

Minnesota Road Research Project

1999 MnROAD SuperPave Tracking (S.P. 8816-40)

Low Volume Road Cells 33-35

Manuscript

Word Count 5,490
24 Tables and 6 Figures

Benjamin Worel, P.E.

Benjamin.Worel@dot.state.mn.us
(651) 779-5522 Fax (651) 779-5616

Tim Andersen, P.E.

Tim.Andersen@dot.state.mn.us
(651) 779-5609 Fax (651) 779-5616

Ronald Mulvaney, P.E.

Ronald.Mulvaney@dot.state.mn.us
(651) 779-5499 Fax (651) 779-5616

Minnesota Department of Transportation
Office of Materials and Road Research
1400 Gervais Avenue
St. Paul, Minnesota 55109

December 2003

ABSTRACT

This paper's purpose is to provide an update on the pavement condition of MnROAD's three low volume road (LVR) Superpave test cells constructed in 1999 with different asphalt binders, see table below. These cells were built to field validate the current low temperature performance grading (PG) system currently being used at Mn/DOT and many other agencies around the world. The paper will document the mix designs, laboratory testing, forensics, environmental conditions, and the resulting distresses observed include rutting, transverse cracking, fatigue cracking and how they are affecting pavement performance and ride.

TABLE MnROAD 1999 Low Volume Road Superpave Test Cells

Cell	Asphalt Binder Used Design (4" HMA / 12" Class-6 base / Clay Subgrade)
33	Unmodified PG 58-28
34	Polymer Modified PG 58-34
35	Polymer Modified PG 58-40

INTRODUCTION

MnROAD Facility

The Minnesota Department of Transportation (Mn/DOT) constructed the Minnesota Road Research Project (MnROAD) between 1990 and 1994. MnROAD is located 40 miles northwest of Minneapolis/St. Paul and is an extensive pavement research facility consisting of two separate roadway segments containing 51 distinct test cells. Each MnROAD test cell is approximately 500 feet long. Subgrade, aggregate base, and surface materials, as well as, roadbed structure and drainage methods vary from cell to cell. All data presented herein, as well as historical sampling, testing, and construction information, can be found in the MnROAD database and in various publications. Layout and designs used for the Mainline and Low Volume Road are shown in figures 2 and 3. Additional information on MnROAD can also be found on its web site at <http://mnroad.dot.state.mn.us/research/mnresearch.asp>.

Mainline Test Road

The 3 ½-mile Mainline Test Road (Mainline) is part of westbound Interstate 94. The two-lane facility contains 31 test cells. The Mainline consists of both 5-year and 10-year pavement designs. The 5-year cells were completed in 1992 and the 10-year cells were completed in 1993. Originally, a total of 23 cells were constructed consisting of fourteen hot mix asphalt (HMA) test cells and nine Portland Cement Concrete (PCC) test cells. In 1997, two Superpave HMA test cells and six ultra-thin whitetopping concrete cells were added.

Traffic on the Mainline comes from the traveling public on westbound I-94. Typically the Mainline is closed once a month and the traffic is rerouted to the original interstate highway to allow MnROAD researchers the ability to collect data and record test cell performance. The traffic volume has increased 40% since the test facility first opened in 1994 and 2003. The Mainline equivalent single axel loads (ESALs) are determined from two weigh-in-motion (WIM) devices located at MnROAD. This data is collected, shared and used to calculate the Mainline ESALs, which are stored in the MnROAD database. An IRD Inc. hydraulic load scale was installed in 1989, east of the mainline test cells. In 2000, a Kistler quartz WIM was installed between PCC cells 10 and 11.

Low Volume Road

Parallel and adjacent to the Mainline is the Low Volume Road (LVR). The LVR is a 2-lane, 2 ½-mile closed loop that contains 20 test cells. Traffic on the LVR is restricted to an MnROAD operated vehicle, which is an 18-wheel, 5-axle, tractor/trailer with two different loading configurations. The "heavy" load configuration results in a gross vehicle weight of 102 kips (102K configuration). The "legal" load configuration has a gross vehicle weight of 80 kips (80K configuration). On Wednesdays, the tractor/trailer operates in the 102K configuration and travels in the outside lane of the LVR loop. The tractor/trailer travels on the inside lane of the LVR loop in the 80K configuration on all other weekdays. This results in a similar number of ESALs being delivered to both lanes. ESALs on the LVR are determined by the number of laps (80 per day) for each day and are entered into the MnROAD database.

LVR SUPERPAVE TEST CELL CONSTRUCTION

In early 1998, six test cells on the MnROAD (LVR) were considered for rehabilitation. The six test cells included four aggregate cells (32, 33, 34, & 35) and two asphalt cells (27 & 28), originally constructed in 1993. The MnROAD Bituminous & Concrete Committee, Local Road Research Board (LRRB) and the MnROAD Rehabilitation Committee came up with a number of research needs during the summer of 1998. The needs were developed into two projects, which were constructed in 1999. This paper serves as a summary of the 1999 construction and the continued monitoring of the Superpave test cells 33, 34, and 35. Cells 27 and 28 are covered in a separate document, as is cell 32, which was reconstructed with PCC in 2000.

Test cells 33, 34 and 35 were reconstructed to field verify the current Superpave criteria related to low temperature cracking (thermal and/or transverse cracking). Each test cell used the same mix design

Worel, Mulvaney & Andersen

which calls for 4" of HMA Superpave mix over a 12" Class-6 Special aggregate base. The only difference in the design is the type of asphalt binder to be used. It was believed that this design would allow thermal cracks to develop before fatigue cracking or significant levels of rutting. The design is based on a 20-year ESAL of 375,000.

The Class 6 Special aggregate base was chosen because past experience at MnROAD indicated that this base material induced more thermal cracks in the HMA pavements. This is based on past performance of the 1993 LVR test cells.

The difference in the HMA mix design for the three test cells is the use of three different Superpave PG binders, they are PG 58-28, PG 58-34 and PG 58-40. Note that each of these binders have the same high-end temperature value of 58°C, but the low-end temperature value varies from -28°C, -34°C, and -40°C. Also note that the PG 58-34 and PG 58-40 are polymer-modified binders, which was required in order to meet the Superpave specifications. This was done despite the fact that PG grading tests developed by SHRP are based on unmodified binders.

In summary, MnROAD wanted to examine the effects of using different PG graded asphalt binders on ride and performance. Each cell was constructed with the same HMA Superpave mix design and materials, is placed in same environment, and are subject to the same traffic loadings (ESALs).

LVR Superpave Test Cell Contract Letting

The project was let on June 11, 1999 as State Project (S.P.) 8816-40. The original bids were 167% over budget and the project was re-evaluated and re-bid. The project was re-bid later in the summer and came within 10% of the estimate. The project was awarded to the apparent low bidder, Bituminous Roadways, Inc., Inver Grove Heights, MN. Construction on the LVR test cells started on July 26 and finished on September 2, 1999. See table 1 for construction related activities for S.P. 8816-40.

TABLE 1 Construction Summary for S.P. 8816-40

Cell	Purpose
27	Remove 3" HMA surface and 11" of aggregate base and replace with 14" of Crushed Stone Base & Double Chip Seal surfacing
28	Remove 3" bituminous pavement & 13" of aggregate base and replace with 14" of Crushed Stone Base & Oil-Gravel surfacing
33	Remove 12" aggregate surfacing & 4" of subgrade material and replace with 4" HMA (PG 58-28) and 12" Class 6 Special
34	Remove 12" aggregate surfacing & 4" of subgrade material and replace with 4" HMA (PG 58-34) and 12" Class 6 Special.
35	Remove 12" aggregate surfacing & 4" of subgrade material and replace with 4" HMA (PG 58-40) and 12" Class 6 Special.

LVR Test Cell Condition Before Construction

The LVR Superpave test cells before reconstruction were aggregate base cells designed to model a typical aggregate road in Minnesota. However, based on the MnROAD method of loading the LVR with the 80K and 102K semi-truck, it was soon discovered that these loading were more consistent with a haul road than a typical aggregate road. The MnROAD Aggregate Committee decided it was best to conduct its research efforts off MnROAD and on actual aggregate roads throughout the state. Therefore, these three cells became available for the Superpave study.

The MnROAD Aggregate Committee cited the these reasons for abandoning cells 33,34 and 35

- Materials needed to be evaluated under the varied traffic of a typical low-volume road.
- Test sections needed a variety of materials, subgrade types, and environments found in Minnesota.

Worel, Mulvaney & Andersen

- The transitions from paved to aggregate surface caused distresses not related to the actual aggregate structural design at MnROAD.
- Longer test sections are needed to develop adequate evaluation.
- High maintenance of test cells, especially in the transition zones between cells.
- Damage to test equipment and the semi-truck caused by driving on the aggregate test cells.

Construction Field Notes

Table 2 is a summary of Mn/DOT’s filed notes taken during construction by Tim Andersen.

TABLE 2 Reconstruction Field Notes

Date	PG Activities Noted (Cells 33-35)
July 26	Milled 2 inches of HMA surface and shoulders in the transition area at the beginning of Cell 33 and end of Cell 35. The bituminous millings were hauled to the MnROAD stockpile area.
July 27-28	The existing Class 1 aggregate surfacing and some of the existing subgrade was excavated and stockpiled at the MnROAD stockpile site.
July 29–August 4	A motor grader was used to tolerance the grade and bring the subgrade up to the correct elevation and cross section. The contractor had some difficulty in shaping the subgrade because of dry conditions.
August 5-10	Mn/DOT researchers placed sensors and the wire leads into the subgrade. The trenches for the wire leads were dug and recompactd by hand. During this time, the St. Cloud survey crew surveyed the sensor locations and cross section the roadway
August 11-18	The contractor hauled, compacted, and tolerance the Class 6 Special on the Cells 33-35.
August 19-24	Mn/DOT researchers placed sensors, the wire leads, and the conduit for the thermal crack tape into the Class 6 Special aggregate base in all the cells.
August 25	The contractor placed the first 2" lift of HMA mix on Cells 33 - 35. Each cell had a different grade of asphaltic cement in the hot mix asphalt (HMA).
	Before each cell was paved, a small area of each mix was paved on the access road, west of the Low Volume Road.
	Three rollers were used in compacting the bituminous mix. A double steel was used for the break down, a new pneumatic roller was used as a intermittent roller, and the finish roller was a double steel.
	Dan Boerner (Asst. Bituminous Engineer) Cassandra Isackson (MnROAD Forensic Engineer) experimented with a infrared camera. They looked at how the bituminous mat cools behind the paver to see how the paver influences the bituminous mix temperature when it comes out of the truck. Locations are documented in a separate spreadsheet.

August 26-27	U of M students and MnROAD site personnel placed the thermal crack tape 11 feet from the centerline on the 102k lane (outside lane) between the two asphalt lifts. This procedure is documented in another document.
August 30	The PG 58-28 mix was paved on the access road before it started to rain and the paving was called off due to rain.
August 31	The contractor placed the last 2" lift of bituminous mix on Cells 33, 34, & 35. Each cell utilized the same type of mix that was placed for the first layer.
	The contractor tried to eliminate the use of the pneumatic roller on the PG 58-40 mix (cell 35) on the access road and found out that density dropped by 2 lbs/cu. ft., so the contractor put it back into the rolling pattern. It continued to pick up some of the fines in the PG 58-40 mix.
Sept 1	The shoulders received a variable depth of Class 2 shoulder aggregate on cells 33-35.
Sept 2	The topsoil was brought up to the edge of the aggregate shoulders.
Sept 8	Dwayne Stenlund, U of M, and St.Cloud Maintenance placed the turf establishment on cells 33-35. The north inslope was divided into 50 foot wide test plots for researching the best methods to grow grasses after the in-place topsoil was disturbed during construction. The south in-slope was planted with typical seed used by St. Cloud Maintenance personnel.

Sensors and Data Collection Systems Installed

Listed below is the equipment used to collect data from the sensors in each test cell.

TABLE 3 Data Collection Equipment Installed

Data Collection Equipment	Purpose
Campbell Scientific – CR10X datalogger	Collects all the data from the sensors in each cell
Tektronix 1502CSI cable tester	Measure travel time for the TDR probes
Campbell Scientific – AM25T multiplexer	Allows the datalogger to read multiple thermocouples
Campbell Scientific – AM416 multiplexer	Allows the datalogger to read multiple thermal crack tape, watermark moisture blocks, and other sensors.
Campbell Scientific - SDMX multiplexer	Allows the datalogger to read multiple TDR traces.

TABLE 4 Sensors Installed

Cell	Sensor Type	# of Sensors	# of Locations
33	TC	6	1
	PK	16	2
	TDR	5	1
	LE	4	4
	PG	6	6
	OS	1	1
34	TC	17	3
	WM	15	2
	TDR	5	2
	OS	1	1
	RS	5	1
	LE	4	4
35	TC	75	1
	TDR	45	2
	LE	14	4
	OS	1	1

Sensor Type Codes / (Use)

- TC Thermal Couple
(measures the temperature of the soil and pavement)
- WM Water Mark / Moisture Block
(measures the depth of frozen/thawed soil)
- TDR Time Domain Reflectometer
(measures the amount of moisture in the soil)
- OS Open Stand Pipe
(measures the location of the water table)
- RS Reflectometer
(measures the amount of soil moisture)
- PK Pressure Sensor
(measures the amount of vertical pressure - top subgrade soil)
- LE Longitudinal Strain Gauge
(measures the strain at the bottom of HMA)
- PG Pressure Gauges
(measures the vertical pressure in the aggregate base)

Note: Aluminum foil tape was installed on the outside of the 102k lane under the fog line. Its purpose is to set a alarm when a thermal crack appears.

Construction Samples Taken

The following samples were taken for testing during construction and are shown in Table 5.

TABLE 5 Samples Taken During Construction

Sample Material	Cell	# of Samples	Test Type
Clay Subgrade	33-35	2	Storage/Future Tests
Class-6 Base	33-35	Stockpile area	See Aggregate Profile of tests done on original cells
HMA (Bulk Mixture)	33	6	Quality Control
		22	Storage/Future Tests
		8	U of M
		5	IDT
	34	6	Quality Control
		18	Storage/Future Tests
		8	U of M
		5	IDT
	35	6	Quality Control
		22	Storage/Future Tests
		8	U of M
		5	IDT
HMA (Asphalt Samples)	33	3	Storage/Future Tests
		3	U of M
	34	3	Storage/Future Tests
		3	U of M
	35	3	Storage/Future Tests
		3	U of M
HMA (Aggregate)	33	6	Storage/Future Tests
	34	3	Storage/Future Tests
	35	3	Storage/Future Tests
Shoulder Aggregate (Class-2)	33-35	3	Quality Control

Construction Testing Results

Tables 6, 7, 8, 9 and 10 show the results of the construction testing performed during this project.

TABLE 6 Aggregate Base Moisture and Densities

Material	Test	Requirements		Ave Field Results	# of Samples	Sample Type
		Min	Max			
Class 6 Special	Relative Moisture	65	102	66	13	From roadway
Class 6 Special	Relative Density	100	-----	112	5	From roadway

Class-6 special was used from the MnROAD stockpile area for the 12” base material.

TABLE 7 Aggregate Base Gradations

Sieve	Requirements		Average Field Result	# of Samples	Sample Type
	Min	Max			
1"	100	100	100	5	Sample from Roadway
¾"	85	100	96		
3/8"	50	70	65		
# 4	30	50	41		
# 10	15	30	27		
# 40	5	15	13		
# 200	0	5	5.7		

Class 6 Special was used for the base material consisted of Class A aggregate (Original class-6 from the stockpile area)

TABLE 8 HMA Aggregate Gradations

Sieve	Requirements		PG 58-28 Average	PG 58-34 Average	PG 58-40 Average
	Min	Max			
¾"	100	100	100	100	100
3/8"	90	100	93	94	93
# 4	79	90	85	86	85
# 10	59	73	68	68	67
# 40	48	58	56	56	55
# 200	2.7	6.7	5.2	5.2	5.0
# of Samples			6 ^a	5 ^b	6 ^a
Sample Type			Mix from Truck Box	Mix from Truck Box	Mix from Truck Box

Aggregate sources and percentages are shown in table 5 in the appendix (Mn/DOT Trial Mix Designs)

^a Two samples from the paver and the rest of the samples were obtained from the truck box

b One sample from the paver and the rest of the samples were obtained from the truck box

TABLE 9 LVR HMA Superpave Mix Testing Results

Material	Test	Required		Average Results	# of Tests	Sample/Test Type
		Min.	Max.			
PG 58-28 HMA	Relative Density	92.0%	-----	93.6%	4	Cores from Roadway
PG 58-34 HMA		92.0%	-----	94.2%	4	
PG 58-40 HMA		92.0%	-----	93.0%	4	
PG58-28 HMA	Pavement Thickness	44 mm	56 mm	51 mm	4	Cores from Roadway
PG 58-34 HMA		44 mm	56 mm	50 mm	4	
PG 58-40 HMA		44 mm	56 mm	50 mm	4	
PG 58-28 HMA	%AC (Field Cores)	5.4%	6.2%	5.5%	6 ^a	Incinerator & Extraction
PG 58-34 HMA		5.4%	6.2%	5.5%	5 ^b	
PG 58-40 HMA		5.4%	6.2%	5.5%	6 ^a	
PG 58-28 HMA	Lottman (TSR ratio)	75	-----	91	4	Mix from Truck Box
PG 58-34 HMA		75	-----	90	4	
PG 58-40 HMA		75	-----	78	6 ^a	
PG 58-28 HMA	SHRP PG Grade (AC Binder)	-----	-----	PG (59.5 - 30.6)	DSR and BBR	
PG 58-34 HMA		-----	-----	PG (60.4 - 35.1)		
PG 58-40 HMA		-----	-----	PG (61.9 - 41.2)		
PG 58-28 HMA	Bulk Specific Gravity	-----	-----	2.381	4	Mix from Truck Box
PG 58-34 HMA		-----	-----	2.390	4	
PG 58-40 HMA		-----	-----	2.393	4	
PG 58-28 HMA	Max. Specific Gravity	-----	-----	2.501	4	Mix from Truck Box
PG 58-34 HMA		-----	-----	2.494	4	
PG 58-40 HMA		-----	-----	2.491	4	
PG 58-28 HMA	Course Aggregate Angularity	75/0	-----	98/98	4	Mix from Truck Box
PG 58-34 HMA		75/0	-----	97/97	4	
PG 58-40 HMA		75/0	-----	98/97	4	
PG 58-28 HMA	Fine Aggregate Angularity	40	-----	41.3	4	Mix from Truck Box
PG 58-34 HMA		40	-----	41.3	4	
PG 58-40 HMA		40	-----	41.2	4	
PG 58-28 HMA	Mix Moisture	-----	0.3%	0.04%	2	Mix from back of Paver
PG 58-34 HMA		-----	0.3%	0.04%	2	
PG 58-40 HMA		-----	0.3%	0.03%	2	
PG 58-28 HMA	Production Air Voids	2.7%	5.3%	4.9%	4	Mix from Truck Box
PG 58-34 HMA		2.7%	5.3%	4.1%	4	
PG 58-40 HMA		2.7%	5.3%	4.3%	4	
PG 58-28 HMA	Voids in Mineral Aggregate	13.7%	-----	15.0%	4	Mix from Truck Box
PG 58-34 HMA		13.7%	-----	14.6%	4	
PG 58-40 HMA		13.7%	-----	14.7%	4	

a Two samples obtained from the paver and the rest of the samples were obtained from the truck box

b One sample obtained from the paver and the rest of the samples were obtained from the truck box

TABLE 10 Aggregate Shoulder Gradations

Sieve	Requirements		Average Field Result	# of Samples	Sample Type
	Min	Max			
¾"	100	100	100	3	Sample from Roadway
3/8"	65	90	79		
#4	35	70	51		
#10	25	45	33		
#40	12	30	16		
#200	5	13	6.7		

Class-2 was used for the gravel shoulder surface consisting of Class A aggregate (Meridian Granite, St. Cloud)

Construction Summary

Final construction comments from the MnROAD Construction & Planning Engineer are shown in table 11.

TABLE 11 Construction Comments

Category	Comments on LVR Test Cells 33-35
Challenges	Due to the short length of each cell, about 560 feet, the transitions between each cell is rough. It should be noted that the paving crew used a 30-foot ski on the paver and the paving crew had very little experience working with electronic controls.
	The paving crew had to back up the paver near the start of the different cells. At the transition area between Cells 34 & 35, 80K lane, the paver backed up four times before the paver continued to pave the rest of the lane. This produced a very noticeable bump between Cells 34 & 35, 80K lane, this was documented.
	The pneumatic roller picked up bituminous fines and oil on Cells 33, 34, & 35
	The contractor tried to warm the tires and reduced the amount of pick up on Cells 33 & 34. But on Cell 35, the PG 58-40 mix still was picked up, without much success
Successes	The contractor got an incentive on density on 4 out of 6 lifts.
	Before each cell was paved, a small area of each mix was paved on the access road, west of the Low Volume Road. This was done to give the contractor an opportunity to try different rolling patterns before the mix was placed on the cells. The mix types are documented for possible further research on non-traffic cells.
Future Construction Practices	Look at different methods of paving short stretches of roadway and still obtain a acceptable ride.
	Examine different methods of preventing the pneumatic roller from picking up the HMA fines.

TESTING COMPLETED SINCE CONSTRUCTION

The following is a partial listing of some of the documents that has been prepared using construction

Worel, Mulvaney & Andersen

materials of the three LVR Superpave test cells.

Worel, Mulvaney & Andersen

Mathy Construction - 2000

Mr. Gerald Reinke of Mathy Construction developed a report based on bulk mix samples from LVR test cells 33-35. The report is available on the MnROAD web page and the data is located in the MnROAD database. (Refer to earlier location of MnROAD website). The report contains the following tests: SHRP PG Grading, Indirect Tensile, Torsional Fatigue, Modulus (High Temperature). The report can be found at,

Reinke, G. *Investigation into the Low Temperature and Fatigue Properties of Three MnROAD Bituminous Mixtures*. December 11, 2000.

<http://mnroad.dot.state.mn.us/research/mnresearch.asp>

University of Minnesota – 2002

The University of Minnesota tested bulk mix samples from cells 33-35. The complex dynamic modulus was measured over a range of temperatures and frequencies, as recommended by the 2002 Design Guide.

The data is available from the MnROAD database. The report is unpublished, but is being prepared at the time this document was being written.

Marasteanu, M., Skok, E., and Clyne, T. *Dynamic and Resilient Modulus of Mn/DOT Asphalt Mixtures* (undated)

University of Minnesota – 2003

The University of Minnesota tested bulk mix samples taken from cells 33-35. This testing was conducted under the current pooled states study for Low Temperature Cracking. The data and final report are not complete at this time.

The University of Minnesota is currently testing mixtures under a newly developed test performed on semicircular samples cut from gyratory-compacted specimens. Fracture mechanics principles are being used to better understand the low-temperature properties of asphalt mixtures. Reports are expected once the testing and data analysis are complete.

LVR SUPERPAVE TEST CELL PERFORMANCE

MnROAD has monitored the test cells since they were constructed in July 1999. Here is a brief summary of the data collected.

Rutting

Rutting has developed in all three Superpave test cells as shown in table 12. Measurements are taken using a six-foot straight edge. More rutting is developing in the 80K lane than the 102K lane despite the same number of ESALs in each lane. This is consistent with the original 1994 HMA test cells on the LVR. These cells also had more rutting in the 80K lane than the 102K lane, which seems to indicate that the number of passes impacts the amount of rutting more than weight or the standard ESAL. Note the inside 80K lane is driven 4 days per week and the 102K lane is driven 1 day per week, each averaging 80 laps per day.

TABLE 12 Rutting (6-foot Straight Edge)

Cell	80K Inside Lane		102K Outside Lane	
	Outside WP	Inside WP	Outside WP	Inside WP
33	.4752"	.4374"	.3064"	.2312"
34	.4628"	.4248"	.3628"	.3002"
35	.5504"	.4624"	.3438"	.2252"

Transverse Cracking

The initial transverse cracking developed during February 2003. Currently, these cracks do not exhibit a

Worel, Mulvaney & Andersen

“typical” thermal cracking pattern, which runs perpendicular and across the entire width of both lanes. These cracks are more random in nature. The forensic observation includes more information on these cracks. See table 13 for the amount of transverse cracks through November, 2003.

TABLE 13 Transverse Cracking

Cell	80K Inside Lane		102K Outside Lane	
	Number of Cracks	Linear Feet	Number of Cracks	Linear Feet
33	0	0	6	13
34	0	0	0	0
35	14	66	5	24

Longitudinal Cracking

Some longitudinal cracking has developed and is shown in table 14. Forensic cores have shown cell 35 is cracking from the top down.

TABLE 14 Longitudinal Cracking

Cell	80K Inside Lane		102K Outside Lane	
	Outside WP	Inside WP	Outside WP	Inside WP
33	0	0	0	0
34	0	0	0	0
35	2	4	3	16

Fatigue Cracking

Cell 35 contains some fatigue cracking, see table 15. These cracks may have developed in areas that were not constructed to the full 4-inch HMA thickness. This is consistent with LVR test cells 27-28 when forensic cores were taken.

TABLE 15 Fatigue Cracking

Cell	80K Inside Lane		102K Outside Lane	
	Outside WP	Inside WP	Outside WP	Inside WP
33	0	0	0	0
34	0	0	0	0
35	0	6 lin-ft	16 lin-ft	0

Ride

Ride is measured with a Pathways data collection van Mn/DOT owns. The data is recorded using the International Roughness Index (IRI) in meters/kilometer (m/km). An IRI of zero indicates a perfectly smooth pavement, while IRI values above 3.00 m/km indicate a very rough ride. The current ride index is very similar for each cell as shown in table 16.

TABLE 16 PATHWAYS IRI Ride Measurements (m/km)

Cell	80K Inside Lane		102K Outside Lane	
	Outside WP	Inside WP	Outside WP	Inside WP

33	2.23	1.91	1.33	1.50
34	2.00	2.62	1.42	1.40
35	1.96	2.10	1.83	1.96

Observed Strain Measurements

A total of eighteen strain gauges were installed in the three Superpave test cells. On average between 50 and 100 passes were recorded using the MnROAD truck in the 80K lane. A typical longitudinal strain trace is shown below in Figure 3. Currently, after four years of service, only one strain gauge of the eighteen original strain gauges remains functional.

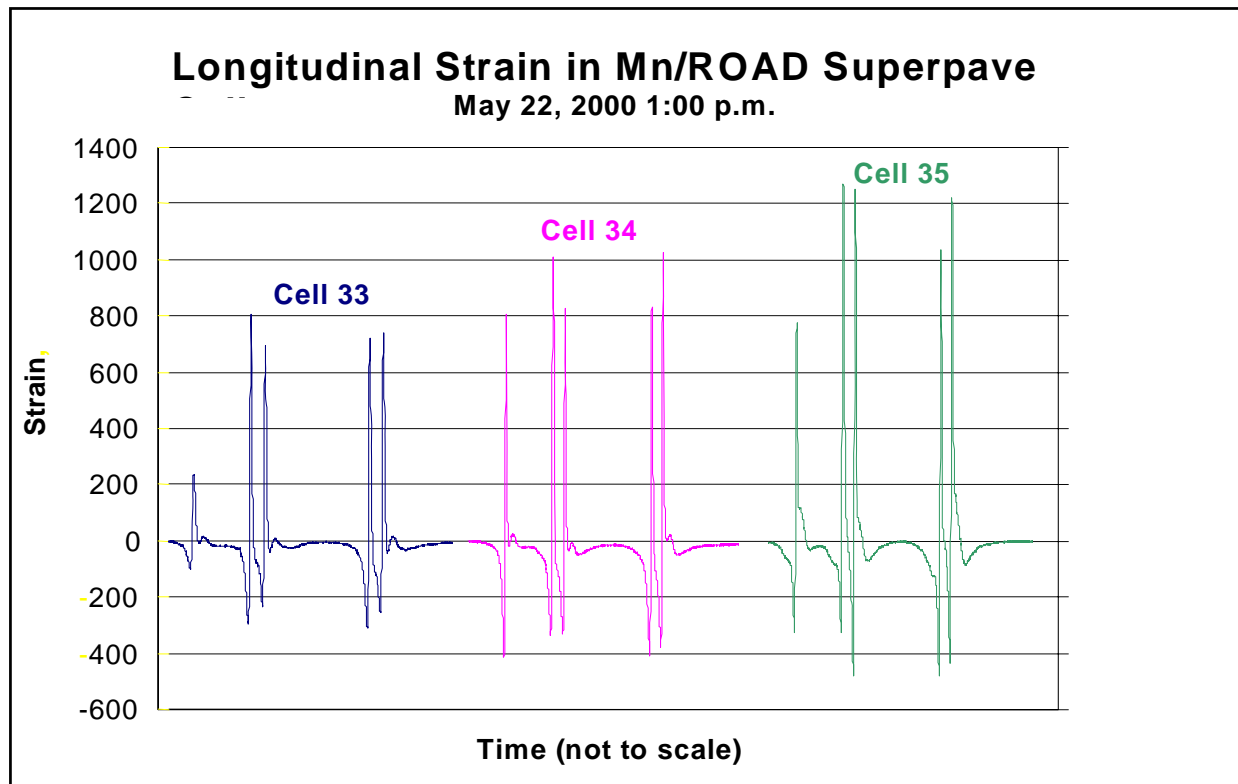


FIGURE 1 Typical Longitudinal Strain Responses

Thermal Crack Tape

Thermal crack tape was installed along the outside lane (102K) for each test cell. The tape was installed between the two HMA lifts placed on each cell. The purpose of the crack tape is to determine the exact time thermal cracks develop. The crack tape system at MnROAD was installed in 65-ft loops (on average) that act as a continuous circuit until the continuity is broken.

As of May 2003, no surface cracks have developed through any of the thermal crack tape installed. Each of the thermal crack tape loops remain continuous, even though the resistance has grown over time. This is caused by the expected corrosion that has developed in the sensor wires that were soldered to the crack tape foil.

Forensic Observations

Since the initial cores were taken during the 1999 construction, only one forensic activity has taken place. The purpose of this forensic activity was to determine the source of the cracking found in cells 33 and 35. This involved coring a transverse and longitudinal crack to determine if the crack developed from the top

Worel, Mulvaney & Andersen

or the bottom of the asphalt layer. The forensic activity involved taking five cores from cell 35 on May 2, 2003. See table 17 for core data and table 18 for forensic observations.

TABLE 17 Forensic Core Locations

Core Number	STA (Ft)	Offset (in) ^a	Thickness ^b Lifts 1+2 =Total (in)	Comment
3503BC001	7828	+ 48	1.75+2.125 = 3.875	On transverse crack #1 / separated at tack coat
3503BC002	7828	+ 32	2.25+2.00 = 4.25	3" off the end of transverse crack #1
3503BC003	7817	+ 28	1.75+1.50 = 3.25	On longitudinal crack in wheel path
3503BC004	7817	+ 70	2.00+2.00 = 4.00	Midlane at same station as longitudinal crack
3503BC005	7731	+ 60	2.50+1.75 = 4.25	On transverse crack #2

a A positive offset indicates the inside 80K lane for cells 33-35.

b Lift (1) is the bottom lift and lift (2) is the surface lift

TABLE 18 Forensic Observations

Observation Category	Observation / Comment
Thickness Variations	The cores taken at the same station as the longitudinal cracking show a ¼" difference in thickness. Air voids and density will be determined but the difference appears to be construction related due to the other cores taken in the wheel path were more consistent thickness than the one containing the longitudinal crack.
Transverse Cracks	<p>Three cores were taken to observe the transverse cracking on two different cracks.</p> <p>On the first crack, one core was taken in the middle of the transverse crack and one just as it disappeared, about 3", from the end. We observed that the core taken on the transverse crack debonded between the two lifts and the crack was observed in both lifts but it appeared it developed from the surface. The bottom lift was "flexed" by hand from the top down to observe the crack better. It was noticeable but only slight at the HMA lift interface before it was broke. The second core contained no visible cracking.</p> <p>The second crack core showed the same as the first crack. The cracking appears to be top down.</p> <p>Overall the transverse cracking appears to be construction related and do not exhibit the same characteristics as traditional thermal cracks at this point.</p>
Longitudinal Cracks	The thickness of the cores in the area of the longitudinal cracking were ¼" thinner than any of the other cores. The crack went all the way through the core and no determination of top down cracking can be made. MnROAD has observed in the past other areas on other cells that contained localized areas of "thinner" spots that eventually fatigued.

PRELIMINARY FINDINGS

The three test cells in the LVR are behaving in such a manner to warrant additional study into the performance of polymer modified asphalt binders.

Rutting in the three cells are similar, however, the 80K lane has more rutting than the 102K lane.

Worel, Mulvaney & Andersen

Each lane has had the same number of ESALs loaded to it by way of the MnROAD semi-truck. Therefore, according to current design practices, this should indicate the same amount of rutting for each lane, which is not the case at MnROAD.

Rutting is occurring the HMA Superpave pavements even though the high temperatures in the pavements have never reached the high-end grade of the asphalt binders, or 58° C. According to SHRP protocol, the mix designs should be rut resistant up to the high-end temperature grade. This inconsistency warrants additional study.

In regards to transverse or thermal cracking, cell # 35 with a PG 58-40 modified asphalt binder has cracked more than the unmodified PG 58-28 test cell and the modified PG 58-34 test cell. While it is uncertain as to whether the cracks are true thermal cracks or cracks caused by the aggregate base, it is known that the lowest pavement temperatures recorded at MnROAD are well above the low-end temperature grade of the PG binders for the three test cells. Again, this inconsistency should be studied.

It is recognized that the SHRP testing protocols for asphalt binders were not established using polymer modified asphalt binders and in fact, they may not be well suited for modified binders. It is this premise that Mn/DOT has begun a national pooled fund study with the University of Minnesota as the lead agency, to address these SHRP protocols and possibly establish new and better test methods. Specifically, the pooled study is looking at the low-end temperature grading for modified asphalt binders since thermal cracking is the number one cause of pavement distress in this part of the country. MnROAD is perfectly situated to be the test site to conduct field-testing of the HMA mix designs that come out of this study.

Worel, Mulvaney & Andersen

List of Figures

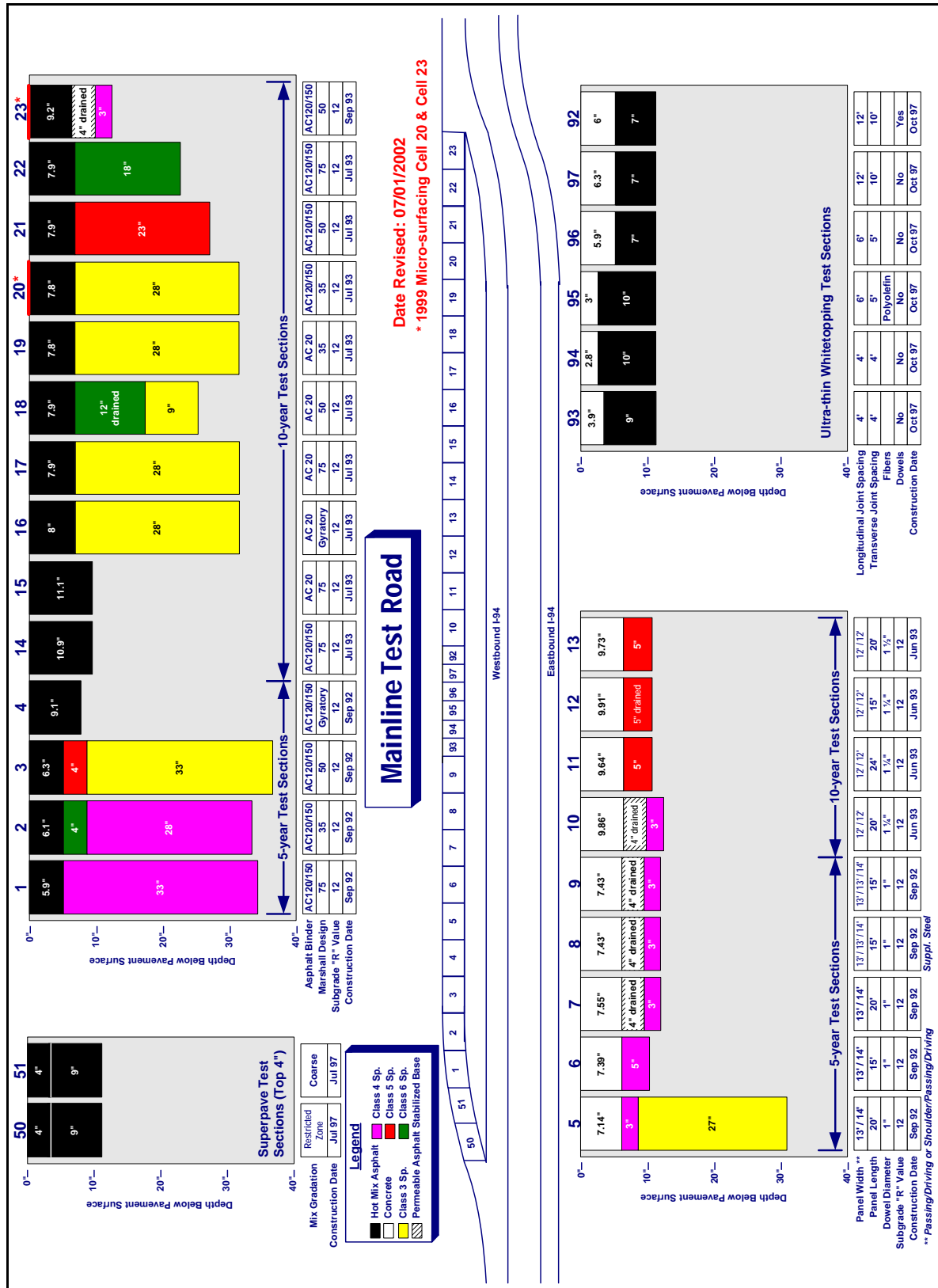
Figure 1 MnROAD Test Cell Layout (Mainline)

Figure 2 MnROAD Test Cell Layout (Low Volume Road)

Figure 4 Cell 33 (PG 58-28) Mix Design

Figure 5 Cell 34 (PG 58-34) Mix Design

Figure 6 Cell 35 (PG 58-40) Mix Design



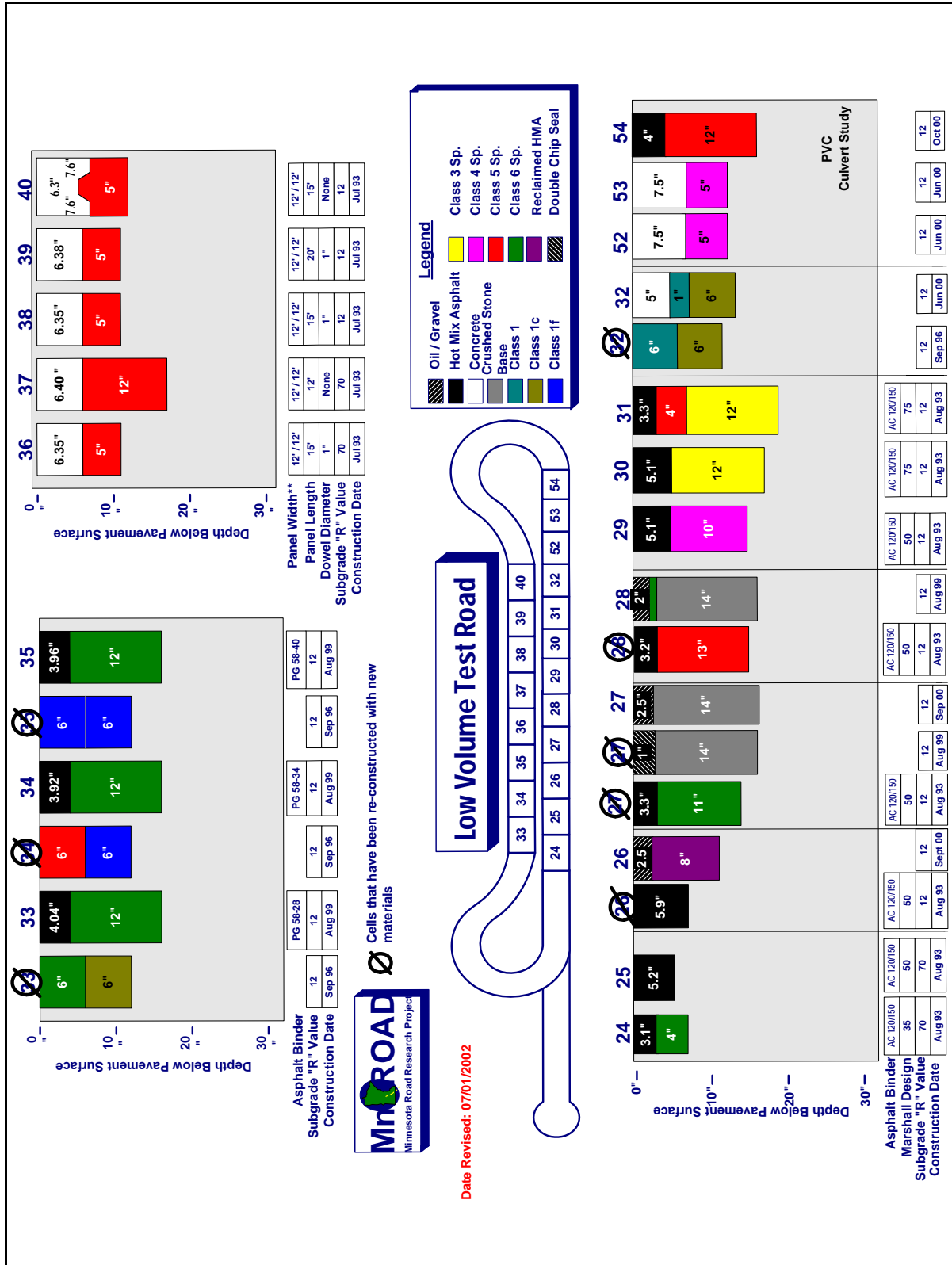


FIGURE 3 MnROAD TEST CELL LAYOUT (Low Volume Road)



BITUMINOUS PLANT RECOMMENDATION

Minnesota Department of Transportation
 Materials and Research Laboratory
 1400 Gervais Avenue
 Maplewood, MN 55109
 Phone: (651) 779-5614
 FAX: (651) 779-5580

#0 - 990274

Date: 8/24/99

To: TIM ANDERSEN Engineer: MN/DOT (MN/ROAD)
 The mix design for Spec. 2360 (1999) Mixture Type SPWEB240C Is hereby approved
 for this project as follows:

STATE PROJ. 8 8 1 6 - 4 0

PLANT NO. 9 0 0 9 0 1 - 9 9 A JOB MIX FORMULA

Begin With Test Number	Sieve Size (mm) (in.)	Composite Formula	WARNING LIMITS	JMF LIMITS	For Information Only Virgin Formula
- - N W - - -	37.5 (1 1/2)		- - -	- - -	P P
	25.0 (1)		- - -	- - -	E A
	19.0 (3/4)	100	- - -	100 - 100	R S
S P W E 3 0 1	12.5 (1/2)	94	- - -	90 - 100	C S
	9.5 (3/8)	86	- - -	79 - 90	E I
	4.75 (#4)	66	- - -	59 - 73	N N
	2.36 (#8)	54	- - -	48 - 58	T G
	0.075 (#200)	4.7	- - -	2.7 - 6.7	
	Spec. Voids	4.0	- - -	2.7 - 5.3	
	Spec. VMA	14.0	-	13.7	
	%AC	5.8	-	5.4	%AC (NEW)
	%AC (TOTAL)			MIN	

TM# 0- 99108 Indicates a Gyrotory Density of 2404.4 (150.1) kg/m³ (lbs/ft³) at 75 Design Gyations
 Use of anti-strip agent required NO

Proportions	Source of Material	Sp.G
12 %	DANNER 3/4" CLASS D ROCK	2.696
20 %	DANNER 1/2" CLASS D ROCK	2.679
23 %	DANNER CRUSHED FINES	2.637
45 %	OTTO PED SAND	2.622
%		
%		
%		

Mix Aggregate Specific Gravity at the Listed Percentages = 2.645
 Remarks: LAB MIXING TEMP. RANGE = 275 - 287°F LAB COMPACTION TEMP. RANGE = 240 - 246°F
 NOTE: TEMPERATURES ARE FOR PG 58-34 KOCH (1999) AC. TEMPERATURES ARE FOR LAB INFORMATION ONLY.

Mix Design approved by:

 Mix Design Specialist

cc:
 Dist. Mat'ls Eng. (Dist. 5 & 9) (2)
 Metro Inspection
 Contractor - BITUMINOUS ROADWAYS #1

FIGURE 5 Cell 34 (PG 58-34) Mix Design



BITUMINOUS PLANT RECOMMENDATION

Minnesota Department of Transportation
 Materials and Research Laboratory
 1400 Gervais Avenue
 Maplewood, MN 55109
 Phone: (651) 779-5614
 FAX: (651) 779-5580

#0 - 990275

Date: **8/24/99**

To: TIM ANDERSEN Engineer: MN/DOT (MN/ROAD)
 The mix design for Spec. 2360 (1999) Mixture Type SPWEB240D Is hereby approved
 for this project as follows:

STATE PROJ. **8 8 1 6 - 4 0**

PLANT NO. **9 0 0 9 0 1 - 9 9 A** JOB MIX FORMULA

Begin With Test Number	Sieve Size (mm) (in.)	Composite Formula	WARNING LIMITS	JMF LIMITS	For Information Only Virgin Formula
- - N W - - -	37.5 (1 1/2)		- - -		P P
	25.0 (1)		- - -		E A
	19.0 (3/4)	100	- - -	100 - 100	R S
S P W E 4 0 1	12.5 (1/2)	94	- - -	90 - 100	C S
	9.5 (3/8)	86	- - -	79 - 90	E I
	4.75 (#4)	66	- - -	59 - 73	N N
	2.36 (#8)	54	- - -	48 - 58	T G
	0.075 (#200)	4.7	- - -	2.7 - 6.7	
	Spec. Voids	4.0	- - -	2.7 - 5.3	
	Spec. VMA	14.0	-	13.7	

%AC 5.8 - **5.4**
 %AC (TOTAL) MIN

TM# 0- **99108** Indicates a Gyrotory Density of **2404.4 (150.1)** kg/m³ (lbs/ft³) at **75** Design Gyration
 Use of anti-strip agent required **NO**

Proportions	Source of Material	Sp.G
12 %	DANNER 3/4" CLASS D ROCK	2.696
20 %	DANNER 1/2" CLASS D ROCK	2.679
23 %	DANNER CRUSHED FINES	2.637
45 %	OTTO PED SAND	2.622
%		
%		
%		

Mix Aggregate Specific Gravity at the Listed Percentages = **2.645**
 Remarks: LAB MIXING TEMP. RANGE = 282 - 294°F LAB COMPACTION TEMP. RANGE = 247 - 258°F
 NOTE: TEMPERATURES ARE FOR PG 58-40 KOCH (1999) AC. TEMPERATURES ARE FOR LAB INFORMATION ONLY.

Mix Design approved by:

 Mix Design Specialist

cc:
 Dist. Mat'ls Eng. (Dist. 5 & 9) (2)
 Metro Inspection
 Contractor - BITUMINOUS ROADWAYS #1

FIGURE 6 Cell 35 (PG 58-40) Mix Design