation rate at the concrete surface is greater than 0.20 $lb/ft^2/hr$ (0.10 $lb/ft^2/hr$ for concrete mixtures containing fly ash or slag), as determined using the American Concrete Institute (ACI) moisture evaporation rate chart (Appendix B - Chart 1). During hot weather, the following actions will be taken:

1) Mixing Requirements - Paving will be suspended when the concrete temperature exceeds XX˚F (*insert the maximum allowed by specification*). Mitigation measures to prevent the concrete temperature from exceeding XX˚F when measured directly in front of the paver include:

    a) Chilled water shall be used to prevent the concrete temperature from exceeding XX˚F as measured directly in front of the paver.
    b) Night placement may be initiated during prolonged periods of hot weather.
    c) Aggregate stockpiles may be sprinkled lightly to cool the outside of the stockpile.
    d) The use of specific supplementary cementing materials may be reconsidered.

2) Hauling Requirements - No provision for alternative haul units is included. Non-agitating dump trucks will be used for all placements. The actions detailed in Section 1 will be used for controlling the concrete temperature.

3) Placing Requirements:
    a) A water truck shall be utilized to sprinkle the subbase ahead of the area where concrete is deposited. The subbase will be kept damp with no areas of standing water.
    b) When side forms are used, they will be sprinkled to maintain a surface temperature below 120˚F.

c) The ambient conditions for relative humidity (%), concrete temperature (˚F), and wind velocity (mph) will be measured and recorded every 30 minutes during concrete placement. These measured values will be used to determine the evaporation rate ($lb/ft^2/hr$) utilizing Chart 1 or an appropriate software.

d) The anticipated placement and finishing techniques listed in order are: 1) dump concrete in front of the paver, 2) consolidate and extrude the pavement using a slipform paver, 3) hand finishing using floats and straightedges, 4) texturing, and 5) curing. When the evaporation rate exceeds 0.20 $lb/ft^2/hr$ (0.10 $lb/ft^2/hr$ for concrete mixtures containing fly ash or slag) **and** the curing application is more than 20 minutes behind the texturing operation, an evaporation retardant will be used to prevent plastic shrinkage cracking.

e) Windscreens and/or shades as referenced in ACI 305R will not be used.

4) Necessary Concrete Placement in Hot Weather:

a) When schedule conflicts cannot be avoided, concrete temperatures above XX˚F will be allowed for placements that are less than 200 feet long. Under these conditions, evaporation retardant will be sprayed at the manufacturers recommended rate between the finishers and the burlap drag and again directly behind the burlap drag.

The above sections are in accordance with standard practices and applicable recommendations of ACI 305R-99.

2.0 Cold Weather Paving

Cold weather paving is defined as paving when the air temperature is forecast to be less than 32˚F at any time within 72 hours of concrete placement. The following actions will be taken during cold weather paving:

1) Mixing Requirements - Paving will be suspended when the concrete temperature is less than 50˚F, mitigation measures to prevent concrete temperatures lower than 50˚F when measured directly in front of the paver include:

a) Heated water shall be used to maintain the concrete temperature above 50˚F as measured directly in front of the paver.

b) An approved accelerating admixture may be used to promote earlier sawing than would otherwise be possible.

c) Approved mixes containing Class F Fly Ash and/or ground granulated blast furnace slag will not be used.

2) Hauling Requirements - No provision for alternative haul units is included. Non-agitating dump trucks will be used for all placements. The actions detailed in Section 1 will be used for controlling the concrete temperature.

3) Placing Requirements - Concrete will be placed only when the subbase temperature is 32˚F or greater and the ambient temperature is at least XX˚F (*insert the minimum allowed by specification*). Placement will cease any time the subbase temperature is less than 32˚F or when the ambient temperature is less than XX˚F.

Protection of Concrete:

a) Concrete pavement surface temperature shall be maintained at or above 32˚F for a period of 72 hours or until in-place concrete compressive strength of 1,500 psi is attained. As necessary, the pavement shall be covered with one layer of polyethylene sheeting and two layers of burlap or curing blankets.
b) Temperature sensors that record the temperature of the pavement at 15 minute intervals will be placed in the edge of the pavement approximately 2 inches below the surface in the first and last 200 feet of placement. These sensors will be monitored to determine when the maturity equivalent of 1,500 psi is achieved. Protective insulation may be removed after the pavement reaches the maturity equivalent of 1,500 psi and the pavement temperature is essentially in equilibrium with the ambient temperature.
c) Protective insulation will be temporarily removed to enable joint sawing at the earliest possible time.
d) Pavement will be opened to traffic in accordance with the proposed specification requirements.

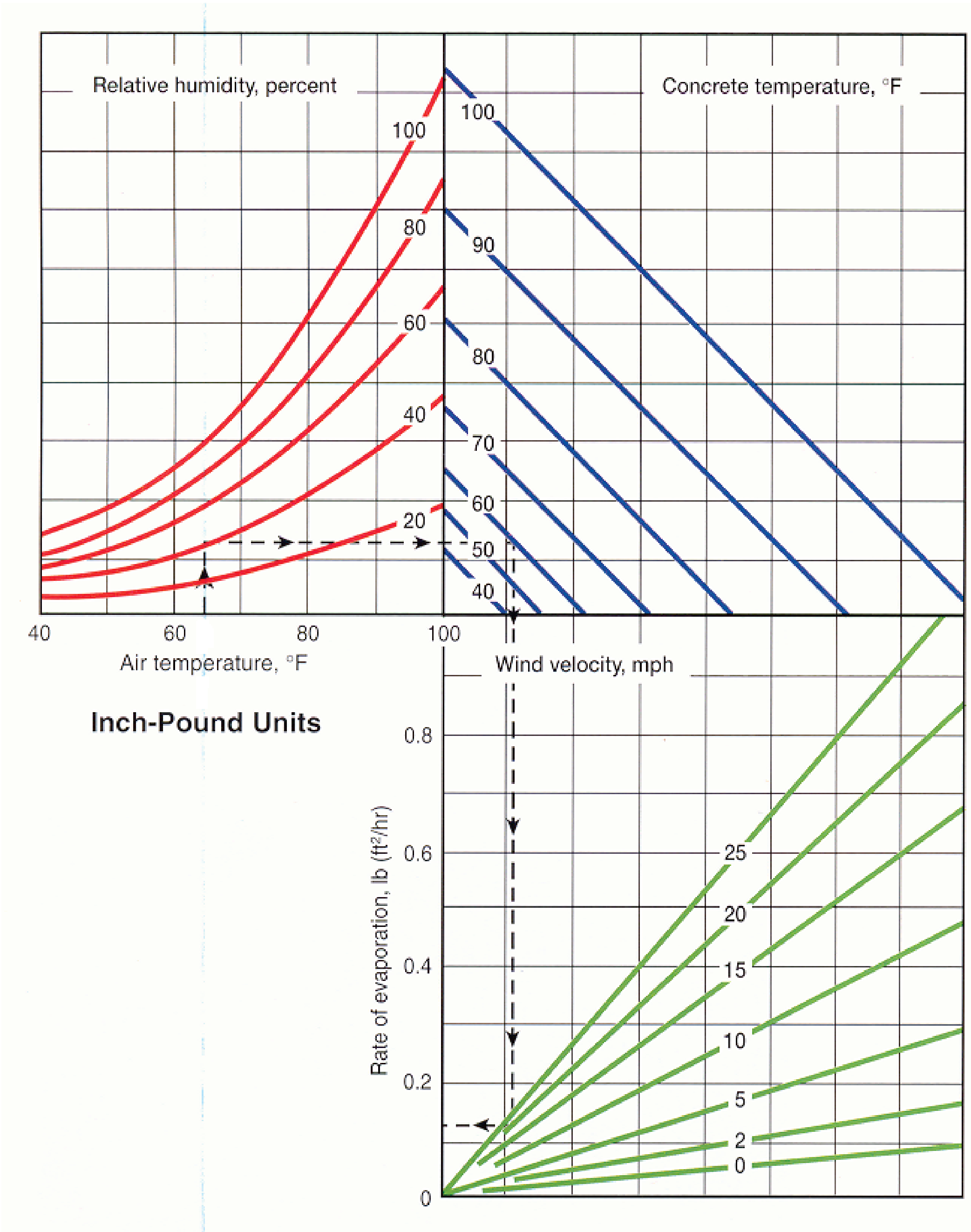
The above sections are in accordance with standard practices and applicable recommendations of ACI 306R.

1.0 Protecting Concrete from Rain Damage

The following steps will be taken, as necessary:

1) Paving will be canceled or ceased when rain storms are imminent. Weather radar will be monitored at the project office at a minimum of 1 hour intervals when the forecast probability of precipitation is 40% or greater.
2) 18 rolls of 4.0 mil polyethylene sheeting, 20 feet by 100 feet, will be stored on the curing machine for use in protecting the pavement from rain damage. In addition, an adequate number of 12-foot by 2-inch by 8-inch boards will be stored on the form truck for use as ballast to prevent the polyethylene from being removed by wind. The quantity of polyethylene is based on the following estimate:
   a) Average initial set time = 3.5 hours.
   b) Average plant production = 250 cubic yard per hour.
   c) Placement dimensions – 26 feet wide by 12 inches thick ≈ 1.0 cubic yard/lineal foot of paving.
   d) 3.5 hours x 250 cubic yards/hour ÷ 1.0 cubic yard/lineal foot = 875 feet of exposed pavement that has not reached initial set.
3) Polyethylene sheeting will be removed after the rain storm to enable curing operations and joint sawing.
4) Cores of rain damaged pavement will be taken at intervals of 100 feet center to center.

Remedial actions for rain damaged pavement shall conform to the proposed specification requirements related to diamond grinding or remove and replace.



Appendix B - Chart 1: Rate of evaporation as affected by ambient conditions (courtesy PCA)

Appendix C: Iowa DOT Field Inspection Checklist

PCC Paving Field Inspection Checklist

Duty	Frequency	Record Checks	Specification/Resource	Commentary
Prior to Concrete Placement				
Check proof rolling of subgrade	Everywhere prior to final trimming of subgrade.		Specification 2301.03, B, 3 all PCC paving Specification 2115.03, B, 2 Modified Subbase	All subgrades should be proof rolled with a sheep's foot roller no more than 1 week prior to trimming of the final grade. In addition, when Modified Subbase is used, the subgrade is to be proof rolled with a loaded truck to identify soft spots, etc.
Check stringline	As needed			Prior to checking subgrade and subbase cross slope and elevation, check to ensure that the stringline is properly placed relative to the paving hub. This can be done simply by measuring from the paving hub up to the stringline. Make sure to factor in the contractor's machine constant when measuring.
Check trimmed subgrade	10/mile (IM-204)	Form E109	Specification 2109.03, A, 10 plus or minus 0.05 foot	Check to ensure subgrade is trimmed to the proper cross slope and elevation. Usually checked by placing string across the subgrade from stringline to stringline and measuring down to top of subgrade. When stringline is not available, a survey rod and level may be used. Laser levels have been used but are less common. GPS

			rovers have also been used, but are not accurate enough to measure within the specification tolerances.
Make sure the contractor is not driving haul vehicles on granular subbase	As needed	Specification 2111.03, E	The specification prohibits the contractor from driving on the granular subbase material. This is a concern because excessive haul traffic on the granular subbase material can cause the material to break down and generate an excessive amount of fines. This is undesirable because granular subbase is intended to be a drainable material. Haul equipment must be operated on the material for delivery and placement purposes. A reasonable expectation of the contractor is that they get on and off the material within a 500 to 1000 foot stretch. When recycled materials are used, the distance should be kept closer to 500 feet. When virgin materials are used, the distance can be extended up to 1000 feet depending upon how much breakdown of the material occurs.

Check trimmed subbase (granular or modified)	10/mile (IM-204)	Form E109	Modified SubbaseSpecification 2115.03 plus 0 and minus 0.05 foot IM 204 Appendix CGranular Subbase Specification 2111.03, D, 4 plus 0 and minus 0.05 foot IM 204 Appendix D	Check to ensure subbase is trimmed to the proper cross slope and elevation. This, along with the subgrade checks, will ensure proper subbase thickness. Usually checked by placing string across the subbase from stringline to stringline and measuring down to top of subbase. When stringline is not available, a level may be used. Laser levels have been used but are less common. GPS rovers have also been used, but are not accurate. The width of the subbase should also be checked at this time to ensure that the proper placement width is being achieved. Note that subbase width typically includes an added three feet on each side of the pavement for a padline.
Check steel reinforcement storage			Specification 4151.03, G	Steel reinforcement should be stored in a manner that reduces the risk of corrosion, damage, and breakdown of epoxy coating. All reinforcement is to be stored on supports to prevent contact with the ground and extended contact with moisture. Epoxy coated bars should be covered with a non-transparent material if exposed for 2 months or more.

Check dowel basket placement	Form E111	Specification 2301.03, E Specification 4151.02, B Road Standard PV-101 Paving typicals in B sheets of project plans	Dowel baskets should be checked for spacing, alignment, proper anchorage, and adequate bond breaker coating. A quick and simple method to check alignment is to sight down the grade. Baskets that are out of alignment will be visible as the dowels will not line up. The baskets should also be checked to ensure that the dowel bars are level and parallel with each other. It is important to check alignment of dowels to ensure that the contraction joint works properly in the pavement. Once the joint is sawed and the pavement cracks, the concrete is intended to slide over the dowel as the pavement expands and contracts. If the dowels are out of alignment, the pavement cannot properly slide on the dowels which may result in random cracking.

				Baskets should be anchored with a minimum of 8 basket stakes per lane width. Dowel baskets are required to be coated with a bond breaker. Typically the bond breakers used are a bituminous material or a paraffin based material called Tectyl. Often the bituminous coating can become dry and brittle and will develop cracks in the material. If this occurs, recoating of the bars may be necessary. The contractor is not required to cut the tie wires on the baskets as long as the basket is manufactured correctly. The PV-101 road standard shows three #10 gauge wires on the basket. If more than three wires are provided, only three may be left uncut. One final check that should be made for dowel baskets is to check that the contractor has marked the center of each end of the basket to identify the location of the basket for purposes of sawing. This is typically done by placing a basket stake off each end of the basket along with a paint mark.
Inspect the finishing machine	Once each paver and when information changes.	Form 830213	Specification 2301.03, A, 3 Construction Manual Appendix 9-3	A few days prior to start of paving, several checks should be made on the paver, and form 830213 should be completed. Use this form to record vibrator spacing and angle. The paver width and cross slope should also be checked. The form can also be used to record vibrator frequency checks during paving.

Check paver vibration monitoring system			Specification 2301.03, A, 3, a Vibration monitoring required for all projects with mainline paving quantities greater than 50,000 square yards	Discuss layout of vibrators with contractor to confirm locations of each relative to data being recorded on monitoring system.
Check paver vibrator spacing	Once each paver and each time the paver width is changed.	Form 830213	Specification 2301.03 A, 3, a 16 inch maximum spacing	Record on form 830213. Spacing may be increased due to structural limitations of finishing machine. Greater spacing should not be allowed for tie steel insertion or lack of the correct number of vibrators.
Check paver vibrator angle	Once each paver.	Form 830213	Specification 2301.03 A, 3, a Vibrators should be mounted parallel to direction of paving and trailing end tilted to approximately 15 degrees below horizontal	Record on form 830213.

During Concrete Placement

Place date in headers	Daily			The date should be stamped in the headers at the beginning and end of each day's run. The date should be placed in the outer 2 feet of the pavement in a position where it will not be destroyed by possible milled shoulder rumble strip placement.

Check subgrade / subbase moisture	As needed.	Specification 2109.03, B Specification 2301.03, B	The subgrade or subbase should be periodically checked throughout the paving day to ensure that the material is uniformly moist. Moisture should be added as needed to keep the material in a uniformly moist condition. As the subgrade or subbase material dries out, moisture will be wicked out of the concrete and can cause loss of strength and reduction in effective pavement thickness. After periods of rain, addition of moisture may not be necessary if sufficient moisture is present.
Check dowel baskets	Periodically	Specification 2301.03, E	It is a good practice to periodically walk out in front of the paving train and check to make sure dowel baskets are still in proper alignment and free from contamination. Occasionally baskets can become damaged or contaminated with mud or other debris during handling and placement. These baskets should be cleaned and repaired or removed and replaced.
Check joint layouts	As needed	Specification 2301.03, E K and L sheets in project plans	There are certain locations on a project where specific joint types and spacings are required. Areas such as turn lanes, paved crossovers, and side road connections will have a specific jointing layout included in the K and L sheets of the project plans. It is important to review the project plans and inspect the contractors jointing layout prior to placing concrete.

Check concrete delivery time	At start of concrete placement and when delivery routes or distances change	Ready mix - Form 830212 Central batch - N/A	Specification 2301.02, C, 4	The specification requires that concrete hauled without continuous agitation be placed within 30 minutes after batching. This time may be extended an additional 30 minutes when a retarder is used with approval of the Engineer. Concrete hauled with continuous agitation must be placed within 90 minutes after batching. When using ready mix concrete, the time batched should be included on Form 830212 (Ready Mix Concrete) when received on grade. After discharge, the discharge time should also be recorded on the form. For central batch concrete, haul routes and haul times should be discussed with the contractor prior to placement. Factors such as delays due to heavy traffic (i.e. - rush hour in an urban area) should be discussed along with possible alternate haul routes. Haul times should be observed and recorded in the daily diary for the project.
Check and document water added on grade	Each load	Form 830212	Specification 2301.02, C, 4	Record water added to each load on the ready mix ticket for that load. Total water added to all loads for the placement should be totaled and reported to the plant inspector for inclusion on the plant report.

Check concrete placement operation	Periodically		Specification 2301.03, F Specification 2301.03, J	Concrete should be placed in a manner that minimizes segregation and disturbance of reinforcement. When a belt placer is being used, check to make sure that a deflector is in place and being used. This will help to minimize segregation. During hand placements, hand operated vibrators should not be used to move the concrete. They should only be used for consolidation purposes. Concrete placement should also be monitored to ensure that concrete does not sit on the grade for more than 30 minutes before consolidation and finishing. This is to ensure that the concrete is plastic and workable when consolidated and finished by the finishing machine.
Test slump of plastic concrete	Minimum 1/700 CY Minimum of 1 test per placement	Form E115 Form E111	Specification 2301.02, B, 3 Slip form paving N/A Non-slip form paving 0.5" to 4" IM 204 Appendix E, IM 317	There are no slump requirements for slip form pavement since the ability of the pavement to hold a slipped edge governs slump.

Test entrained air content of plastic concrete	Minimum 1/700 CY Minimum 1/100 CY for transit mix Minimum of 1 test per placement	Form E115Form E111	Specification 2301.02, B, 4 Slip form paving target of 8% with a tolerance of plus or minus 2% Non slip form paving target of 7% with a tolerance of plus or minus 1.5% IM 204 Appendix E, IM 318, IM 327, IM 527, IM 530 Construction Manual 9.63	As concrete is placed, consolidated, and finished, air entrainment is lost. It is desirable to have an entrained air content of approximately 6% after finishing. The specification limits for air content are set up to account for air loss during placement and finishing. It is important that verification tests for air content are random. Testing frequency must be random in order for the test to be valid. Testing should not be performed at regular intervals or at fixed times each day. Verification testing should not be timed to match contractor quality control testing.
Observe and record contractor quality control air tests	As requested by contractor	Form E115	Construction Manual 9.63	Witnessing and documenting contractor QC tests is important because it may reduce the amount of non-compliance and/or testing that a contractor may be responsible for when non-complying material is incorporated.

Check concrete mixture temperature	Daily when near specification limits	Form E111	Specification 2301.03, S Minimum 40 degrees F at time of placement	It is important to check concrete temperatures in the early spring and late fall to ensure that the minimum mixture temperatures are achieved. Early spring is the more critical time to ensure minimum mixture temperatures since the subgrade/subbase as well as all of the mixture ingredients are much colder after the winter. Typically mixture temperatures are not an issue in the late fall as the mixture ingredients are usually warmer than the ambient air temperatures. While Iowa does not have an upper limit for concrete mixture temperatures, temperatures should be taken and recorded when complications with air entrainment or finishing are encountered during hot weather.
Check pavement width and cross slope	At start of paving and when paving widths change	Form E111	Specification 2301.03, A, 3 Specification 2301.03, F and G Paving typicals in B sheets of project plans	Similarly to checks made on the finishing machine prior to start of paving, the pavement itself should be checked to ensure that the proper width and cross slope are provided. Cross slope checks can be accomplished by running a stringline across the pavement from one stringline to another. Measurements can then be made down from the stringline to top of pavement at the centerline and both pavement edges to determine the cross slope of the pavement.

Check depth of plastic concrete	Daily	Form E111 Form E110	Specification 2301.03, A, 3 Paving typicals in B sheets of project plans	Typically contractors check the thickness of the pavement in the plastic concrete to ensure that they are paving plan thickness or thicker. This activity should be observed by the grade inspector. The grade inspector should perform the checks on their own if the contractor is not.
Check concrete yield	1/1000 CY	Form E 137 Form E111		Comparison should be made between the cubic yards of concrete batched and the cubic yardage of concrete required for a given area of pavement. Typically the quantity batched will be between 103% and 106% of the quantity required.

Check paver vibrator frequency	2/day	Form 830213Form E111	Specification 2301.03, A, 3	It has been proven that excessive vibration can cause significant entrained air loss in concrete, and can result in non-durable concrete and premature deterioration. For this reason, vibration should be monitored very closely on every project. The specifications require contractors to use vibration monitoring systems for all slip form paving on projects with quantities 50,000 square yards and greater. These systems record significant information such as vibration rate, station location, paver speed, etc. The systems have a display that shows the vibration rate for each individual vibrator. When a vibration monitoring system is in use, inspectors should still check the vibration rate of individual vibrators by hand to ensure that the monitor is accurate. Vibration monitoring data is required to be submitted to the Engineer. This information should be reviewed on a regular basis to ensure that vibrators are run within the specification limits. For projects less than 50,000 square yards and no vibration monitors, each vibrator on the paver should be checked twice per day to ensure that the vibrator is within the allowable tolerances. The paver operator should never be allowed to adjust the paver vibrator rates prior to or during vibration rate checks.

Check hand operated vibrator frequency	Once per unit	Form E111	Specification 2301.03, A, 3	The specification requires the vibration rate of vibrators used for hand finished pavement to operate between 3500 vpm and 6000 vpm. This should be checked for each vibrator used prior to the first hand pour. Document the check in the daily diary and on Form E111.
Check centerline tie steel insertion in plastic concrete	Daily	Form E111	Specification 2301.03, ERoad Standard PV-101	The final location and alignment of tie steel should be checked in the plastic concrete behind the finishing machine. Often a hack saw blade or trowel is inserted into the concrete at centerline to determine the location and depth of centerline tie steel. Once located at centerline, the depth and alignment of the ends of the bar should also be checked to ensure that the bar is not shifted horizontally or vertically out of alignment. Spacing of tie bars can be determined by observing the frequency of insertion on the finishing machine.

Check finishing operation	Periodically	Specification 2301.03, H	The primary purpose for hand finishing behind the finishing machine is to remove small imperfections in the final pavement surface and provide a uniform surface. The surface of the slab should be observed behind the finishing operation to determine if finishing operations are adequate. Occasional "bug holes" are permissible, but should be kept to a minimum. Over finishing is also undesirable as it can affect pavement smoothness and potentially cause a loss of entrained air at the surface. A balance must be reached between the positive and negative effects of finishing. During finishing, free water may not be added to the surface of the pavement. A small amount of water may be added to a burlap drag attached to the back of the finishing machine. A good indicator that too much water is being added to the burlap drag is the presence of bubbles off the trailing end of the burlap. Another indicator that excessive water has been added to the burlap is the collection of excessive amounts of mortar by the floats. When excessive amounts of mortar are collected, this material should be wasted over the edge of the pavement and not finished into the surface. Addition of water to the burlap should be restricted. For smoothness purposes, the contractor is required to periodically check the

			pavement longitudinally with a 10 foot straightedge. The surface should not deviate more than 1/8" in 10 feet. Edge slump should also be checked. Up to 1/2" of edge slump is permissible if abutting pavement is not to be placed. If abutting pavement is to be placed, up to 1/4" of edge slump is permitted.
Check structural rumble strip placement (when required)	Periodically	Road Standard PV-11	Check spacing and depth of structural rumble strips in plastic concrete.

Check texture placement in plastic concrete	Periodically	Form E140Form E111	Specification 2301.03, HConstruction Manual 9.40	Microtexture should be placed using artificial turf, coarse carpet, or burlap. Placement of microtexture roughens the pavement surface and provides grip for tires to assist with stopping. Macrotexture (tining) can be placed either longitudinally or transversely (longitudinal tining is most common). Macrotexture is placed to provide a break in the pavement surface to allow water to escape from under tires during a rain and reduce the tendency for hydroplaning. When tining is placed transversely, a 4 to 6 inch gap centered around each transverse joint is to be left untined. Longitudinal tining should be straight and as parallel to centerline as possible. The depth of tining should be kept at or slightly less than the specified 1/8" target to minimize noise created by tires interacting with the pavement surface. When tining is placed longitudinally, a 2 to 3 inch gap centered around each longitudinal joint is to be left untined.
Check cure brand and lot number	Periodically			White pigment cure is typically delivered to a project in reusable totes. The totes should periodically be inspected to ensure that the proper brand and lot number of the cure are identified on the tote. The lot number should also be cross checked with the list of approved lots of cure found on the Office of Materials web site.

Check cure placement	Periodically for uniformity of coverage Daily for yield	Form E111	Specification 2301.03, K	The specifications require cure placement within 30 minutes after finishing. Timing of the cure placement should be observed throughout each day to ensure that this requirement is being met. The specification also allows an extension of the 30 minute requirement when weather and/or mixture properties require an extended period before curing. This is allowed to ensure tining can be placed at the proper depth. If a mixture is still too plastic within the 30 minutes after finishing, it is not desirable to proceed with tining and curing if the tining depth will be too deep. Cure placement should be checked to ensure uniformity of application. Streaks should be minimal and areas of visible gray should be recured. Yield checks should be performed daily based upon the total cure applied throughout the days run and the total square yardage of pavement cured including the sides of the pavement. If forms are used to support the edge of pavement, the pavement edge should be cured by hand if the forms are removed prior to the pavement reaching opening strength.

Place station markers in plastic concrete	Each station			Station markers should be placed in the outside two feet of the mainline pavement and in a position where they will not be removed or destroyed by possible milled shoulder rumble strip placement. If a station marker happens to fall on a transverse joint location, shift the marker to avoid falling on the joint. Place station markers facing outward so they can be read from the shoulder.
Check cold weather protection	When used	Form E137 Form E111	Specification 2301.03, K Specification 2301.05, J	Monitor forecast temperature conditions to determine if cold weather protection will be necessary during curing. Table 2301.03-1 identifies the required covering necessary based on forecast low temperatures. The table also includes conditions under which the cold weather protection may be removed. Quantities of cold weather protection must be tracked and recorded since payment is made to the contractor for providing it (see 2301.05, J).
Cast concrete beams to determine pavement opening strength	Two per day when maturity is not used to determine opening strength	Form E114	Specification 2301.03, UIM 328IM 316	On projects in which the contractor chooses not to use maturity to determine pavement opening strength, opening strength is determined based upon a combination of time and flexural strength. Two beams are cast daily. Beams should be cured similarly to the pavement and stored on site overnight. The following day the beams can be moved to plant inspector's lab for further curing until broken. Care should be taken in handling the beams to

				avoid detrimental cracking that may cause low strength results.
Cast concrete beams for pavement design purposes	One set of two beams every 10,000 CY	N/A Beams tested in Central Materials	IM 328 QM-C Developmental Specification	Inspectors should cast one set of two beams every 10,000 CY. These beams are to be delivered to Central Materials to be tested for 28 day flexural strength. Information obtained from testing of these beams is used to assist in future pavement designs.
Monitor maturity probe placement on projects where maturity is used to determine pavement opening strength	Daily	Form E141 Form M142	Specification 2301.03, U IM 383	On projects in which the contractor chooses to use maturity to determine opening strength, the contractor is responsible for placement of the maturity probes and taking temperature readings. However, probe placement should be observed to ensure the temperature readings accurately reflect the temperature of the pavement. For instance, if portions of the pavement are in shaded areas, additional probes should be placed there as that pavement will gain temperature and strength more slowly than the unshaded areas. Maturity probe locations should be recorded on Form E141.

After Concrete Placement

Report water added on grade to plant inspector	Daily/each placement	Form 830212	IM 527	The plant inspector is required to report average water/cement ratio for each placement on the project plant report. When using ready mix concrete, this requires water added on the grade to be tracked and reported back to the plant inspector. Water added on the grade should be reported to the plant inspector on a daily basis to allow for timely completion of the plant report.
Check milled rumble strip placement		N/A	Road Standard PV-12 and PV-13	Milled rumble strips may be placed on the shoulder or centerline of the roadway. They are placed in the hardened concrete after opening strength is achieved. Rumble strip placement should be checked to ensure proper spacing, depth, and location requirements are being met.

Check saw cuts	Daily	Joint Check Worksheet	Specification 2301.03, N Road Standard PV-101 K and L sheets in project plans Construction Manual 9.20	Saw cuts should be checked daily to ensure proper depth, width, layout, straightness, and spacing. It is important to keep in mind that even though the joint layout may be correct during placement, the saw crew may not saw joints at the correct locations. Occasionally saw cutting errors are made in irregular areas due to lack of adequate marking of the joint layout in the plastic concrete. This may result in the saw operator not knowing where and/or what type of joints to saw. Saw cuts should also be checked to make sure the saw operator is pulling up the blade before reaching the edge of pavement as shown on the PV-101 standard. This is important for early entry sawing as the backward rotation of the saw blade can "blow out" the edge of the pavement if the saw cut is not stopped short of the pavement edge.
Check joint filling	Daily	Joint Check Worksheet	Specification 2301.03, P Road Standard PV-101 Construction Manual 9.20	Joints should be checked to ensure that they are properly cleaned before filling, and joint filler should be placed to the proper level. Unless otherwise approved, joint filling should only be performed when pavement and ambient air temperatures are above 40 degrees F.

Check texture placement in hardened concrete	Daily	Form E140	Specification 2301.03, H Construction Manual 9.40	In addition to the checks made in plastic concrete, macrotexture should also be checked in the hardened concrete. The depth of the tining should be checked to ensure that it falls within the specification requirements. The procedure outlined in Construction Manual 9.43 should be followed to determine compliance with tining depth requirements.
Review initial contractor smoothness information	Daily until 3 consecutive days of 100% pay or better	N/A	Specification 2317 Specification 2316 IM 341	The contractor is required to submit smoothness information daily until they have paved for three consecutive days resulting in 100% payment or better. There are several reasons for this requirement. First is to identify if there are equipment or process issues causing placement problems in the paving operation. It is not desirable to allow the contractor to continue paving if acceptable smoothness levels are not being achieved. This requirement also may identify problems in the contractor's smoothness evaluation. It also gives inspection staff the opportunity to review the contractor's profilograph settings to make sure they are correct.

Review final contractor smoothness information	After submittal of final profilograph reports and traces	N/A	Specification 2317 Specification 2316 IM 341	The contractor is required to submit all final profilograph reports and traces to the Engineer within 14 days after completion of paving. After receipt of all final reports and traces, the information should be reviewed to ensure that all sections of pavement have been evaluated. In addition, the smoothness information should be evaluated to determine if the incentive or disincentive requested by the contractor is accurate.
Determine time for opening pavement for use	Daily/as needed	Form E114	Specification 2301.03, U Form E141	The contractor is responsible for curing and breaking beams to determine time of opening. The contractor is also responsible for placing probes, taking temperature readings, and calculating TTF when maturity is used. However, the Engineer is responsible to determine if a section of pavement may be opened to traffic. For this reason, beam break and maturity information should be obtained from the contractor and reviewed prior to opening the pavement to traffic. Maturity information should be recorded on Form E141.
Check longitudinal tie steel placement in hardened concrete	Spot check in each day's run	Form E111	Specification 2301.03, E Road Standard PV-101 Construction Manual 9.26 and 9.27	Check tie steel in hardened concrete to ensure proper alignment and that the correct number of bars are included in each panel (see Construction Manual 9.27). This check is important to determine that the bars are centered across the joint, level, and perpendicular to the centerline. Tie

			steel checks in hardened concrete are typically made using a survey pin finder.
Determine pavement thickness	Once per project	Specification 2301.04 and 2301.05 IM 346 and 347	There are several steps to take In evaluating pavement thickness. First, random core locations for each section of pavement, as defined by IM 346, should be obtained from District Materials. Then the core locations should be marked on the pavement. Taking of the cores must be witnessed by inspection staff and inspectors must take immediate possession of the cores after removal from the pavement by the contractor. Cores should then be measured according to IM 347 and a thickness index determined for each section of pavement. After measurement, the cores should be delivered to District Materials for assurance testing.

General

Check traffic control	When travelling on the project		Even though traffic control checks are a responsibility of the contractor, if problems or deficiencies are observed, inform the contractor when the observations are made so that corrections can be made in a timely manner.

Check contractor's traffic control daily diary	As needed	N/A	Specification 2528.1, C	The contractor is required to check traffic control and record significant information. It is a good practice to review the contractor's diary occasionally to ensure that documentation is being recorded as required. For instance, after noting damaged signing or deficiencies in the traffic control devices or setup, review the daily diary to ensure the deficiencies and the remedies are recorded.
Monitor the project for fugitive dust	Daily	N/A	Specification 1107.07, E	The contractor is responsible for controlling fugitive dust on the project. When dust is being generated and leaving the project site, the contractor should be reminded of their responsibility to control dust and a request should be made to take measures to do so. In urban areas, it is even more critical that dust be controlled as property owners will be more sensitive to dust generated by the project.
Monitor contractor haul roads	Daily	N/A	Construction Manual 2.12	The contractor is required to submit a request for haul road designation for roads used to haul materials for the project. Once designated as a haul route, the contractor is expected to use the haul route for the designated purpose. The contractor's operations should be observed daily to ensure that haul traffic is using the appropriate, approved haul routes.

Issue noncompliance notices	When noncompliance occurs	Form 830245		The owner is obligated to notify the contractor in writing when noncompliance occurs. This is done using Form 830245. Noncompliance notices should be issued as quickly as is practical after observation of the noncompliance to give the contractor ample time to take corrective action. The noncompliance notice also provides a written record of notification being provided to the contractor.

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Appendix D: Suggested Meetings Between the Agency and Contractor

The information presented in this resource is provided as a starting point or guide to quality concrete performance in portland cement concrete pavement. The information serves as a way to identify the key elements that are required of the pavement owner and contractor for each project. They provide an outline for success, but are not detailed in nature and are open to enhance or delete items that are already common to the participants in a given state or local government.

To accomplish the construction objectives for concrete pavements, it is necessary to have meetings during the design (pre-bid) and construction (pre-pour/preconstruction) period, between the contracting agency and the contractor(s) in order to work out the details. The purpose of the Pre-Bid, Preconstruction and Pre-Pour conferences and the key elements (checklist) of each are shown below.

PRE-BID MEETING CHECK LIST

Pre-bid meetings provide an opportunity for the owner to review project requirements and receive input with the contractors who may have an interest in bidding for the project. Although pre-bid meetings tend to be primarily a review of administrative and contractual matters, it is important to use them to highlight modifications implemented in the plans and specifications with the contractors.

The pre-bid meeting gives the contracting agency an opportunity to identify new and different items in the areas of specifications, materials and construction processes that are expected in the construction project. It is also a good time to receive input from the contractors on important design and construction items such as jointing, surface preparation of the existing pavement, paving exceptions, schedules and staging.

It is the opportunity to discuss the intent of the work changes. Critical material supply/availability issues, and specific acceptance testing requirements also need to be addressed. Minutes of the meeting should be distributed to all potential bidders (those who have requested bid documents) whether they are in attendance or not. Paving related items for discussion include:

PRE-BID MEETING

I. Overlay Project Items of Special Attention
   1. Phasing and staging plan
   2. Scheduling criteria, including which areas are accessible, restrictions on site access, and working hours
   3. Scheduling milestones with incentives/disincentives
   4. Allowable mixtures and special conditions
   5. Strength requirements and strength testing measurement methods
   6. Traffic control, clearances, staging requirements and edge drop restrictions
   7. Expected and unexpected delay resolution
   8. Plant and staging area locations
   9. Paving sequence, paver clearance and pavement drop off limitations

10. Haul road locations
11. QA, acceptance testing and QC requirements
12. Issuance of design and specification changes
13. Special conditions such as tie-bar locations, widening details, etc.
14. Saw cut depths and timing and importance of early joint development
15. Curing, particularly curing for thin pavement sections
16. Incentives and disincentives applied to concrete pavement construction
17. Pavement ride requirements on the finished product.
18. Importance of reducing the length of time for job completion

II. Alternative Bid Provisions
1. Materials selection
2. Management method (conventional, A+B, etc)

III. Discussion of questions from the prospective contractors

IV. Issuance of addendums to clarify questions raised at the Pre-bid conference.
1. Minutes of the meeting to all who attended and those who call for plans on the project.

PRE-POUR / PRECONSTRUCTION REVIEW CHECKLIST

Pre-pour or pre-construction meetings can be very productive when the contractor is tasked with addressing the pertinent items. They may be conducted as one combined meeting or two separate meetings depending on the level of detail the contractor is able to provide at the Preconstruction Meeting. The contractor should be able to present their plan for addressing each of the items on the review checklist for review and comment at this meeting. Forcing the contractor to think about the project and build it on paper before the pre-work meeting will pay big dividends. The overlay team should be involved in the pre-work to the extent that we can provide guidance and answers to unresolved issues and/or to identify potential problems with the contractor's approach.

I. General Items
1. Identify the chain of command in the decision making process
2. Identify roles and responsibilities of key staff for all involved parties
3. Review of all design and construction changes issued since bid
4. Certification of materials sources
5. Mixture design submittals
6. QMP/CQC laboratory and personnel certifications
7. Batch plant certification and mixer efficiency tests
8. Construction schedule
9. Payment schedules
10. Sub-contractor activities
11. Construction survey
12. Haul roads and access points
13. Traffic control plan for each phase of the work
14. Working days allowed and method of counting
15. Expected start date
16. Phone numbers and email addresses of key personnel such as contractor and agency representatives, traffic control manager, material suppliers and utility location representatives.
17. Liquidated damages

18. EEO/AA requirements
19. Public information notification process to be used during construction
20. Pollution control plans
21. Safety inspections
22. Change order process

II. Contractor Project Plan
   1. Identify the chain of command in the decision making and construction process
   2. Work schedule breakdown by major task, starting date and expected duration
   3. Field lab location
   4. Field office location
   5. Subcontract documentation
   6. Material source and quality certifications
   7. Material testing lab and technician certifications
   8. Submittal of concrete mixture design
   9. Water sources and testing
   10. Traffic control plan for each phase of the work
   11. Haul road and access point location and duration identification
   12. Construction survey
      a. Method – contract or owner
      b. Type and amount of available information
      c. Stringline or stringless construction
      d. Development of the profile grade and concrete quantity by whom and when. Is there an approval process and timeline before construction?
      e. Reestablishment of land corners and centerline control points
   13. Public information notification process to be used during construction

III. Utility Concerns
   1. Locations in the project limits, key personnel for location contact , and expected plans for relocation where necessary

IV. Local Jurisdiction Concerns
   1. Coordination with local road projects or city/county special activities (festivals)

V. Concrete Placement Activities (This can be part of the preconstruction conference or a separate pre-pour conference)
   1. Batching Activities
      a. Identification of central mix or ready mix supply source.
      b. Stockpile management to eliminate segregation
      c. Batch plant certification and mixer efficiency testing
      d. Anticipated plant production rates
      e. Concrete haul route identification and estimated truck number needed for existing traffic along the route.
      f. Consideration of alternative mixtures to meet weather changes
      g. Aggregate stockpile moisture
      h. Identify washout areas for trucks

2. Concrete Paving (Placement, finishing, texturing and curing)
   a. Concrete pavement temperature planning and management.
      On site weather condition monitoring - Who and how it entered into the decision to pave and cover or not to pave
   b. Placement and filler lane scheduling
   c. Base preparation (patching, milling, recycling)
   d. Equipment breakdown procedures
   e. Maximum allowable concrete haul times
   f. Placement procedures (equipment and methods)
   g. Estimated mixture temperature at the time of placement
   h. Thickness verification during placement
   i. Estimated time from placement to time that allows for joint sawing
   j. Hot/cold weather specifications and precautions
      1.) Changes in mixture for weather or material changes
      2.) Identification of method and materials to be used to protect the concrete in case of changes in weather (rain, snow or hot/cold)
   k. Temperature control of existing ACC surfaces
   l. Vibrator testing/consolidation issues
   m. Curing and texturing equipment, rates and construction procedures
   n. Tie bar/dowel location, insertion, alignment, spacing, offset verification
   o. Straight edge and edge slump tolerances
   p. Plastic shrinkage cracking, edge slump, joint spalling, and full-depth cracking treatments

3. Joint Development (Longitudinal and transverse)
   a. Review of contractor saw cutting QC plan (number, type, and method of sawing)
   b. Consideration of employing early entry saws
   c. Backup saw availability (number, personnel and location to project)
   d. Rain conditions and skip sawing procedures
   e. Joint reservoir size, shape, depth cut dimension tolerances and dimensions
   f. Joint sealing installation and acceptance procedures
   g. Saw cutting sequence and acceptable degree of saw cut raveling
   h. Joint sealant and backer rod material certification submittals
   i. Requirements on removal and flushing of joint sawing residue
   j. Joint beveling procedures (if required)
   k. Joint sealant and concrete curing time requirements and methods
   l. Joint sand blasting, reservoir cleanliness, and moisture condition requirements before sealing
   m. Joint sealant surface depth tolerances Sealant pump, water truck, and saw cutting equipment
   n. Allowable ambient temperatures during sealing operations and compression seal reservoir requirements
   o. Joint inspection procedures

4. QA Activities
    a. Delineation of owner and contractor responsibilities in testing and sampling.
    b. Review of contractor's QC plan
    c. Aggregate durability, soundness, abrasion, and gradation test data and requirements
    d. Reinforcing steel and dowel bar submittals
    e. Materials sampling and testing procedures
    f. Development and use of control charts
    g. Concrete mixture designs and water-cementitious ratio effects on strength
    h. Concrete sampling, fabrication, curing, and testing procedures
    i. Sampling and pay factor computation overview
    j. Documentation of test results and deviations
    k. Verification of failing acceptance tests, retesting, and referee testing
    l. Actions to be taken if specification requirements are not met
    m. Pavement smoothness testing and timing
    n. Treatment of premature cracking and spalling
    o. Resolution procedures for expected and unexpected delay