NORTH DAKOTA
DEPARTMENT OF TRANSPORTATION

MATERIALS AND RESEARCH DIVISION

Experimental Study ND 2004-01

Maximum Percentage of Asphalt Material in a Blended Base

Construction

Project NH-5-012(027)034

April 2006

Prepared by

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Disclaimer

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U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

EXPERIMENTAL PROJECT REPORT

EXPERIMENTAL PROJECT	EXPERIMENTAL PROJECT NO. 1 STATE ND 2 Y EAR 004 - NUMBER 01 SURF	CONSTRUCTION PROJ NO 8 NH-5-012(027)034	LOCATION 28 Bowman County
	EVALUATION FUNDING 48 1 HP&R 3 DEMONSTRATION 2 x CONSTRUCTION 4 IMPLEMENTATION	NEEP NO. 49	PROPRIETARY FEATURE? Yes 51 X No
SHORT TITLE	TITLE 52 Maximum Percentage of Asphalt Material in a Blended Base		
THIS FORM	DATE MO. 140 April -- YR. 2006	REPORTING 1 X INITIAL 2 ANNUAL 3 FINAL	

KEY WORDS	KEY WORD 1 145 Asphalt pavement	KEY WORD 2 167 base
	KEY WORD 3 189 Performance	KEY WORD 4 211 Shoulders
	UNIQUE WORD 233	PROPRIETARY FEATURE NAME 255

	Date Work Plan Approved	Date Feature Constructed:	Evaluation Scheduled Until:	Evaluation Extended Until:	Date Evaluation Terminated:
CHRONOLOGY	277 281	10/2005	10/2015 285	289	293

	QUANTITY OF UNITS (ROUNDED TO WHOLE NUMBERS)	UNITS		UNIT COST (*Dollars, Cents*)
QUANTITY AND COST	297	305 1 LIN. FT 2 SY 3 SY-IN 4 CY	5 TON 6 LBS 7 EACH 8 LUMP SUM	306

AVAILABLE EVALUATION REPORTS	CONSTRUCTION 315 X	PERFORMANCE	FINAL

EVALUATION	CONSTRUCTION PROBLEMS 318 1 NONE 2 X SLIGHT 3 MODERATE 4 SIGNIFICANT 5 SEVERE	PERFORMANCE 319 1 EXCELLENT 2 GOOD 3 X SATISFACTORY 4 MARGINAL 5 UNSATISFACTORY
APPLICATION	320 1 ADOPTED AS PRIMARY STD. 2 PERMITTED ALTERNATIVE 3 ADOPTED CONDITIONALLY	4 X PENDING 5 REJECTED 6 NOT CONSTRUCTED *(Explain in remarks if 3, 4, 5, or 6 is checked)*
REMARKS	321 Laboratory tests have not shown that increasing the percentage of salvaged HBP in blended base will negatively change the performance of the base material. Test segments have been constructed as part of a project on US 12 near Bowman. These segments contain 60, 70, and 80% salvaged HBP. There were no difficulties constructing the test segments. Currently there are no apparent differences between the control segment and the test segments.	

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Purpose and Need

The North Dakota Department of Transportation (NDDOT) uses a process that is referred to as "Mine and Blend" to rehabilitate distressed pavement. This is a process that salvages the existing aggregate base and hot bituminous pavement (HBP) as base material for new pavement. A reclaiming machine blends together the existing HBP with the existing aggregate base. The blended material is then compacted and acts as base material for the new pavement. An alternative practice is to remove the existing HBP and aggregate base and process it off-site.

The current NDDOT specification for Mine and Blend requires that the blended material to contain less than 50% salvaged HBP material. Often, projects have pavement sections that have thicker HBP sections than aggregate. To keep the blend from containing more than 50% salvaged HBP, either virgin aggregate is added and/or some salvaged HBP is discarded.

Currently, blended base material is limited to no more than 50% salvaged HBP due to concerns that greater percentages will reduce the performance of the pavement structure. Concerns about allowing blended base material to contain a greater percentage of asphalt pavement material include;

- May require more effort to achieve proper compaction. Lack of proper compaction may cause rutting or cracking in the pavement.
- May cause the base to behave as an asphalt pavement which may experience thermal cracking. Thermal cracks in the base may reflect through the new pavement.
- May reduce the permeability of the base and its ability to drain water from the pavement structure. Water in the pavement structure, especially during freeze-thaw cycles, may cause pavement distresses and a reduction in ride quality.
- May require adjustments to base and pavement thickness design procedures.

The NDDOT needs to establish if it is practical to construct bases that contain more than 50% salvaged HBP. Transportation agencies of several other states allow up to 100% salvaged HBP to be used as base material. Laboratory analysis of sample material and a test section will be used to evaluate base material containing different blend ratios and to determine the maximum allowable percentage of salvaged HBP.

Objective

The objective of this research project is to determine the maximum percentage of salvaged HBP I that may be contained in base material without compromising pavement performance.

Laboratory Testing

Scope

Laboratory tests were conducted on samples of salvaged HBP and virgin aggregate that were obtained from a NDDOT project. Laboratory tests included;

- Asphalt extraction to determine the asphalt cement content of the salvaged HBP.
- Gradations on both the salvaged HBP and virgin aggregate.
- Moisture-density tests on material blended with 50, 60, 70, 80, 90, and 100% salvaged HBP.
- Relative compactive effort tests with a gyratory compactor. The different blends were placed in a gyratory compactor and compacted until the material no longer compacted. The amount of compactive effort was compared to determine the affect that the different salvaged HBP contents have on the amount of effort required to reach compaction in the field. The tests were performed on material blended with 50, 60, 70, 80, 90, and 100% asphalt material.
- Relative compactive effort tests were performed at different moisture contents to help determine the affect that moisture content will have on the ability to compact the material.
- Relative permeability tests were conducted with material blended with 50, 60, 70, 80, 90, and 100% salvaged HBP to determine the affects of salvaged HBP content on the drainage characteristics of the blended base.

Material

Samples of salvaged HBP and Class 5 aggregate were obtained for performing laboratory tests. The material was sampled from contractor stockpiles used for project NHU-094(082)925. The salvaged HBP was material that the contractor already had stockpiled from previous projects and did not originate from NDDOT roadways.

Project NHU-094(082)925 was the reconstruction of Bismarck Expressway (I-94 Business Loop) from Rosser to Divide Avenues in Bismarck, ND. The roadway was reconstructed with 10" of doweled PCC pavement with 12" of blended base. The blended base is a blend of 50% Class 5 aggregate and 50% salvaged HBP.

Sampling

Material samples were obtained on February 17, 2004. Samples were taken from a stockpile of Class 5 aggregate and from a stockpile of salvaged HBP.

Sieve Analysis

Sieve analyses were run on samples of the salvaged HBP and the Class 5 aggregate. The required gradation for the Class 5 aggregate is a NDDOT standard specification. Table 1 shows the sieve analysis results compared to the NDDOT specifications. Table 2 shows the theoretical gradation produced by mixing together salvaged HBP and Class 5 at different ratios. There was a note in the project plans that specified the gradation for the blended base.

Table 1

Sieve Size	Salvaged HBP Results	Class 5 Results	Class 5 Specification
1 ½”	100 100		-
1”	98 100		100
3/4"	94 100		90-100
#4	51 66		35-70
#30	17 37		16-40
#200	3.5 8.2		4-10

Table 2

Sieve Size	Blended Base Spec.	Actual Gradation		Theoretical Gradation					
		Class 5	Salvaged HBP	50%	60%	70%	80%	90%	100%
1-1/2"	100	100	100	100	100	100 100	100	100	
1"	90-100	100	98	99	99	99 98	98		98
3/4"	-	100	93	97	96	95 95	94		93
5/8"	-	100	90	95	94	93 92	91		90
1/2"	-	94	83	88	87	86 85	84		83
3/8"	-	84	72	78	77	76 75	73		72
#4	35-85 66		51	59	57	56 54	53		51
#8	-	57	38	47	45	44 42	40		38
#10	-	54	35	45	43	41 39	37		35
#16	-	47	27	37	35	33 31	29		27
#30	16-50 37		17	27	25	23 21	19		17
#40	-	30	13	22	20	18 17	15		13
#50	-	24	10	17	16	14 13	11		10
#100	-	13	5	9	8	7 7 6			5
#200	4-12	8.2	3.5	5.9	5.4	4.9 4.4	4.0 3.5		

The Bismarck District sampled and tested the blended base on this project as part of project inspection. The sieve analysis results of the field lab and district lab are included in table 3.

Table 3

Sieve Size	Specified	8/5/04		5/21/04		5/04/04	
		Field	District	Field	District	Field	District
1-1/2"	100 100		100	100 100		100	100
1"	90-100 100		99	98	98	100	99
#4	35-85 63		64	52	55	63	64
#30	16-40 30		29	24	26	30	29
#200	4-10 5.9		4.5	6.2	5.9	5.9	4.5

Extraction and Gradation

Asphalt cement was extracted from a sample of salvaged HBP. The asphalt cement was then tested for hardness and viscosity and a sieve analysis was performed on the aggregate. The results of the tests are given in Tables 4 and 5.

Table 4

Sieve Size	Extracted Aggregate
1-1/2" 100.0	
1" 100.0	
3/4" 100.0	
5/8" 99.7	
1/2" 97.2	
3/8" 89.2	
#4 71.6	
#8 57.8	
#16 46.9	
#30 37.8	
#50 28.9	
#100 19.1	
#200 14.3	

Table 5

Percent Asphalt	3.99 %
Penetration @ 25°C(77°F)	24
Viscosity @ 60°C (140°F) poises	19,076
Viscosity @ 135°C (275°F) cSt	996

The results of the extraction show that the asphalt cement is very hard as the penetration was 24 mils. Also the percent asphalt is lower than typical for NDDOT projects. Typically NDDOT projects have asphalt content in the range of 5 to 6 percent. The low asphalt content is likely because the source material was not from NDDOT projects.

Moisture - Density Tests

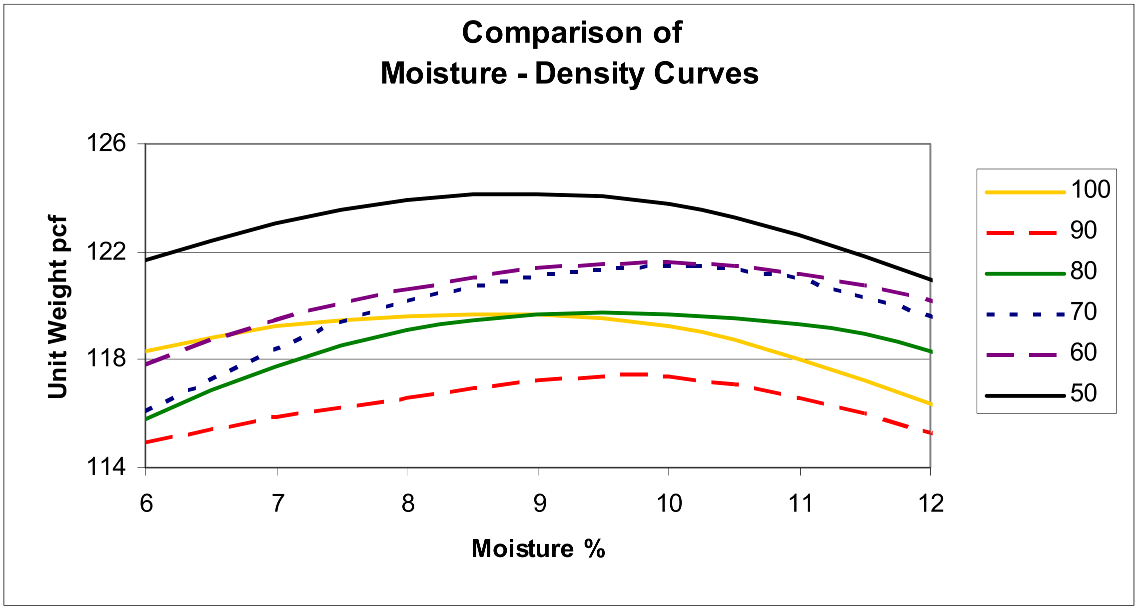
A modified version of AASHTO T-99 with a six inch mold was performed with material samples containing 50%, 60%, 70%, 80%, 90%, and 100% salvaged asphalt material. This version of the proctor test was chosen because there was a concern that the pounding action of the proctor hammer would break down the material.
AASHTO T-99 with a six inch mold requires the least amount of compactive energy of any of the standard proctor tests and it was hoped that this would limit the amount that the material was broken down. Because this test uses the least energy, the unit weights will be the lowest and the optimal moistures will be the highest of any of the standard proctor tests.

The procedure for AASHTO T-99 Method D requires that the sample material pass through a ¾” sieve and the results of the tests would then be adjusted for the amount of plus ¾” material. The plus ¾” material was not removed for these tests. Instead, the sample was passed through a 1” sieve. Typically, three or four chunks of material, per sample, were retained on the 1” sieve. These chunks were then evenly distributed among the three lifts as the proctor molds were filled and compacted.

Before the material was placed into the proctor mold, water was added to the material for the test. The material was mixed by hand with a large spoon. Added water had a tendency to run off the salvaged asphalt material and to collect at the bottom. This may have caused some difficulties with determining the moisture contents of the material. Material that was not needed to fill the proctor mold was used for the moisture sample. The results of moisture tests typically showed more moisture than expected. This may have been because the water collected at the bottom of the material and this material was used for the moisture test.

The resulting graph of moisture-density curves is given below. It was expected that a large percentage of salvaged asphalt material would result in a relatively lower unit weight because of the increase in the amount of asphalt cement which has a relatively low specific gravity. The results generally follow expectations except for the sample with 100% salvaged asphalt material. This is probably because the actual amount of moisture was greater than the moisture test showed. An adjustment for this type of error would shift the curve downwards and to the right to its expected position.

Chart 1



Compaction Tests

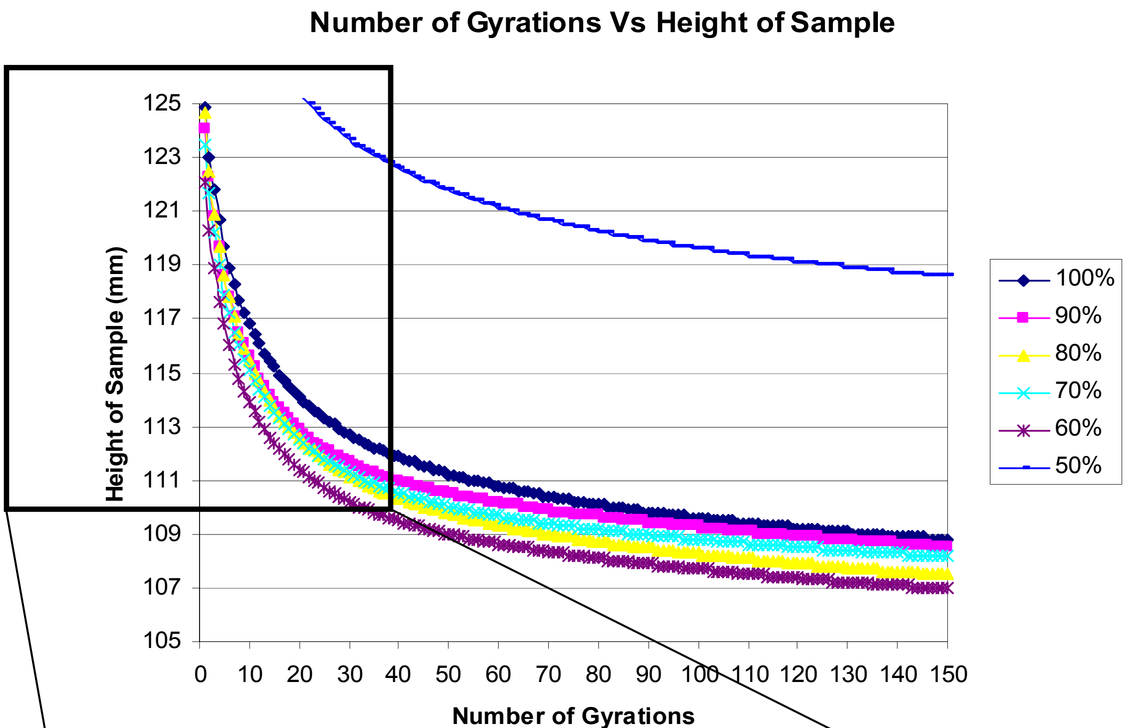
To test the relative amount of effort required to compact material with different percentages of salvaged material, a test was devised using a gyratory compactor that is normally used for superpave asphalt pavement testing. Test samples were blends of 50%, 60%, 70%, 80%, 90%, and 100% salvaged HBP mixed with Class 5 aggregate. The tests were conducted on 4,500 grams of blended material that was mixed with 400 ml of water. Two samples with 50% salvaged HBP were prepared with 300 ml and 100ml of water.

The gyratory compactor applied a seating force of 600 kPa or 87.02 psi and then applied 150 gyrations to the test sample. The gyratory compactor recorded the number of gyrations and the height of the sample. On completion of the gyrations the samples commonly had standing water on top of them that contained a large amount of fines. An example of a compacted sample is shown in Photo 1.

Photo 1 – Water on the surface of a gyratory compactor sample as it is being pushed out of the mold.

During analysis of the data from testing it was discovered that the gyratory compactor did not operate correctly during compaction of the blends that contained 50% salvaged HBP with 400 ml and 300 ml of water. These tests were not repeated because it had been discovered that water from the samples had been seeping into the bearings of the gyratory compactor and there was a concern that this may damage the machine. The blend with 50% salvaged HBP with 100 ml of water had compacted properly. This sample was much drier than the other samples and was the only properly compacted sample that did not have standing water on its surface after completion of compaction. The results of the gyratory compaction tests are shown in the following graph. The results for the material that did not compact properly are not shown.

Chart 2



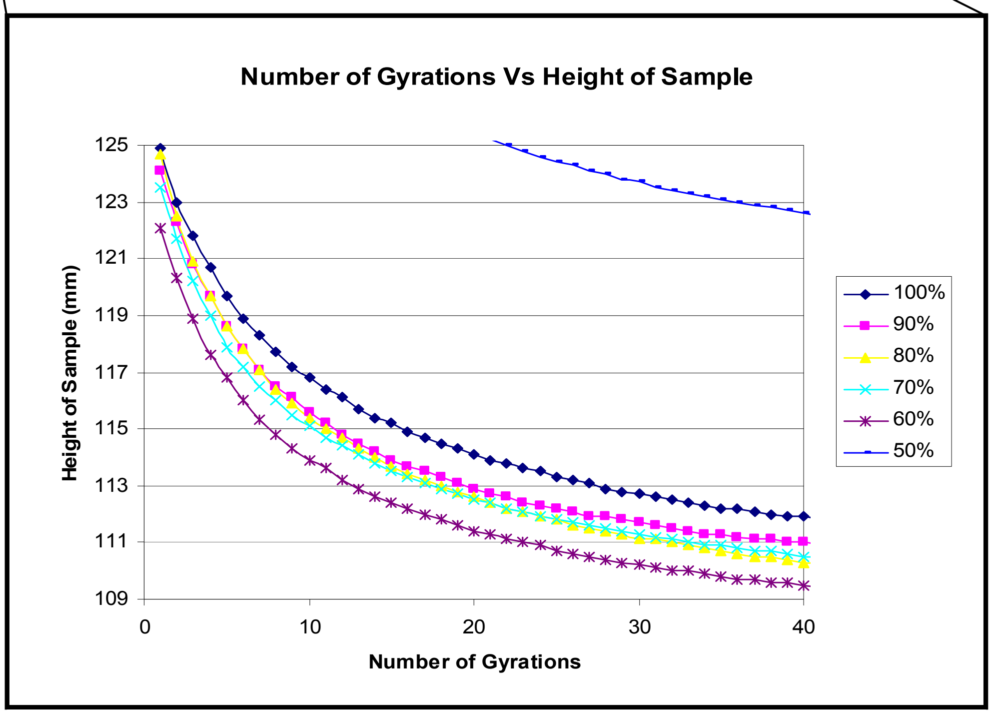


Chart 3

Moisture samples were taken from material that was not used in the compaction test. The moistures for each of the sample are given below.

Table 6

Percent Asphalt Material	50% 60	% 70	%	80% 90	%	100%
Percent Moisture	2.9% 8.9	% 8.7%		8.7% 8.7	% 8.7%	

It appears that the different blends of material compact at approximately the same rate. The difference in height is likely due to the difference in the density of the material. It appears that, after being compacted for a short time the material will not compact any more and further gyrations result in “squishing” the water out of the sample and standing water on the samples at the end of compaction. Using an estimated value for specific gravity of the material it appears all of the samples reached 100% of their dry unit weight as determined from the proctor tests.

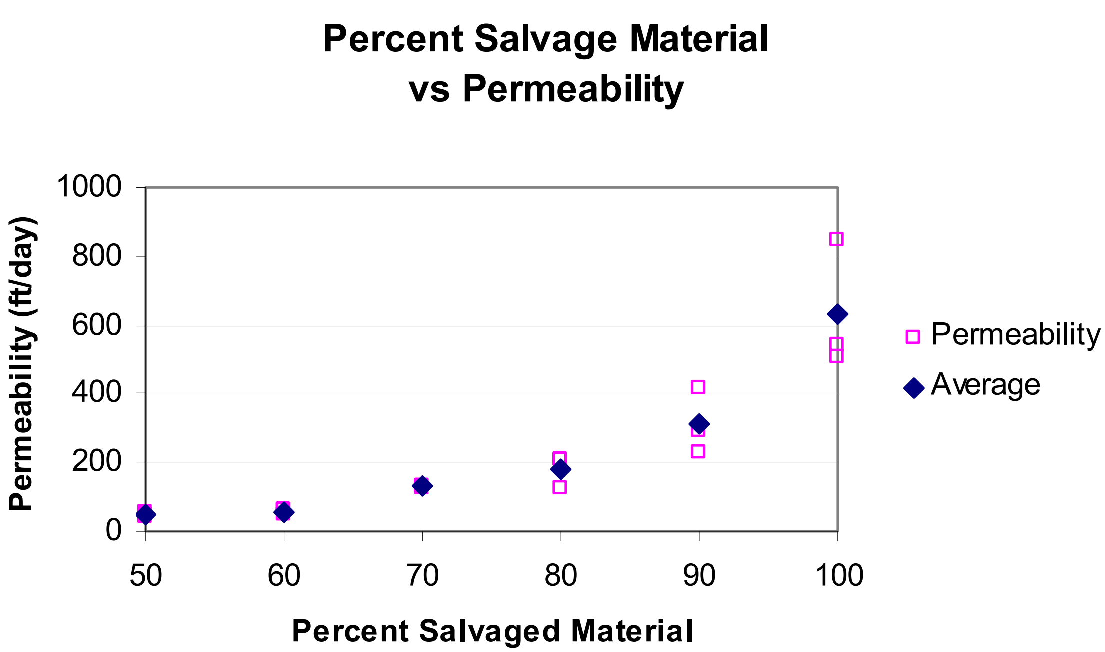
Permeability

A falling head permeability test was run according to FHWA procedures. The apparatus used for this procedure consisted of two 4” molds and a clear 4” tube. One of the 4” molds had a #16 sieve soldered across one end of it. The other 4” mold had a flap-gate on one end and stood on three legs. The clear 4” tube had two lines scribed on it 30.5” apart.

The mold with the sieve was filled with 1600 grams of sample material. The mold was then secured onto a vibrating table and vibrated for 30 seconds. The vibrated mold was then weighed and the distance from the top of the mold to the material sample was measured. The 4” mold with the sample material in it was then placed on top of the 4” mold with the flap-gate. The clear 4” tube was then secured to the top of the 4” mold with the sample material. The entire apparatus was then placed into a sink. The flap-gate was closed and water was introduced to the top of the 4” tube. The apparatus was filled with water until the water level was above the highest scribe line on the 4" tube. The flap-gate was then opened and a stopwatch was started when the water level reached the highest scribe line. The stopwatch was stopped when the water level reached the lower scribe line and the time recorded. The time trial was then repeated two more times. The sample was then removed and this entire procedure was repeated with two more samples of the same material for a total of 9 time trials for each blend of material. The results of the tests were than used to calculate the permeability of the material in feet/day.

The results are shown in Chart 4. The graph includes both the average permeability of each sample of material (3 trials) and the average permeability of all three samples of material (9 trials). The results show a relatively linear relationship between permeability and the percent of salvaged HBP that the samples contained. This is probably because the salvaged HBP has a coarse gradation and provides many voids for the water to flow through. Also the asphalt material appears to repel water and this may help the material to drain faster.

Chart 4



Test Section

Scope

Test segments were constructed, as part of a NDDOT Mine and Blend project, with blended base that contain 60%, 70%, and 80% salvaged HBP. Base sections that contain 50% salvaged HBP will be used as the control.

After construction, the test section was evaluated with a falling weight deflectometer (FWD) to establish the strength of the different base sections.

The test sections will be evaluated annually with the NDDOT “Pathways Van” and visually by NDDOT personnel. The “Pathways Van” will measure ride, distress, and rut depths. Also, a lightweight profiler (LWP) was used to obtain the International Roughness Index (IRI) of the roadway. NDDOT personnel will evaluate the test sections for pavement performance, including ride, rut depth, crack size, and crack spacing.

Location

Test segments were constructed to evaluate the performance of pavement sections with base material that contain greater than 50% salvaged HBP. The test segments were constructed as part of the rehabilitation of US 12, project NH-5-012(027)034, with a Mine and Blend. The test segments were constructed with blended base that contain 60%, 70%, and 80% salvaged HBP. The project and test segments are shown in Figure 1.

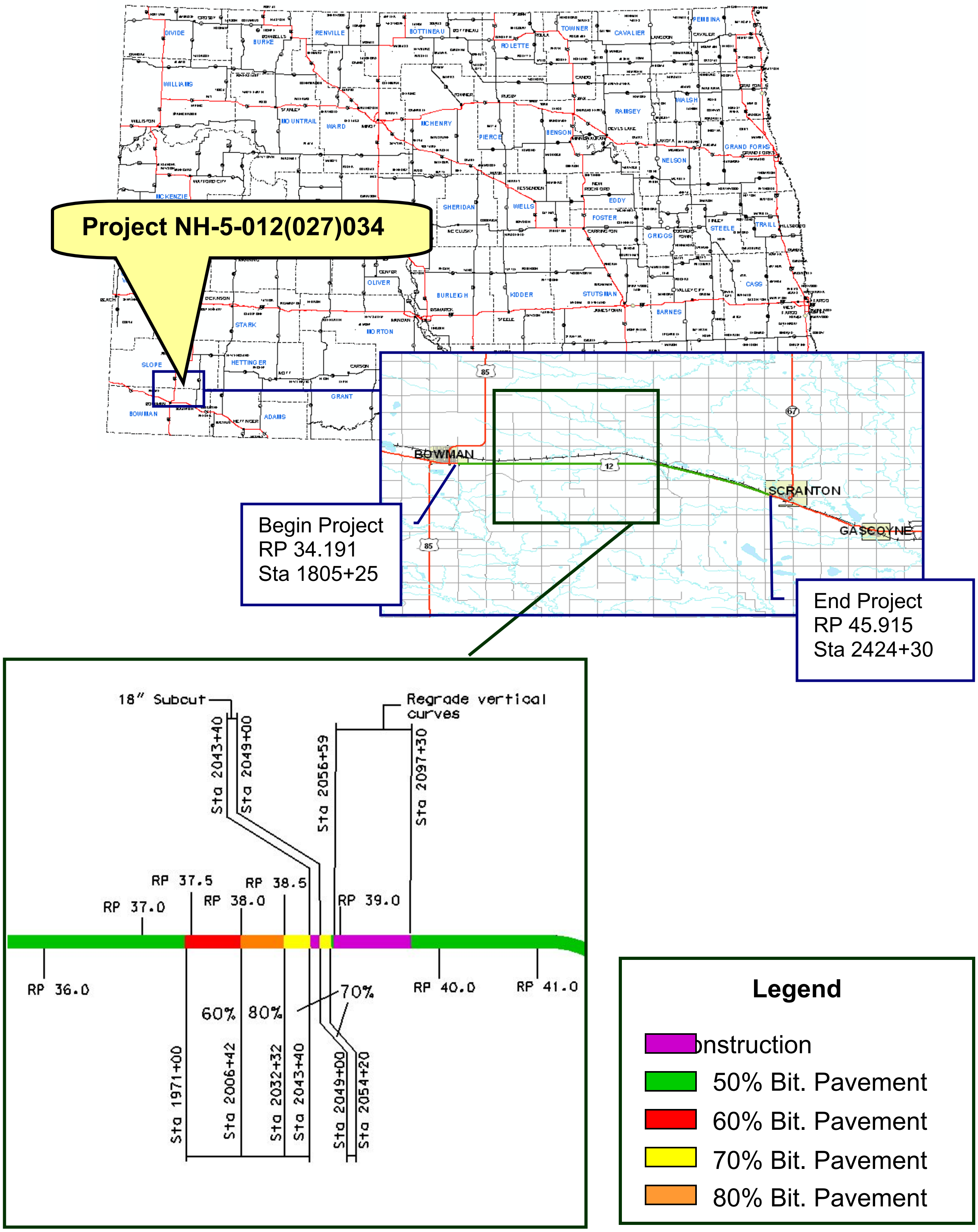


Figure 1 – Project Location

Project Historical Information

Rims Data

RIMS provides the following section for US 12 from Bowman to Scranton. This section is before construction of project NH-5-012(027)034. The existing roadway section in RIMS is shown in Table 7:

Table 7

RP 34.1700	**Bowman East to Scranton**				**12.2529 Miles**	
Surface Components	Left Shld.	Roadway Width	Right Shld.	Year	Material	Depth
Grade		36’		1947		
Traffic Service Gravel		22’		1947		3.0”
Aggregate Base		34’		1949		5.0”
Stabilized Base		32’		1949		2.0”
Hot Bit Pavement		22’		1949	150-200	2.5”
Hot Bit Pavement		27’		1984	120-150	2.0”
Drive Slope Flattening				1985		
Contract Chip Seal		27’		1994	MC-3000	
Comments: From Mile 34.170 to 34.226 of this segment has blended base (1999 See SS-5-012(023)020)						

Traffic

The one-way traffic used for the pavement design of the control and test segments is shown in Table 8.

Table 8

Year	Passenger Car	Trucks	Total	30^{TH} Max Hr	Flex. ESALs
2003 810		190	1,000	100	135

Design

Test segments were constructed as part of Project NH-5-012(027)034, which was the rehabilitation of US 12 with a mine and blend. The project was designed so that the blended base would contain a maximum of 50% salvaged HBP. Test segments were designed with blended base that contained 60%, 70%, and 80% salvaged HBP.

The Materials and Research Division provided a pavement thickness recommendation for this project. The recommendation includes options for new construction and for Mine and Blend. The required pavement and base thicknesses were developed using Darwin 3.1 software and according to "AASHTO guide for the Design of Pavement Structures, 1993". Table 9 shows the recommended pavement sections for Project NH-5-012(027)034. The entire Materials and Research pavement thickness recommendation is included in Appendix A.

Table 9

Location	Station	New Construction		Mine and Blend			
		Base	HBP Class 29	Added Aggregate	Blend Depth	Total Base	HBP Class 29
RP 34.191 to RP 35.168	1805 +25 to 1817+50	18.0"	4.5"	3.5"	14.5"	17.0"	4.5"
RP 35.168 to RP 40.000*	1817+50 to 2111+77	16.0"	4.5"	1.5"	14.0"	15.0"	4.5"
RP 40.000 to RP 45.915	2117+77 to 2424+30	16.0"	4.5"	2.0"	14.0"	15.0"	4.5"

* The test segments and control segment are entirely within this segment.

The existing HBP was not thick enough to provide the high percentages of salvaged HBP required to construct the test segments. To increase the percentage of salvaged HBP in the finished blended base, salvaged HBP, from the regraded section, was added instead of virgin aggregate. In the 60% section 1.5" of salvaged HBP was added instead of 1.5" of virgin aggregate. In the 70% and 80% sections 2.5" of salvaged HBP was added instead of 1.5" of virgin aggregate. This resulted in the 70% and 80% test segments having a 1.0" thicker base than the 60% section and the control section. Also, to attain the high percentage of salvaged HBP in the test segments, it was required to change the blend depth from 14.0” to 12.5 “.

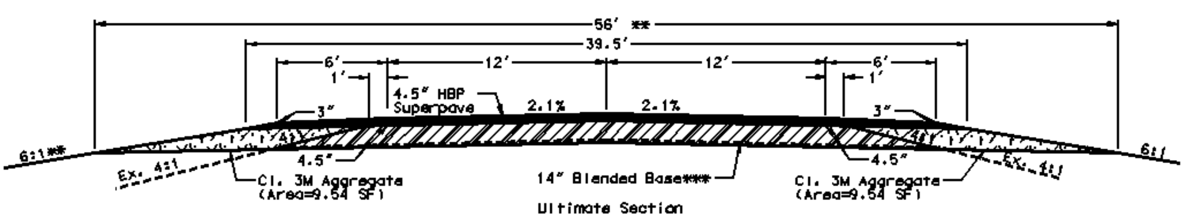
Because of poor subgrade conditions there is subcut within the 70% salvaged HBP segment. Table 10 shows the mine and blend designs for the control and test sections. Because it may be used for comparison, the design of the regraded section is also shown.

Table 10

Section	Station	Added Aggregate	Added Salvaged HBP	Blend Depth	Total Base Depth	HBP
Control		1.5”	0.0”	14.0”	15.0”	4.5”
60%		0.0”	1.5”	12.5”	15.0”	4.5”
80%		0.0”	2.5”	12.5”	16.0”	4.5”
70%		0.0”	2.5”	12.5”	16.0”	4.5”
Subcut		No Mine and Blend			33.0”	4.5”
70%		0.0”	2.5”	12.5”	16.0”	4.5”
Regrade		No Mine and Blend			16.0”	4.5”

As part of rehabilitation the roadway was widened. Figure 2 shows the typical ultimate pavement section through the control and test segments. The test segments’ blend depths and aggregate depths were modified by a plan note.

Figure 2



Construction

The construction of the project began on May 4, 2005. The Prime and paving contractor was Northern Improvement and E.H. Schwartz Construction was the dirt contractor. Bill Gathman was the project engineer for the NDDOT.

Construction of the control and test segments began with widening the graded shoulder. Virgin Class 3M aggregate was placed on the shoulders to provide the base for the widened pavement and onto the pavement surface of the control section. When salvaged HBP was available from the construction of the regraded segment, it was placed onto the surface of the pavement in the test segments. Traffic was allowed to travel over the surface of the added aggregate and salvaged HBP during construction. Photo 4 shows the test segment with the salvaged HBP on top of the pavement and Class 3M aggregate on the shoulders.

Photo 4 – Test segment with salvaged HBP on top of the pavement.

During construction, the 60% test segment was extended approximately 900’. Also, the approximately 200’ long segment between the 70% test segment and the regrade segment received added salvaged HBP instead of added aggregate. This short segment will be included with the 70% segment for evaluation.

Materials and Research Division personnel measured the thickness of the salvaged HBP after traffic had driven on it. Where the salvaged HBP was specified to be 1.5" the thickness was 1.25" and where the salvaged HBP was specified as 2.5" the thickness was measured as 2.0". The material appeared to have been compacted by the traffic and probably had been the specified thickness when placed on the pavement.

It took the mining machine 3 passes to mine and blend the width of the roadway. The contractor would mine and blend the full width of a segment of roadway each day. Traffic was allowed to pass through the construction area, with a pilot car and flaggers, during the mine and blend process. A sheepsfoot roller followed the mining machine and was used to compact the blended base. After the sheepsfoot roller, the base was shaped with a motor-grader and then the compaction was completed with a pneumatic wheeled compactor.

Samples were taken of the blended base material. Some samples were collected during the mine and blend process and other samples were collected from the completed base just before the prime coat was applied. The completed base was quite hard and a pick axe was used to remove the samples. The sample material came out as large chunks.

The surface tolerance of the completed base was specified as type 'B'. Type 'B' requires automatic grade controls and the surface of the finished base must be within .04 feet of the grade line.

After the blended base was primed, 2 lifts of superpave HBP were paved for a total thickness of 4.5". The paving was completed October 15, 2005. Photo 5 shows the completed pavement surface just after application pavement markings and shoulder rumble strips.

Photo 5 – US 12 just after placement of pavement markings and shoulder rumble strips.

Post Construction Evaluation

The test segments were designed with blended bases that contained specified percentages of salvaged HBP. However, the depth of existing HBP and base always has variability and this will result in variability in the percentage of salvaged HBP in the blended base. Because of the variability, a method for estimating the percentage of salvaged HBP in the blended base, as constructed, was developed.

Two samples were obtained of the salvaged HBP from the regrade section that was added to the test segments. For this procedure, this material was assumed to represent any HBP in the test or control segments. Nine samples of blended base were obtained from within the control and test segments.

Asphalt extraction tests (AASHTO T 164) were performed on the samples to determine the percentage of asphalt cement (AC) in each sample. The estimated percent salvaged HBP in a sample of blended base was calculated by dividing the percent AC in the blended base samples by the average percent AC content of the HBP samples. The results are shown below in Tables 11 and 12.

Table 11

100% Salvaged HBP		
AC %	5.45%	5.72%
Average AC%	**5.59%**	

Table 12

	Control		**60%**		**70%**	**80%**	
AC %	1.95 2.76	4.31	4.88	3.68		4.78	3.04
Estimated % HBP ($AC\% / 5.59\%$)	**35 49**	**77**	**87**	**66**		**86**	**55**

FWD Testing

The roadway was tested with a Falling Weight Deflectometer (FWD) on November 2, 2005 from RP 36.00 to RP 41.00. The FWD took tests at 100 foot intervals. Chart 5 shows the #1 sensor deflections of the FWD. This sensor is located at the center of the load plate of the FWD and it is the maximum deflection of the pavement. Generally, lower deflections are associated with a stiffer pavement structure than areas with higher deflections. Charts 6, 7, and 8 are the back-calculated moduli of the HBP pavement, base, and subgrade. Table 13 shows the averages and standard deviations for each segment.

The FWD data shows that the regrade section has the strongest overall pavement section. This section has the lowest sensor deflections and the highest back-calculated base and subgrade modulus. These results are likely because this section was reconstructed instead of Mine and Blend. As part of reconstruction, the subgrade was compacted and the base was compacted in lifts. Also, some of the base material in this section is virgin Class 5.

The FWD data shows the subcut section as having unusually strong subgrade modulus and low pavement modulus. This is likely an error of the back-calculation software caused by the unusually thick base section in the subcut section.

Table 13 shows that the control and the various test segments do have different average moduli and deflections. However, from the graphs there doesn’t appear to be any significant changes at the boundaries of the segments and the variations in the segment averages is likely due to random variations in the materials.

Chart 5

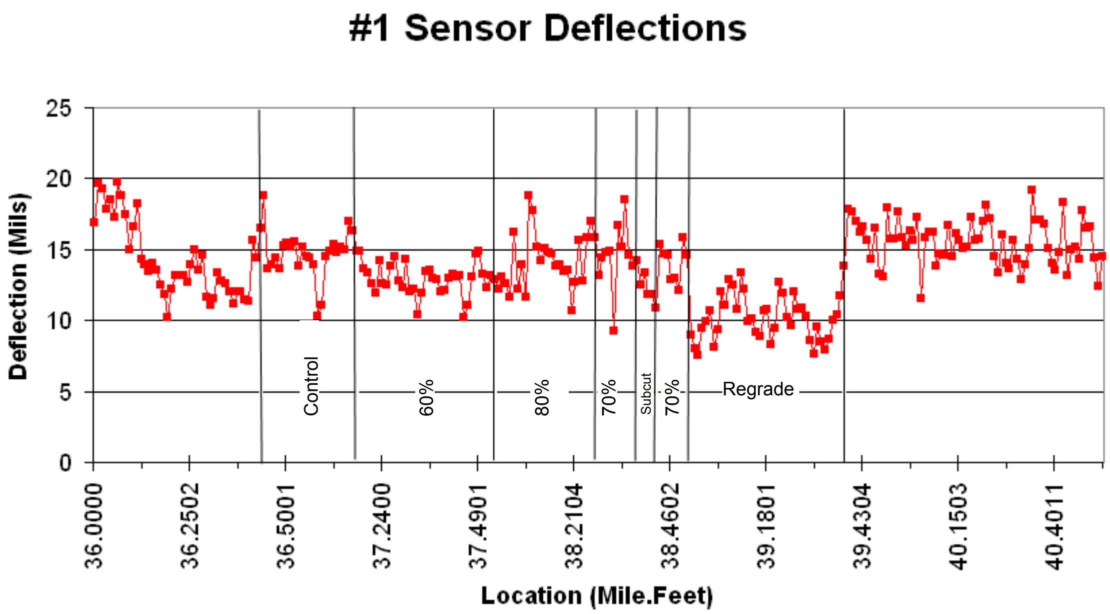


Chart 6

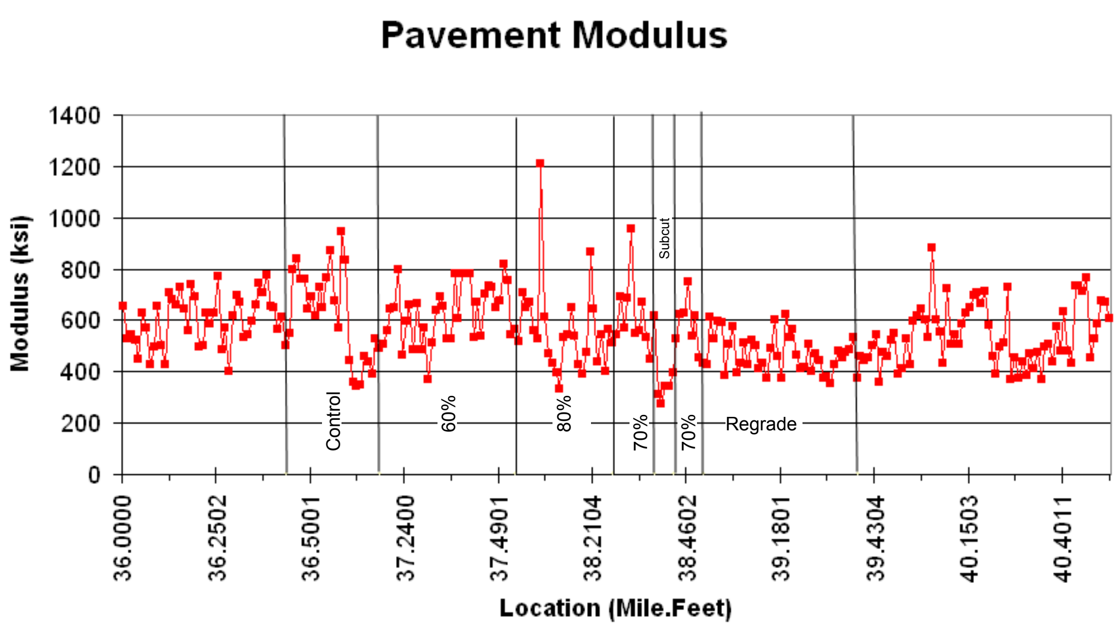


Chart 7

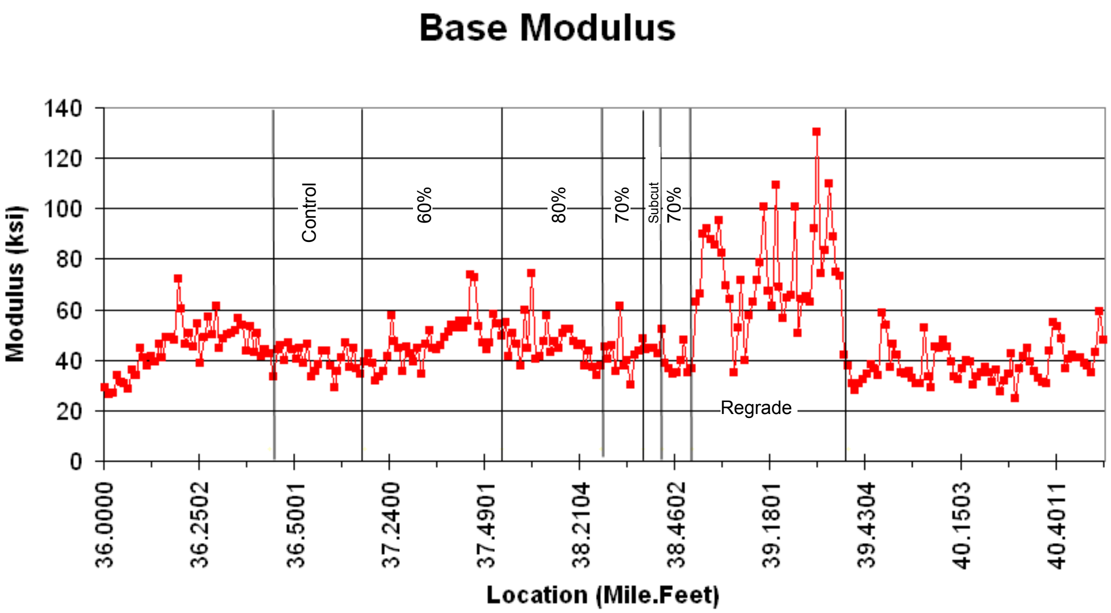


Chart 8

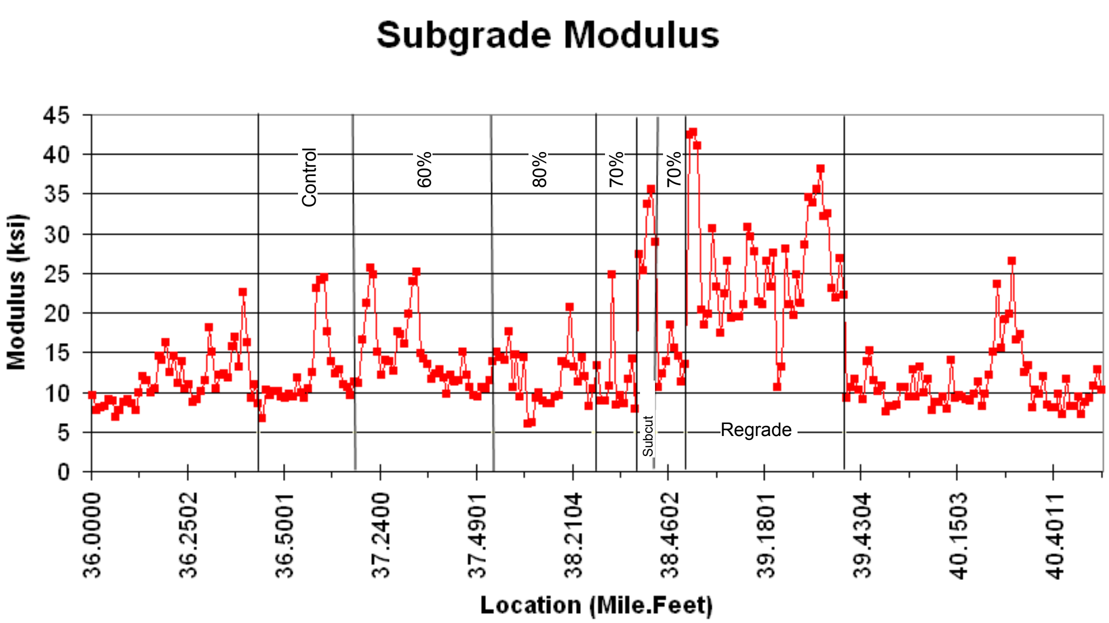


Table 13

Segment	#1 Sensor Deflection		Pavement Modulus		Base Modulus		Subgrade Modulus	
	Avg.	Std. Dev.	Avg.	Std. Dev.	Avg.	Std. Dev.	Avg.	Std. Dev.
Control 14.68		1.63	620.50	178.94	40.06	4.86	12.35	4.79
60% 12.92		1.09	629.93	111.23	47.64	9.40	14.61	4.59
70% 14.34		1.90	600.10	121.94	40.74	7.05	12.49	4.12
80% 14.20		1.97	562.63	176.15	46.77	8.55	11.70	3.49
Subcut 12.07		0.92	333.27	45.00	45.67	3.70	30.18	4.35
Regrade 10.23		1.63	472.18	75.06	73.44	20.51	25.88	7.52

Light Weight Profiler Testing

IRI data was collected with both the “Pathways Van” and with a LWP. The average IRI of the entire project was 35.4 according to the “Pathways Van” and 35.8 according to the LWP. The LWP also collected the IRI from the research section separately. The IRI collected by the LWP for the entire project is shown in Graphs 9 & 10 in 264’ increments and the IRI collected separately from the test segments is shown in Graphs 11 and 12 in 100’ increments.

There doesn’t appear to be any difference in the IRI from the test segments and control segments. Graph 12 shows that there does appear to be a significant bump in the 60% salvaged HBP section in the WB direction and Graph 11 shows a smaller bump in the 80% WB segment. From Graphs 11 and 12 it appears that there may be a bump across both lanes at the boundary of the 70% salvage HBP segment and the Subcut segment.

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Chart 9

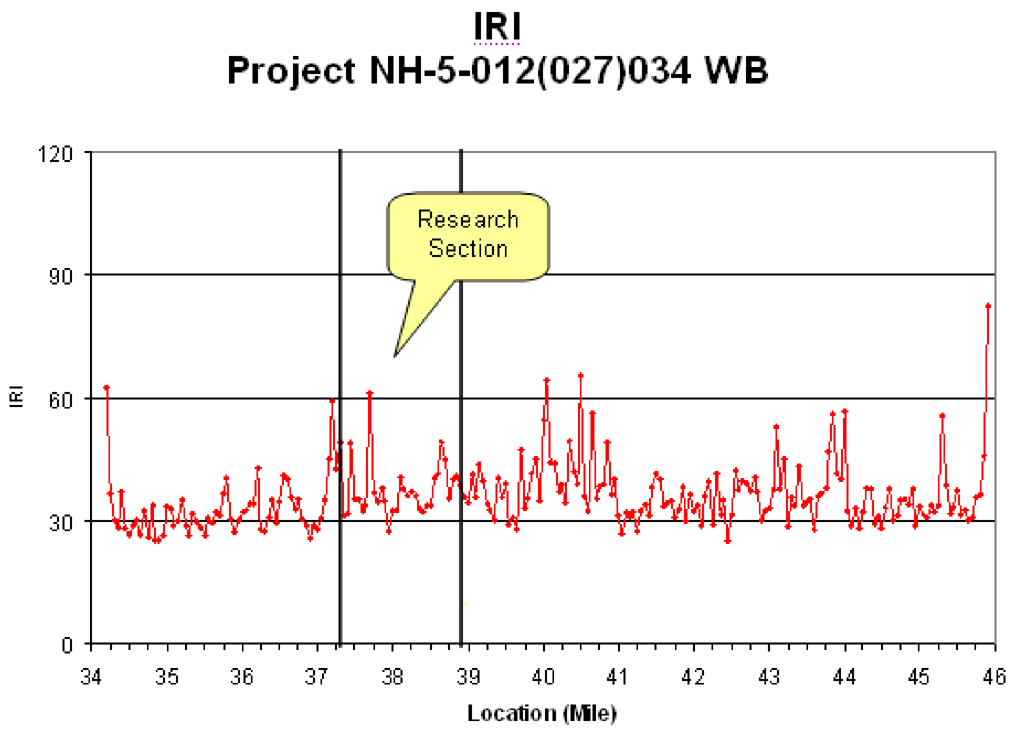


Chart 10

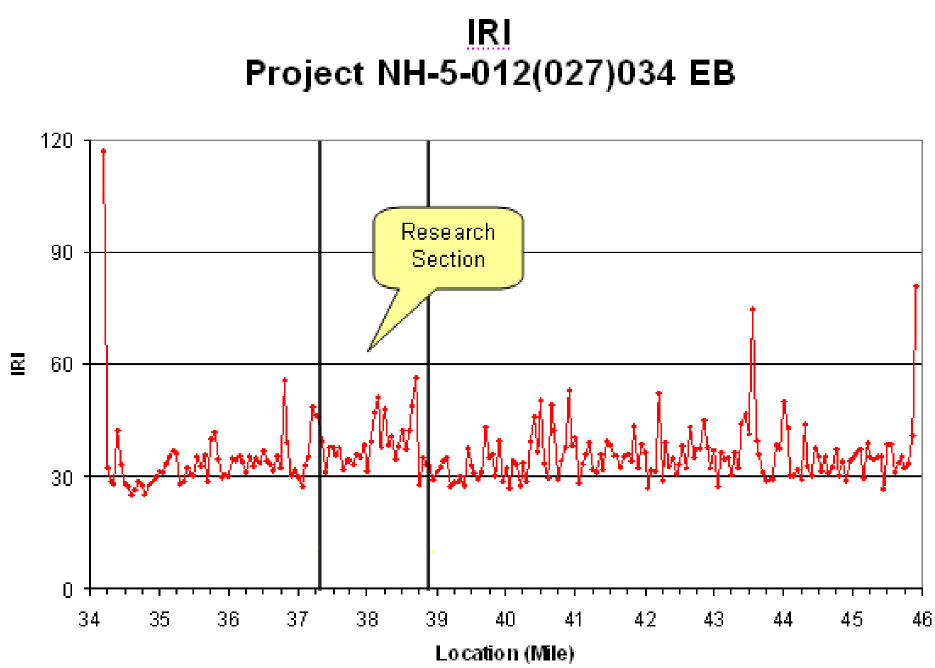


Chart 11

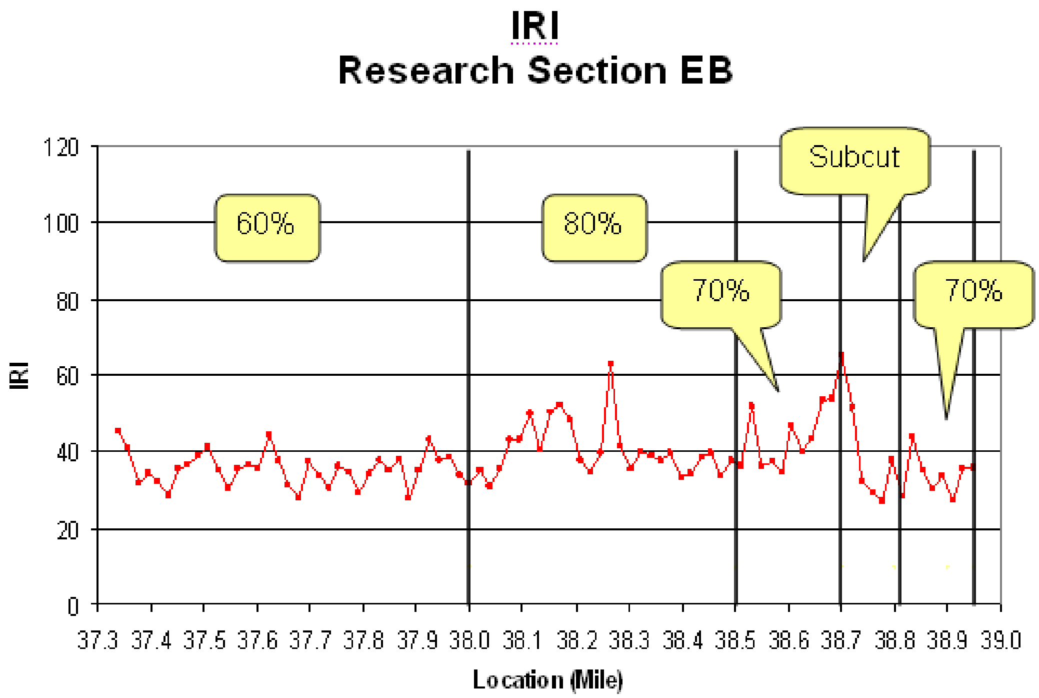
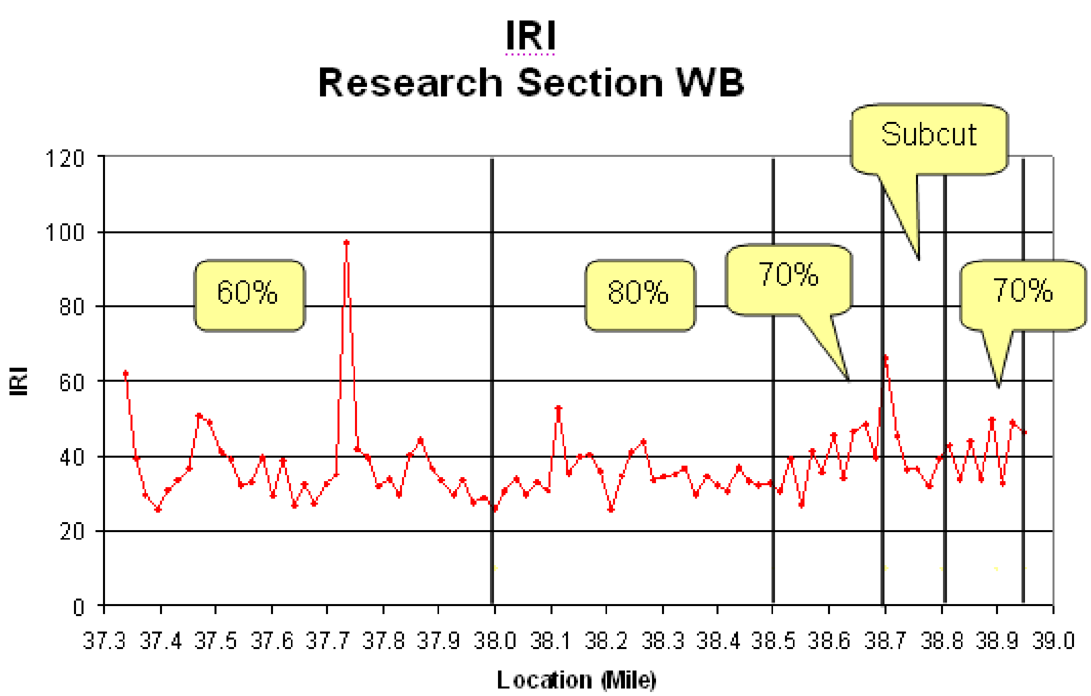


Chart 12



Summary

Laboratory tests show that properties associated with increasing the percentage of salvaged base in blended material include an increase in permeability, a decrease in dry unit weight, and an increase in optimal moisture. All of these properties are likely related to the additional salvaged HBP increasing the coarseness of the blended material. Gyratory compaction tests showed no differences in the effort required to compact the blended material with different percentages of salvaged HBP. Tests performed on extracted asphalt cement show that it presently is very hard.

Test segments were constructed as part of a mine and blend project on US 12 near Bowman. Test segments are each approximately ½ mile long and were designed to contain 60%, 70%, and 80% salvaged HBP. There were no unusual construction problems caused by the test segments. The percentage of salvaged HBP in the constructed blended base of the test segments was estimated using asphalt extractions. The results showed a large amount variation in the estimated percentage of salvaged HBP but all of the samples from within the test segments were estimated to contain greater than 50% salvaged HBP. There were visually no obvious differences between the test segments and the control segment. The control and test segments were tested with a FWD for pavement moduli and a LWP for ride. There were no obvious differences in the pavement moduli and ride from the different test segments.

The control and test segments will continue to be monitored for a period of ten years with interim reports every two years. Data will be collected visually for distress, rutting, and ride. The “Pathways Van” will be used to collect rut, distress, and ride data. The maintenance costs of the test segments will be compared to the maintenance costs of the control segment.

Appendix A

MEMORANDUM

TO: Mark Gaydos
Design Engineer

ATTN: Stacy Hanson

FROM: Steven Henrichs
Materials & Research

DATE: December 15, 2003

SUBJECT: NH-5-012(027)034 - Highway 12 - Bowman to Adams County Line
Pavement Thickness Recommendation

This is a pavement thickness recommendation for Highway 12 which is classified as an interregional corridor.

This project may include reconstruction of the Highway 67 structure at Scranton. Pavement thickness recommendations for reconstruction of Highway 67 and the overlay of a proposed detour are included for this option.

Mainline

RIMS defines this section of roadway as:

RP 34.1700 **Bowman E to Scranton** **12.2529 Miles**

Surface Components Width	Left Shld.	Roadway Width	Right Shld. Width	Year	Material	Depth
Grade		36'		1947		
Traffic Service Gravel		22'		1947		3.0"
Aggregate Base		34'		1949		5.0"
Stabilized Base		32'		1949		2.0"
Hot Bit Pavement		22'		1949	150-200	2.5"
Hot Bit Pavement		27'		1984	120-150	2.0"
Drive Slope Flattening				1985		
Contract Chip Seal		27'		1994	MC-3000	

Comments: From mile 34.170 to 34.226 of this segment has blended base (1999 see SS-5-012-023-020)

RP 46.4130 Scranton to Gascoyne RR Bridge 2.6231 Miles

Surface Components Width	Left Shld.	Roadway Width	Right Shld. Width	Year	Material	Depth
Grade		36'		1947		
Traffic Service Gravel		22'		1947		3.0"
Aggregate Base		33'		1949		7.0"
Stabilized Base		32'		1949		2.0"
Hot Bit Pavement		22'		1949	150-200	2.5"
Plant Mix Seal				1968		0.8"
Hot Bit Pavement		27'		1984	120-150	2.0"
Drive Slope Flattening				1985		
Contract Chip Seal		27'		1994	MC-3000	

Comments: None

RP 49.0341 0.3 Mi W of Milwaukee RR to 0.3 Mi E of Milwaukee RR 0.7409 Miles

Surface Components Width	Left Shld.	Roadway Width	Right Shld. Width	Year	Material	Depth
Grade		53'		2001		
Aggregate Base		43'		2001		15.0"
Hot Bit Pavement	8'	24'	8'	2001	PG 58 -28	4.0"

Comments: None

RP 49.7750 0.3 Mi E of Milwaukee RR to Adams Co Line 4.3260 Miles

Surface Components Width	Left Shld.	Roadway Width	Right Shld. Width	Year	Material	Depth
Grade		36'		1947		
Traffic Service Gravel		22'		1947		3.0"
Aggregate Base		33'		1949		7.0"
Stabilized Base		32'		1949		2.0"
Hot Bit Pavement		22'		1949	150-200	2.5"
Plant Mix Seal				1968		0.8"
Hot Bit Pavement		27'		1984	120-150	2.0"
Drive Slope Flattening				1985		
Contract Chip Seal		27'		1994	MC-3000	

Comments: None

From the years of 1992 through 2003, maintenance costs total $301,931 for this section of roadway. These costs are detailed in the following table.

Maintenance Costs

Ref. Pt.	Total	Blade Patch	Hand Patch	Scotch Patch	Crack Pour	Seal Coat	Milling	Shoulder Repair	Routine Roadway
34	$25,673	$14,313	$2,015	$924	$217	$7,242	$7	$26	$929
35	$4,155	$730	$2,021	$399	$139	$18	$7	$26	$815
36	$4,222	$730	$2,082	$399	$139	$18	$7	$26	$821
37	$4,137	$678	$2,060	$399	$139	$18	$7	$26	$810
38	$4,406	$927	$2,081	$399	$139	$18	$7	$26	$809
39	$4,166	$687	$2,081	$399	$139	$18	$7	$26	$809
40	$10,703	$7,201	$2,107	$399	$139	$18	$7	$26	$806
41	$15,709	$12,212	$2,104	$399	$139	$18	$7	$24	$806
42	$20,368	$16,871	$2,104	$399	$139	$18	$7	$24	$806
43	$24,624	$20,727	$2,504	$399	$139	$18	$7	$24	$806
44	$11,353	$7,703	$2,257	$399	$139	$18	$7	$24	$806
45	$11,301	$7,160	$2,748	$399	$139	$18	$7	$24	$806
46	$9,674	$5,462	$2,819	$399	$139	$18	$7	$24	$806
47	$19,961	$16,239	$2,329	$399	$139	$18	$7	$24	$806
48	$7,811	$4,149	$2,329	$399	$141	$18	$7	$24	$744
49	$27,111	$23,247	$2,531	$399	$141	$18	$7	$24	$744
50	$23,061	$19,399	$2,329	$399	$141	$18	$7	$24	$744
51	$26,430	$22,725	$2,374	$399	$141	$18	$7	$24	$742
52	$24,543	$20,857	$2,374	$399	$141	$18	$7	$24	$723
53	$22,523	$18,211	$3,000	$399	$141	$18	$7	$24	$723
Total	**$301,931**	**$220,228**	**$46,249**	**$8,505**	**$2,870**	**$7,584**	**$140**	**$494**	**$15,861**

Materials and Research personnel took 40 depth checks within the project limits and measured the depth of the gravel. Scoria material was not included with the gravel depth. The minimum depth was 1.2" and the maximum depth was 12.0". The average depth was 5.1" with a standard deviation of 1.9”.

RIMS describes the pavement sections from RP 46.413 to RP 49.034 and RP 49.775 to RP 54.116 as having 7.0" of aggregate base. From existing plans and the gravel depth check it was determined that the 7.0" of aggregate base is constructed of scoria. Because of poor material properties, scoria was not included as existing base in the overlay or mine and blend designs.

District personnel took 78 cores within the project limits. The average core length was 8.28" with a standard deviation of 1.93". The shortest and longest cores were 5.00 and 14.50" respectively. The core lengths, in inches, are provided in the following table.

REF. POINT	LENGTH INCHES	REF. POINT	LENGTH INCHES	REF. POINT	LENGTH INCHES
34.25	7.00	40.50	6.50	46.75	9.00
34.50	6.50	40.75	9.50	47.00	7.75
34.75	6.50	41.00	8.00	47.25	9.25
35.00	7.00	41.25	10.00	47.50	10.50
35.25	6.50	41.50	10.00	47.75	9.00
35.50	6.25	41.75	9.50	48.00	8.50
35.75	6.50	42.00	6.00	48.25	5.00
36.00	6.50	42.25	6.50	48.50	8.50
36.25	6.75	42.50	10.25	48.75	7.00
36.50	7.50	42.75	11.00	49.80	7.75
36.75	7.25	43.00	10.50	50.00	12.50
37.00	8.00	43.25	8.75	50.25	8.75
37.25	7.00	43.50	11.25	50.50	9.50
37.50	6.00	43.75	8.50	50.75	11.75
37.75	5.75	44.00	10.00	51.00	8.50
38.00	7.25	44.25	10.50	51.25	7.50
38.25	7.25	44.50	7.50	51.50	14.50
38.50	6.00	44.75	7.50	51.75	8.75
38.75	6.75	45.00	7.50	52.00	8.25
39.00	6.50	45.25	8.00	52.25	12.50
39.25	6.00	45.50	8.75	52.75	14.25
39.50	6.00	45.75	8.50	53.00	7.00
39.75	6.00	46.00	10.75	53.25	8.50
40.00	6.25	46.25	10.00	53.50	8.00
40.25	7.00	46.50	8.75	53.75	8.75
				54.00	7.50

The Falling Weight Deflectometer (FWD) shows an average soil modulus of 9,180 psi with a standard deviation of 3,610 psi.

Field Review Comments: The major distress on this road is depressed transverse cracks. The transverse cracks are spaced 10' to 20' apart and contribute to a rough ride.

The thickness recommendations are in the following tables.

Location	One-way Daily Flexible ESALs	One-way 20-Year Accumulated ESALs	Overlay	Structural Crack Retardation Overlay*	New Construction	
			HBP Class 29	HBP Class 29	Base	HBP Class 29
RP 34.226 to RP 35.168	85	703,453	2.5”	3.5”	18.0"	4.5"
RP 35.168 to RP 42.250	68	558,625	2.5"	3.5"	16.0"	4.5"
RP 42.250 to RP 46.410	68	558,625	2.5”	3.5”	16.0"	4.5"
RP 46.410 to RP 49.034	48	393,106	2.5”	3.5"	16.0"	4.5"
RP 49.034 to RP 49.775	48	393,106	No Overlay Required	No Overlay Required	No Reconstruction Required	
RP 49.775 to RP 54.212	48	393,106	2.5"	3.5"	16.0"	4.5"

*The Structural Crack Retardation Overlay proposed in the Supplemental Scoping Report is a structural overlay with an additional inch of HBP.

Location	One-way Daily Flexible ESALs	One-way 20-Year Accumulated ESALs	Mine and Blend			
			Added Aggregate	Blend Depth	Total Base	HBP Class 29
RP 34.226 to RP 35.168	85	703,453	3.5”	14.5”	17.0”	4.5”
RP 35.168 to RP 40.000	68	558,625	1.5”	12.5”	15.0”	4.5”
RP 40.000 to RP 45.000	68	558,625	2.0”	14.0”	15.0”	4.5”
RP 45.000 to RP 49.034	48	393,106	5.5”	14.0”	15.0”	4.0”
RP 49.034 to RP 49.775	48	393,106	No Mine and Blend Required			
RP 49.775 to RP 54.212	48	393,106	5.5”	14.0”	15.0”	4.0”

These designs are based on 1.3% annual ESAL growth rate; 80% reliability for overlay and for mine and blend; 85% reliability for new construction: 6,000 psi soil modulus; and a 20 year design period.

Highway 67

The recommended pavement thickness for reconstruction of Highway 67 is

15.0" of aggregate base with 4.0" of HBP Class 29.

This design is based on 1.0% annual ESAL growth rate; 62.5 one-way daily flexible and 502,309 accumulated one-way flexible ESALs; 70% reliability; 6,000 psi soil modulus; and a 20 year design period.

Proposed Detour

The District describes the existing section of the proposed detour as

East-West Segment
Length = 3 miles
Surfacing = 1" Armour coat over 4-5" gravel

North-South Segment
Length = 2 miles
Surfacing = 5" gravel

The recommended pavement thickness for the proposed detour required for reconstruction or repair of the structure over Highway 12 is

3.5" HBP Class 27 overlay.

This design is based on 1.0% annual ESAL growth rate; 62.5 one-way daily flexible and 22,813 accumulated one-way flexible ESALs; 70% reliability; 6,000 psi soil modulus; and a 1 year design period.

91:st

Highway 67

The recommended pavement thickness for reconstruction of Highway 67 is

15.0" of aggregate base with 4.0" of HBP Class 29.

This design is based on 1.0% annual ESAL growth rate; 62.5 one-way daily flexible and 502,309 accumulated one-way flexible ESALs; 70% reliability; 6,000 psi soil modulus; and a 20 year design period.

Proposed Detour

The District describes the existing section of the proposed detour as

East-West Segment
Length = 3 miles
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North-South Segment
Length = 2 miles
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The recommended pavement thickness for the proposed detour required for reconstruction or repair of the structure over Highway 12 is

3.5" HBP Class 27 overlay.

This design is based on 1.0% annual ESAL growth rate; 62.5 one-way daily flexible and 22,813 accumulated one-way flexible ESALs; 70% reliability; 6,000 psi soil modulus; and a 1 year design period.

91:st