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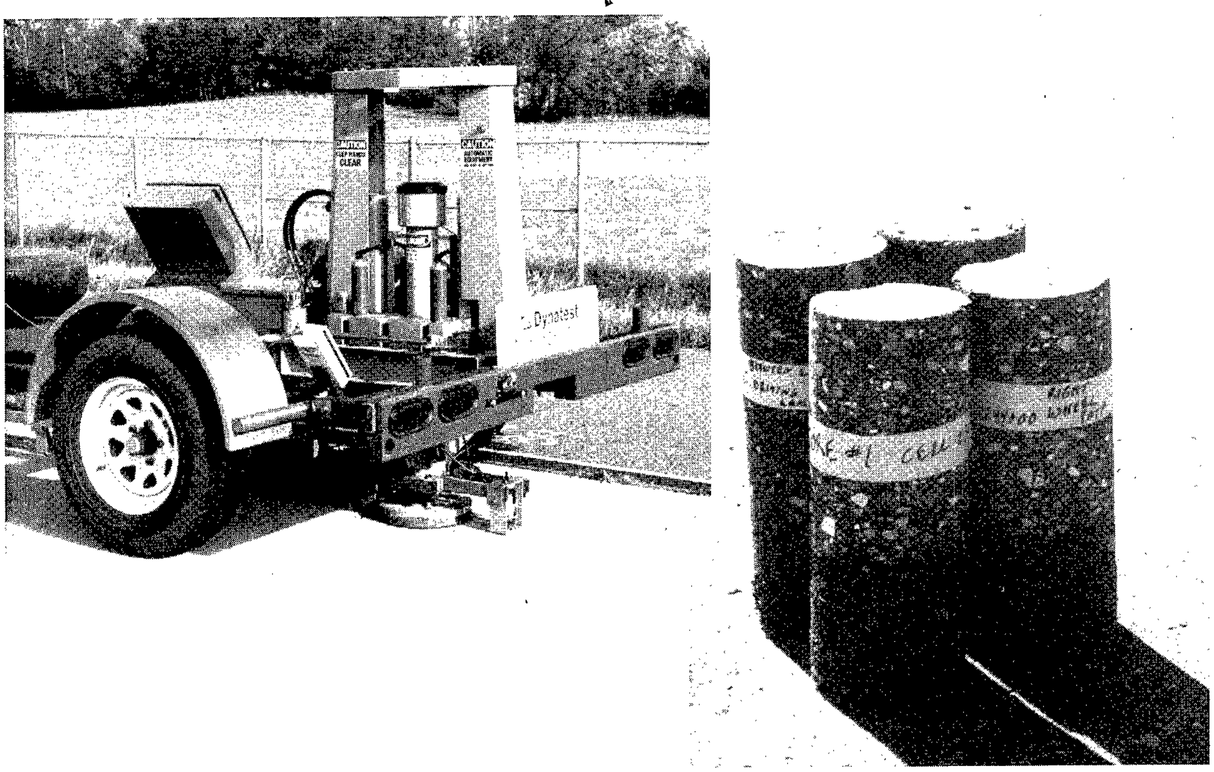

Mn/ROAD Testing Protocols
Volume I

Mn/ROAD
Office of Minnesota Road Research

Technical Report Documentation Page

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This report presents a series of testing protocols used at the Minnesota Road Research Project (Mn/ROAD), the Minnesota Department of Transportation's (Mn/DOT) pavement testing facility. This report helps establish a history of the tests conducted and testing procedures, and also serves as a reference for researchers outside of Mn/DOT to compare the values found in independent or cooperative studies to Mn/ROAD test results and procedures.

The following protocols are included:
- pavement condition testing plan and testing protocols
- deflection test protocols
- subsurface temperature testing protocols
- frozen soil measurements testing protocols
- traffic measurements testing protocols
- material samples testing protocols
- soil moisture measurements testing protocols
- climate data testing protocols
- bituminous testing protocols.

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Mn/ROAD Testing Protocols
Volume 1

Interim Report 1993 to 1996

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CONTENTS

Mn/ROAD Testing Protocols - Volume 1

Introduction

The Minnesota Department of Transportation (Mn/DOT) is in the process of compiling a list of testing protocols used at the Minnesota Road Research Project (Mn/ROAD). There are two main reasons that this is being done.

The first, is to establish a history so there is a reference of exactly which tests were conducted and what testing procedures were used. The second, is to serve as a reference for researchers outside of Mn/DOT to compare the values found in independent or cooperative studies to Mn/ROAD test results and procedures.

It is important to do this now because it will be more difficult to do with the passage of time. Ultimately what we will have is a list of every kind of test conducted, either in the field or the laboratory, and a reference for that testing procedure.

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Pavement Condition Testing

David Palmquist

Mn/ROAD conducts a variety of standard tests to monitor the condition of the pavement. These tests include: ride performance, crack maps and distress surveys, transverse profiles and rut depths, faulting, and friction tests. These tests are done at various times throughout the year.

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PAVEMENT CONDITION TESTING PLAN AND TESTING PROTOCOLS

Test	Data Collected	Frequency	Protocol
Distress surveys	Crack Mapping	2/year	SHRP-P-338
PaveTech Van - Pathways Van	Video Tape (3 cameras) IRI PSR Surface Rating PQI Rut Depth Texture Faulting Longitudinal Profiles	Every 2 months	South Dakota Profiler FHWA-DP-89-072-002
Dipstick - Face Technologies	AC Transverse Profiles and Rut Depths	3/year	SHRP-P-338
6 Foot Straight Edge	AC Rut Depths	4/year	None
Arizona Profiler	AC Transverse Profiles and Rut Depths	To be determined (under construction)	None
Georgia Digital Faultmeter	Concrete Joint Faulting	1/year	SHRP-P-338
Friction Tests	Friction Number	1/year	None
Ground Penetrating Radar	Pavement Thickness	To date - initial baseline readings only	None

Deflection Tests - Falling Weight Deflectometer

David Van Deusen

In many current pavement management and research programs bearing capacity is determined using a falling weight deflectometer (FWD). The deflection data from this can be used to obtain information regarding the relative strengths of the various layers within the structure. Testing that is done over the course of seasonal periods can be used to track changes in layer strength. These data are an essential part of the development of mechanistic design procedure, which is one of the primary goals of the Minnesota Road Research Project (Mn/ROAD).

FWD testing at Mn/ROAD has been conducted during different stages of construction: embankment (subgrade), granular and/or stabilized base, and finished pavement surface construction. Since the pavement surface layers have been constructed the emphasis is:

1) the determination of seasonal changes and spatial variability of pavement strength, and

2) specific research studies on dynamic sensor response, temperature effects on deflection and response, and localized failures.

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TESTING PROTOCOL - MN/ROAD DEFLECTION TEST

TYPES OF TESTING

Routine or Inventory

Tests are conducted at pre-defined locations within each test section. These are points that have been tested numerous times every year since prior to construction.

Specific Sensor Testing

The FWD is positioned over a specific sensor. Data from the sensor is collected simultaneously using one of the mobile data acquisition systems. The deflection data can be used to estimate the particular response that the sensor is measuring. The objectives of this type of test are to (1) determine how an individual sensor is performing and (2) track pavement response changes along with pavement structural changes.

Temperature Effects Testing

These tests are done throughout the course of a day in such a way that data from specific test points are collected at different temperatures.

Special Research Studies

Examples are the Load Response and the Curl and Warp projects currently being conducted by the University of Minnesota, Department of Civil Engineering. The FWD testing is done at specific times and locations and serves as either the main focus or supporting data for the study.

FLEXIBLE PAVEMENT SECTIONS

The testing protocol for routine inventory tests is similar to the LTPP FWD testing protocol (*1*) with a few exceptions as noted in this document. Routine FWD testing on the Mn/ROAD flexible sections consists of deflection testing at 10 stations spaced at 50-foot intervals. Four different transverse offsets from the centerline are tested. The FWD data files contain data from the 10 stations along a given longitudinal offset. These centerline offsets are:

- Mainline, -9.8 feet, offset code 1, driving lane, outer wheel track;

- Mainline, -6.5 feet, offset code 2, driving lane, between wheel tracks;
- Mainline, +6.5 feet, offset code 6, passing lane, between wheel tracks;
- Mainline, +9.8 feet, offset code 7, passing lane, outer wheel track;
- Low volume, -9.5 feet, offset code 1, outer wheel track, westbound lane;
- Low volume, -6.25 feet, offset code 2, between wheel tracks, westbound lane;
- Low volume, +6.25 feet, offset code 6, between wheel tracks, eastbound lane;
- Low volume, +9.5 feet, offset code 7, outer wheel track, eastbound lane.

Each FWD data file is uniquely named as shown below:

File name: `14721897.F25`

Positions: `12345678.F25`

In the 8-character DOS filename, positions 1-2 indicate the test section number (01 - 04, 14 - 31), position 3 gives the transverse offset code (1, 2, 6, or 7), positions 4-6 are the day of the year (001 - 365) and positions 7-8 contain the year.

Loads

The target load levels for the flexible test sections depends on the facility being tested as shown in Table 1. Two seating drops at the drop height 1 load level are used before the test sequence is started.

Configuration

The radius of the load plate is 5.91 inches (150.1 mm). Two different sensor configurations have been used as described in Table 2. With the exception of joint-efficiency testing in the rigid test sections the sensor spacing should not be changed.

Test Acceptance

The data are evaluated by the operator during the testing. Normally, data for a given test are rejected and a re-test is performed in accordance with the guidelines set forth in the LTPP FWD manual (*1*). However, testing on the mainline is done only during traffic diversions. Due to the large number of tests required these tolerances are occasionally loosened and a re-test is not done if time constraints are severe.

RIGID PAVEMENT SECTIONS

The testing pattern used for the rigid sections is dictated by slab geometry. Five evenly spaced panels within each lane of each test section were selected. These panels were assigned numbers based on the beginning and ending test section station. In addition, the panels were assigned a directional designation suffix that describes the particular lane that is being tested. In the low volume sections, panels in the outer lane are given the "W" suffix for "westbound" and panels in the inner lane are given an "E" for "eastbound". Since the concrete sections are only on the north side of the low volume facility, this convention yields a unique file-naming system. On the mainline facility a "R" or "L" suffix is assigned to panels in the right (R, driving) or left (L, passing) lane, respectively. Four test points are tested within each of these panels in each lane. These are:

- Test point 0, load-transfer efficiency, outer wheel path, 6 inches down-traffic from transverse joint;
- Test point 1, load-transfer efficiency, outer wheel path, 6 inches up-traffic from transverse joint (across from test point 0);
- Test point 2, panel mid-slab (longitudinal sense), 6 inches in from edge stripe;
- Test point 3, geometric center of panel.

When test point 0 and/or 1 are tested the FWD must be specially configured for joint-efficiency testing.

The file naming scheme for rigid sections is similar to that used in the flexible sections. In the file name, positions 1-2 indicate the test section number, position 3 can be either "J" for joint testing, "2" for test point 2 tests or "3" for test point 3 tests. Positions 4-6 give the day-of-year and positions 7-8 contain the year. In general, when the FWD operator saves rigid section deflection data, data from both lanes can be contained in the same file. The directional designation suffixes are entered on the subsection line that immediately precedes the station identifier line within the data files.

Loads

The target load levels for both mainline and low-volume rigid test sections is the same as those for the mainline flexible sections as shown in Table 3. Two seating drops at drop height 1 load level are used before the test sequence is started.

Configuration

The radius of the load plate is 150.1 mm (5.91 inches). Different sensor configurations have been used as described in Table 4. With the exception of joint-efficiency testing the sensor spacing should not be changed. For joint-efficiency testing the 203 mm-offset sensor is moved behind the plate at 305 mm as shown in Table 4.

Test Acceptance

The data are evaluated by the operator during the testing. Normally, data for a given test are rejected and a re-test is performed in accordance with the guidelines set forth in the LTPP FWD manual (*1*). However, testing on the mainline is done only during traffic diversions. Due to the large number of tests required these tolerances are occasionally loosened and a re-test is not done if time constraints are severe.

AGGREGATE SURFACED SECTIONS

The testing protocol for routine inventory tests on the aggregate sections is similar to the flexible test section protocol with a few exceptions. Routine FWD testing on the Mn/ROAD flexible sections consists of deflection testing at 10 stations spaced at 50-foot intervals.

Each FWD data file is uniquely named. In the 8-character DOS filename, positions 1-2 indicate the test section number, position 3 gives the transverse offset code (1, 2, 6, or 7), positions 4-6 are the day of the year and positions 7-8 contain the year.

Loads

The target load levels for the aggregate test sections are shown in Table 1. Two seating drops at the drop height 1 load level are used before the test sequence is started.

Configuration

The radius of the load plate is 150.1 mm (5.91 inches). Two different sensor configurations have been used as described in Table 2.

Test Acceptance

The data are evaluated by the operator during the testing. Normally, data for a given test are rejected and a re-test is performed in accordance with the guidelines set forth in the LTPP FWD manual (*1*). However, test results on lighter structures (such as aggregate or chip-sealed pavements) are affected by the surface condition of the section. Due to the variability in surface condition (ruts, dust, gravel, washboarding, etc.) the tolerances are occasionally loosened.

CALIBRATION

FWD Machine

Both reference and relative calibrations of the FWD load cell and geophones are performed at least once per year in accordance with the guidelines set forth in the LTPP FWD manual (*1*). The calibrations are performed in the North Central region FWD calibration center at the Mn/DOT Laboratory in Maplewood, MN.

Pavement Surface Temperature

During deflection tests, pavement surface temperatures are measured using an infrared thermometer mounted on the FWD trailer. The infrared thermometer on each of the Mn/ROAD machines is calibrated using a specially developed temperature-sensing plate. The plate consists of a 19.05 mm (0.75-inch) thick, 203.2 mm (8-inch) square plate with four thermocouple pairs embedded just beneath the top and bottom surfaces. The wire pairs are arranged in such a way that temperature gradient and variation effects can be accounted for.

To calibrate the infrared thermometer the plate is placed in a refrigerator for a period of time prior to the test. The plate is then placed beneath the infrared thermometer and allowed to warm to the ambient room temperature. Both the plate and infrared temperatures are recorded periodically. The next step is to place a heat source beneath the plate. Periodic temperature measurements are recorded as the temperature of the plate rises. In doing this a source temperature span from about 0 to 50 °C can be attained.

These data are used to derive a calibration curve from which the coefficients required by the FWD field software can be calculated. It is recommended that this procedure be done on a yearly basis.

REFERENCES

- "MANUAL FOR FWD TESTING IN THE LONG TERM PAVEMENT PERFORMANCE STUDY." PCS/Law Engineering, Braun Intertec Pavement, Inc., Version 2.0, 1993.

Table 1. Target loads for Mn/ROAD flexible and aggregate pavement inventory testing.

FACILITY	HEIGHT	TARGET LOADS (lbs)	REPETITIONS	ACCEPTABLE RANGE (lbs)
Mainline	1	6,000	3	5,400 - 6,600
	2	9,000	3	8,100 - 9,900
	4	15,000	3	13,500 - 16,500
Low-volume Aggregate	1	5,000	3	4,500 - 5,500
	2	7,500	3	6,750 - 8,250
	4	9,000	3	8,100 - 9,900

Table 2. Sensor configurations for Mn/ROAD flexible and aggregate pavement testing.

YEAR	SENSOR NUMBER	DISTANCE FROM CENTER OF PLATE (inches)
1993-1995	DF1	0
	DF2	8
	DF3	12
	DF4	18
	DF5	24
	DF6	36
	DF7	60
1996-	DF1	0
	DF2	8
	DF3	12
	DF4	18
	DF5	24
	DF6	36
	DF7	48
	DF8	60
	DF9	72

Table 3. Target loads for Mn/ROAD rigid pavement inventory testing.

FACILITY	HEIGHT	TARGET LOADS (lbs)	REPETITIONS	ACCEPTABLE RANGE (lbs)
Mainline Low-volume	1	6,000	3	5,400 - 6,600
	2	9,000	3	8,100 - 9,900
	4	15,000	3	13,500 - 16,500

Table 4. Sensor configurations for Mn/ROAD rigid pavement testing.

YEAR	SENSOR NUMBER	TYPE OF TEST	DISTANCE FROM CENTER OF PLATE (inches)
1993-1995	DF1	JOINT EFFICIENCY	0
	DF2	(Test Points 0 and 1)	8
	DF3		12
	DF4		-8
	DF5		24
	DF6		36
	DF7		60
	DF1	MID-PANEL, EDGE	0
	DF2	(Test Points 2 and 3)	8
	DF3		12
	DF4		18
	DF5		24
	DF6		36
	DF7		60
1996-	DF1	JOINT EFFICIENCY	0
	DF2	(Test Points 0 and 1)	-12
	DF3		12
	DF4		18
	DF5		24
	DF6		36
	DF7		48
	DF8		60
	DF9		72
	DF1	MID-PANEL, EDGE	0
	DF2	(Test Points 2 and 3)	8
	DF3		12
	DF4		18
	DF5		24
	DF6		36
	DF7		48
	DF8		60
	DF9		72

Subsurface Temperatures - Thermocouples

Greg Johnson

The sensor installed at Mn/ROAD to measure the temperature in a pavement system is a thermocouple. The thermocouples are a type T (Copper-Constantan). The sensors are placed at discrete depths, and at specific offsets, within the pavement profile in each section.

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SUBSURFACE TEMPERATURES

In each test section there is an installation of thermocouples (tree) located in the outer wheel path. These thermocouples are typically placed according to following plan. The top thermocouple is 25 mm (1 in) from the pavement surface. The next is at the midpoint for the pavement structure approximately 75 mm (3 in). The final thermocouple in the pavement layer is located 25mm (1 in) from the bottom of the pavement. Then there are sensors installed below the pavement surface in the base and subgrade located 305 mm (12 in), 457 mm (18 in), 610 mm (24 in), 915 mm (36 in), 1220 mm (48 in), and 2438 mm (96 in). Depending on the pavement layer thickness, there may also be another sensor located within the pavement, or between the bottom of the pavement and the 305 mm (12 in) sensor,for better resolution. In some test sections there are also trees of sensors located at centerline, shoulder, and embankment.

Location	Offset from Centerline
Centerline	-0.00 m (-0.0 ft)
Outer Wheel Path	-2.95 m (-10 ft)
Shoulder	-4.90 m (-16 ft)
Embankment	-7.60 m (-25 ft)

These sensors are automatically sampled every 15 minutes and stored in the Mn/ROAD database. The data acquisition units used to sample the sensors are Optim 3008 Megadacs base unit with a AD816TC card and a JP816 reference panel into which the thermocouple are connected. These data acquisition units are located in cabinets next to the test sections being sampled. The cabinets have a heater and cooling fans to help maintain an acceptable operating temperature. The reference panels in which the reference thermistor and the thermocouple wires are attached to the data acquisition equipment are insulated with 50 mm (2 in.) of polystyrene insulation to minimize temperature gradients. Each channel in the data acquisition units has an individual amplifier and a micro-voltage offset due to manufacturing and temperature effects. These micro-voltage offsets are balanced out on these amplifiers before every reading.

A test is currently being conducted to determine the accuracy of the thermocouple wire and data acquisition units. The thermocouple wire reads -0.3 to -0.2 degrees C low of a checked point of 0.0 degrees C. We are in process of testing the data acquisition equipment by placing an ice bath (0.0 degrees C) in the cabinets and letting the data acquisition equipment read the temperature over a period of 3 days to look for offset due to cabinet temperature fluctuations and drift in the amplifiers. The results are published in a May of 1997 report. The reports accuracy statement will apply to all of the thermocouple data in the Mn/ROAD database after December 15, 1995.

A procedure is being written to scan all the thermocouple data before it is loaded into the database table to check for values which are statistical outlyers. This will be accomplished by checking all the thermocouple sensors at a certain depth range against each other and those that are over 3 standard deviations beyond the average value from all the sensors in that group will be tagged and checked manually before the data is loaded.

The thermocouples temperature data is critical in environmental factors affecting the pavement structure during freeze/thaw, determination of the soil modulus, curling and warping studies on the concrete, thermal cracking, and most other research.

Frozen Soil Layers - Resistivity Probe

Greg Johnson

A resistivity probe (RP) uses resistance readings to determine the layers of the subsurface that are frozen. In each of the 40 test sections at Mn/ROAD there is one RP installed in the outer wheel path, and in some sections, an RP is also located at the centerline, shoulder, and embankment.

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FROZEN SOIL MEASUREMENTS

Specific locations of the resistivity probes (RPs) in each of the 40 test sections at Mn/ROAD are:

Location	Offset from Centerline
Centerline	-0.00 m (-0.0 ft)
Outer Wheel Path	-2.95 m (-10 ft)
Shoulder	-4.90 m (-16 ft)
Embankment	-7.60 m (-25 ft)

A resistivity probe consists of a PVC pipe, 50 mm (2 in.) in diameter, with rings installed at regular intervals along the length of the pipe. The rings are made with copper wire wrapped around the pipe at 50 mm (2 in.) intervals. One wire, from a multi-conductor cable, is connected to each ring. The RP is constructed as such to place a constant amplitude current between two rings and measure the drop in voltage between them. The resulting data is used to determine where the soil is frozen and thawed. This determination is based on the significant difference between the volume resistivity of frozen soil and unfrozen soil.

Data from the RP is read manually every other week from December through February. From then until there is no longer frost in the soil, the RPs are read 3 times per week. The data is collected with a Campbell CR10 data logger and two AM416 multiplexers. The CR10 measures the resistance between all the adjacent rings and stores the result. These results are downloaded and placed into the Mn/ROAD database.

The data is analyzed to determine the zone where frozen soil is located, and is used for environmental research, FWD calculations, and other research. When the resistance between individual rings is greater than twice the resistance of baseline readings taken when the soil was unfrozen, the soil is considered frozen. This result is checked by comparing the RP results to the thermocouples and watermark blocks in the test cell. A controlled laboratory test is underway to verify this procedure.

Traffic Measurements - Weigh In Motion

David Palmquist

The Weigh In Motion (WIM) system documents all traffic, approximately 20,000 vehicles daily, that travels over Mn/ROAD. The operation and performance of the WIM system is verified by a program which involves both field and office procedures. Field procedures are done primarily on an as needed basis while the office procedures are conducted on a continuous basis.

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TESTING PROTOCOL AT WIM

FIELD TESTING

Purpose of Testing

- Verify scale calibration.
- Verify speed and axle spacing.

5 Axle Semi Test Truck

- Same axle configuration as the most significant truck using the facility.
- Load to 75 or 80 kips as that is where most of the ESAL's come from.
- Perform runs at the same speeds as the trucks using the facility.
- Have a minimum of 10 runs in each lane.

Frequency of Testing

- Prior to the opening of the mainline test road.
- Upon the reinstallation of new or refurbished scales.
- For a special project.

Conformity with Testing Standards

- We do not conform to ASTM E 1318 which concern WIM. ASTM E 1318 requires an extensive look at the road profile and weighing selected traffic stream vehicles both with the WIM and statically. We are unable to do this.

OFFICE PROCEDURES

Purpose of testing

- Provide the means to verify data on a continuing basis
- Establish credibility so that the users will have confidence in the data

Type of Tests

- Check the distribution of gross weight of 5 axle semis, verifying the placement of the peaks for loaded and unloaded vehicles. A shift in the peaks can indicate a shift in scale calibration.
- Monitor volumes of 5 axle semis, checking to see that they are in acceptable ranges for each respective day of the week.
- Monitor the spacing between the tandem axles on 5 axle semis. These typically have 4 foot spacings. A change indicates a problem with loops which are used to calculate the vehicles speed.

Conformity with Testing Standards

- The "AASHTO Guidelines for Traffic Data Programs" from 1992 suggests looking at the distribution of gross weight, front axle weights and ESAL factors for 5 axle semis. We track these and other things in our process, so we conform with these guidelines.
- The SHRP/LTPP program developed and use software which looks at the distribution of gross weight for 5 axle semis, searches for missing hours and compares numbers of vehicles in vehicle classification and truck weight records. Mn/ROAD procedures conform with the first two of these.

Testing Material Samples

Tom Burnham

The following describes the protocols used for testing the soil and concrete material samples taken from the Mn/ROAD project. Both standard and modified versions of ASTM, AASHTO, and Mn/DOT testing standards were utilized. Modifications are noted.

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PROTOCOL FOR TESTING MATERIAL SAMPLES

SOILS TESTS

Atterberg Limits: including liquid limit, plastic limit, plasticity index.

- Standards: AASHTO T89-90 (Liquid limit)
  AASHTO T90-87 (Plastic limit and Plasticity index)

Density: including wet and dry weight

- Standard: Mn/DOT procedure
  Samples are measured to determine volume. Weight of sample is measured at original moisture content (wet density), then weighed after sample has been oven dried overnight (dry density).

Gradation: including sieve analysis of fine and coarse aggregates, particle size analysis of soils.

- Standard: AASHTO T27-88 (Sieve analysis)
  AASHTO T88-90 (Particle size analysis)

Resilient Modulus

- Standard: SHRP Protocol P46, Mn/DOT modified
  Modifications - Load cell within triaxial chamber. Test performed at moisture content of 100% of optimum moisture content and at maximum density.

Organic Content

- Standard: AASHTO T267-86 (Determination of organic content in soils by loss on ignition), Mn/DOT modified
  Modifications - 1 to 2 gram sample, 445° C for 6 hours
  500° C for 1 hour.

Proctor Curve Formulation

- Standard: AASHTO T99-90 (Used for Mn/ROAD subgrade soils)
  AASHTO T180-90 (Used for Mn/ROAD base and subbase materials)

Resistance (R-value)

- Standard: AASHTO T190 (Resistance R-value and expansion pressure of compacted soils), Mn/DOT modified
  Modifications - Compacted specimen preparation done in 4 lifts; 3 lifts with 10 tamps per lift at 100 psi, final lift with 100 tamps at 250 psi. Final result is R-value at 240 psi.

Moisture Content

- Standard: AASHTO T265-86

Specific Gravity of Soils

- Standard: AASHTO T100-90

Unconfined Compressive Strength (cohesive soils)

- Standard: AASHTO T208-90

CONCRETE TESTS

Slump

- Standard: AASHTO T119

Air Content, Unit Weight

- Standard: AASHTO T121

Compressive Strength of Cylinder

- Standard: ASTM C39, 6"x12" cylinder

Splitting Tensile Strength of Cylinder

- Standard: ASTM C496-86, 6"x12" cylinder

Flexural Strength of Simple Beam: third-point loading

- Standard: ASTM C78-84, 6"x6"x21" beam

Flexural Strength of Simple Beam: center-point loading

- Standard: ASTM C293-79, 6"x6"x30" beam

Compressive Strength of 4" Nominal Diameter Cores

- Standard: ASTM C42-87

Splitting Tensile Strength of 4" Nominal Diameter Cores

- Standard: ASTM C496-86

Static Modulus of Elasticity and Poisson's Ratio in Compression

- Standard: ASTM C469-87a

  Note: Performed at test ages of 28, 180, 365 days.

Air Voids Analysis of Cores

- Standard: ASTM C457-90

Petrographic Analysis of Cores

- Standard: ASTM C856-83

Rapid Freezing and Thawing of Beams: Method A

- Standard: ASTM C666 - Proc. A

PLATE BEARING TESTS

Static Plate Load (Bearing) Test

- Standard: ASTM D1196-64, Mn/DOT modified

  Modifications - Deflections measured by Benkelman beams.

Soil Moisture - Time Domain Reflectometer and Watermark Blocks

Craig Schrader

Mn/ROAD currently uses two instruments to measure in situ soil moisture, the time domain reflectometer and the watermark block. A time domain reflectometer (TDR) measures liquid volumetric soil water content, and the watermark block (WM) measures soil water potential as negative pressure.

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MEASUREMENTS PROCEDURES

TIME DOMAIN REFLECTOMETER, TDR

The Mn/ROAD TDR system was designed specifically for the Mn/ROAD project using state of the art technology for the time of design (circa 1990-91). The waveguide (sensor) is a two-prong balanced waveguide 200 mm in length. RG/8 coaxial cable runs from cabinets along the roadside to the waveguide which is buried at prescribed depths (0.30,0.45,0.61,0.91,1.22,1.52, and 2.44 m). A standard installation was always located at the outer wheel path to the driving lane in all 40 test cells and selected test cells also have TDR locations at the centerline, shoulder, and embankment. The transition from the coaxial cable to the waveguide went through an impedance matching transformer (balun) to minimize signal loss. The balun used was a TP103 impedance matching transformer. This was considered to be the best balun available at the time. The RG/8 coaxial was chosen for the same reason, to minimize signal attenuation.

Measurements are taken manually approximately every two weeks throughout the season and more often during spring thaw. A Tektronix 1502C cable tester is used for this purpose. A laptop computer is interfaced to the Tektonix to electronically capture the trace seen at the waveguide. Analysis of the trace is performed back at the laboratory using a computer program to determine the inflection points of the trace. The distance between the inflection points is used to calculate the dielectric value of.the soil being measured. The standard Ledieu equation is used for the analysis of coarse textured soils. A calibration was obtained for the analysis of clay loam subgrade soils, as it appeared that the universal equation failed in soils with higher clay contents.

Currently there is some concern that the unusually long cable runs used in some areas of the Mn/ROAD project have had a deleterious effect on the soil moisture readings. Work is currently being done to determine the effect of cable length on the accuracy of TDR moisture measurements. Also, the waveguide will likely be reconfigured for future installations. The instrumentation industry is developing less expensive automated installations. Currently it costs in excess of $10,000 to automate a single site with TDR technology, which to date has restricted the use of automation.

WATERMARK BLOCK, WM

The Watermark sensor is an online sensor which is polled approximately every 15 minutes. The data is collected by an Optim 3008 Megadac base unit and uses an AC 3884WM card to read the resistance of the WM sensor. The sensor reads out in centibars and has a working range of 0-200 centibars. Data within the working range is sent to one table of the Mn/ROAD database and values falling outside this range are sent to a second table. At the time of installation a certain amount of optimism existed about the effectiveness of the WM. It was thought that by calibrating the WM in the specific soils in which it would be installed that it could be used as a reasonable measurement of liquid volumetric water content. The moisture potential was calibrated against a moisture release curve to achieve the measure of water content. Subsequent work has cast some suspicion on whether the initial calibration will hold up against repeated freeze-thaw cycles. Laboratory testing will look into this question.

Interestingly enough, the WM has proven to be a useful instrument in frost measurements. As the soil freezes and consequently the WM, the readings change dramatically indicating a phase change in the soil water. The WM is being used as an ancillary measurement for frost penetration along with the Resistivity Probe.

Climate Data - Weather Stations

Craig Schrader

Climate data is being collected at two locations on the Mn/ROAD site. A Campell Scientific Inc. weather station is located on the west end of the site near Cell 8, and approximately two miles away to the east, a Vaisala weather station is located near the Weigh in Motion building.

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CLIMATE DATA

WEATHER STATIONS

The Campbell Scientific Inc. weather station and the Vaisala weather station both collect climate data at the Mn/ROAD site every 15 minutes.

Campbell Scientific Inc. Weather Station

Climate data is currently being collected on the west end of the Mn/ROAD Project near Cell 8 by the Campbell Scientific Inc. weather station. This station collects the following data:

- Air temperature at 1.5 m elevation. Vaisala Humidity - Temperature Meteorological Probe. Temperature accuracy ± 0.5 °C
- Relative humidity located with air temperature. See above. Humidity accuracy ± 2.0%
- Barometric pressure.
- Wind speed at 3 meters, R.M. Young model 05103 Wind Monitor. Range 0-60 m/s.
- Wind direction at 3 meters. R.M. Young model 05103 Wind Monitor.
- Heated precipitation gauge.
- Incoming solar radiation measures 0.3 to 3 υm.

Vaisala Weather Station

The Vaisala weather station is located on the east end of the Mn/ROAD site, near the Weigh in Motion building. This station collects the following data:

- Air temperature.
- Relative humidity.
- Barometric pressure.
- Wind speed and direction.
- Precipitation is measured with a heated tipping bucket precipitation gauge.
- Incoming solar radiation and reflected solar radiation.

Bituminous Mixture Testing

David Newcomb

There were eight asphalt mixtures used in the original construction at Mn/ROAD. A soft and a stiff asphalt binder were used in mixtures having four different asphalt contents. Testing of these was accomplished in pre-construction, construction, and post-construction conditions. Testing included volumetric characteristics, moisture sensitivity, resilient modulus, and creep behavior.

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Mn/ROAD BITUMINOUS TESTING PROTOCOLS

Table 1. Mn/ROAD Bituminous Testing Protocols

TEST	PROTOCOL
Marshall Mix Design	ASTM D1559
Mixture Design Using Level 1 Superpave	Asphalt Institute - SP 2
Bulk Specific Gravity of Coarse Aggregate	ASTM C127
Bulk Specific Gravity of Fine Aggregate	ASTM C128
Penetration of Asphalt Cement	ASTM D5
Absolute Viscosity of Asphalt Cement	ASTM D2171
Kinematic Viscosity of Asphalt Cement	ASTM D2170
Bulk Specific Gravity of Bituminous Mixtures	ASTM D2726
Theoretical Maximum Specific Gravity of Bituminous Paving Mixtures	ASTM D2041
Gradation of Extracted Aggregate	ASTM D5444
Asphalt Extraction	ASTM D2172