STEARNS COUNTY SUPERPAVE RESEARCH PROJECT 1996

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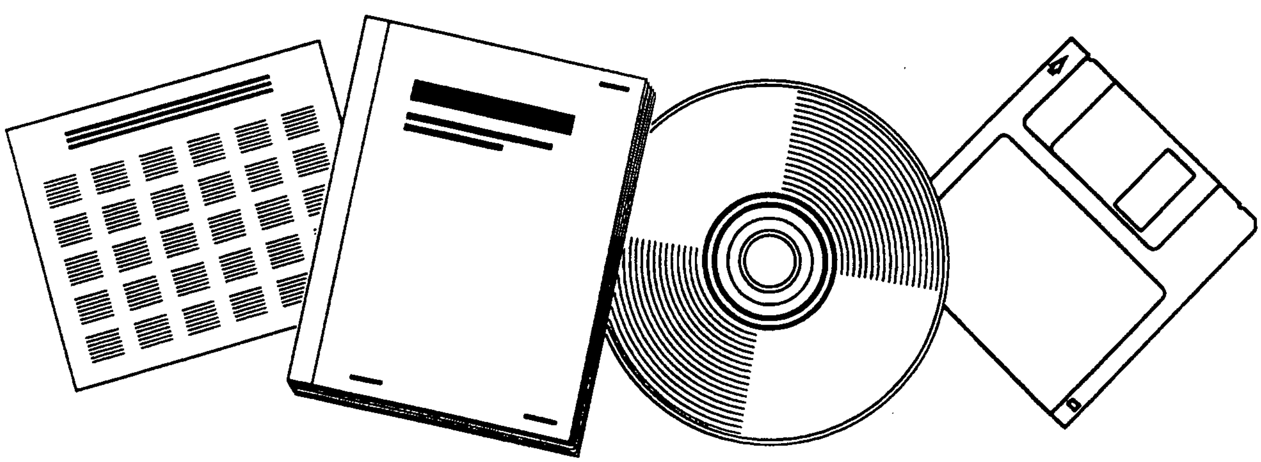

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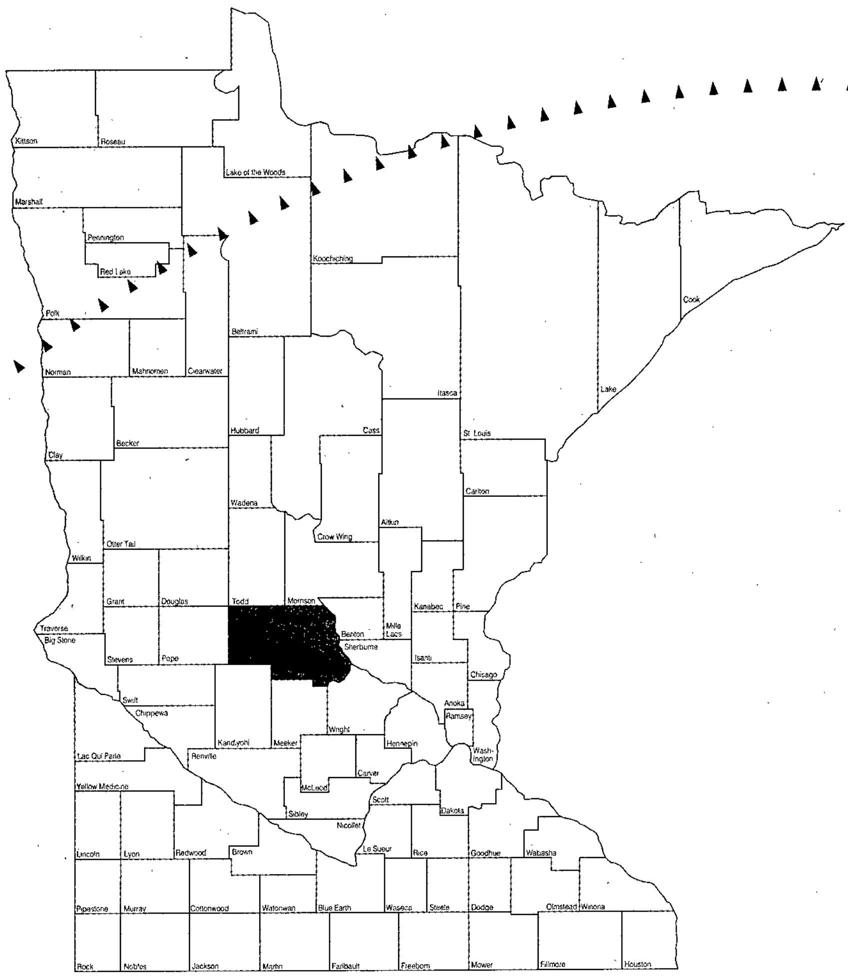

1996 Stearns County Superpave Research Project

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16. Abstract (Limit: 200 words)

During 1996, Stearns County constructed eight asphalt pavement test sections on C.S.A.H. near St. Cloud, Minn., with six test sections composed of Superpave wear courses and two others composed of Mn/DOT traditional mixes.

The six sections included two coarse Superpave mix designs with a 19.0 mm nominal maximum aggregate size. One Superpave mix design included polymer modified PG 58-34 asphalt binder and the other one used a traditional 120/150 pen graded asphalt, which tested as a PG 58-28. The PG 58-34 Superpave mix was used in the wear and binder courses in one location and just in the wear coarse in the adjacent section. The PG 58-28 Superpave mix only was used in the wear course. Then, portions of the three Superpave areas were sawed and sealed to create six sections.

The surface texture of the two Mn/DOT sections was much tighter than the Superpave wear courses. The Mn/DOT wear courses required 1 percent more asphalt binder than the Superpave mixes. The construction of the project proved successful and future project evaluation will provide information about saw and seal, appropriate PG grades, and the performance of Superpave mixtures in the pavement structure at various depths.

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1996 Stearns County Superpave Research Project

Final Report

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All contractor personnel for their assistance during the project.

<u>The list of people below had preliminary design and construction input into this project</u>:

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I. Executive Summary

In 1987, the Strategic Highway Research Program (SHRP) began developing the Superior Performing Asphalt Pavements (SUPERPAVE ™) system. The five year, $50 million research effort created a new way of specifying testing and design for asphalt materials. Superpave is not only a computer program, but also an improved system for specifying component materials, pavement performance predictions, asphalt mixture design and analysis.

Some of the new Superpave criteria are as follows:

- The Gyratory Compactor replaces the Marshall Hammer.
- AASHTO tests T-166 (bulk specific gravity), T-209 (Rice), and ASTM-D4867 (Modified Lottman) provide part of the data required for design.
- Incorporation of volumetric mix design properties into field quality control and quality assurance systems can help identify mix-related problems.
- Testing involves; Voids in Total Mix (VTM), Voids in Mineral Aggregate (VMA), Voids filled with asphalt (VFA), and Fines to Effective Asphalt ratio (F/A).
- Compaction effort is determined based on average high air temperatures and estimated traffic levels at the project location.

The Stearns County Engineer, Doug Weiszhaar, was interested in constructing an asphalt pavement using Superpave Technology. Based on pavement distresses experienced on existing asphalt pavements, Stearns County personnel decided to evaluate the Superpave technology at C.S.A.H. 75. This highway has some of the highest traffic volumes in the county. During August of 1996, the Minnesota Department of Transportation (Mn/DOT) and the Asphalt Institute provided Superpave Volumetric Mix Design testing for Stearns County on the westbound lanes. Additional paving was completed in September on the eastbound lanes and the Quality Control testing was provided by Mn/DOT. Eight test sections were constructed to compare Superpave to current practices used in Minnesota. This comparison is an ongoing study at the time of this publication.

II. Introduction

This section of C.S.A.H. 75 is a four lane divided highway located west of St. Cloud. The project passes through the town of St. Joseph and its length is 5.8 miles which results in 11.6 miles of two lane roadway. The traffic level is about 3 million ESALs.

A. Pavement History and Current Conditions

C.S.A.H. 75 is a four-lane rural arterial section with 61.0 to 70.1 meters (200 to 230 feet) of right-of-way and a design speed of 95 kilometers per hour (60 miles per hour). Although the facility's current functional classification transitions from principle to minor arterial west of the Sauk River, the entire section of roadway is designed as a principle arterial in the St. Cloud area.

C.S.A.H. 75 from Interstate 94 to C.S.A.H. 81 is a four-lane asphalt roadway without curb, gutter, or sidewalks. The shoulder-to-shoulder width of the cross section is 36.3 meters (119 feet). Included in both directions of this cross section are two 3.7 meter (12 foot) travel lanes, a 3.0 meter (10 foot) outside shoulder, and a 0.9 meter (3 foot) inside shoulder. There are open type ditch medians on the majority of the project. C.S.A.H. 75 is generally flat, straight, and orientated in and east/west direction. Fronting development is mixed between commercial, residential, industrial, and retail.

The soil borings at the sampled locations indicate generally good base and subgrade conditions. The primary soil encountered was sand and gravel mixed in the upper three to four feet. The borings indicate that the soils were generally in a moist condition. Due to the fact that the soils encountered are considered to be free draining and the water table doesn't appear to approach the subgrade surface, it indicates that the groundwater conditions aren't a significant contributing factor in the stripping of the asphalt layers which was noted during the pre-design soils and pavement investigation. There is no sub-surface drainage system in place.

This road was originally graded in 1955. The re-construction in 1996 was required because the previous pavement had experienced stripping, thermal cracking, ride problems, and required continuous maintenance.

B. Traffic Conditions

The design Equivalent Single Axle Loads (ESALs) for the project were determined to be about 3 million ESALS. This chosen design requirements were for the 1-3 million ESALs category. The Superpave mixture design and analysis system requires performance prediction testing to be conducted when traffic levels are between one and ten million ESALs. Since Mn/DOT doesn't have this testing equipment, a Superpave volumetric mix design was utilized.

C. Layout of Test Sections

A total of eight test sections were constructed. Four sections were constructed in the westbound lanes and four in the eastbound lanes. The test sections included a variety of combinations of Superpave and Mn/DOT mixes of varying thicknesses. Four of the test sections employed saw and seal techniques to evaluate thermal cracking relief. See Figure 1 for a layout of test sections and Table 1 for the mix descriptions and prices.

Table 1: Project Mix Descriptions

Mix Descriptions	Asphalt Binder Type	Asphalt Binder Content	RAP %	Price
Superpave Wear	PG 58-34	5.0%	0%	$24.93 / ton
Superpave Binder	PG 58-34	5.0%	0%	$25.28 / ton
Superpave Wear	PG 58-28	5.0%	0%	$15.06 / ton
47A Wear	PG 58-28	6.0%	0%	$15.06 / ton
47B Binder	PG 58-28	5.9%	0%	$14.64 / ton
42B Binder	** PG 58-28	5.9%	30%	$11.24 / ton
32B Base	** PG 58-28	5.9%	50%	$10.00 / ton
32B Shoulder	** PG 58-28	5.9%	50%	$10.00 / ton

** Grade of "add oil" used for RAP mixtures.

Note: In all of the tables in this report, a shaded box represents an area of concern or interest.

Figure 1: Research Pavement Sections. W.B. C.S.A.H. 75

	1759+00 – 1802+20 (2.5" S & S All the Way Across the Road)	1802+20 – 1878+90 (1835+50 St. Joseph 1876+00)
1.5" Wear Course	Superpave 5.0% PG 58–34	Superpave 5.0% PG 58–34
1.5" Binder Course	42B 5.9% PG 58–28	42B 5.9% PG 58–28
3.0" Base Course	32B 5.9% PG 58–28	32B 5.9% PG 58–28
	40' Saw and Seal	None
SECTIONS	1WB	2WB

	1878+90 – 1922+10 (Double Cut S & S 1895+30)	1922+10 – 2063+95	
	Superpave 5.0% PG 58–34	Superpave 5.0% PG 58–34	2.0" Wear Course
	Superpave 5.0% PG 58–34	Superpave 5.0% PG 58–34	2.0" Binder Course
	32B 5.9% PG 58–28	32B 5.9% PG 58–28	2.5" Base Course
	40' Saw and Seal	None	
SECTIONS	3WB	4WB	

A = 1/2" mix
B = 3/4" mix
None = No Saw and Seal

E.B. C.S.A.H. 75

	1759+00 – 1785+50	1785+50 – 1812+00	1812+00 – 1878+90 (1835+50 St. Joseph 1876+00)
1.5" Wear Course	Superpave 5.0% PG 58–28	Superpave 5.0% PG 58–28	47A 6.0% PG 58–28
1.5" Binder Course	42B 5.9% PG 58–28	42B 5.9% PG 58–28	42B 5.9% PG 58–28
3.0" Base Course	32B 5.9% PG 58–28	32B 5.9% PG 58–28	32B 5.9% PG 58–28
	40' Saw and Seal	None	None
SECTIONS	1EB	2EB	3EB

	1878+90 – 2063+95	
	47A 6.0% PG 58–28	2.0" Wear Course
	47B 5.9% PG 58–28	2.0" Binder Course
	32B 5.9% PG 58–28	2.5" Base Course
	40' Saw and Seal	
SECTIONS	4EB	

NOTE: 3WB, 1EB, & 4EB have a 4" deep S & S that goes 1' into the shoulder.

III. Asphalt Binder Selection

Mn/DOT provided $100,000 of funding to Stearns County for the use of polymer modified asphalt binders. Based on asphalt materials typically used in Minnesota, a PG 58-34 grade was chosen to result in a polymer modified asphalt binder. See Table 2 for project environmental conditions from SHRP Superpave Binder Selection Software Version 2.0. For the asphalt binder used on the remainder of this project, Stearns County specified a 120/150 penetration graded material. The asphalt binder tests performed on the 120/150 material indicated a performance grading of PG 58-28.

Table 2: Project Environmental Conditions

(Collegeville St. Johns University Weather Station from Superpave Software)

Mean of Annual Low Temperatures, Standard Deviation	-32 °C, ± 2.8 °C
Mean of Mean 7-Day High Temperatures, Standard Deviation	+32 °C, ± 1.7 °C

The two asphalt binders were tested for performance grading and the results are shown in Tables 3 and 4. The PG 58-34 asphalt binder was supplied by Jebro Inc. and it received additional testing by the Asphalt Institute. The polymer modification in the PG 58-34 was a styrene butadiene rubber (SBR) latex. The PG 58-28 (120/150) asphalt binder originated from Koch Materials.

Table 3: PG 58-34 Asphalt Binder Test Results from the Asphalt Institute

Test	Method	Specification	Test 1	Test 2	Test 3	Test 4
Flash Point	AASHTO T 48	230 ^{0}C Min.	291 ^{0}C	254 ^{0}C	282 ^{0}C	293 ^{0}C
Viscosity @ 135 ^{0}C	ASTM D 4402	3 Pa-sec Max.	0.717 Pa-s	0.775 Pa-s	0.725 Pa-s	0.758 Pa-s
Dynamic Shear, 10 rad/sec G*/sinδ @ 58 ^{0}C	AASHTO TP5	1.00 kPa Min.	1.20 kPa	1.24 kPa	1.17 kPa	1.15 kPa
Mass Loss (RTFO)	AASHTO T240	1.00% Max	0.646%	0.605%	0.562%	0.551%
Dynamic Shear 10 rad/sec (RTFO) G*/sinδ @ 58 ^{0}C	AASHTO TP5	2.20 kPa Min.	2.64 kPa	2.56 kPa	2.38 kPa	2.46 kPa
Dynamic Shear 10 rad/sec (PAV) G*/sinδ @ 16 ^{0}C	AASHTO TP5	5,000 kPa Max.	2,124 kPa	2,124 kPa	----	----
Creep Stiffness 60 sec S @ -24 ^{0}C	AASHTO TP1	300 MPa Max.	198.0 MPa	228.9 MPa	224.0 MPa	231.1 MPa
Creep Stiffness 60 sec M @ -24 ^{0}C	AASHTO TP1	0.300 Min.	0.316	0.321	0.313	0.313
Binder Classification	N.A.	N.A.	**PG 58-34**	**PG 58-34**	**PG 58-34**	**PG 58-34**

Table 4: PG 58-28 Asphalt Binder Test Results from Koch Materials

Test	Method	Specification	Test 1
Flash Point	AASHTO T 48	230 ^{0}C Min.	N.A.
Viscosity @ 135 ^{0}C	ASTM D 4402	3 Pa-sec Max.	0.285 Pa-s
Dynamic Shear, 10 rad/sec $G^*/\sin\delta$ @ 58 ^{0}C	AASHTO TP5	1.00 kPa Min.	1.261 kPa
Mass Loss (RTFO)	AASHTO T240	1.00% Max	0.330%
Dynamic Shear 10 rad/sec (RTFO) $G^*/\sin\delta$ @ 58 ^{0}C	AASHTO TP5	2.20 kPa Min.	3.027 kPa
Dynamic Shear 10 rad/sec (PAV) $G^*/\sin\delta$ @ 19 ^{0}C	AASHTO TP5	5,000 kPa Max.	4,020 kPa
Creep Stiffness 60 sec S @ -18 ^{0}C	AASHTO TP1	300 MPa Max.	220.3 MPa
Creep Stiffness 60 sec M @ -18 ^{0}C	AASHTO TP1	0.300 Min.	0.322
Binder Classification	N.A.	N.A.	**PG 58-28**

IV. Aggregate Selection and Mix Design

The project environmental conditions and the traffic levels also affect the gyratory compaction effort a shown in Table 5. Minnesota will always be in the in the less than 39 °C category. This project has about 3 million ESALs.

Table 5: Gyratory Compaction Effort

Design ESALs Millions	Average 7 - Day Design High Air Temperature											
	< 39 °C			39 - 41			41 - 43			43 - 45		
	N_i	N_d	N_m	N_i	N_d	N_m	N_i	N_d	N_m	N_i	N_d	N_m
< 0.3	7	68	104	7	74	114	7	78	121	7	82	127
0.3 - 1	7	76	117	7	83	129	7	88	138	8	93	146
1 - 3	7	86	134	8	95	150	8	100	158	8	105	167
3 - 10	8	96	152	8	106	169	8	113	181	9	119	192
10 - 30	8	109	174	9	121	195	9	128	208	9	135	220
30 - 100	9	126	204	9	139	228	9	146	240	10	153	253
> 100	9	143	235	10	158	262	10	165	275	10	172	288

Stearns County decided to designate the source for the aggregate used in the Superpave mixture. A local granite quarry owned by Meridian Aggregates was specified. The County Engineer had confidence in this aggregate source based on previous experience. Meridian Aggregates agreed to provide the same price to all prospective bidders for the material used in the Superpave mixes.

The Superpave designation for a gradation is based on the nominal maximum aggregate size. The initial mix design was performed with a 9.5 mm (3/8") nominal maximum aggregate size but it failed the tensile strength ratio (TSR) criteria (See Table 6). The research team decided to not use anti-stripping additives because it would be another variable in our research efforts. The results of mixing a anti-stripping additive with a polymer modified asphalt binder were unknown. The failure of the 9.5 mm mix caused concern because the aggregates had been sole sourced and other options were limited.

The next mix design was performed with a 19.0 mm (3/4") nominal maximum aggregate size and it easily passed the TSR criteria. The 19.0 mm mix had less surface area and a greater film thickness of asphalt binder which is likely the reason the TSR value improved so dramatically.

Table 6: Tensile Strength Ratios

Nominal Maximum Aggregate Size	Maximum Aggregate Size	Tensile Strength Ratio (minimum = 80)	Result
9.5 mm (3/8")	12.5 mm (1/2")	60.0 Failed	Not Chosen
19.0 mm (3/4")	25.4 mm (1")	96.1 Passed	Chosen

A. Aggregate Quality Analysis

In addition to sieve analysis and specific gravity determination, the Superpave design method requires conformance to consensus properties (see Table 7). These tests ensure that the aggregate blend selected for the mix design provides an acceptable aggregate structure in the mix. Criteria are established based upon current projected traffic conditions and locations in the pavement structure.

<u>The following four tests are required by Superpave:</u>

- Coarse Aggregate Angularity
- Fine Aggregate Angularity
- Flat and Elongated particle percentage
- Sand Equivalent test

<u>Optional Mn/DOT tests:</u>

- Magnesium Sulfate test (soundness test)
- L.A. Abrasion test (toughness test)
- Spall Litho, Shale Test (deleterious materials)
- Insoluble Residue (soundness test)

The optional tests listed are source specific (see Table 8). These tests are recommended but not required. These optional tests, while periodically performed on a source basis, were not specifically conducted for this project.

Table 7: Required Aggregate Quality Test Results

Test Type	Superpave Criteria < 3 Mil. ESALs	Results
Coarse Aggregate Angularity +4.75 mm material	Minimum = 75 % single face fracture or 75%/---	100% / 100%
Fine Aggregate Angularity -2.36 mm material	Minimum = 40	49.1
Flat & Elongated Particles +4.75 mm material	Maximum = 10% of 3:1 material.	0.6 %
Sand Equivalent Test -4.75 mm material	Minimum = 40%	71.4%

Table 8: Optional Aggregate Quality Test Results

Test Type	Mn/DOT Criteria	Results
Magnesium Sulfate test (soundness test) Class B, C, D, and E. +4.75 mm material	Maximum Loss by mass = 15%	Not required for Class A material.
L.A. Abrasion test (toughness test) Class A, B, C, D, and E. +4.75 mm material	Maximum Loss by mass = 35%	This test was not performed. It was passed by visual inspection.
Spall Litho, Shale Test (deleterious materials) Class B, C, D, and E. +4.75 mm material (litho) - 4.75 mm mat. (shale float)	Combined total spall percentage by mass = 1.0%	Not required for Class A material.
Insoluble Residue Test on Carbonate Materials (soundness test) Class B.	(See Mn/DOT Lab Manual 1221) Maximum Loss by mass = 10%	Not required for Class A material.

The Meridian Aggregates used in the Superpave mixes were tested for net absorption, bulk and apparent specific gravities as shown in Table 9.

Table 9: Aggregate Specific Gravity and Net Absorption

Aggregate Type	Bulk Specific Gravity (G_{sb})	Apparent Specific Gravity (G_{sa})	Net Water Absorption %
Meridian 3/4" Unwashed (60%)	2.739	2.768	0.38 %
Meridian CA-50 (35%)	2.747	2.774	0.35 % (+4.75mm)
Meridian FA-2 (5%)	2.692	2.743	0.70% (+2.36 mm)
Total Blend	2.739	2.769	0.39%

B. Design Aggregate Proportioning

Selection of the design aggregate structure was performed by mathematically combining the gradations of individual materials into a single gradation that fit the design criteria for this project (see Table 10).

Table 10: Aggregate Stockpile Gradations

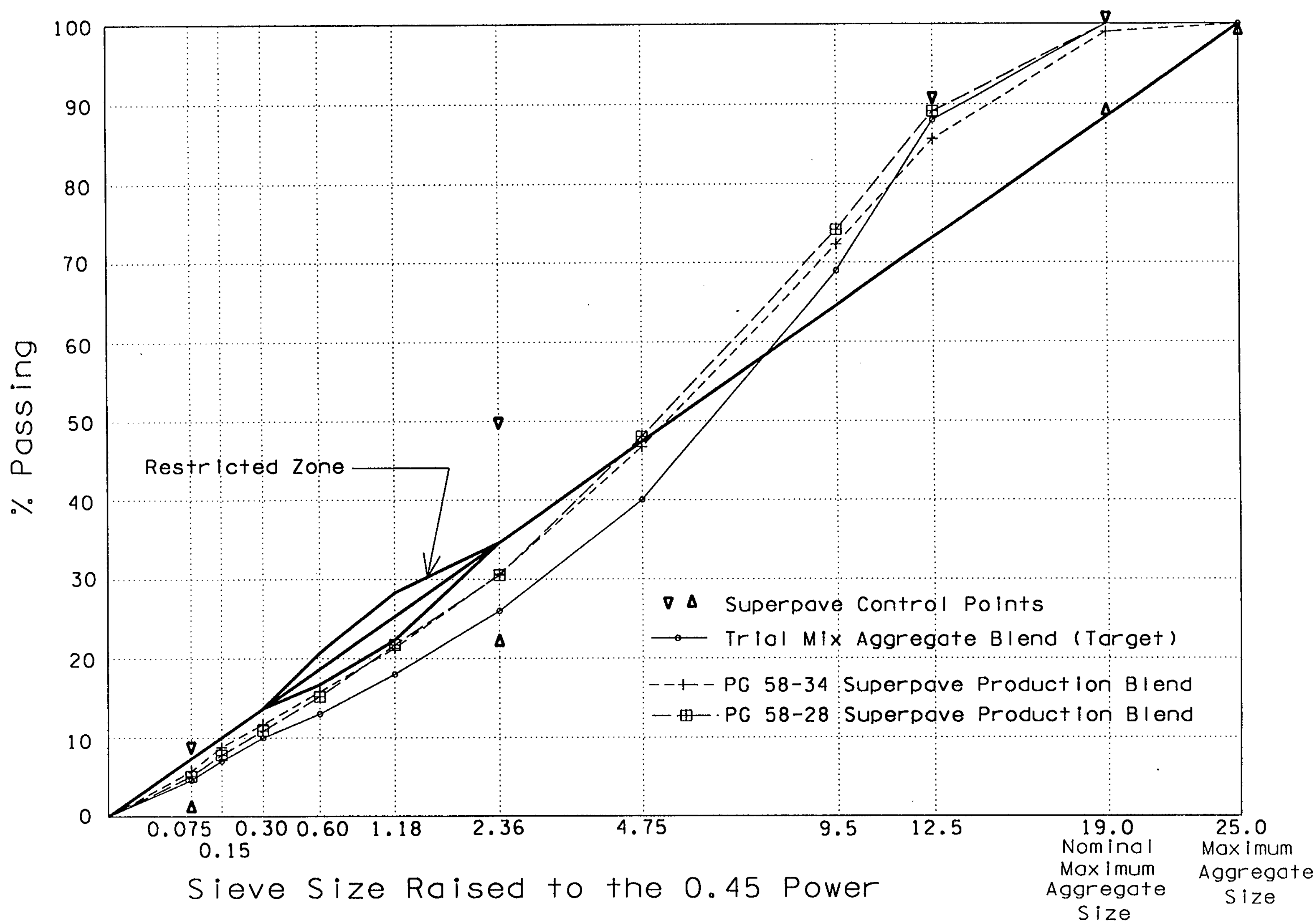
Sieve Size		Percent Passing			
mm	inch	Meridian 3/4" Unwashed (60%)	Meridian CA-50 (35%)	Meridian FA-2 (5%)	Trial Mix Agg. Blend (Target)
25	1	100	100	100	100
19	3/4	100	100	100	100
12.5	1/2	93	77	100	88
9.5	3/8	83	41	100	69
4.75	#4	56	6	94	40
2.36	#8	40	3	12	26
1.18	#16	29	1	1	18
0.6	#30	21	1	0	13
0.3	#50	16	1	0	10
0.15	#100	11	0	0	7
0.075	#200	7.4	0.3	0.1	4.6

The nominal maximum aggregate size is defined as one sieve size larger than the first sieve to retain more than 10%. Table 10 shows that 88% (12% retained) of the target blend passed the 12.5 mm sieve. Therefore, the nominal maximum aggregate size is 19.0 mm. The blends must comply with the appropriate specification requirements at several sieves. Gradation control is based upon four sieves: the maximum sieve size, the nominal max sieve size, and specific control sieves specified by Superpave. The trial mix aggregate blend is shown in Figure 2.

Many different blends were tested for this project before one passed all of the Superpave criteria. Superpave recommends that three different aggregate blends be used for designing an optimal mix. The gradation of the three blends should be fine, medium, and coarse. The objective is to establish three trial blends that provide the following:

- Specified consensus properties.
- Specified gradation requirements.
- A good starting point for optimal design.
- Flexibility in design.
- A range of suitable mixes.
- Establishment of a defined cost / benefit ratio.

Figure 2: 0.45 Power Chart: 19.0 mm Superpave Gradations



V. Laboratory Design Results of PG 58-34 Superpave Mixture

The final results of the Superpave mixture design performed in the Mn/DOT Trial Mixture Laboratory at Maplewood are shown in Table 11. All of the results passed Superpave criteria. Due to time constraints, no Superpave mix design was performed using a PG 58-28 asphalt binder.

Table 11: Trial Mix Design Results of PG 58-34 Superpave Mixture

Superpave Properties	**Superpave Criteria (19 mm nom. mix)**	**Testing Results**
$\%G_{mm}$ @ $N_{Initial}$ = 7 gyrations	< 89 %	85.4
$\%G_{mm}$ @ N_{design} = 86 gyrations	96%	96.0
$\%G_{mm}$ @ N_{final} = 134 gyrations	< 98%	97.4
VMA	≥ 13%	15.0
VFA	65 - 78 %	74.7
TSR	> 80	96.1
Dust Proportion	0.6 - 1.2	0.98
Asphalt Binder Grade	PG 58-34	PG 58-34
Optimum Asphalt Binder Content	-----	5.0%

VI. Production Results

It is always interesting to take a good laboratory Superpave mix design and see what field production does to its characteristics. The amount of problems in the field were minimal. The FHWA Superpave Trailer performed comprehensive testing on production samples as shown in Tables 12, 13, and 14. All of the testing results pass the Superpave criteria. Therefore, the contract was successful in providing passing Superpave mixtures. The results in Table 12 compare very favorably with the trial mix results shown in Table 11.

Table 12: Production Results of Superpave Mixtures

Superpave Properties	**Superpave Criteria (19 mm nom. mix)**	**P.G. 58-34 Superpave Test Results By FHWA**	**P.G. 58-28 Superpave Test Results By FHWA**
$\%G_{mm}$ @ $N_{Initial} = 7$ gyrations	< 89 %	85.8	85.7
$\%G_{mm}$ @ $N_{design} = 86$ gyrations	96% (±1%)	96.1	96.4
$\%G_{mm}$ @ $N_{final} = 134$ gyrations	< 98%	97.4	97.7
VMA	≥ 13%	15.6	14.7
VFA	65 - 78 %	75.0	75.5
TSR w/Freeze	> 80	89.9	105.2
Dust Proportion	0.6 - 1.2	0.9	0.9
Actual Asphalt Binder Content	Mn/DOT JMF Limit = ± 0.4%	** 4.9%	** 4.6%

** Determined by the ignition oven method.

The data in Table 13 compares the consensus aggregate tests of the trial mix process to the ignition oven results from plant produced mix. The results are quite close and favorable.

Table 13: Aggregate Quality Tests from Ignition Oven

Test Type	**Superpave Criteria < 3 Mil. ESALs**	**Trial Mix Test Results**	**PG 58-28 Superpave Test Results from Ignition Oven**
Coarse Aggregate Angularity +4.75 mm material	Minimum = 75 % single face crushed	100% / 100%	100% / 100%
Fine Aggregate Angularity (FAA) -2.36 mm material	Minimum = 40	49.1	48.4
Flat & Elongated Particles +4.75 mm material	Maximum = 10% of 3:1 material.	0.6%	4.0%
Sand Equivalent Test -4.75 mm material	Minimum = 40%	71.4%	71.0%

The aggregate stockpile gradations from the ignition oven are shown in Table 14. The contractor did a good job of maintaining a gradation close to the target on most of the sieves with the exception being the 4.75 mm size. The production gradations maintained the 19.0 mm nominal maximum aggregate size that was used in the trial mixture stage. These gradations are plotted on Figure 2 shown earlier in this report.

Table 14: Aggregate Gradations from Ignition Oven

Sieve Size		Percent Passing			
mm	inch	Trial Mix Agg. Blend (Target)	1997 JMF Limits	PG 58-34 Superpave Production Blend	PG 58-28 Superpave Production Blend
25	1	100	-----	100.0	100.0
19	3/4	100	-----	99.0	100.0
12.5	1/2	88	±5.5	85.6	89.1
9.5	3/8	69	±5.5	72.3	74.2
4.75	#4	40	±5.5	46.7	48.0
2.36	#8	26	±5.0	30.6	30.5
1.18	#16	18	-----	21.3	21.7
0.6	#30	13	-----	15.8	15.2
0.3	#50	10	-----	11.7	10.9
0.15	#100	7	-----	8.8	7.8
0.075	#200	4.6	±2.0	5.7	5.1

The Asphalt Institute provided a gyratory compactor for quality control testing on the project site for westbound paving. The Mn/DOT Trial Mix Laboratory in Maplewood provided Quality Assurance testing. The testing results from the Asphalt Institute and Mn/DOT are shown in Table 15. The test results show some variability between the Asphalt Institute and Mn/DOT. The average of the 19 tests performed by the Asphalt Institute resulted in a maximum specific gravity of 2.541 and air voids of 4.1% (4.0% target) for the PG 58-34 Superpave mixture.

Table 15: Production Testing of Air Voids and Maximum S.G.

PG 58-34 Superpave Paving Date	Asphalt Institute G_{mm} (Max S.G.) V_a (Air Voids)	Mn/DOT G_{mm} (Max S.G.) V_a (Air Voids)
8-26-96	2.535 5.1%	2.550 3.5%
8-26-96	2.531 4.4%	---- ----
8-26-96	2.540 4.1%	---- ----
8-26-96	2.537 3.7%	---- ----
8-26-96	2.537 4.1%	---- ----
8-26-96	2.536 Average, N=5 4.3% Average, N=5	2.550 Average, N=1 3.5% Average, N=1

PG 58-34 Superpave Paving Date	Asphalt Institute G_{mm} (Max S.G.) V_a (Air Voids)	Mn/DOT G_{mm} (Max S.G.) V_a (Air Voids)
8-27-96	2.549 4.7%	---- ----
8-27-96	2.541 4.4%	---- ----
8-27-96	2.544 4.0%	---- ----
8-27-96	2.543 3.1%	---- ----
8-27-96	2.544 Average, N=4 4.1% Average, N=4	---- ----

PG 58-34 Superpave Paving Date	Asphalt Institute G_{mm} (Max S.G.) V_a (Air Voids)	Mn/DOT G_{mm} (Max S.G.) V_a (Air Voids)
8-28-96	2.536 4.5%	2.540 3.5%
8-28-96	2.553 4.3%	2.547 2.9%
8-28-96	2.551 4.3%	---- ----
8-28-96	2.535 4.5%	---- ----
8-28-96	2.544 4.6%	---- ----
8-28-96	2.544 Average, N=5 4.4% Average, N=5	2.544 Average, N=2 3.2% Average, N=2

PG 58-34 Superpave Paving Date	Asphalt Institute G_{mm} (Max S.G.) V_a (Air Voids)	Mn/DOT G_{mm} (Max S.G.) V_a (Air Voids)
8-29-96	2.537 3.6%	2.535 3.5%
8-29-96	2.546 4.1%	---- ----
8-29-96	2.537 3.7%	---- ----
8-29-96	2.542 3.7%	---- ----
8-29-96	2.541 Average, N=4 3.8% Average, N=4	2.535 Average, N=1 3.5% Average, N=1

PG 58-34 Superpave Paving Date	Asphalt Institute G_{mm} (Max S.G.) V_a (Air Voids)	Mn/DOT G_{mm} (Max S.G.) V_a (Air Voids)
8-30-96	2.541 Average, N=1 3.6%, Average, N=1	---- ----

The contractor obtained averages of 93-94% compaction on the Superpave mixes and only 91-92% on the Mn/DOT mixes at the time of construction. The minimum compaction requirement is 91% of maximum specific gravity or 9% maximum air voids. The Superpave mixes were quite stiff directly behind the paver and they didn't exhibit any signs of softness. The contractor realized that it was critical for the breakdown roller to closely follow the paver when using polymer modified asphalt binders because the mix sets up quickly as it cools and it can become impossible to compact if there are any delays. During the rolling operation, the Superpave mats were very stable and did not experience any noticeable deformation or transverse movement.

VII. Field Results

The entire project has a good ride quality and no maintenance has been required. There are a few areas of concern that will continue to be monitored by Mn/DOT and Stearns County.

After the Superpave sections 1EB and 2EB were paved in September of 1996, about 20 wet spots or puddles appeared on the surface of the pavement. This occurred many hours after it had rained. No traffic had been placed on the PG 58-28 Superpave sections at the time when the wet spots appeared. The 1.5" wear course was compacted in one lift. The 1.5" lift thickness is equal to two times the nominal maximum aggregate size of 19.0 mm (3/4") and this may not have been sufficient to obtain adequate compaction levels. Starting in 1997, the Florida DOT is recommending a lift thickness equal to four times the nominal maximum aggregate size for coarse Superpave mixtures. Therefore, the Florida DOT would recommend a 3.0" lift thickness for a 19.0 mm nominal maximum aggregate size as compared to the 1.5" lift that was used on sections 1EB and 2EB.

A. Cores

There was concern that some large air voids in the lower portion of the wear course could trap water. Therefore, cores were taken from this project on October 4, 1995 by a consulting firm. The inplace air void results are shown in Table 16. The results don't seem to indicate any problems with inplace density but a visual check revealed some open voids on the sides of the cores. The testing of the cores was performed without using the optional parafilm coating to determine bulk specific gravity. Parafilm is wrapped completely around the specimen to make it water tight. Mn/DOT was concerned that water ran out of the open voids after the cores were removed from the bath and this resulted in low inplace air void data. The data obtained from using parafilm is considered to be more accurate than the current methods of computing air voids.

The initial traffic tightened the surface texture enough so that the wet spot situation never happened again but the voids in sections 1EB and 2EB may still be somewhat permeable.

Table 16: Air Voids from PG 58-28 Superpave on Oct. 4, 1996

VTM in Cores from Wet Areas (1.5" Lift Thickness / No Parafilm)	**VTM in Cores from Dry Areas (1.5" Lift Thickness / No Parafilm)**
6.5%	9.1%
9.2%	8.8%
7.0%	7.2%
6.0%	10.3%
7.2% Average, N=4	8.9% Average, N=4

Mn/DOT decided to further investigate the air voids on April 24, 1997 by taking additional cores and using para-film on the samples to check the inplace air voids data. The results are shown in Tables 17 and 18. The 8.7% air voids from Table 17 compares well with the values of 7.2% and 8.9% from Table 16. The 11.8% average air voids (9.0% maximum) obtained using parafilm is not satisfactory and its permeability may cause accelerated deterioration from yearly freeze-thaw cycles. Using parafilm resulted in a substantial 3.1% increase on the air voids. This data appears to justify the use of parafilm for all mixture gradations which pass below the restricted zone and appear to have some large air voids.

Table 17: Air Voids from PG 58-28 Superpave on April 24, 1997

VTM in Cores (1.5" Lift Thickness / Using Parafilm)	VTM in Cores (1.5" Lift Thickness / No Parafilm)	Difference in VTM Resulting from the use of Parafilm
11.6%	9.0%	+2.6%
11.6%	8.6%	+3.0%
11.7%	9.2%	+2.5%
12.1%	8.3%	+3.8%
12.0%	8.5%	+3.5%
11.8% Average, N=5	8.7% Average, N=5	+3.1% Average, N=5

The results of Table 18 indicate a 0.8% increase in air voids from the use of parafilm. This value is substantial less than the 3.1% difference from Table 17. The main difference between the two areas is the 1.5" lift thickness for the PG 58-28 Superpave sections and a 2.0" lift thickness for the PG 58-34 Superpave sections. The polymer modification of the PG 58-34, the 0.3% higher actual asphalt binder content (Table 12), and the increased compaction temperatures may have also contributed somewhat to the reduced inplace air voids.

Table 18: Air Voids from PG 58-34 Superpave on April 24, 1997

VTM in Cores (2.0" Lift Thickness / Using Parafilm)	VTM in Cores (2.0" Lift Thickness / No Parafilm)	Difference in VTM Resulting from the use of Parafilm
6.3%	4.7%	+1.6%
7.1%	6.8%	+0.3%
7.6%	6.3%	+1.3%
6.8%	6.8%	0.0%
8.9%	8.1%	+0.8%
6.4%	5.7%	+0.7%
7.2% Average, N=6	6.4% Average, N=6	+0.8% Average, N=6

A visual inspection of the cores corresponded to the results. The samples from the 1.5" lift thicknesses had many large air voids. The samples from the 2.0" lift thicknesses had a few large air voids. Therefore, a 1.5" lift is unsatisfactory and a 2.0" lift is marginal for a 19.0 mm nominal maximum aggregate size. A 3.0" lift thickness might have made it visually impossible to notice large air voids and the results from the use of para-film probably wouldn't have been so substantially different.

The compaction of the Mn/DOT mixes was generally good except for the 32B shoulders as shown in Table 19.

Table 19: Air Voids from Mn/DOT Mixeson April 24, 1997

47A Wear (0% RAP)	**47B Binder** (0% RAP)	**42B Binder** (30% RAP)	**32B Shoulder** (50% RAP)	**32B Base** (50% RAP)
7.5%	7.2%	7.7%	9.3%	4.6%
7.0%	6.9%	7.6%	10.1%	5.7%
7.5%	6.0%	8.3%	12.3%	5.0%
5.1%	4.1%	8.2%	10.2%	5.0%
----	----	7.9%	10.0%	5.6%
----	----	----	----	7.8%
----	----	----	----	6.6%
----	----	----	----	6.0%
----	----	----	----	3.9%
----	----	----	----	5.7%
----	----	----	----	6.8%
----	----	----	----	5.7%
6.8% Average N=4	6.1% Average N=4	7.9% Average N=5	10.4% Average N=5	5.7% Average N=12

B. Actual Compaction Levels with the use of Parafilm

Based on the parafilm data from the April 24, 1997 cores, the previously stated compactions levels of 93-94% compaction on the Superpave mixes is too high. The limited core data suggests a satisfactory PG 58-34 Superpave compaction level of 92.8% (7.2% air voids) and a unsatisfactory PG 58-28 Superpave compaction level of 88.2% (11.8% air voids) on sections 1EB and 2EB.

The average compaction results of the Mn/DOT mixes varied from 89.6% (10.4% air voids) to 94.3% (5.7% air voids) as compared to the contractor's values of 91-92% at the time of construction. The compaction of the Mn/DOT mixes in the driving lanes was good.

C. Crack Surveys

Stearns County performed a crack survey on February 28, 1997 to determine the number of cracks in the driving lanes for the entire project and these results are shown in Table 20. Mn/DOT performed an additional crack survey on April 9, 1997 which included a 500 foot segment on each of the eight test sections as shown in Table 21. The Mn/DOT crack survey included the linear feet of cracking in the driving lanes and shoulders. It also included a mapping of the current surface so that future crack propagation can be analyzed.

The results of the two crack surveys are inconclusive because the pavement is less than one year old. The only obvious item is the increased cracking in the shoulders which may have resulted from the inclusion of 50% RAP. The Table 21 crack survey shows that 85.1% of the linear feet of cracking occurred in the shoulders and some of those cracks have propagated into the driving lanes.

Table 20: Crack Survey of Entire Project on February 28, 1997

Pavement Sections	Stationing of Sections	Section Distances (Feet)	Number of Cracks per Section	Average Spacing of Cracks in Driving Lanes (Feet)
1EB	1759+00 to 1785+50	2,650	1	2,650
4EB	1878+90 to 2063+95	18,505	11	1,682
4WB	1922+10 to 2063+95	14,185	14	1,013
3EB	1812+00 to 1878+90	2,640	5	528
2EB	1785+50 to 1812+00	2,650	8	331
1WB	1759+00 to 1802+20	4,320	15	288
3WB	1878+90 to 1922+10	4,320	15	288
2WB	1802+20 to 1878+90	3,620	29	125
Total	------	**52,890**	**98**	**540**

Notes: The Table 20 survey only encompasses the 12' driving lanes and the 3' shoulder. The 10' outside shoulders were not included in this survey. The overlayed section of pavement through St. Joseph from station 1835+50 to 1876+00 (4,050') was not considered in sections 2WB and 3EB due potential reflective cracking. Gene Thyen of Stearns County performed this survey.

Table 21: Crack Survey Using 500' Sections on April 9, 1997

Pavement Section	Station	10' Shoulder Cracks (L.F.)	Driving Lane Cracks (L.F.)	Total Cracks (L.F.)
4EB	1990+45 to 1995+45	19	0	19
1WB	1792+80 to 1787+80	14	12	26
1EB	1771+50 to 1776+50	26	1	27
3EB	1816+70 to 1821+70	42	0	42
2EB	1788+45 to 1893+50	78	0	78
2WB	1823+20 to 1818+20	46	87	133
4WB	1996+40 to 1991+40	229	0	229
3WB	1908+80 to 1903+80	239	21	260
TOTAL L.F.	-----	**693**	**121**	**814**
TOTAL %	-----	**85.1%**	**14.9%**	**100.0%**

Notes: The 3' shoulders in Table 21 are grouped with the 12' driving lanes because they are the same mix. The pavement was only about seven months old. The construction was performed during August and September of 1996. The crack survey was performed by John Isackson and Gene Skok on April 9, 1997. The 10' shoulders on 1EB, 2EB, 3EB and 4EB were placed on the existing grade. The 10' shoulders on 3WB and 4WB were placed on 1"-3" of inplace mix. The 10' shoulders of 1WB and 2WB were placed on 0-3/4" of inplace mix which was spotty. Some of the shoulder cracks have extended into in the 12' driving lanes.

A visual inspection of the Mn/DOT wear courses showed some deleterious aggregates in the pavement. There were some popouts and broken aggregate at the surface. The Superpave sections didn't appear to have any deleterious material problems.

D. Performance Grading of Inplace Asphalt Binders

Mn/DOT performed testing on cores to analyze how RAP, winter weather, and polymers affected the performance grade (PG) of the asphalt binders. Centrifuge extraction with a toluene solution was used to recover the asphalt binders from the cores. The results are shown in Table 22.

Table 22: PG Grading of Inplace Asphalt Binders on April 24, 1997

Mix Descriptions	Original Asphalt Binder	Total Asphalt Binder Content	RAP%	Non-Rounded PG Grade	Rounded PG Grade
Superpave Wear	PG 58-34	5.0%	0%	PG 56.9-37.4	PG 52-34
Superpave Binder	PG 58-34	5.0%	0%	PG 56.9-38.7	PG 52-34
Superpave Wear	PG 58-28	5.0%	0%	PG 60.4-29.7	PG 58-28
47A Wear	PG 58-28	6.0%	0%	PG 60.2-30.3	PG 64-28
47B Binder	PG 58-28	5.9%	0%	PG 59.6-31.2	PG 58-28
42B Binder	* PG 58-28	5.9%	30%	PG 64.7-29.2	PG 64-28
32B Base	* PG 58-28	5.9%	50%	PG 66.8-26.7	PG 64-22
32B Base	* PG 58-28	5.9%	50%	PG 66.4-27.4	PG 64-22
32B Base	* PG 58-28	5.9%	50%	PG 67.7-25.9	PG 64-22
32B Shoulder	* PG 58-28	5.9%	50%	Pg 65.8-26.8	PG 64-22

* Grade of "add oil" used for RAP mixtures.

As expected, the addition of 50% RAP stiffened the Mn/DOT 32B mixtures on the high and low temperature PG grade. The PG 58-28 add oil when combined with 50% RAP became PG 64-22 in Table 22. The reduced thermal cracking characteristics of a PG 64-22 corresponds to the accelerated shoulder cracking which is shown in Table 21.

This was the first time Mn/DOT experimented with the centrifuge extraction of polymer modified PG 58-34 and it was not successful. Some of the polymers remained in the filter of the centrifuge extractor. Toluene was the material used in the extraction process.

Since polymers are a high temperature extender for PG grading, it seems understandable that the inaccurate test results were PG 52-34 (Table 22) instead of the assumed PG 58-34. The polymer modified binder certainly wouldn't have become softer after it went through the asphalt plant and one cold winter. Therefore, Mn/DOT doesn't advise the testing of polymer modified asphalt binders with the extraction process.

E. Superpave Aggregate Testing on Mn/DOT Mixtures

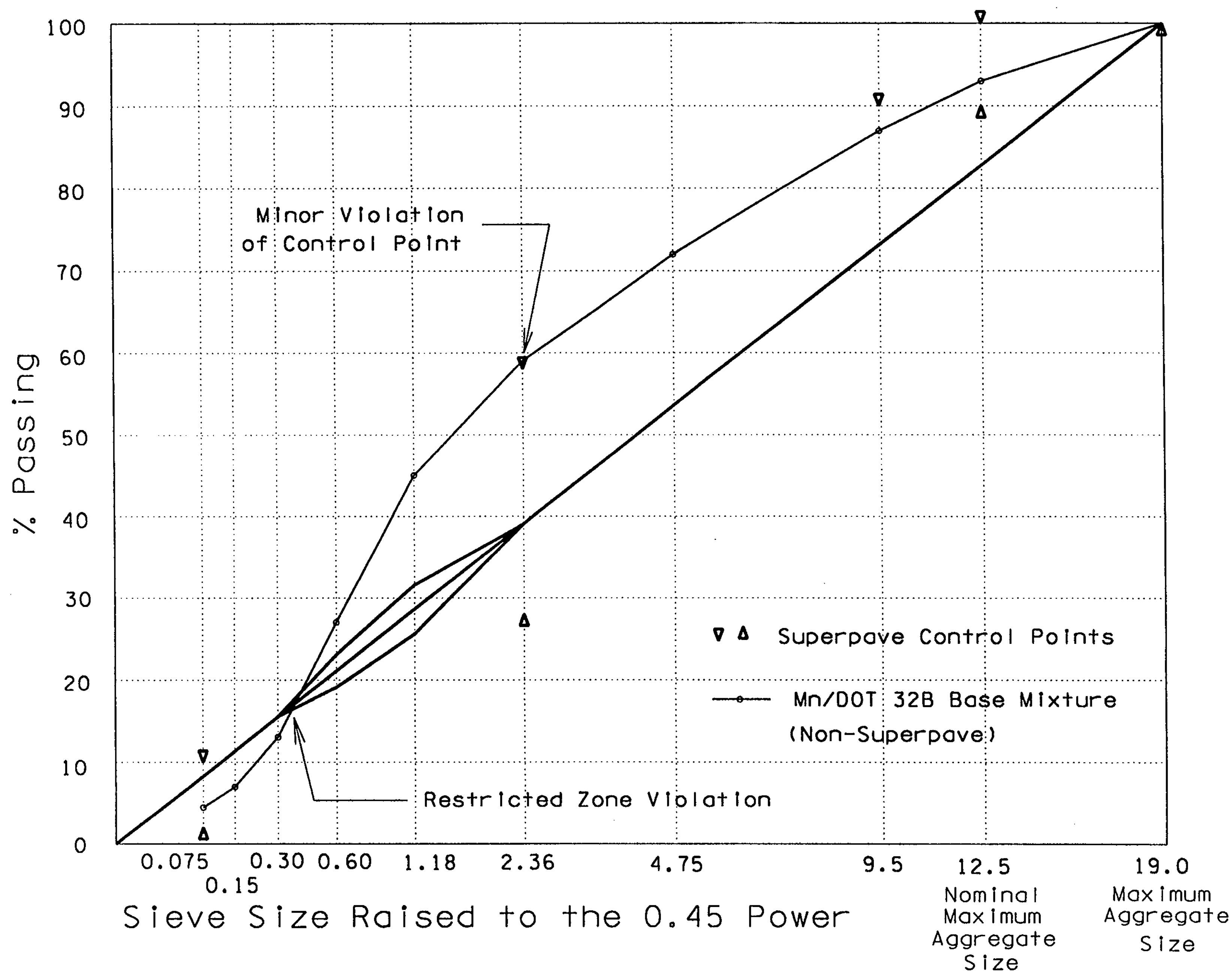
Table 23 lists the Superpave aggregate tests which were performed on the Mn/DOT mixtures. These tests were performed to give Mn/DOT an indication of the quality of the non-Superpave mixtures on this project. The 32B Binder, 32B Base, and 32B Shoulder mixtures failed the minimum crushing requirement of 75% single faces for less than 3 million ESALs of traffic. The 47A Wear and 47B Binder passed this crushing requirement.

Figure 3 is a Superpave 0.45 chart which includes a plot of the Mn/DOT 32B Base mixture gradation. The 32B Base gradation violates two of the criteria on the 0.45 chart. First of all, this fine mixture violates the top control point on the 2.36 mm sieve. The gradation is very fine and this results in reduced film thickness which may minimize durability. Secondly, the gradation passes through the restricted zone between the 0.30 mm and 0.60 mm sieves. The violation of the restricted zone may offer reduced resistance to permanent deformation.

Table 23: Superpave Aggregate Testing Performed on Mn/DOT Mixtures

Test Type	Superpave Criteria < 3 Mil. ESALs	47A Wear	47B Binder	32B Binder	32B Shoulder	32B Base
Coarse Aggregate Angularity +4.75 mm material	Minimum = 75 % single face crushed	77.8 / 84.5%	82.3 / 84.5%	71.2 / 75.9%	55.9 / 67.5%	65.0% / 68.8%
Fine Aggregate Angularity (FAA) -2.36 mm material	Minimum = 40	---	---	---	---	40.9
Flat & Elongated Particles +4.75 mm material	Maximum = 10% of 3:1 material.	---	---	---	---	---
Sand Equivalent Test -4.75 mm material	Minimum = 40%	---	---	---	---	87.0%

Figure 3: 0.45 Chart: 12.5 mm Mn/DOT Gradations



VIII. Conclusions / Recommendations

1) The production results yielded mixes which passed all of the Superpave criteria.

2) The whole project still has a good ride quality. There are no current pavement failures.

3) In the future, Mn/DOT recommends a 2" minimum lift for compaction with all Superpave mixes. A 1.5" lift thickness was unsatisfactory on this project. For a 19.0 mm nominal maximum aggregate size, a minimum lift thickness of 2" may be marginal.

4) The contractor obtained 93-94% compaction on the Superpave mixes but this compaction data is questionable because parafilm was not used on the cores during testing.

5) Mn/DOT's limited core data from April 24, 1997 with the use of parafilm suggests a satisfactory PG 58-34 Superpave compaction level of 92.8% (7.2% air voids) and a unsatisfactory PG 58-28 Superpave compaction level of 88.2% (11.8% air voids). Mn/DOT recommends using parafilm for all Superpave mixtures which appear to have some large air voids.

6) It is critical that the breakdown roller closely follows the paver when using polymer modified asphalt binders because the mix sets up quickly as it cools and it can become impossible to compact

7) All of the current cracks are of low severity and no maintenance has been required due to a minimum crack spacing of 125 feet in the driving lanes of all eight test sections.

8) The Superpave mixes are darker in appearance than the grey Mn/DOT surface mixes. This is most likely due to a greater film thickness of asphalt binder on the Superpave mixes. This may lead to reduced aging and raveling in the future.

9) Sawing and sealing has minimized the initial cracking of this project. The Stearns County Engineer recommends that future sawing extend all the way across wide shoulders.

10) The $10.00/ton 32B shoulder mix with 50% RAP and PG 58-28 has experienced about 85% of the linear feet of thermal cracking. Some of the shoulder cracks have extended into the driving lanes. Therefore, the initial cracking of the driving lanes appears to be dependent on the lower quality shoulders. If a softer asphalt binder such as PG 52-34 had been used, it may have reduced shoulder cracking. The large percentages of RAP in the shoulder mix reduced its ability to resist thermal cracking.

11) The Quality Control tests closely matched the trial mix results. Therefore, there were little or no changes in the Superpave mixes in the field.

12) The subgrade wasn't re-worked before the paving of this project and this may have contributed to some of the surface cracks.

13) Cost/Benefit issues:
   - The pavement life will determine the ultimate cost/benefit ratios for all of the segments.
   - The future analysis of this project will determine the long term benefits of using saw and seal as well as using a PG 58-34 polymer modified asphalt binder.
   - The performance of the Mn/DOT convention mixes will be compared to the Superpave sections.
   - The Mn/DOT 47A wear course at the intersection of C.S.A.H. 2 and eastbound C.S.A.H. 75 has some visible surface raveling. The deterioration of the pavement's surface will be a critical comparison of performance between the eight different sections.

14) A visual inspection of the Mn/DOT 47A wear courses showed some deleterious aggregates in the pavement. There were some popouts and broken aggregate at the surface. The Superpave sections didn't appear to have any deleterious material problems.

15) Centrifuge extraction didn't work properly for the PG 58-34 asphalt binders because the polymers remained in the filter of the machine. Mn/DOT has not found a solution for accurately testing polymer modified asphalt binders in cores.

16) Figure 3 indicates that the Mn/DOT 32B Base mixture violates one Superpave control point and the restricted zone. The gradation is very fine and this results in a reduced film thickness which may minimize durability. The violation of the restricted zone may offer reduced resistance to permanent deformation.

IX. References

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