

# Minnesota Local Road Research Project

## **2004 MnROAD Mesabi Select Hot Mix Asphalt (LRRB Inv. 819)**

Cell-31 Low Volume Road  
Construction Report

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This report documents construction practices observed by the authors and does not necessarily represent the view or policy of the Minnesota Department of Transportation. This report does not contain a standard or specified technique

## **EXECUTIVE SUMMARY**

In a partnership formed with the Minnesota Department of Natural Resources (DNR), the Local Road Research Board (LRRB) investigation 819, the Minnesota Department of Transportation (Mn/DOT), and other partners, MnROAD test cell 31 was reconstructed with a hot mix asphalt (HMA) that contained 80% (by volume) Mesabi Select Hard Rock aggregate. It marked the first asphalt mix of its kind that utilized Mesabi Select Hard Rock aggregate as both the coarse and fine aggregates of the asphalt mix in the twin cities area. The purpose of this test cell is to demonstrate to the industry that Mesabi Select Hard Rock can be used to produce a HMA mixture meeting Mn/DOT specifications. It also demonstrates that the mixture can be placed like other HMA mixtures, and through instrumentation installed at the MnROAD site, its performance can be documented and quantified.

Construction took place on August 19, 2004. Test cell 31 measures 500-ft long by 24-ft wide. Being located within the Low Volume Road (LVR) of MnROAD, the design 20-year ESAL's were 110,000, which resulted in a 4" mat thickness in accordance to MnPAVE software.

Commercial Asphalt Company, Maple Grove, MN performed the mix design for a Mn/DOT designation SPWEB240F. The General Contractor for the project was Frattalone Paving, Inc, St. Paul, MN. Mn/DOT provided construction management and inspection for the construction.

The unique characteristic of the Mesabi Select Hard Rock HMA was its unit weight, which was approximately 160 pounds per cubic foot (pcf), which is about 10% heavier than the typical HMA mix in Minnesota. Because of its increased density and angularity, heavy rollers were specified for its compaction in the field. In order to meet Mn/DOT specifications for a traffic level 2 design, the amount of asphalt binder was 6.4%. A polymer modified PG 64-34 binder was specified to provide rutting resistance and thermal cracking resistance, and to see how this mixture laid down with a modified asphalt binder. The thought is that the Mesabi Select Hard Rock aggregate would be appropriate for higher traffic levels where modified binders are more common.

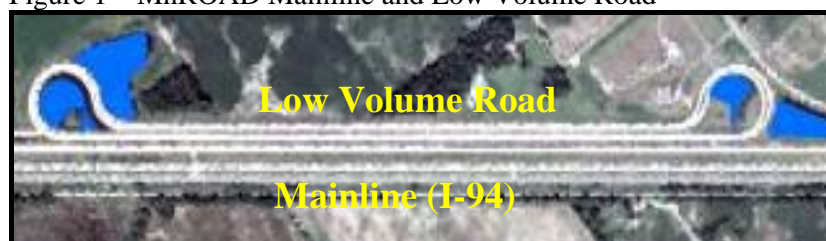
Construction of the Mesabi Select Hard Rock HMA was described as "typical", with a tender zone identified between the 220°F to 180°F range. The only problem that occurred was with the pneumatic rollers, which picked up the HMA because of the rich mixture and lack of time to adequately warm the tires because of the cell's short length.

Mn/DOT will monitor the Mesabi Select Hard Rock test cell for performance and document its rutting, ride, strength and crack formation. A one-year follow-up report will be issued in the fall of 2005.

## 1 MNROAD FACILITY

The Minnesota Department of Transportation (Mn/DOT) constructed the Minnesota Road Research Project (MnROAD) between 1990 and 1994. MnROAD is located along Interstate 94 forty 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 appendix C. Additional information on MnROAD can also be found on its web site at <http://mnroad.dot.state.mn.us/research/mnresearch.asp>.

Figure 1 – MnROAD Mainline and Low Volume Road



### 1.1 Low Volume Road

Parallel and adjacent to Interstate 94 and the Mainline is the Low Volume Road (LVR). The LVR is a 2-lane, 2½-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 on average) for each day and are entered into the MnROAD database.

### 1.2 MnROAD Mainline

The mainline consists of a 3.5-mile 2-lane interstate roadway carrying "live" traffic. Cell design/layout can be found in Appendix-B. 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 14 HMA cells and 9 Portland Cement Concrete (PCC) test cells.

Traffic on the mainline comes from the traveling public on westbound I-94. Typically the mainline traffic is switched to the old I-94 westbound lanes once a month for three days to allow MnROAD researchers to safely collect data. The mainline ESALs are determined from an IRD hydraulic load scale was installed in 1989 and a Kistler quartz sensor installed in 2000. Currently the mainline has received roughly 5 million flexible Equivalent Single Axle Loads (ESALS) and 7.8 million Rigid ESALS as of December 31, 2004.

### 1.3 MnROAD Instrumentation and Performance Database

Data collection at MnROAD is accomplished with a variety of methods to help describe the layers, the pavement response to loads and the environment, and actual pavement performance. Layer data is collected from a number of different types of sensors located throughout the pavement surface and sub-layers, which initially numbered 4,572. Since then we have added to this total with additional installations and sensors types. Data flows from these sensors to several roadside cabinets, which are connected by a fiber optic network that is feed into the MnROAD database for storage and analysis. Data can be requested from the MnROAD database for each sensor along with the performance data that is collected thought the year. This includes ride, distress, rutting, faulting, friction, forensic trenches, material laboratory testing and the sensors measure variables such as temperature, moisture, strain, deflection, and frost depth in the pavement along with so much more.

## 2 CELL-31 EXISTING PAVEMENT CONDITION

Test cell 31 was originally constructed in August 1993. The cell was designed as a 3-year design life cell, following Mn/DOT 2350 specifications for hot mix asphalt. The cell was constructed on a four-inch base of class 5 over a twelve-inch base of class 1 material, over a clay sub-grade. The subgrade design 'R-value' was 12. The average HMA thickness was 3.3-in, and the mix used a 75-blow Marshall design. The asphalt binder was the 120/150 viscosity (PG 58-28) binder. The design Equivalent Single Axle Loads (ESALs) was 110,000.

Traffic was applied to the test cell beginning in 1994 in the form of a MnROAD operated 18-wheel, 5-axle semi tractor-trailer. The loading was applied in a legal load configuration of 80,000-lbs. four days per week and an 'overload' 102,000-lbs. configuration once per week. The legal load limit, or 80K lane, was the inside lane, while the 'overload', or 102K lane, was the outside lane of the test cell. This loading configuration resulted in a similar number of Equivalent Single Axle Loads (ESALs) being applied to each lane and provided researchers a method of quantifying the distresses caused in each lane for the ESALs applied. Through the summer of 2004, the number of ESALs applied on the 80K lane totaled 121,700, and the 102K lane totaled 112,700. The condition of cell-31 was deteriorating rapidly. Fatigue cracking, transverse cracking, rutting, and ride quality had all reached levels that required either extensive repair or reconstruction. Some select patching was performed within the cell during the past two years, typically in the form of full-depth HMA repairs to fill rutting or highly fatigued areas. It was determined that the useful life of cell 31 had come to an end and was therefore chosen for reconstruction using the Mesabi Select Hard Rock HMA.

### 2.1 Cell-31 Pavement Condition (before construction)

Tables 1 through 5 show the pavement performance data (cracking, ride, rutting) for the test cell 31 before this reconstruction effort. More detailed information can be obtained from the MnROAD database its website at <http://mnroad.dot.state.mn.us/research>.

Table 1 - Cell 31 Pre-Construction Fatigue Areas

Lane	Fatigue Low (ft <sup>2</sup> )	Fatigue Med (ft <sup>2</sup> )	Fatigue High (ft <sup>2</sup> )
80K	18	217	50
102K	45	117	49

Definition: Fatigue cracking can be a series of interconnected cracks which develop into many-sided, sharp-angle pieces, characteristically with a chicken wire / alligator pattern in later stages. Severity levels are defined as:

- Low – An area of cracks with no or only a few connecting cracks; cracks are not spalled or sealed; pumping is not evident.
- Medium - An area of interconnected cracks forming a complete pattern; cracks may be slightly spalled; cracks may be sealed; pumping is not evident.
- High – An area of moderately or severely spalled interconnected cracks forming a complete pattern; pieces may move when subjected to traffic; cracks may be sealed; pumping may be evident.

Table 2 - Cell 31 Pre-Construction Transverse cracks

Lane	Transverse (# of Low Sealed)	Transverse (Low Sealed (ft))	Transverse (# of Low)	Transverse (Low (ft))
80K	3	24	6	27
102K	12	72	25	119

Definition: Transverse cracks are predominantly perpendicular to pavement centerline. Severity levels are defined as:

- Low – An unsealed crack with a mean width  $\leq \frac{1}{4}$ " or a sealed crack with a sealant material in good condition and with a width that cannot be determined.
- Medium – Any crack with a mean width  $> \frac{1}{4}$ " and  $\leq \frac{3}{4}$ "; or any crack with a mean width  $\leq \frac{3}{4}$ " and adjacent low severity random cracking.
- High – Any crack with a mean width  $> \frac{3}{4}$ "; or any crack with a mean width  $\leq \frac{3}{4}$ " and adjacent moderate to high severity random cracking.

Table 3 - Cell 31 Pre-Construction Patch Areas

Lane	# of Patches Low	Patch Area Low (ft <sup>2</sup> )	# of Patches Med	Patch Area Med (ft <sup>2</sup> )
80K	7	1640	1	288
102K	1	228	0	0

Definition: Portion of pavement surface, greater than 1 square foot (ft<sup>2</sup>) that has been removed or replaced or additional material applied to the pavement after original construction. Severity levels are defined as:

- Low – Patch has at most low severity distress of any type.
- Medium – Patch has at most moderate severity distress of any type.
- High – Patch has high severity distress of any type.

Table 4 - Cell 31 Pre-Construction Ride Data

Lane	AVG IRI LWP (m/km)	AVG PSR LWP
80K	4.28	1.34
102K	1.86	2.83

Definitions:

- IRI – International Roughness Index, a standardized roughness measurement, which is mathematical measurement of a surface profile using lasers. A perfectly smooth pavement would have an IRI of zero, while a pavement with roughness would have IRI values greater than zero. IRI is measured in meters per kilometer (m/km) and values above 2.5 m/km indicate a poor ride quality that usually requires maintenance activities to correct.
- PSR – Present Serviceability Rating, is Mn/DOT's rating system to measure ride quality and is derived using the IRI value. A PSR between 3.6 and 5.0 indicates a "very good" ride, between 3.2 to 3.6 indicates a "good" ride, between 2.8 and 3.2 indicates a "fair" ride, and anything below 2.8 as a "poor" ride. A PSR of 2.5 or below is used as a 'trigger' value for Mn/DOT maintenance activities.

Table 5 - Cell 31 Pre-Construction Rutting

Lane	AVG Rutting LWP (in)	AVG Rutting RWP (in)
80K	0.4375	0.625
102K	0.3285	0.461

Definition: A rut is a longitudinal surface depression in the wheel path. It may have associated transverse displacement. Severity levels are not applicable. Mn/DOT has set ½” of rutting as a ‘trigger’ value for maintenance.

### 3 CELL-31 CONSTRUCTION

Mn/DOT was approached by the Minnesota Department of Natural Resources, Minerals Coordinating Committee (MCC) to provide a pavement constructed out of hot mix asphalt that utilized Mesabi Select Hard Rock as the mix’s primary aggregate. The goal was to demonstrate that Mesabi Select Hard Rock material could be crushed, transported, and used in the production of an asphalt mixture meeting Mn/DOT specifications.

The MCC had created a partnership that included United Taconite, Ulland Brothers, Cliff-Erie, and Edward Kraemer & Sons to make this aggregate available for research as a pavement material. Commercial Asphalt Companies joined the partnership and provided the asphalt mix design using the aggregate crushed in Eveleth, MN. Mn/DOT became partners by offering advanced instrumentation of the pavement available at its MnROAD test facility.

Mesabi Select Hard Rock comes from the Mesabi Iron Range from a specific taconite layer that is removed from production in order to access taconite with higher iron content. This so-called “waste product” is plentiful in Northern Minnesota and its potential use as a roadway aggregate has great potential as a viable product. Mesabi Select Hard Rock is a very durable hard rock with low absorption qualities, which is desirable for use in roadways.

#### 3.1 Construction using Mesabi Select Hard Rock

MnROAD test cell 31, the Mesabi Select Hard Rock was crushed to make the course and fine aggregate rock fractions of a Superpave, or Gyratory, hot mix asphalt design. The final design of the HMA mixture performed by Commercial Asphalt utilized the following aggregate:

- 45% Mesabi Select Hard Rock - ¾” minus material
- 13% Mesabi Select Hard Rock – 9/16” chip
- 22% Mesabi Select Hard Rock – manufactured washed sand
- 20% #2 screened sand

The mix was to meet Mn/DOT 2004 Specification 2360 for a gyratory, or Superpave, mixture. The final mix design was designated a SPWEB240F, with the asphalt binder specified by Mn/DOT as PG 64-34, a polymer modified binder. Use of the PG 64-34 binder is designed to provide rutting resistance and thermal cracking resistance, and provide Mn/DOT information on how constructalbe this mix is in the field. The thought is that the Mesabi Select Hard Rock aggregate would be appropriate for higher traffic levels where modified binders are more common. The original intent of Mesabi Select Hard Rock was to provide a traffic level 4 (3 to 10 million ESALs) or a traffic level 3 (1 to 3 million ESALs) mixture, but the course aggregate exceeded Mn/DOT’s maximum percentage for flat and elongated particles (Table 2360.3-B2a). Since a traffic level 2 (less than 1 million ESALs) does not have a flat and elongated maximum percentage, the mix was designed accordingly. The design percent asphalt cement was 6.4%. The Bituminous Plant Mix Design Report can be found in Appendix B.

Cell-31 structural design thickness was determined using Minnesota’s MnPAVE flexible design software. It included a 4” HMA Mesabi Hard Rock Select surface with a PG64-34

binder, 12” class-6 special aggregate base (crushed granite) over a clay subgrade with a R-value of 12. Design variables included the materials, Low Volume Road (LVR) traffic ESALS of 110,00 for the 20-year design.

The project was awarded to Frattalone Paving, Inc., St. Paul, MN as part of Local Road Research Board (LRRB) study 819. The contract specified 425 tons of HMA, which Frattalone bid at \$21.87 per ton. Note the unique characteristic of the Mesabi Select Hard Rock HMA will provide less yield due to its unit weight, which was approximately 160 pounds per cubic foot (pcf), or about 10% heavier than the typical HMA mix in Minnesota. The cost for the milling of cell 31 was awarded at \$2.65 per square yard. The cost for paving did not include the design or production of the Mesabi Select HMA. Commercial Asphalt Company provided this work through the partnership with the DNR.

Construction for the milling work took place on August 11, 2004. Construction for the HMA paving took place on August 19, 2004. Both components were completed on time. Table 6 shows the chronological order of activities for the reconstruction of cell # 31.

Table 6 - Construction Summary for Test Cell 31

Date	Activity
8/11/04	Mill test cell, FWD testing, DCP testing, Loadman testing and soil moisture testing performed, cell regraded and compacted. Approximately four cubic yards of class 4 special was added in the transition zone between cells 31 & 32.
8/12/04	MnROAD prepared trenches and cabinet for sensors, thinwall samples taken, U of MN arrives for installation of acoustic emission sensors.
8/17/04	Open standpipe installed, strain gages installed, thermocouples installed, acoustic emission sensors installed, GPR plates installed and district 3 survey crew located all instruments.
8/19/04	Hot mix asphalt paving of test cell 31.

### 3.2 Construction Field Notes

Construction of the Mesabi Select Hard Rock HMA was described as “typical”, with a tender zone identified between the 220°F to 180°F range. The only problem that occurred was with the pneumatic rollers, which picked up the HMA because of the rich mixture and lack of time to adequately warm the tires because of the cell’s short length. Table 7 contains a summary of Mn/DOT’s field notes taken during construction by Chris Cochran and Bill Zerfas. Ron Mulvaney also assisted in documenting the field construction.

Table 7 - Cell 31 Field Notes

Date	Activities Noted
Aug 8 2004	<p><b>6:45 am:</b> Midstate &amp; Frattalone Paving arrive with milling machine, water truck and 3 trucks for hauling millings to MnROAD stockpile area; milling machine has computer controls and a ski for grade and depth of cut.</p> <p><b>7:30 am:</b> milling begins. Frattalone &amp; Mn/DOT check depth of cut, milling depth varies but is close to 4”, outside is high, center is low, 203+00 to the cell 32 (mostly transition area) is very soft and a deeper cut is made.</p> <p><b>10:30 am:</b> milling completed, grade checked &amp; staked by Frattalone; it is believed we might be short of material for grading; we will haul material from MnROAD stockpile if necessary (we wish to avoid adding different base material).</p> <p><b>11:00 am:</b> Chris Nadeau arrives to test base with FWD before grading and compaction; Frattalone brings steel roller, power broom &amp; bobcat.</p> <p><b>12:30 pm:</b> Midstate hauling material off site; Frattalone grader to arrive shortly (after testing is complete); grading and compaction to be completed this afternoon &amp; evening.</p> <p>Also: Mulvaney has arranged to have sensors surveyed in, Cochran has agreed to help Stromen and Doug place sensors Thursday (we hope to get all sensors placed in one day); Cochran &amp; Mulvaney have taken</p>

	<p>pictures and more detailed notes in log about equipment used.</p> <p><b>1:30 pm:</b> FWD testing by Nadeau &amp; Larson done.</p> <p><b>2:00 pm:</b> Frattalone grader arrives.</p> <p><b>2:30 pm:</b> DCP, Loadman, &amp; soil moisture testing by Siekmeier, Roberson, Johnson, and Cochran.</p> <p><b>2:45 pm:</b> Midstates arrives to pick up milling machine.</p> <p><b>3:00 pm:</b> Cochran measures milled area at 26.6' x 558.5', Doug arrives with a load of base material from MnROAD stockpile, waiting for arrival of grader operator. One truckload, approx. 4 yards of class 4 special added to 203+00 to 31/32 end point. Doug also hauled away one final load of millings to stockpile.</p> <p><b>4:00 to 4:45 pm:</b> Grading by Frattalone</p> <p><b>4:45 to 5:05 pm:</b> Rolling</p> <p><b>5:05 to 5:30 pm:</b> Final Grading</p> <p><b>5:30 to 6:00 pm:</b> Handwork &amp; final rolling. Trenches not cut to avoid unnecessary repair work. MnROAD capable of cutting trenches if needed. According to operator, cell 31 graded at 0.02 with taper at either end to match in-place pavements. I was not equipped to check cross slope.</p> <p>Existing pavement thickness:</p> <table border="1"> <thead> <tr> <th>Station</th> <th>Right</th> <th>Left (as you are going up station)</th> </tr> </thead> <tbody> <tr> <td>203+00</td> <td>5.6"</td> <td>4.8"</td> </tr> <tr> <td>202+00</td> <td>3.0"</td> <td>3.1"</td> </tr> <tr> <td>201+00</td> <td>2.6"</td> <td>2.4"</td> </tr> <tr> <td>200+00</td> <td>2.5"</td> <td>2.9"</td> </tr> <tr> <td>199+00</td> <td>2.6"</td> <td>2.6"</td> </tr> <tr> <td>198+00</td> <td>2.3"</td> <td>2.6"</td> </tr> </tbody> </table> <p>Grade (top of base) to finished grade of shld offset 13.3' (top of bit shld at fogline):</p> <table border="1"> <thead> <tr> <th>Station</th> <th>Right</th> <th>Left (as you are going up station)</th> </tr> </thead> <tbody> <tr> <td>203+00</td> <td>3.7"</td> <td>4.1"</td> </tr> <tr> <td>202+00</td> <td>4.2"</td> <td>3.8"</td> </tr> <tr> <td>201+00</td> <td>4.0"</td> <td>4.3"</td> </tr> <tr> <td>200+00</td> <td>4.2"</td> <td>4.1"</td> </tr> <tr> <td>199+00</td> <td>3.6"</td> <td>4.1"</td> </tr> <tr> <td>198+00</td> <td>3.6"</td> <td>4.1"</td> </tr> </tbody> </table> <p>one foot elevation difference from 31/32 to 30/31 (high end) soil moisture samples delivered to Maplewood Research Lab.</p>	Station	Right	Left (as you are going up station)	203+00	5.6"	4.8"	202+00	3.0"	3.1"	201+00	2.6"	2.4"	200+00	2.5"	2.9"	199+00	2.6"	2.6"	198+00	2.3"	2.6"	Station	Right	Left (as you are going up station)	203+00	3.7"	4.1"	202+00	4.2"	3.8"	201+00	4.0"	4.3"	200+00	4.2"	4.1"	199+00	3.6"	4.1"	198+00	3.6"	4.1"
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Aug 12 2004	<p><b>AM:</b> Cochran, Doug &amp; Strommen prepared trenches for cabinet installation of sensors. Drill Crew (Zerwas &amp; Winter) and Roberson, E. Johnson collect thinwall samples.</p> <p><b>PM:</b> Cochran, Doug, Strommen, Dai, Zollers, Prof Labuz, and two U of MN students install sensors, final adjustments will be needed. More collection of thinwalls.</p> <p><b>4:30 pm:</b> Stopped Work</p> <p>Thinwalls delivered to Maplewood Research Lab.</p> <p>Thinwall collection complete, thermocouple tree &amp; open standpipe yet to be installed.</p>																																										
Aug 17 2004	<p>The open standpipe was installed, final wiring to be completed on 8/18.</p> <p>The six strain gauges were installed, three each in the outside wheelpath of both the 80K &amp; 102K lanes.</p> <p>The thermocouple tree was installed between the wheelpaths of the 80K lane.</p> <p>The acoustic emission sensors were installed in the 102K lane.</p> <p>The GPR plates were installed on top of the base material in two locations.</p> <p>D-3 Survey crew located all of the above sensors with GPS coordinates; they will forward us with the data.</p>																																										
Aug 19 2004	<p><b>6:35 am:</b> Start rolling with CC21 DynaPac roller.</p> <p><b>7:00 am:</b> tack sidewalls of shoulder with CSS-1h tack.</p> <p><b>7:21 am:</b> HMA trucks arrive.</p> <p><b>7:26 am:</b> Start HMA paving, start at west end of the 80K lane. (CAT AP-1055B)</p> <p><b>8:53 am:</b> end pass one. Pass 1 notes: some mat slippage between temps 220 to 190, stay off mats in next lifts. Pneumatic roller having a lot of mat sticking to it, do not use for next lifts.</p> <p><b>9:05 am:</b> Pass 2 starts and ends at 10:20 am.</p> <p>Applied tack coat to pass 1 with CSS-1h for pass 3.</p> <p><b>10:30 am:</b> Pass 3 starts and ends at 11:39 am.</p> <p>Applied tack coat to pass 2 with CSS-1h for pass 4.</p> <p><b>11:52 am:</b> Pass 4 starts and ends at 1:00 pm.</p>																																										

	HMA temps behind paver between 275°F and 300°F. Place around 400 tons of HMA. Steel Roller (CAT CB-634C); pneumatic roller (CAT PS-150B); finish roller (Bomag BW 141 AD-2) <b>1:30 pm:</b> Finish roller complete. Trenches patched. Frattalone did a good job in working their paver around sensors placed within cell. Could have used one more transport truck, each pass ended about ½ truck short, resulting in a paver stop near the transition of cell 32/31. {Used 5 trucks, needed 6.} MnROAD will take cores.
Aug 20 2004	D-3 Survey Crew located sensors and surveyed in-place HMA.

### 3.3 Pre-Paving Base and Subgrade Testing Results

The following Dynamic Cone Penetrometer (DCP) data on the base material was collected at Cell 31 prior to paving due to concerns that the base and the subgrade did not have consistent strength throughout the 500 test cell. Tables 8-9 show the locations which DCP testing was completed. Appendix A.1 graphically shows the DCP base and sub-grade results. The DCP testing showed a relatively uniform base material and subgrade material throughout the entire length of the cell.

Table 8 - Cell 31 DCP Testing Location and Moisture Content in 80K Lane

Lane	Stationing				
	20250	20200	20100	19950	19850
80K	9' offset	9' offset	9' offset	9' offset	9' offset
Moisture	6.0%	5.7%	5.7%	5.1%	6.3%

Table 9 - Cell 31 DCP Testing Location and Moisture Content in 102K Lane

Lane	Stationing				
	20250	20150	20100	20000	19900
102K	9' offset	9' offset	9' offset	9' offset	9' offset
Moisture	6.0%	4.9%	5.7%	5.0%	5.5%

Falling Weight Deflectometer (FWD) testing was also performed at regular intervals on cell-31 in accordance to MnROAD's procedures. The last FWD prior to reconstruction occurred on August 11, 2004 after the old hot mix asphalt surface had been removed in preparation for the new taconite Superpave surface. Table 10 shows the location of the FWD testing performed on August 11, 2004. The class-5 base FWD data showed a fairly consistent unbound base and subgrade material that did not need any corrective action before the new taconite Superpave surface was constructed. See Figure-A.2 and A.3 in Appendix A, the raw data is located in the MnROAD database.

Table 10 - Cell 31 FWD Testing Locations

Lane	Offset	Testing
80K	9' offset	Every 50' +1 test 10' away from the original 50' test (20 points total)
102K	9' offset	Every 50' +1 test 10' away from the original 50' test (20 points total)

### 3.4 Sensors and Data Collection Systems Installed

Sensors were installed in this test cell as with the rest of the MnROAD test cells. Information will be collected relating to temperature, strains, water table, acoustic emission throughout the pavement's life. Table 11 lists the equipment installed in test cell-31.

Table 11 - Cell 31 Sensors Installed

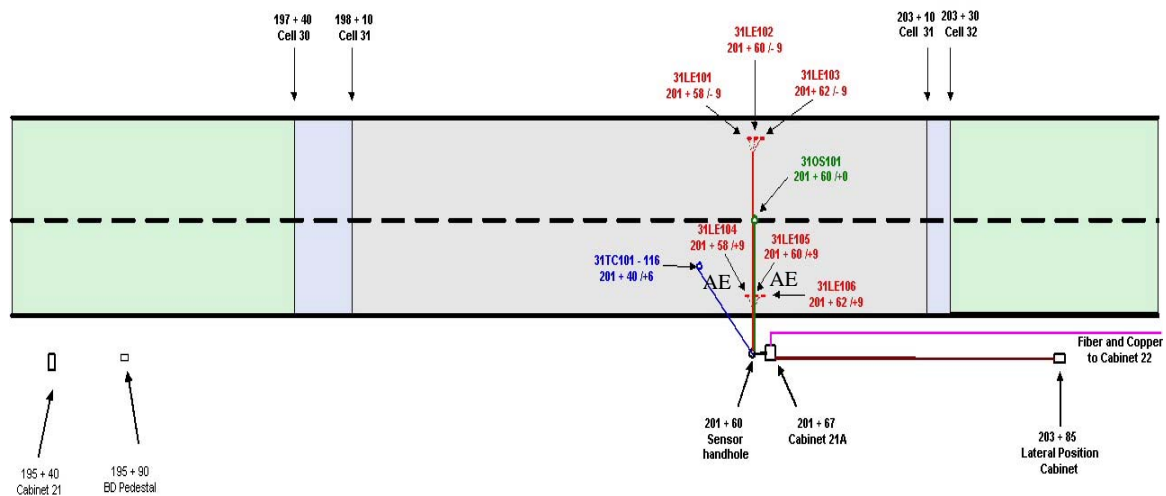
Cell	Sensor Type	# of Sensors	# of Locations
31	TC	12	1
	OS	1	1
	LE	6	2
	AE	2	2
	GPR	2	2

**Sensor Type Codes / (Use)**

- TC Thermal Couple
- OS Open Stand Pipe  
(measures the location of the water table)
- LE Longitudinal Strain Gauge  
(measures the strain at the bottom of HMA)
- AE Acoustic Emission Sensors  
(measures the formation of cracks in HMA)
- GPR Ground Penetrating Radar plates  
(plates installed at bottom of HMA mat)

Figure 2, shows the approximate location of the longitudinal strain gauges, the open standpipe and the thermal couple sensors placed within cell 31. Note the University of Minnesota is working with the acoustic Emissio (AE) sensors placed at MnROAD. They want to listen to the pavement as it cracks in low temperatures, as they have demonstrated in the laboratory. The AE sensors locations were added later to Figure 2. The AE sensors were installed in the wheelpaths near the thermo couples.

Figure 2 – Cell 31 Sensor Layout



### 3.5 Construction Samples Taken

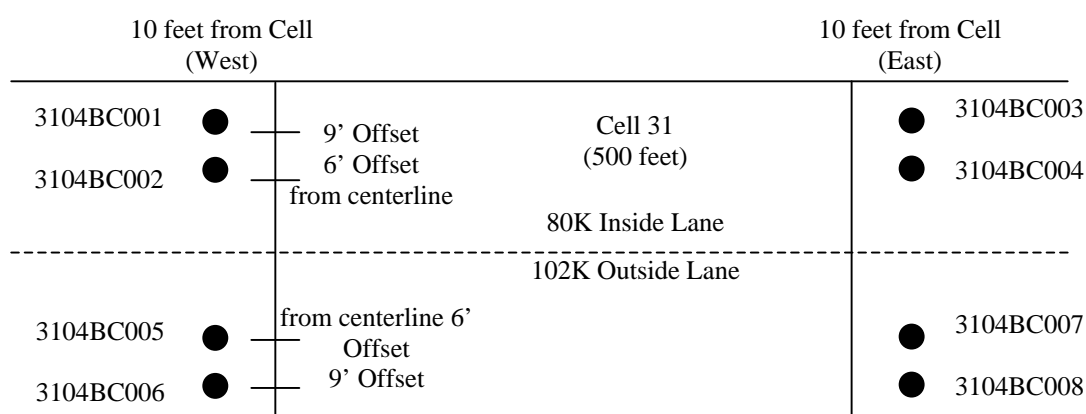
The following samples were taken during construction and are shown in Table 12. Some of these samples will be tested and shown in Table 13-14 and other samples will be stored for future researchers needs.

Table 12 - Cell 31 Material Samples

Sample Material	Sample Numbers	Number – Type of Samples	Storage Location
HMA (Binder)	3104AC001 - 006	(6) - 5 Gallon Buckets	MnROAD Pole Barn
HMA (Mix)	3104AC001 - 024	(24) - 5 Gallon Buckets	MnROAD Pole Barn
HMA (Mix)	3104AC025 - 026	(2) Cylinder molds	Metro Inspection
HMA Aggregate (Mesabi Select ¾" minus)	N/A	Stock Pile	MnROAD
HMA Aggregate (Mesabi Select 9/16" Chip)	N/A	Stock Pile	MnROAD
HMA Aggregate (Mesabi Select manufactured washed sand)	N/A	Stock Pile	MnROAD
HMA (Cores)	3104BC001 - 008	6" Cores	Maplewood Lab
Subgrade (Surface Moisture)	3104MS001 - 010	Quart Buckets	Maplewood Lab
Subgrade (Sub-surface Moisture)	3104TW001 - 021	Thinwalls	Maplewood Lab
Subgrade (Sub-surface Moisture/Resilient Modulus)	3104TW022 - 036	Thinwalls	Maplewood Lab

Figure 2 shows the core location of the eight HMA cores taken in cell 31. Station at the western coring is 198+00, station at the eastern coring is 203+20. It should be noted that both locations are in the transition area of the cell and that in-place density of these cores may not be representative of the entire cell.

Figure 3 - Cell 31 HMA Core Locations



### 3.6 Construction Testing Results

Tables 13 and 14 show the results of the construction testing performed during this study. Mn/DOT measured the relative density of the HMA with a Seaman Model C-200 nuclear gage on August 23, 2004. (Note, the Contractor did not supply a nuclear gage for density checking

during construction). The results of the testing are shown in table 14, with results shown with companion cores and within the test cell. The calibration factor is (-6.2).

Table 13 - Cell 31 HMA Aggregate Gradations

Sieve	Requirements		Mesabi Select Average
	Min	Max	
¾"	100	100	100
½"	88	100	96
3/8"	77	90	85
# 4	59	73	65
# 8	40	52	45
# 200	2.0	5.5	4.7
Sample type	Verification		

Table 14 - Cell 31 HMA Testing Results

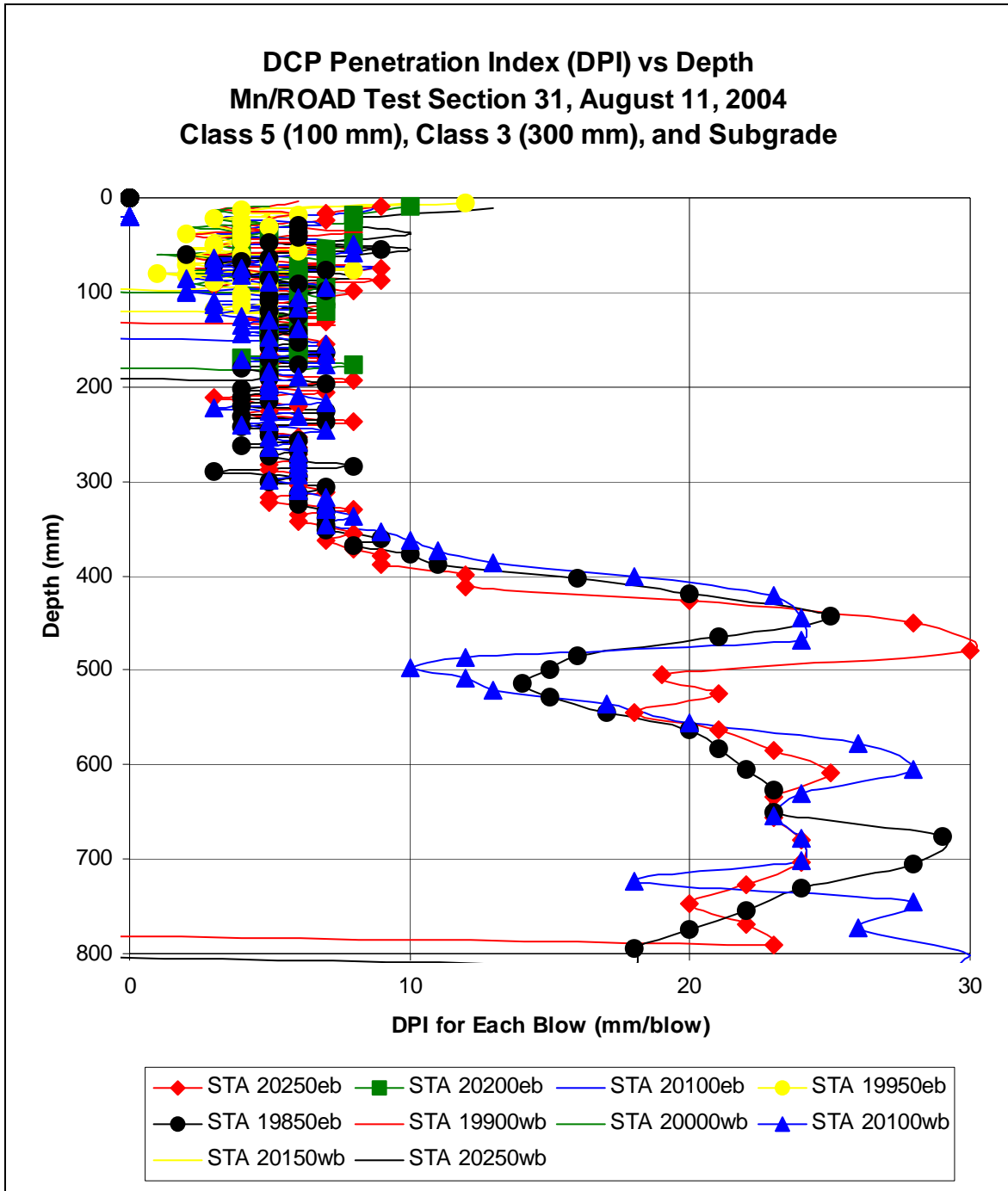
Material	Test		Required		Ave.	# of	Sample/Test
			Min	Max			
PG 64-34 HMA	Relative Density	Top lift			91.3%	8	Cores from test cell
		Bot lift			92.8%	8	Cores from test cell
PG 64-34 HMA	Relative Density, companion		-	-	91.0%	12	Seaman Model C-200
PG 64-34 HMA	Relative Density, within cell		-	-	92.7%	24	Seaman Model C-200
PG 64-34 HMA	Pavement Thickness		4" design	4½" to 5"		8	Cores from test cell
PG 64-34 HMA	% AC				6.1%	2	Incinerator & Extraction
PG 64-34 HMA	Lottman		75%	-	87.1%	3	Mix from plant
PG 64-34 HMA	SHRP PG Grade		PG 65.3-34.1		PG 65.2-34.2		DSR & BBR
PG 64-34 HMA	Bulk Specific Gravity		-	-	2.512	8	Mix from plant
PG 64-34 HMA	Max. Specific Gravity		-	-	2.659	8	Mix from plant
PG 64-34 HMA	Course Aggregate Angularity		30%	-	100%		Mix from plant
PG 64-34 HMA	Fine Aggregate Angularity		40%	-	46.6		Mix from plant
PG 64-34 HMA	Production Air Voids		4%	-	6.8%		Mix from plant
PG 64-34 HMA	Voids in Mineral Aggregate		14.0	-	19.7		Mix from plant

4 FUTURE WORK

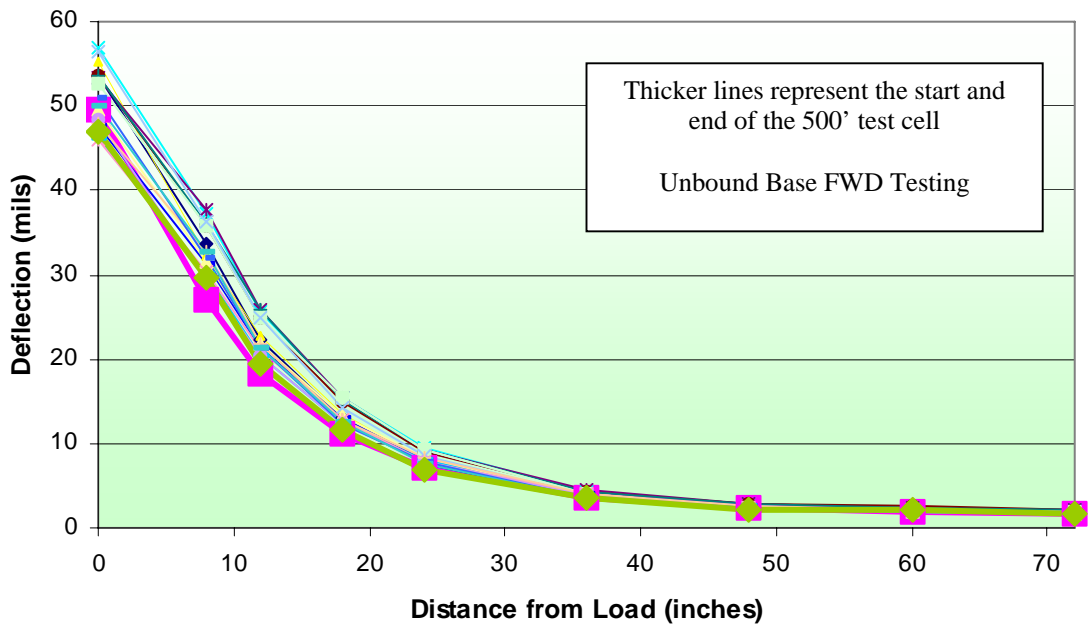
Mn/ROAD will monitor the performance of test cell # 31 in the same fashion as the other test cells at the site. Data will be collected daily from the instrumentation placed within the test cell and observations of the test cell will occur monthly. A one-year report on the performance of the Mesabi Select Hard Rock test cell will be written in the fall of 2005.

APPENDIX A – DCP and FWD Subgrade Testing

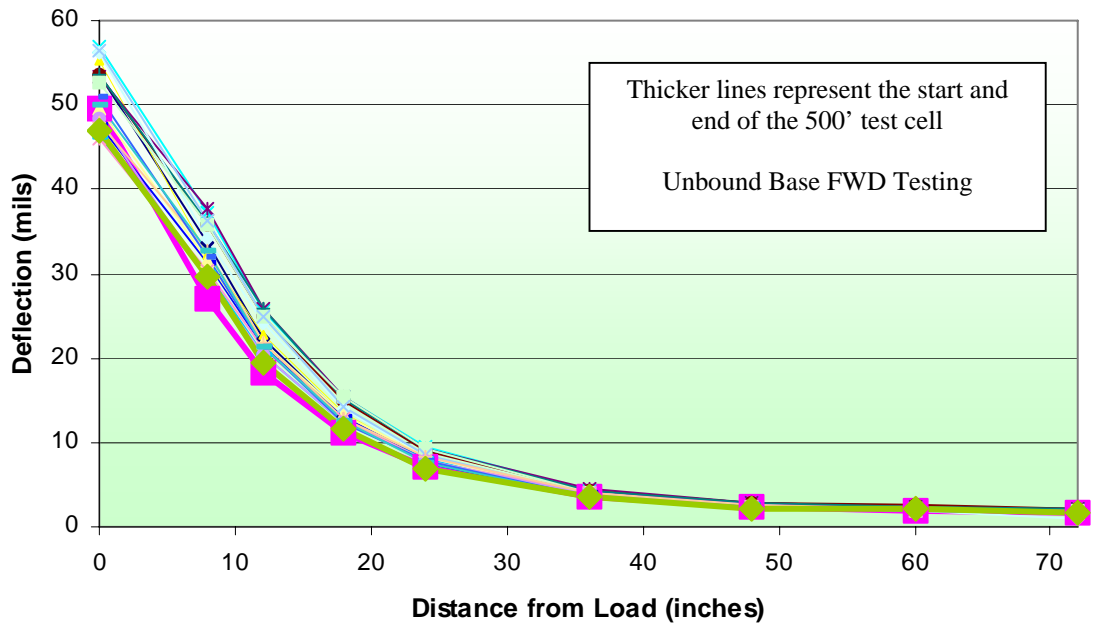
Appendix A1 - Cell 31 DCP Subgrade Testing Results



Appendix A2 – FWD Deflections on the unbound Class-5 Base (80K Lane)



Appendix A3 - FWD Deflections on the unbound Class-5 Base (102K Lane)



APPENDIX B - BITUMINOUS PLANT MIX DESIGN REPORT

Appendix B1 - SPWEB240F - Cell 31 - August 2, 2004



**BITUMINOUS PLANT MIX DESIGN REPORT**

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

# 0-2004-259

Date: 8/2/04

THIS MIX DESIGN REPORT IS NOT VALID UNTIL PLANT NO. INDICATED BELOW IS CERTIFIED.

TO BE FILLED IN BY CONTRACTOR	
ENGINEER	FOR
PROJECT NUMBER	
CONTRACTOR SIGN.	
FOR ALL STATE, COUNTY, AND CITY PROJECTS, CONTRACTORS MUST FAX A COPY TO MN/DOT TWO WORKING DAYS PRIOR TO PRODUCTION AT (651) 779-5580	

SPEC	2360
SPEC YEAR	2004
MIX TYPE	SPWEB240
AC GRADE	PER PROPOSAL

THIS MIXTURE HAS BEEN REVIEWED FOR VOLUMETRIC PROPERTIES ONLY, IT DOES NOT ASSURE THAT FIELD PLACEMENT AND COMPACTION REQUIREMENTS HAVE BEEN MET.

PLANT NO. 901204 - 2004A JOB MIX FORMULA

Begin With Test Number			
SP	WE	201	
--	--	--	--

Sieve Size (mm) (in.)	Composite Formula
37.5 (1 1/2)	
25.0 (1)	
19.0 (3/4)	100
12.5 (1/2)	95
9.5 (3/8)	84
4.75 (#4)	66
2.36 (#8)	46
0.075 (#200)	3.5
Spec. Voids	4.0
Spec. VMA	14.0
% AC	6.4

JMF LIMITS	
100	100
88	100
77	90
59	73
40	52
2.0	5.5
3.0	5.0
13.7	
6.0	

For Information Only Virgin Formula

P	P
E	A
R	S
C	S
E	I
N	N
T	G
%AC (NEW)	

(TOTAL)

TM # 0-2004-085 Indicates a Gyrotory Density of 159.4 (lbs/ft3) at 40 Design Gytrations  
 Use of anti-strip agent required: N

Proportions	Source of Material	Sp.G
45 %	MESABI 3/4" MINUS	2.994
13 %	MESABI 9/16" CHIP	3.094
22 %	MESABI MANUFACTURED WASHED SAND	3.013
20 %	BARTON ELK RIVER #2 SCREENED SAND PIT #71059	2.650
%		
%		
%		
%		

Mix Aggregate Specific Gravity at the Listed Percentages = 2.934

FOR LAB INFORMATION ONLY: LAB MIXING TEMP. RANGE = 294-306 °F LAB COMPACTION TEMP. RANGE = 257-265 °F

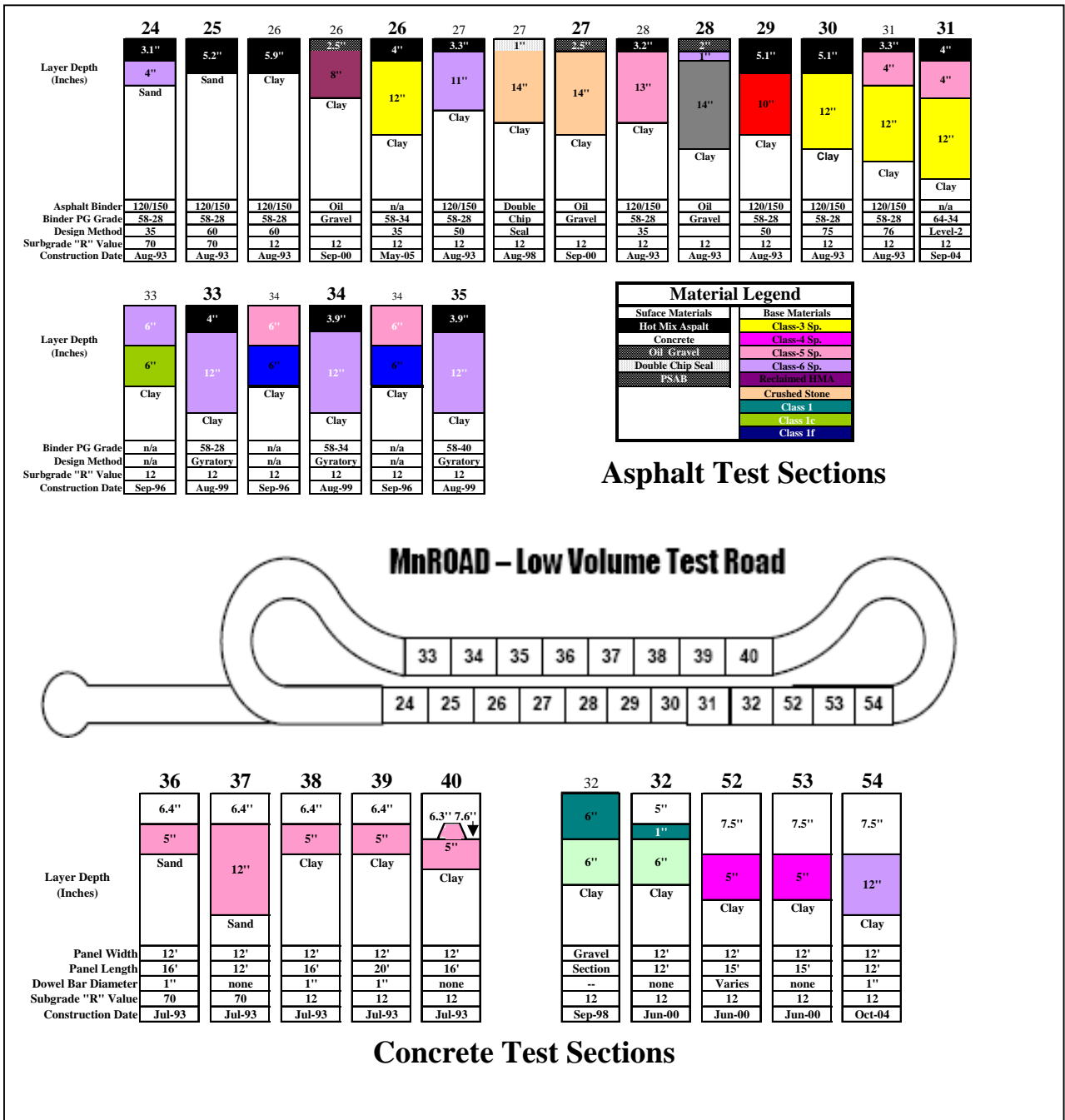
Remarks MINUS #4 AGGREGATE SPG'S AT THE LISTED PERCENTAGES = 2.910. TEMPERATURES ARE FOR PG 64-34 KOCH AC.

Mix Design Reviewed by:  
  
 Mix Design Specialist

cc:  
 Dist. Mat'ls Eng. Metro East & West (2)  
 Contractor - COMMERCIAL ASPHALT #4  
 METRO INSPECTION

# APPENDIX C - MNROAD TEST CELLS

## Appendix C1 – Low Volume Road Test Sections



## Appendix C2 – Mainline Test Sections

