FUNDING ACKNOWLEDGEMENT

This project was conducted with funding provided by the Minnesota Local Road Research Board (LRRB). The LRRB's purpose is to develop and manage a program of research for county and municipal state aid road improvements. Funding for LRRB research projects comes from a designated fund equivalent to 1/2 of one percent of the annual state aid for county and city roads.
Superpave technology was developed under the Strategic Highway Research (SHRP) to provide superior performing pavements. In 1996, Blue Earth County paved a newly graded, two-lane County State Aid Highway using this technology. The County wanted to explore Superpave's potential in offering a higher quality, more durable pavement with lower life cycle costs.

MTE of Onalaska, Wis., designed the mix and Loveall Construction of Winnebago, Minn., constructed the mix, with construction inspection and contract administration by Blue Earth County. The aggregate structure was on the coarse side of the maximum density line. Separate pay items for gravel, quartzite, asphalt, and produce and lay allowed the County to modify the mix design based on design and to gain construction information for the highest quality pavement. PG 52-34 binder was used. Aggregate was about 45 percent gravel and 55 percent crushed, coarse quartzite.

The constructibility and performance to date have been excellent. Initial construction cost was about 18 percent higher than the County's traditional, fine mix designs. Total pavement structure costs, including aggregate base and pavement, ran about 9 percent higher. The County will continue to monitor the relatively open texture and tendency of the pavement to weep at isolated locations after rains for potential problems.
Blue Earth County
Superpave Level I Project
CSAH 8 From TH 22 to TR 167

Final Report

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April 1997

Published by:
Minnesota Local Road Research Board
Office of Research Administration
200 Ford Building
Mail Stop 330
117 University Avenue
St. Paul, Minnesota 55155

The opinions, findings, and conclusions expressed in this publication are those of the authors and do not necessarily those of the Minnesota Local Road Research Board or the Minnesota Department of Transportation.
Acknowledgments

The author on the behalf of Blue Earth County wishes to express his sincere thanks to the following people and organizations for their participation in this demonstration project:

• The Local Road Research Board for funding the additional costs of the Superpave design above a traditional 2331 bituminous pavement design.

• Gerald Reinke and Gail Jenson of Mathy Technology and Engineering Services, Inc. (MET) for providing the mix design and technical assistance under contract to Blue Earth County.

• Roger Olson and the Office of Minnesota Road Research at the Minnesota Department of Transportation (Mn/DOT) for technical assistance.

• Larry LaPoint and Jack Hermer of the Blue Earth County Highway Department for providing the plans, specifications, construction administration, and construction inspection. Without their continuing interest and support, the project would not have been possible.

• H.R. Loveall Construction for their cooperation and support for new paving technologies during construction of the project.
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Executive Summary

Blue Earth County has about 400 miles of bituminous paved roads. This hard surfacing has provided a good driving surface for the public. However, despite seal coating, patching, and crack sealing maintenance, the hot-mix bituminous mixes constructed since 1960 have typically deteriorated and required costly maintenance overlays after about 12 to 15 years and total rehabilitation after about 30 to 40 years. Failure modes including oxidation, raveling, and cracking often appear to be more age related than load related.

Blue Earth County has limited aggregate supplies. Recent years have seen the depletion of the higher quality, coarse aggregate. As a consequence, mixes have tended to become sandier with more deleterious materials. A higher quality mix, by reducing overlay needs and supplementing our lower quality aggregate with imported durable quarry rock, would extend the life of our gravel resources.

The purpose of this project was to explore the feasibility of providing a higher quality hard surface with lower life cycle costs using the Superpave Level I technology.

Blue Earth County constructed Superpave projects on CSAH 30 in 1995 and on CSAH 8 in 1996. We found the mix is readily constructible using county engineering and private local construction
forces. Both projects resulted in excellent ride quality and appearance. Although several years of observation will be needed to evaluate the performance and life cycle costs, based on Strategic Highway Research Program (SHRP) research, the pavements are expected to yield a substantially more durable pavement than the traditional mixes.

The 1995 project used an aggregate structure on the fine side of the maximum density line. The reduction in asphalt demand associated with this mix almost compensated for the increased cost of the 25 percent coarse quartzite needed to construct the pavement. The 1996 project used an aggregate structure on the coarse side of the maximum density line. This mix required about 55 percent coarse quartzite and was about 25 percent more expensive than the traditional mixes. Both projects used PG 52-34 binder and no stability or rutting problems were experienced. Traffic on both roads is relatively low with few heavy trucks.

Two questions raised by these projects are currently being addressed by research being conducted at the University of Minnesota:

• What are the asphalt demand and durability implications of using softer, locally available limestone rather than quartzite?

• Is the higher cost of the aggregate structure on the coarse side of the maximum density line compensated by a more stable mix not requiring polymers?
Blue Earth County will continue to construct Superpave Level I mix design overlays and pavements. Due to the higher cost and questions relating to the open texture and weeping of the coarse mixes, the County will select designs on the fine side of the maximum density line until more cost and performance information is available on the coarse mixes. The County also will continue to use quartzite rather than limestone until more information is available on the use of softer, more absorptive coarse aggregates.
I. Introduction

A. Project Purpose

Blue Earth County has about 400 miles of bituminous paved roads. This hard surfacing has provided a good driving surface for the public. However, despite seal coating, patching, and crack sealing maintenance, the hot mix bituminous mixes constructed since 1960 have typically deteriorated and required costly maintenance overlays after about 12 to 15 years and total rehabilitation after about 30 to 40 years. Failure modes including oxidation, raveling, and cracking often appear to be more age related than load related.

Blue Earth County has limited aggregate supplies. Recent years have seen the depletion of the higher quality, coarse aggregate. As a consequence, mixes have tended to become sandier with more deleterious materials. A higher quality mix, by reducing overlay needs and supplementing our lower quality aggregate with imported durable quarry rock, would extend the life of our gravel resources.

The purpose of this project was to explore the feasibility of providing a higher quality hard surface with lower life cycle costs using the Superpave Level I technology.
FINN ROAD / OIL GRAVEL PROJECT

BETWEEN: TH No. 22 & TWP. RD. No. 167, 1.0 MI. SOUTH OF MANKATO
FROM: NORTH 1/4 CORNER OF SEC. 21-107-26
TO: NORTHWEST CORNER OF SEC. 31-108-26

GROSS LENGTH 27532.24 FEET 5.214 MILES
BRIDGE LENGTH 237.75 FEET 0.045 MILES
NET LENGTH 27294.49 FEET 5.169 MILES

GRADED IN 1995 UNDER S.A.P. 07-608-10

DESIGN DESIGNATION
ADT (Current Year)  604 1996    DESIGN SPEED 55 MPH
ADT (Future Year)   965 2016    SOIL FACTOR 130
7 ULT. 9 TON DESIGN  SHOULDER WIDTH 8.0'

END S.A.P. 07-608-11
STA 375+00

EQUATION
STA 320+68.03 = 320+35.79

BRIDGE EXCEPTION 237.75'
STA 224+15.58 TO 226+53.33

BEGIN S.A.P. 07-608-11
STA 100+00
B. Pavement History

CSAH 8 was graded and 6 inches of Mn/DOT class 5 gravel base placed in 1995. Four inch drain tile was installed under both future pavement edges. The tile was placed as deep as possible while still ensuring positive tile outlet drainage into the ditches. The road was designed for a 7 ton ultimate 9 ton bituminous pavement. Figure 1 shows the project location.

C. Traffic Conditions

The current ADT is 604 and projected 2016 year ADT is 965.

Traffic consists predominantly of farm to market auto and light truck traffic. However, the road also must carry occasional heavy agricultural loads of fertilizer, agricultural machinery, and crops during planting and harvest. With completion of the South Route CSAH 90 project, the road is projected to carry additional commuter traffic for Mankato State University.
II. Demonstration Project Design

Blue Earth County in cooperation with Mn/DOT and the Local Road Research Board constructed a Superpave Level I mix design for a maintenance overlay of CSAH 30 in 1995. This project was a test of the cost and constructibility of the Superpave Level I mix on a low volume County road. An aggregate structure on the fine side of the maximum density line was chosen. The mix was found to be comparable in cost to the traditional mix design. A reduced asphalt demand compensated for additional aggregate costs. The mix also was found to be readily constructible using our regular construction and inspecting methods.

A. New Pavement, Coarse Design Test

The CSAH 8 project was a test of the feasibility of the Superpave Level I mix design on a newly graded embankment. It also was a coarser mix design with the aggregate structure lying on the coarse side of the maximum density line. This was recognized to be a more costly design requiring additional coarse crushed quartzite compared to the 1995 project; however, potentially it would require less asphalt and be a more stable, durable mix.

B. Pavement Structural Section

Figure 2 is flexible pavement design data. Figure 3 is a typical section. The pavement was analyzed using both the soil factor and sigma N18 methods. The soil factor method was chosen since it gave slightly more conservative results and was consistent with past
successful County experience for these conditions. A total of 12 inches of gravel base, 2 inches of bituminous base, and 1.5 inches of wearing course were specified by this design method.
III. Bituminous Mix Design

The mix design was done by MTE under contract to Blue Earth County. Superpave Level I design methods were specified. After completion of the design using the gyratory compactor, MTE did a companion Marshall sample to determine the appropriate voids with this tool. This would provide an alternative method to measure voids during construction using locally available Marshall testing equipment. The MTE design report is Appendix A.

A. Aggregate Structure

Figure 4 shows tabular data and Figure 5 plotted curve information for the selected aggregate structure. The aggregate design consisted of 15 percent natural sand from the Prang pit, 20 percent crushed medium gravel, and 15 percent crushed coarse gravel from the Cedar Grove pit, and 50 percent 3/4 inch clean, 100 percent crushed quartzite from New Ulm quarries. No measure of crushing of the gravel sources was made.

There was some concern about stripping of asphalt from the quartzite. The Lottman test did not find this to be a problem.

B. Binder Selection

The County wished to avoid the higher costs of polymer modified asphalts, minimize cracking, raveling, and age-related deterioration, and have sufficient stability for the projected traffic. Mn/DOT binder recommendation for our area is PG 58-28. However, due to the stability anticipated from the coarse, crushed
mix and good performance of PG 52-34 binder on the County's 1995 Superpave project, the County selected the PG 52-34 binder. The County also considered the projected low heavy truck traffic on the road. The selected binder provides about a 50 percent probability the high temperature and 80 percent probability the low temperature will not be exceeded.
FLEXIBLE PAVEMENT DESIGN
BLUE EARTH CO HIGHWAY DEPARTMENT
CSAH 8 PROJECT 07-608-11

GEOMETRIC DESIGN STANDARDS

SOIL FACTOR 130 %
TRAFFIC MAP YEAR 1995
ADT. FROM TRAFFIC MAP 590
PRESENT YEAR 1996
ADT. PRESENT YEAR 604
ANNUAL GROWTH 2.37 % (ROAD DESIGN MANUAL) FROM TABLE 7-5.03E
GROWTH FACT. 20 YEAR 25.21
PROJECTION FACTOR 1.60
PROJECTED 20 YEAR ADT 965
HCADT 10% 96

DESIGN SPEED 55 MPH
LANE WIDTH 12 FEET
SHOULDER WIDTH 6 FEET
INSLOPES 4 : 1
RECOVERY AREA 37 FEET

DESIGN USING SOIL FACTORS

DESIGN STRENGTH 9 TON
REQUIRED G.E. = 22 (FROM STATE AID MANUAL FIG. 8-892.201)

MATERIAL DEPTH G.E. FACTOR G.E.
FUTURE WEAR 2341 0 2.25 0.00
FUTURE WEAR 2331 1.5 2 3.00
BITUM WEAR 2331 1.5 2 3.00
BITUM BINDER 2331 2 2 4.00
BITUM BASE 2331 0 2 0.00
CLASS 5 AGGR BASE 12 1 12.00

DESIGN USING SIGMA N-18

DESIGN STRENGTH 10 TON
REQUIRED G.E. = 19

MATERIAL DEPTH G.E. FACTOR G.E.
FUTURE WEAR 2341 0 2.25 0.00
FUTURE WEAR 2331 1.5 2 3.00
BITUM WEAR 2331 1.5 2 3.00
BITUM BINDER 2331 2 2 4.00
BITUM BASE 2331 0 2 0.00
CLASS 5 AGGR BASE 9 1 9.00

DISTRIBUTION OF VEHICLE (USE UP DATED N18 FACTORS 1-10-92)

VEHICLE TYPE DIST FACTOR SINGLE LANE ADT N18 FACTOR DESIGN LANE DAILY N18
1 PASSENGER CARS 75.1 229 0.0004 0.00
2 PANELS & PICKUPS UNDER 1 TON 166 48 0.007 0.34
3 SINGLE UNIT-2 AXLE 1 TIRE 2.4 7 0.01 0.07
4 SINGLE UNIT-2 AXLE 5 TIRE 2.61 8 0.25 1.96
5 SINGLE UNIT-3 AXLE 1 TIRE 1.7 5 0.88 2.98
6 TRACTOR SEMI-3 AXLE 1 TIRE - 0 0.39 0.00
7 TRACTOR SEMI-3 AXLE 5 TIRE 0.1 0 0.51 0.15
8 TRACTOR SEMI-3 AXLE 10 TIRE 0.5 2 1.13 1.71
9 TRACTOR SEMI-3 AXLE 20 TIRE 0 0 0 0.00
10 TRUCKS W/ TRAILERS & BUSES - 0 2.4 0.00
11 PRESENT DAILY N18 = 9.02

TIME GROWTH FACTOR FOR 20 YEARS @ 1.6 PROJECTION FACTOR FROM TABLE 7-5.03 E = 25.21
(SIGMA N18)20 = 365 x DAILY N18 x GROWTH FACTOR = 83,049

Figure 2
TYPICAL SECTION

Figure 3
1. Aggregate Gradations:

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percent Passing</th>
<th>Percent Passing</th>
<th>Percent Passing</th>
<th>Percent Passing</th>
<th>Percent Passing</th>
<th>Gradation Ranges</th>
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<tbody>
<tr>
<td></td>
<td>New Ulm 3/4</td>
<td>Prange Sand</td>
<td>Cedar Grove Med</td>
<td>Cedar Grove Cor.</td>
<td>Total</td>
<td>Minimum</td>
</tr>
<tr>
<td>1</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>3/4</td>
<td>96.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>1/2</td>
<td>72.0</td>
<td>100.0</td>
<td>99.0</td>
<td>66.0</td>
<td>80.7</td>
<td>77.0</td>
</tr>
<tr>
<td>3/8</td>
<td>38.0</td>
<td>99.0</td>
<td>91.0</td>
<td>47.0</td>
<td>59.1</td>
<td>55.0</td>
</tr>
<tr>
<td>#4</td>
<td>4.4</td>
<td>93.0</td>
<td>67.0</td>
<td>30.0</td>
<td>34.1</td>
<td>30.0</td>
</tr>
<tr>
<td>#8</td>
<td>4.0</td>
<td>86.0</td>
<td>48.0</td>
<td>24.0</td>
<td>28.1</td>
<td>24.0</td>
</tr>
<tr>
<td>#16</td>
<td>4.0</td>
<td>68.0</td>
<td>32.0</td>
<td>19.0</td>
<td>21.5</td>
<td>19.0</td>
</tr>
<tr>
<td>#30</td>
<td>3.5</td>
<td>41.0</td>
<td>21.0</td>
<td>16.0</td>
<td>14.5</td>
<td>16.0</td>
</tr>
<tr>
<td>#50</td>
<td>3.5</td>
<td>25.0</td>
<td>12.0</td>
<td>9.7</td>
<td>7.0</td>
<td>9.7</td>
</tr>
<tr>
<td>#100</td>
<td>2.0</td>
<td>12.0</td>
<td>8.1</td>
<td>9.1</td>
<td>5.8</td>
<td>9.1</td>
</tr>
<tr>
<td>#200</td>
<td>1.5</td>
<td>6.4</td>
<td>5.8</td>
<td>6.7</td>
<td>3.9</td>
<td>6.7</td>
</tr>
</tbody>
</table>

Blend % = 50% 15% 20% 15% 100.0

2. Aggregate Portions and Source:
- New Ulm Quartzite 3/4 Class A = 8-28-96 8-28-96 8-29-96
- Prange Sand = 50% 60% 55%
- Cedar Grove Medium = 15% 10% 12%
- Cedar Grove Coarse = 20% 15% 18%

3. Bituminous Material
- Koch PG Grade 52-34 = 5.0% 4.7% 4.9%

4. Mix Density = 147.1 lbs/c.f.
IV. Contracting Method

A. Procurement

Public advertisement and low bid procurement under Minnesota law and County State Aid requirements for local governmental agencies was followed.

B. Pay Items and Agency Control

The contract included separate pay items for quartzite, gravel, asphalt, and produce and lay. The contract also provided the County with the authority to require changes in the relative quantities of these materials depending on construction tests to ensure the highest quality product for the County. Ordinary compaction was specified with a nuclear density gauge used to establish the optimum rolling pattern. The contractor was required to provide both a steel vibratory and rubber tire roller.

C. Construction Quality Control

County forces regularly took gradation and asphalt content measurements. These tests were all within specifications. Voids updates were taken by sending samples to MTE for gyratory compaction and to Mn/DOT District 7 and American Testing of Mankato for Marshall compaction. Cores were cut and densities calculated by American Testing.
V. Construction

H.R. Loveall Construction of Winnebago was awarded the construction contract.

Prior to paving, an additional 6 inches of Mn/DOT class 5 gravel base providing a total of 12 inches of gravel base was laid. The gravel base was trimmed using string line control to ensure a uniform pavement thickness and good ride.

A. Equipment

A continuous drum plant was set up in the Prang pit about 5 miles from the construction site. Piles of aggregate appeared to be uniform and non-segregated. The imported quartzite was off loaded from truck trailers and pushed into a pile with a dozer. No significant segregation was noted. The aggregate and asphalt were fed into the drum and heated to 290 degrees Fahrenheit to ensure uniform mixing and coating. The mix was transferred by conveyor into a silo for storage and weighing before being dropped into "Flo boy" conveyor type truck trailers. The silo was kept partially full and included a baffle at the top to reduce segregation effects. The production rate was about 2,700 tons per day.

The mix was trucked to the construction site and conveyed from the rear of the trailers into Cedar Rapids brand paver. The paver used a long ski automatic grade control to ensure uniform paving depth.
Compaction consisted of a breakdown steel vibratory roller, intermediate rubber tire roller, and steel non-vibratory roller.

Figure 7 shows construction photos. Figure 8 is contract cost information.

B. Construction Observations

No significant construction problems were encountered. The mix was extremely stable and could be compacted immediately after lay down. Even during high air temperatures, loaded trucks did not deform the mat during paving or shouldering operations. The pavement smoothness was excellent, perhaps due to its stability during rolling operations.

Early in the paving, it was found voids were below the 4 percent optimum. The gradation was adjusted from 50 percent quartzite to 60 percent and then to 55 percent. This resulted in voids near the optimum.

During placement of the first lift, it was noted that the rubber tire roller was leaving random, occasional clumps of asphalt and fines. For the final wearing coarse a second steel roller was used in place of the rubber tire intermediate roller.

Bituminous cores were taken by American Testing under contract to the County soon after paving. Figure 6 is a summary of these tests.
The densities were within specifications recommended for Mn/DOT QA/QC projects.
<table>
<thead>
<tr>
<th>No.</th>
<th>Location</th>
<th>Thickness</th>
<th>Density</th>
<th>Max Density</th>
<th>% Max Density</th>
<th>Max Density % Voids</th>
<th>Mar % Max Density</th>
<th>Mar % Voids</th>
</tr>
</thead>
<tbody>
<tr>
<td>1W &amp; 1B</td>
<td>370+40</td>
<td>3.6&quot;</td>
<td>144.0</td>
<td>93.5</td>
<td>6.5</td>
<td>97</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>2W &amp; 2B</td>
<td>326+60</td>
<td>3.6</td>
<td>136.5</td>
<td>88.5</td>
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<td>8</td>
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<tr>
<td>3W &amp; 3B</td>
<td>278+00</td>
<td>No.</td>
<td>138.9</td>
<td>89.5</td>
<td>10.4</td>
<td>94</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>4W &amp; 4B</td>
<td>203+94</td>
<td>6.4</td>
<td>138.6</td>
<td>90.0</td>
<td>10.0</td>
<td>94</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>5W &amp; 5B</td>
<td>119+07</td>
<td>3.1</td>
<td>138.5</td>
<td>90.0</td>
<td>10.0</td>
<td>94</td>
<td>6</td>
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</table>

**Note:** Maximum density value of 154.0
Marshall Density value of 148.0
## CONTRACT COST

<table>
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<tr>
<th>ITEM NO.</th>
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<th>UNIT</th>
<th>QUANTITY</th>
<th>UNIT PRICE</th>
<th>CONTRACT AMOUNT</th>
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<tbody>
<tr>
<td>2104.505</td>
<td>REMOVE BITUMINOUS PAVEMENT</td>
<td>SQ YD</td>
<td>22</td>
<td>10.00</td>
<td>220.00</td>
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<tr>
<td>2104.513</td>
<td>SAWING BITUMINOUS PAVEMENT</td>
<td>LIN FT</td>
<td>65</td>
<td>3.00</td>
<td>195.00</td>
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<tr>
<td>2105.525</td>
<td>TOPSOIL BORROW (LIV)</td>
<td>CU YD</td>
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<td>8000.00</td>
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<tr>
<td>2118.501</td>
<td>AGGREGATE SURFACING, CL-2 (M)</td>
<td>TON</td>
<td>200</td>
<td>10.00</td>
<td>, 2000.00</td>
</tr>
<tr>
<td>2211.501</td>
<td>AGGREGATE BASE CL-5</td>
<td>TON</td>
<td>40000</td>
<td>5.40</td>
<td>216000.00</td>
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<tr>
<td>0211.507</td>
<td>BASE PREPARATION (STRINGLINE)</td>
<td>RD STA</td>
<td>273</td>
<td>45.00</td>
<td>12285.00</td>
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<tr>
<td>2221.501</td>
<td>AGGREGATE SHOULDERING, CL-1 (M)</td>
<td>TON</td>
<td>4500</td>
<td>6.25</td>
<td>28125.00</td>
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<tr>
<td>2331.504</td>
<td>BITUMINOUS MATERIAL FOR MIXTURE</td>
<td>TON</td>
<td>1321</td>
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<td>175693.00</td>
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<td>0331.508</td>
<td>BITUMINOUS AGGREGATE (COARSE &amp; FINE)</td>
<td>TON</td>
<td>17010</td>
<td>3.00</td>
<td>51030.00</td>
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<tr>
<td>0331.509</td>
<td>BITUMINOUS AGGREGATE (M) (CLASS A ROCK)</td>
<td>TON</td>
<td>5669</td>
<td>12.50</td>
<td>70862.50</td>
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<tr>
<td>0331.510</td>
<td>BITUMINOUS (PRODUCE, HAUL &amp; LAY)</td>
<td>TON</td>
<td>24000</td>
<td>7.60</td>
<td>182400.00</td>
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<tr>
<td>2357.502</td>
<td>BITUMINOUS MATERIAL FOR TACK COAT</td>
<td>GAL</td>
<td>6400</td>
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<td>4800.00</td>
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<tr>
<td>2575.501</td>
<td>SEEDING</td>
<td>ACRE</td>
<td>0.90</td>
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<td>2610.00</td>
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<tr>
<td>2575.505</td>
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<tr>
<td>2580.501</td>
<td>TEMPORARY LANE MARKING</td>
<td>RD STA</td>
<td>273</td>
<td>3.00</td>
<td>819.00</td>
</tr>
</tbody>
</table>

**PRODUCTION RATE AVERAGE FOR "GOOD" DAY 2700 TON PER DAY.**

Figure 8
Cedarapids paver, base course with long ski.

Paver with Flo-Boy trailer trucks.

Closing base course with each day's paving.

Moisture weeping after rainfall. Figure 7
VI. Conclusions

A. Performance

The project has an excellent ride and appearance. It received a MAPA award for its class in 1996. After one winter, there does not appear to be any thermal cracks, raveling, or other damage.

The pavement has a very open texture compared to the traditional 2331 mix. This has raised some concerns about potential water and ice damage. None has been noted to date.

Several hours after rains, the pavement may weep water at isolated locations. Typically, these are on hills or superelevation areas where wet embankments are often found. No stripping or loose aggregate has been noted in these areas to date. We are planning on taking cores and testing for permeability during the summer of 1997. During the 1997 spring thaw, some weeping has been noted; however this is generally similar or less than experienced on our other pavements.

One of the cores cut for density tests was stored on an inclined surface and has slumped. This has raised some concern about the stability of the mix. However, this is probably due to the thick oil film and soft asphalt used for the design. No problems relating to stability have been noted on the actual pavement.
In accordance with Superpave Level I design criteria for this traffic volume, no fine aggregate angularity tests were run. However, the County has purchased this test equipment and is conducting the test on sand commonly used in our contracts. Preliminary results show marginal conformance with the specification for 3 million plus ESALS. Addition of a relatively small amount of manufactured sand would clearly meet this specification and will be considered in future contracts.

B. Costs

The Superpave mix design for CSAH 30 in 1995 was about 3 percent more per ton and for CSAH 8 about 18 percent more per ton than the traditional 2331 mix design. As discussed earlier, the reduced asphalt demand for the CSAH 30 fine gradation Superpave mix almost compensates for the higher cost of the 25 percent imported quartzite. However, we found that the 55 percent quartzite required for the coarse gradation Superpave mix was not sufficiently balanced by reduced asphalt demand.

A new pavement structure consists of gravel base and pavement. Comparing the total pavement structure costs is a better measure than comparing only the per ton bituminous costs. The total pavement structure cost is about 2 percent more for the fine graduation Superpave mix and about 9 percent more for the coarse gradation Superpave mix. This additional cost could be readily recaptured if Superpave has a lower life cycle cost as indicated by SHRP research.
Additional projects and maintenance experience collected over several years is needed to adequately determine the cost effectiveness of Superpave.

However, based on positive experience to date, Blue Earth County will continue to build Superpave fine gradation mixes.
VII. Further Research

The University of Minnesota is currently researching the following items related to the economics of Superpave Level I design decisions:

• Use of limestone rather than quartzite for the coarse, crushed aggregate needed to supplement fine gravel sources. What are the life cycle cost implications of the additional asphalt demand and lower durability associated with the softer limestone?

• Use of coarse Superpave mixes in lieu of polymers to achieve adequate stability. Is the cost of the additional imported quartzite needed to design on the coarse side of the maximum density line returned by a more stable mix not requiring polymers to modify the high temperature characteristics of the asphalt?
Appendix A
MTE Design Report
INTRODUCTION
This report is a summary of the SHRP Superpave Level I mix design work performed by MTE services for Blue Earth County, Minnesota. Our instructions were to provide a Level I mix design for a pavement with a design life of approximately 100,000 design ESAL's. The asphalt binder chosen for this project was a SHRP PG 52-34 to be supplied by Koch Materials Co. Based on the SHRP criteria as shown in Attachment 1 a pavement of 100,000 design ESAL's in a the climate of Blue Earth County will use a $N_{\text{max}}$ gyratory compaction value of 104 gyrations and a $N_{\text{design}}$ gyratory compaction value of 68 gyrations. We were also told that if at all possible the goal was to provide a coarse aggregate skeleton structure that would lie beneath the maximum density line and meet the SHRP gradation requirements. Aggregate samples were provided by Blue Earth County. The gradations of individual samples are provided in Attachment 2. In addition to the SHRP Level I mix design, we were also asked to perform a standard Marshall mix design for comparison. It was hoped that a correlation between the Gyratory and Marshall designs could be obtained and that the Marshall design could be used for field quality control of the project.

INITIAL TESTS FOR SKELETON SELECTION
SHRP recommends a procedure for combining trial mix designs at a single binder content in an effort to find an aggregate blend that will provide sufficient VMA at a reasonable binder

---

1No binder tests were performed by MTE. We requested samples of PG-52-34 from Koch and were sent samples labeled as such.
content so that a 4% voids level can be achieved. This approach as outlined by Huber and Shuler$^2$ is based on earlier work where the aggregate gradation is chosen to maximize the distance of the blend from the maximum density line. As the authors point out it is important that the maximum density line be defined according to the SHRP specifications. The aggregate blends for this project conformed to a 25 mm maximum sized aggregate or a 19 mm nominal maximum size aggregate. The SHRP design procedure uses a a trial and error method to establish the aggregate skeleton that will provide the optimum voids level for a reasonable asphalt level. Multiple blends are selected and then each blend is prepared at a single binder level and voids are determined. MTE has advanced this process by several steps. We have devised, using a mixed integer linear program, an approach whereby the distance from the maximum density line can be maximized for any combination of aggregates. Specific control points can be input to the program and the final gradation can be forced beneath (or above) the maximum density line as one desires. As long as the aggregates used do not change, one can be assured that if a blend yields a greater area factor, then it will yield a blend with a greater VMA and voids level than other blends with a smaller area factor. This is essentially the goal of the aggregate selection phase of the Level I mix design process with the exception that our approach is more systematic.

To determine the appropriate aggregate skeleton Blends A, B, and C as shown on Table 1 were mixed with 5% PG 52-34 and compacted to 68 gyrations. Graph “BEAVOID2” is a plot of the resulting mix air voids versus the area factor. The R$^2$ for this plot was 0.86 and if the aggregate blend graph “BLENDABC” is examined, the variation of area factor with aggregate trace is obvious. After Blends A, B and C were evaluated; a second set of blends were prepared, Blends 1, 2, and 3. These blends were prepared using 4.5% PG 52-34 and 2 of the same aggregate skeletons as use previously. As can be seen from the plot of “BEAVOID2", it appears as though the blend of 50% Quartzite, 15% Cedar Grove Coarse, 20% Cedar Grove Medium and 15% Prange Sand can produce a mix that will have the desired air voids of 3.5% to 4% at somewhere in the range of 4.7 to 5% PG 52-34. In addition Table 2 shows a summary of the Superpave determination of volumetric properties for the Blends 1, 2, and 3.

$^2$Huber, Gerald and Shuler, Scott; “Providing Sufficient Void Space for Asphalt Cement: Relationship of Mineral Aggregate Voids and Aggregate Gradation” ASTM STP 1147, Richard C. Meininger, editor, 1992
As can be seen, all 3 blends meet the criteria at 4.5% AC, but Blend 1 has the lowest predicted air voids. Since the mix was to be coarse, our goal was to achieve the required mix properties without using excessive asphalt. For all of these reasons we decided to carry blend #1 forward and perform the full gyratory mix design covering the range of 5.0 to 6.5% AC using 5.0, 5.3, 5.7, 6.1 and 6.5% AC in the blends.

SUPERPAVE VOLUMETRIC MIX DESIGN

Because of anomalous results using the target AC levels, we actually performed this mix design three different times. There were slight variations in values from one mix design to another, but the inconsistent results replicated from one mix design effort to the next. Specifically, we found that the voids level at 5.3% AC was lower than the voids level at 5.7% AC and this carried through into the Marshall design as well. We also found that there was little discernible difference between the results obtain at 5.0, 5.3 and 5.7% AC. What started out as an effort to fine tune the percent of binder needed for this mix, ended up showing us that random variation between laboratory blends and testing variability is more than enough to overcome the difference in measured mix properties if the AC level only changes by 0.3%. In the final analysis we were able to obtain data by combining the results of several trails that enabled the Superpave software to provide us with a viable model. The actual Superpave gyratory data tables have been appended as Table 3A, 3B and 3C. The summary of Blend information from Superpave has been reproduced as Table 4. A TSR test was run on 100 mm diameter specimens because we did not have the equipment needed to run TSR tests on 150 mm diameter specimens. The TSR value for the mix at 5.0% AC was 88.6%. The reports from FHWA have been that 150 mm diameter specimens typically yield TSR values higher than 100 mm specimens. Since the 100 mm specimens gave us a value greater than 80%, we felt that this mix would comply with the Superpave TSR requirements of 80% minimum retained tensile strength.
MARSHALL MIX DESIGN

The Marshall Mix Design for this blend is attached to this report. An examination of the Voids vs. AC% plot shows that the predicted AC level is approximately 5.3% for a 4% voids level. A goal of this work was to determine if a correlation could be established between the Superpave gyratory mix design and the Marshall mix design so that field QC could be performed using Marshall equipment. As can be seen from the attached plot "GMVOIDS" the correlation between the two different mix design procedures has an R^2 of 0.56. Not only do the two procedures fail to produce equivalent results (note the line of equality versus the fitted curve), but the correlation coefficient is very low.

PRODUCTION SAMPLE TEST RESULTS

Mix samples were delivered to our lab on two different occasions for evaluation. On 8/29/96 a sample was evaluated for % binder and voids because of concern that the field voids were too high. The attached summary sheet of aggregate gradations, TABLE 5, shows the results of these tests. Table 6 is a summary of the voids comparison of field mix that was compacted in our lab using the Gyratory and the Marshall procedures. This is not enough data from which to draw conclusions regarding Marshall and Gyratory voids; however the inability of the lab generated blends to produce a correlation argues against making the attempt to find a correlation.

CONCLUSIONS

The approach of searching for an aggregate skeleton as outlined in the SHRP mix design manual appears to be a sound one. Rather than performing full mix designs only to find that voids and VMA are inadequate, the stepwise approach of SHRP enables the designer to find a reasonable aggregate blend prior to producing an excessive number of blends. This project showed that the use of a mixed integer linear program can simplify the task of finding the aggregate skeleton and make it more rational. The correlation developed between distance from the maximum density line (reported as Area Factor) and mix air
voids were quite good and could be used for predictions as long as the specific aggregates being evaluated did not change.

Trying to "fine tune" the mix design by using asphalt contents of less than 0.5% intervals proved to be counterproductive. While it would seem that choosing %AC in a narrow range surrounding the anticipated target value would help to zero in on the exact value; it would appear that the inherent variability of producing a mix sample is as great or greater than the variation in air voids that results from modest changes in the asphalt content. As a result of this experience, the SHRP recommendation of target + 0.5% and target + 1% AC should be adhered to.

Although I went into this project believing that a relationship between Marshall voids and Gyratory voids should be obtainable; I am forced to conclude that if such a relationship could be obtained for a given project there would be no guarantee that one could develop a reasonable relationship for any subsequent project. Coarser mixes, such as the one produced in Blue Earth County and the type that SHRP favors, are most likely to cause problems because of the difficulty of a compressive blow compaction method, such as the Marshall procedure, to effect compaction without fracturing particles. The end result of the laboratory efforts to find a reasonable relationship and the leads to the conclusion that Superpave projects should use field gyratory compactors to QC the work. It should be kept in mind that the industry is in a period of transition and that some accommodation of the low installed base of field gyratories may be needed for the next year or two. However, the goal should be to use the gyratory for field control as soon as practicable.

During and shortly after the project, concerns were expressed about the "softness" of field cores. Blue Earth County is in a SHRP PG 58 region based on the 50% confidence interval. However, I have shown on the attached map of Minnesota the actual high pavement temperature at the 50% confidence level. You can see from this data that the entire area shown in pink is into the PG 58 grade by less than 0.5° C. Given the low design ESAL's of the project, a PG 52 grade should perform adequately. You have to ask yourself whether the substantial cost increase of using a PG 58-34 is worth the added protection of 0.5° C between the region shown in pink and that shown in blue. The other factor to keep in mind regarding soft field cores is that due to the coarse aggregate structure and high film thickness, this freshly cored mix will not exhibit a high degree of unconfined strength. It should
be noted that we had several samples of field mix that had been gyratory compacted to the $N_{\text{MAX}}$ level and over a period of several months those specimens never exhibited any structural degradation. I believe that once this mix has a chance to consolidate under traffic that you will have no cause for concern.
MINNESOTA HIGH TEMPERATURE CONTOURS BASED ON THE 50% CONFIDENCE INTERVAL. CALCULATED AT 20 mm PAVEMENT DEPTH.

Data calculated from SHRP SUPERPAVE weather database

This data presentation provided courtesy of MTE
### TABLE 2
SUPERPAVE MIX DESIGN SUMMARY OF TRIAL BLENDS

<table>
<thead>
<tr>
<th>BLEND ID</th>
<th>AC%</th>
<th>AIR Voids %</th>
<th>VMA %</th>
<th>VMA NEEDED</th>
<th>% Gmm @ N_initial &lt;89%</th>
<th>% Gmm @ N_max &lt;98%</th>
<th>% Gmm @ N_design</th>
</tr>
</thead>
<tbody>
<tr>
<td>BLEND 1</td>
<td>4.5</td>
<td>6.4</td>
<td>16.4</td>
<td>13</td>
<td>85.4</td>
<td>95.2</td>
<td>93.6</td>
</tr>
<tr>
<td>BLEND 2</td>
<td>4.5</td>
<td>7.7</td>
<td>17.1</td>
<td>13</td>
<td>83.6</td>
<td>93.9</td>
<td>92.3</td>
</tr>
<tr>
<td>BLEND 3</td>
<td>4.5</td>
<td>9.2</td>
<td>18.5</td>
<td>13</td>
<td>82.5</td>
<td>92.3</td>
<td>90.8</td>
</tr>
</tbody>
</table>

### TABLE 3
Properties at Design Gyrations

<table>
<thead>
<tr>
<th>AC%</th>
<th>Density, kg/m³</th>
<th>Air Voids, %</th>
<th>VMA %</th>
<th>VFA%</th>
<th>Meas Max Gmm</th>
<th>Dust Eff AC Ratio</th>
<th>Density @ N_initial, 7</th>
<th>Density @ N_max, 68</th>
<th>Density @ N_max, 104</th>
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<tbody>
<tr>
<td>5</td>
<td>2,347</td>
<td>5.4</td>
<td>16.1</td>
<td>66.4</td>
<td>2.5</td>
<td>0.7</td>
<td>86.4</td>
<td>94.6</td>
<td>96.1</td>
</tr>
<tr>
<td>5.3</td>
<td>2,357</td>
<td>4.6</td>
<td>16</td>
<td>71.2</td>
<td>2.5</td>
<td>0.7</td>
<td>86.4</td>
<td>65.4</td>
<td>97.1</td>
</tr>
<tr>
<td>5.7</td>
<td>2,387</td>
<td>2.8</td>
<td>15.3</td>
<td>81.7</td>
<td>2.5</td>
<td>0.6</td>
<td>88.3</td>
<td>97.2</td>
<td>98.9</td>
</tr>
<tr>
<td>6.1</td>
<td>2,358</td>
<td>1.6</td>
<td>16.3</td>
<td>90.2</td>
<td>2.4</td>
<td>0.6</td>
<td>90</td>
<td>98.4</td>
<td>99.9</td>
</tr>
<tr>
<td>6.5</td>
<td>2,337</td>
<td>2.2</td>
<td>17.7</td>
<td>87.6</td>
<td>2.4</td>
<td>0.6</td>
<td>89</td>
<td>97.8</td>
<td>99.4</td>
</tr>
</tbody>
</table>

### TABLE 4
SUMMARY OF BLEND INFORMATION

<table>
<thead>
<tr>
<th>Design parameter</th>
<th>Test Value</th>
<th>Criteria Value</th>
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<tbody>
<tr>
<td>Air Voids</td>
<td>3.8</td>
<td>4</td>
</tr>
<tr>
<td>Asphalt%</td>
<td>5.4</td>
<td>N/A</td>
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<tr>
<td>VMA</td>
<td>15.5</td>
<td>13</td>
</tr>
<tr>
<td>VFA</td>
<td>76.1</td>
<td>70-80</td>
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<tr>
<td>Density</td>
<td>2325 kg/m³</td>
<td>N/A</td>
</tr>
<tr>
<td>Max Gravity</td>
<td>2.5</td>
<td>N/A</td>
</tr>
<tr>
<td>Density @ N_initial</td>
<td>87.6</td>
<td>89.0 max</td>
</tr>
<tr>
<td>Density @ N_max</td>
<td>97.9</td>
<td>98.0 max</td>
</tr>
<tr>
<td>Dust Proportion</td>
<td>0.7</td>
<td>0.6-1.2</td>
</tr>
<tr>
<td>Tensile Strength Ratio (TSR)</td>
<td>88.6%</td>
<td>80%</td>
</tr>
<tr>
<td>Fine Aggregate Angularity</td>
<td>60</td>
<td>0</td>
</tr>
<tr>
<td>Sand Equivalency</td>
<td>84</td>
<td>40</td>
</tr>
<tr>
<td>Flat &amp; Elongated</td>
<td>Not tested</td>
<td>0</td>
</tr>
<tr>
<td>1 Crushed face &lt; 100 mm</td>
<td>100</td>
<td>55</td>
</tr>
</tbody>
</table>
## TABLE 5

<table>
<thead>
<tr>
<th>GRADATIONS FOR BLUE EARTH COUNTY</th>
<th>3/4&quot; Quartz</th>
<th>Cedar Grove Coarse</th>
<th>Cedar Grove Medium</th>
<th>Prange Sand</th>
</tr>
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<tbody>
<tr>
<td>Sieve in mm size^0.45</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25.4</td>
<td>4.287214</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>19</td>
<td>3.762176</td>
<td>96</td>
<td>93</td>
<td>100</td>
</tr>
<tr>
<td>12.5</td>
<td>3.116086</td>
<td>72</td>
<td>66</td>
<td>99</td>
</tr>
<tr>
<td>9.4999999</td>
<td>2.754074</td>
<td>38</td>
<td>47</td>
<td>91</td>
</tr>
<tr>
<td>4.7499999</td>
<td>2.0161</td>
<td>4.4</td>
<td>30</td>
<td>67</td>
</tr>
<tr>
<td>2.36</td>
<td>1.47167</td>
<td>4</td>
<td>24</td>
<td>48</td>
</tr>
<tr>
<td>1.18</td>
<td>1.077</td>
<td>4</td>
<td>19</td>
<td>32</td>
</tr>
<tr>
<td>0.6</td>
<td>0.7946357</td>
<td>3.5</td>
<td>16</td>
<td>21</td>
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<tr>
<td>0.3</td>
<td>0.5817074</td>
<td>3.5</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>0.07500002</td>
<td>0.3117293</td>
<td>1.5</td>
<td>6.7</td>
<td>5.8</td>
</tr>
</tbody>
</table>

| Specific Gravity                  | 2.667       | 2.666              | 2.64              | 2.64        |
| Before blend                      |             |                    |                   |             |
| After blend                       |             |                    |                   |             |
| change                            |             |                    |                   |             |
| change                            |             |                    |                   |             |
| Extracted Gradation 8/29/96       | 100         | 100                | 100               |
| Extracted Gradation 8/29/96       | 96.5        | 100                | 100               |
| Extracted Gradation 10/4/96       | 78.5        | 70.3               | 77.1              |
| Gradation                         | 63.9        | 54.4               | 61.1              |
| Gradation                         | 37.3        | 27.9               | 33                |
| Gradation                         | 27.3        | 20.3               | 23.1              |
| Gradation                         | 19.6        | 15.2               | 17.1              |
| Gradation                         | 13.9        | 11.3               | 12.5              |
| Gradation                         | 9.5         | 7.9                | 8.6               |
| Gradation                         | 4.4         | 3.9                | 4                 |
| % AC content                      | 4.9%        | 4.14%              | 5.2               |
TABLE 6  
SUMMARY OF FIELD MIX DATA

<table>
<thead>
<tr>
<th>DATE</th>
<th>GYRATORY VOIDS AT N_{DESIGN}</th>
<th>MARSHALL VOIDS</th>
<th>% AC</th>
</tr>
</thead>
<tbody>
<tr>
<td>8/29/96</td>
<td>5.3</td>
<td>5.8</td>
<td>4.9</td>
</tr>
<tr>
<td>9/26/96</td>
<td>3.4%</td>
<td>3.5%</td>
<td>5.2</td>
</tr>
</tbody>
</table>
AIR VOIDS FOR BLUE EARTH COUNTY BLENDS USED TO DETERMINE AGGREGATE SKELETON

- Blends A, B, & C at 5.0% PG 52-34; $R^2 = 0.861$
- Blends 1, 2, & 3 at 4.5% PG 52-34; $R^2 = 0.951$
GRADATION CHART REPORT DATE: 04/24/97

0.45 MAX DENSITY CHART FOR 25 mm MAX AGGREGATE;

19 mm NOMINAL MAX

PERCENT PASSING

SIEVE SIZES RAISED TO 0.45 POWER

- Blend of 50% Quartzite, 20% Cedar Grove Coarse
  20% Cedar Grove Fine, 10% Prange Sand
- Blend of 50% Quartzite, 15% Cedar Grove Coarse
  20% Cedar Grove Fine, 15% Prange Sand
- Blend of 60% Quartzite, 20% Cedar Grove Coarse
  15% Cedar Grove Fine, 5% Prange Sand

BLENDS:
- BLEND A; AREA FACTOR = 68.8
- BLEND B; AREA FACTOR = 57.6
- BLEND C; AREA FACTOR = 94.6

04/24/97 16:37:02 C:\PLOTIT\BLUEARTH\BLENDABC.SPF
COMPARISON OF VOIDS FROM GYRATORY AND MARSHALL COMPACTION PROCEDURES

\[ Y = 1.25697 + 0.55513X \]

\[ \text{EMS} = 0.740082 \]

\[ R^2 = 0.592 \]
SHRP GRADATION CHART

REPORT DATE: 10-8-96

0.45 MAX DENSITY CHART FOR 25 mm MAX AGGREGATE;

.19 mm NOMINAL MAX

Blue Earth County mix sample, tested 10-4-96
Extracted asphalt content = 5.2%

Gradation of extracted aggregate, Blue Earth County

SIEVE SIZES RAISED TO 0.45 POWER
Report of Bituminous Mix Design

Test #............: August 23, 1996
Date...............: August 23, 1996
Project Number....: BLUE EARTH COUNTY SUPERPAVE PROJECT
Project Name......: BLUE EARTH COUNTY SUPERPAVE PROJECT
County.............: BLUE EARTH
Specifications.....: SHRP SUPERPAVE

AGGREGATE SOURCES

<table>
<thead>
<tr>
<th>Percent</th>
<th>Material</th>
<th>Supplier\Source</th>
<th>SpG</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:</td>
<td>50.00 : 3/4&quot; QUARTZITE</td>
<td>NEW ULM QUARTZITE</td>
<td>2.677</td>
</tr>
<tr>
<td>2:</td>
<td>15.00 : 3/4&quot; COARSE GRAVEL</td>
<td>CEDAR GROVE PIT</td>
<td>2.661</td>
</tr>
<tr>
<td>3:</td>
<td>20.00 : 1/2&quot; MEDIUM GRAVEL</td>
<td>CEDAR GROVE PIT</td>
<td>2.640</td>
</tr>
<tr>
<td>4:</td>
<td>15.00 : BLEND SAND</td>
<td>PRANGE PIT</td>
<td>2.640</td>
</tr>
<tr>
<td>5:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total:</td>
<td>100.00</td>
<td>Effec SpG:</td>
<td>SpG Total: 2.662</td>
</tr>
</tbody>
</table>

Virgin Aggregate Blend: N/A

AGGREGATE GRADATIONS

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<thead>
<tr>
<th>Gradations</th>
<th>#1</th>
<th>#2</th>
<th>#3</th>
<th>#4</th>
<th>#5</th>
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<th>Spec.</th>
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<tr>
<td>1&quot;</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
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<tr>
<td>5/8</td>
<td>96.0</td>
<td>93.0</td>
<td>100.0</td>
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<tr>
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<td>5.8</td>
<td>6.4</td>
<td>3.9</td>
<td>6-2</td>
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</table>

Crush:        |
Thin:         |
&:            |
Elong:        |


Report of Bituminous Mix Design

Test # .............:  
Date ..............: August 23, 1996  
Project Number ....:  
Project Name ......: BLUE EARTH COUNTY SUPERPAVE PROJECT  
County ...........: BLUE EARTH  
Specification ......: SHRP SUPERPAVE

MIX PROPERTIES

<table>
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<th>#1</th>
<th>#2</th>
<th>#3</th>
<th>#4</th>
<th>#5</th>
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<tbody>
<tr>
<td>AC Content % By Weight</td>
<td>5.00</td>
<td>5.30</td>
<td>5.70</td>
<td>6.10</td>
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<tr>
<td>Rice SpG</td>
<td>2.473</td>
<td>2.470</td>
<td>2.456</td>
<td>2.443</td>
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<tr>
<td>Air Voids %</td>
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<td>Density Lbs @ 77 F.Bulk</td>
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<td>148.6</td>
<td>147.5</td>
<td>148.3</td>
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<tr>
<td>Density SpG Bulk</td>
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<td>2.386</td>
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<td>2.380</td>
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<td>Stability @ 140 Deg F</td>
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<td>1533</td>
<td>1492</td>
<td>1533</td>
<td>1658</td>
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<tr>
<td>Flow 0.01 In.</td>
<td>9.8</td>
<td>9.5</td>
<td>8.3</td>
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<td>9.8</td>
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<tr>
<td>VMA</td>
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<td>15.1</td>
<td>16.1</td>
<td>16.0</td>
<td>16.3</td>
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</table>

Asphaltic Material......: PG 52-34  
Asphalt Source.........: KOCH  
AC Specific Gravity.....: 1.024  
Recommended AC Binder. :  
Recommended AC Surface : 5.0  
Density Bulk SpG......: 2.361  
Density lbs/cu ft.Bulk.: 147.1  
Density Max SpG.......: 2.473  
TSR @ Blow Count........: +70  
Blow/Side (Beveled)....: 50  
Mix Temp/Degrees F.....: 270-290

Dry Back %..............:  
Stability..............: 1487  
Flow...................: 9.8

Voids Total Mix : 4.5  
VMA ...................: 15.7

Since this design is material specific, the conclusions and recommendations contained within are obtained from material submitted to and subjected to observations under laboratory conditions. Adjustments may become necessary when field laboratory data is obtained from plant produced mix. No guarantee or warranty is implied or offered.

John E. Jorgenson  
Materials Lab Manager