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14. Supplementary Notes			
15. Abstract <b>Purpose and Need</b> 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. 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. The NDDOT needs to establish if it is practical to construct bases that contain more than 50% salvaged HBP. <b>Objective</b> The objective of this research project is to determine the maximum percentage of salvaged HBP that may be contained in base material without compromising pavement performance. <b>Scope</b> Test segments were constructed, as part of a NDDOT Mine & 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. <b>Summary</b> 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. Gyrotory compaction tests showed no differences in the effort required to compact the blended material with different percentages of 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 significant 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 no obvious visual differences between the test segments and the control segment. All sections show minimal rut depth and transverse cracking. All sections have intermittent longitudinal cracks, primarily in the outside wheel paths, ranging from 5ft to 20ft in length. The control and test segments were tested with a FWD for pavement moduli and a LWP for ride. There were no major differences in the pavement moduli or ride between the different test segments.			
16. Key Words  Mine and Blend Asphalt Percent in Blended Base	17. Distribution Statement No restrictions. This document is available electronically by <a href="#">clicking this link.</a>  North Dakota Department of Transportation Materials and Research Division: 300 Airport Road Bismarck ND 58504-6005 Office: (701) 328-6900		18. No. of Pages 25  19. File type/Size PDF / 1.7 MB

**NORTH DAKOTA  
DEPARTMENT OF TRANSPORTATION**

**MATERIALS AND RESEARCH  
DIVISION**

Experimental Study ND 2004-01

**Maximum Percentage of Asphalt Material  
in a Blended Base**

**Evaluation Report 2**

Project NH-5-012(027)034

June 2010

Prepared by

**NORTH DAKOTA DEPARTMENT OF TRANSPORTATION  
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## **Disclaimer**

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EXPERIMENTAL PROJECT REPORT

EXPERIMENTAL PROJECT	EXPERIMENTAL PROJECT NO.					CONSTRUCTION PROJ NO	LOCATION		
	1	STATE ND	YEAR 2004	NUMBER 01	SURF 8	NH-5-012(027)034	Bowman 28 County		
SHORT TITLE	EVALUATION FUNDING						NEEP NO.	PROPRIETARY FEATURE?	
	48	1	HP&R	3	DEMONSTRATION		Yes		
THIS FORM	DATE		MO.	YR.	REPORTING				
	140	June	--	2010	1	INITIAL	2 x ANNUAL	3 FINAL	
KEY WORDS	KEY WORD 1				KEY WORD 2				
	145 Asphalt pavement				167 Base				
	KEY WORD 3				KEY WORD 4				
CHRONOLOGY	Date Work Plan Approved		Date Feature Constructed:		Evaluation Scheduled Until:		Evaluation Extended Until:		Date Evaluation Terminated:
	277		10/2005		10/2015		289		293
	281		285		285		289		293
QUANTITY AND COST	QUANTITY OF UNITS (ROUNDED TO WHOLE NUMBERS)			UNITS				UNIT COST (Dollars, Cents)	
	297			305				306	
AVAILABLE EVALUATION REPORTS	CONSTRUCTION			PERFORMANCE			FINAL		
	315 X								
EVALUATION	CONSTRUCTION PROBLEMS				PERFORMANCE				
	318				319				
APPLICATION	1 ADOPTED AS PRIMARY STD.		4 X PENDING		<i>(Explain in remarks if 3, 4, 5, or 6 is checked)</i>				
	2 PERMITTED ALTERNATIVE		5 REJECTED						
REMARKS	320		3 ADOPED CONDITIONALLY		6 NOT CONSTRUCTED				
	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 in performance between the control segment and the test segments.								

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# Maximum Percentage of Asphalt Material in a Blended Base ND 2004-01

## Purpose and Need

The North Dakota Department of Transportation (NDDOT) uses a process that it refers 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 contains 50% or less salvaged HBP. 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 of the existing HBP is milled off and 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. There are concerns about allowing blended base to contain a greater percentage of asphalt pavement material. These concerns include the following:

Blended base with a high percentage of asphalt material may...

- Require more effort to achieve proper compaction. Lack of proper compaction may cause rutting or cracking in the pavement.
- 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.
- 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.
- 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 that may be contained in base material without compromising pavement performance.

## **Scope**

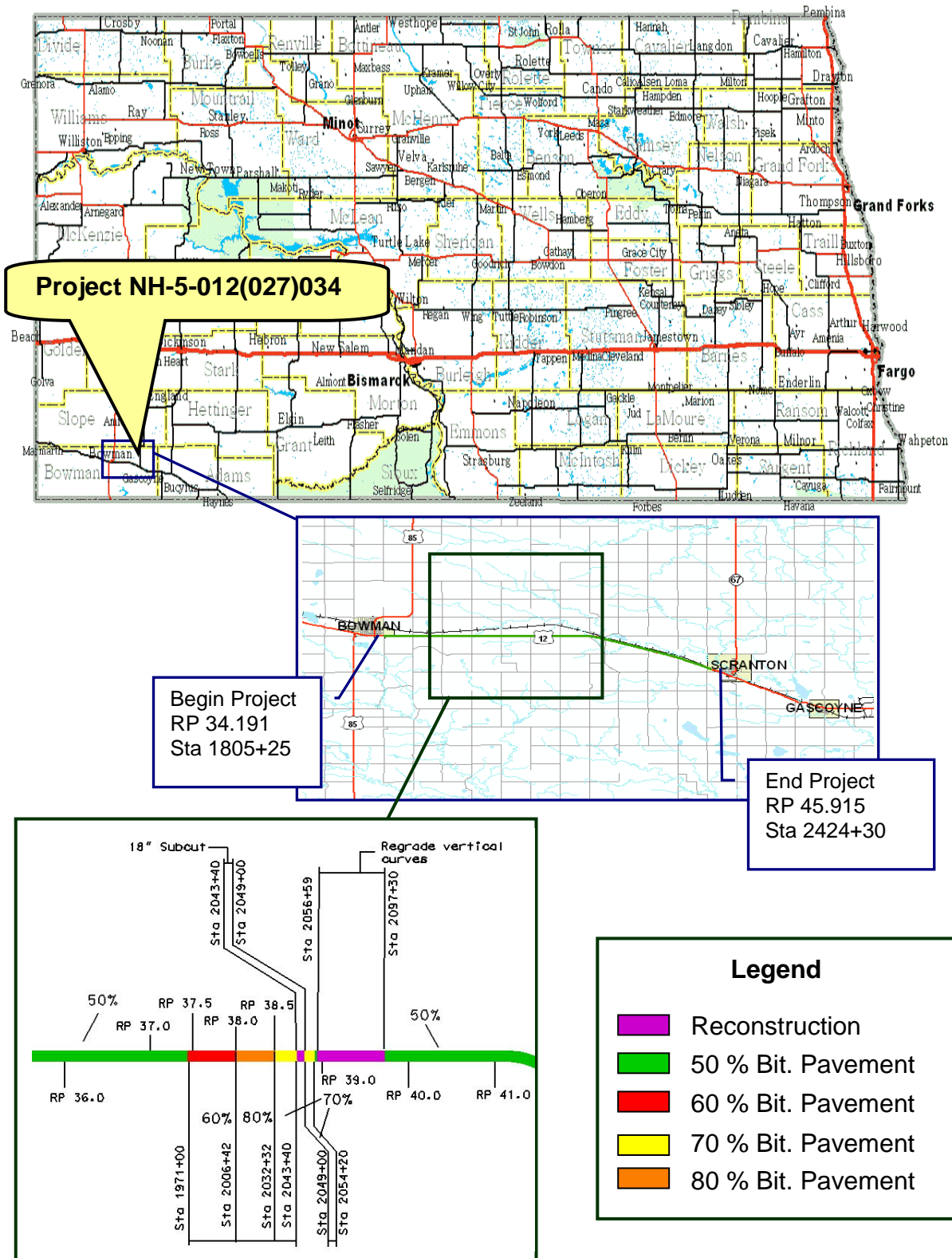
Test segments were constructed as part of a NDDOT mine & blend project with blended base that contain 60%, 70%, and 80% salvaged HBP. Base sections that contained 50% salvaged HBP will be used as the control.

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

The test segments will be evaluated annually with the NDDOT “Pathways Van” and visually by NDDOT personnel, a report will be produced biannually. The “Pathways Van” will measure ride, distress, and rut depths. Also, a lightweight inertial profiler (LWP) will be 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**

The test segments were constructed as part of the rehabilitation of US 12, project NH-5-012(027)034, 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.



## 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 1:

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)						

**Table 1**

### Traffic Data

The one-way traffic used for the pavement design of the control and test segments is shown in Table 2.

Year	Passenger Car	Trucks	Total	30 <sup>TH</sup> Max Hr	Flex. ESALs
2003	810	190	1,000	100	135

**Table 2**

## **Design**

Test segments were constructed as part of Project NH-5-012(027)034. 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 included options for new construction and for mine and blend. The required pavement and base thicknesses were developed using Darwin 3.01 software and according to "AASHTO Guide for the Design of Pavement Structures, 1993". Table 3 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.

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 section.

**Table 3**

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 was a subcut within the 70% salvaged HBP segment. Table 4 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.

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"

Table 4

As part of the 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.

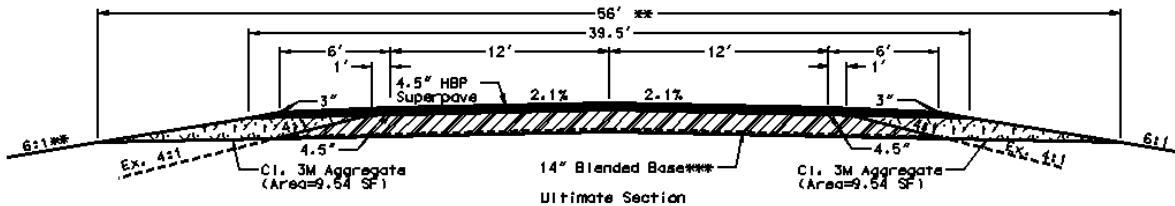


Figure 2

## **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 earthwork contractor. Bill Gathman was the project engineer for the NDDOT, Dickinson District.

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 1 shows the test segment with the salvaged HBP on top of the pavement and Class 3M aggregate on the shoulders.



**Photo 1 – Test segment with salvaged HBP on top of the pavement.**

During construction, the 60% test segment was extended approximately 900'. Also, the 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 sheepfoot roller followed the mining machine and was used to compact the blended base. After the sheepfoot 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 & 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 0.04 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 first lift was paved with a PG 58-28 binder and the top lift was paved with a PG 58-34 binder. The paving was completed October 15, 2005. Photo 2 shows the completed pavement surface after application of pavement markings and shoulder rumble strips.



**Photo 2 – US 12 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 this variability, a method for estimating the percentage of salvaged HBP in the blended base, as constructed, was developed.

Two samples of the salvaged HBP were obtained 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 5 and 6.

100% Salvaged HBP		
AC %	5.45%	5.72%
<b>Average AC%</b>	<b>5.59%</b>	

Table 5

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

Table 6

## **Evaluation Report 1**

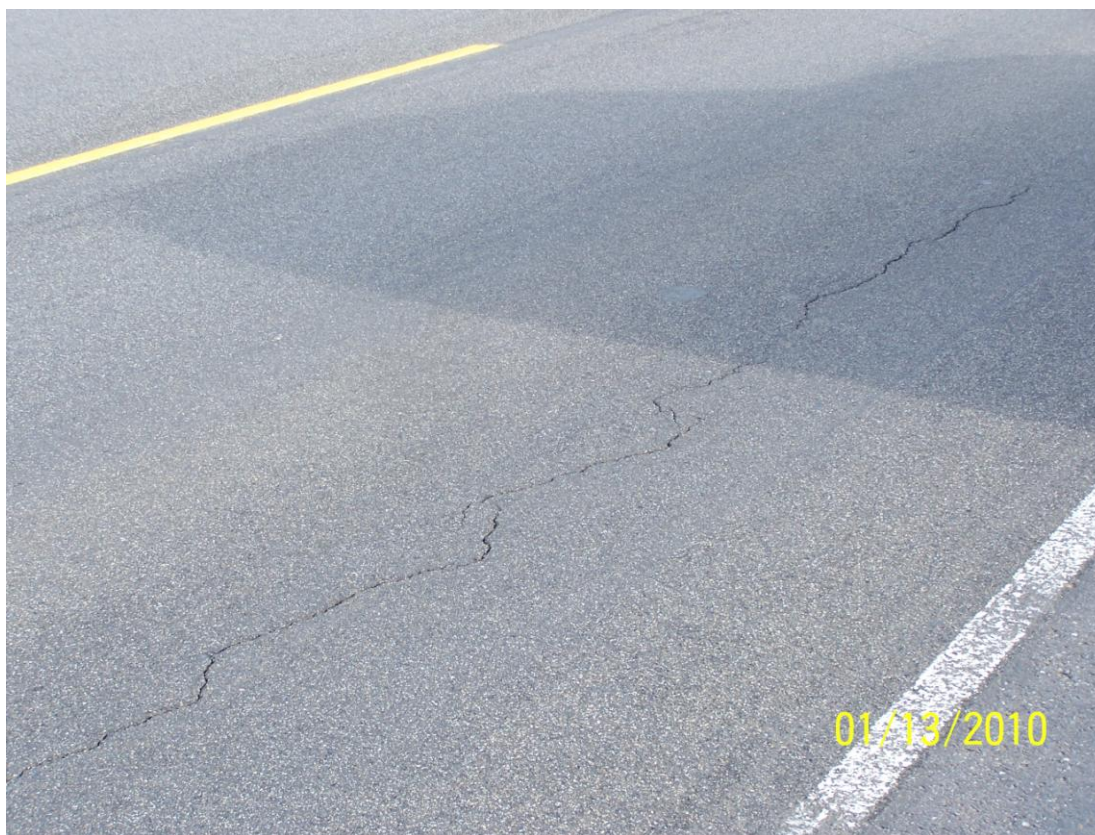
The test segments were evaluated on June 16, 2008. Visual inspection of the roadway revealed minimal transverse cracking and minimal rutting on all segments. The only notable distress observed was intermittent longitudinal cracking. These cracks appeared at random intervals and were not specific to any one test segment. Most of these cracks occurred in the outside wheel path in both east bound and west bound directions. The cracks were hairline cracks and varied in length from 1ft to 5 ft in length. The surrounding areas of these cracks had a slightly raveled look to it, with some of the surface rocks removed (See Photo 3). This condition is possibly the result of a dry mix or a defect of the paving process. Cores would need to be taken to investigate the depth of the cracks.



**Photo 3 –Longitudinal Crack in Wheel Path with Slightly Raveled Surface.**

## **Evaluation Report 2**

The test segments were evaluated again on January 13, 2010. Maintenance activities between the evaluations consisted of a slurry seal during the 2009 construction season. Visual inspection of the roadway revealed minimal transverse cracking and minimal rutting on all segments. The primary distress observed was longitudinal cracks that had reflected through the slurry seal (See Photo 4). The length of the longitudinal cracks now ranged from 5 ft to 20 ft in length. Table 7 quantifies the distresses that were observed.



**Photo 4 –Longitudinal Crack in Wheel Path Reflected Through Slurry Seal.**

Roadway Distress Table					
Location	Length	Longitudinal Cracks		Transverse Cracks	
		6/16/2008	1/13/2010	6/16/2008	1/13/2010
Control Section RP 36 to RP 37.5	1.5 Miles	4	9	0	2
60% Asphalt Material RP 37.5 to RP 38.0	0.5 Miles	1	3	0	0
80% Asphalt Material RP 38.0 to RP 38.5	0.5 Miles	2	4	0	0
70% Asphalt Material RP 38.5 to RP 39.0	0.5 Miles	0	3	0	0

**Table 7**

**Rut Data**

Rut data was collected by the Pathways Van in 2008 and 2009. The average rut was nearly the same for all test sections at just over 1/8". The average for each section is shown in Table 8.

Average Rut Depth (IN)				
Location	Control (RP 36 to RP 37.5)	60% (RP 37.5 to RP 38)	80% (RP 38 to RP 38.5)	70% (RP 38.5 to RP 39) [less subcut]
East Bound 2008	0.15	0.14	0.14	0.14
West Bound 2009	0.14	0.18	0.14	0.14

**Table 8**

**FWD Data**

The roadway was tested with a Falling Weight Deflectometer (FWD) from RP 36.00 to RP 41.00. The FWD tested at 100 foot intervals. Figure 3 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. Figures 4, 5, and 6 are the back-calculated moduli of the HBP pavement, base, and subgrade. Table 9 shows the averages 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 aggregate.

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 9 shows that the control and the various test segments do have different average moduli and deflections. However, from the charts 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.

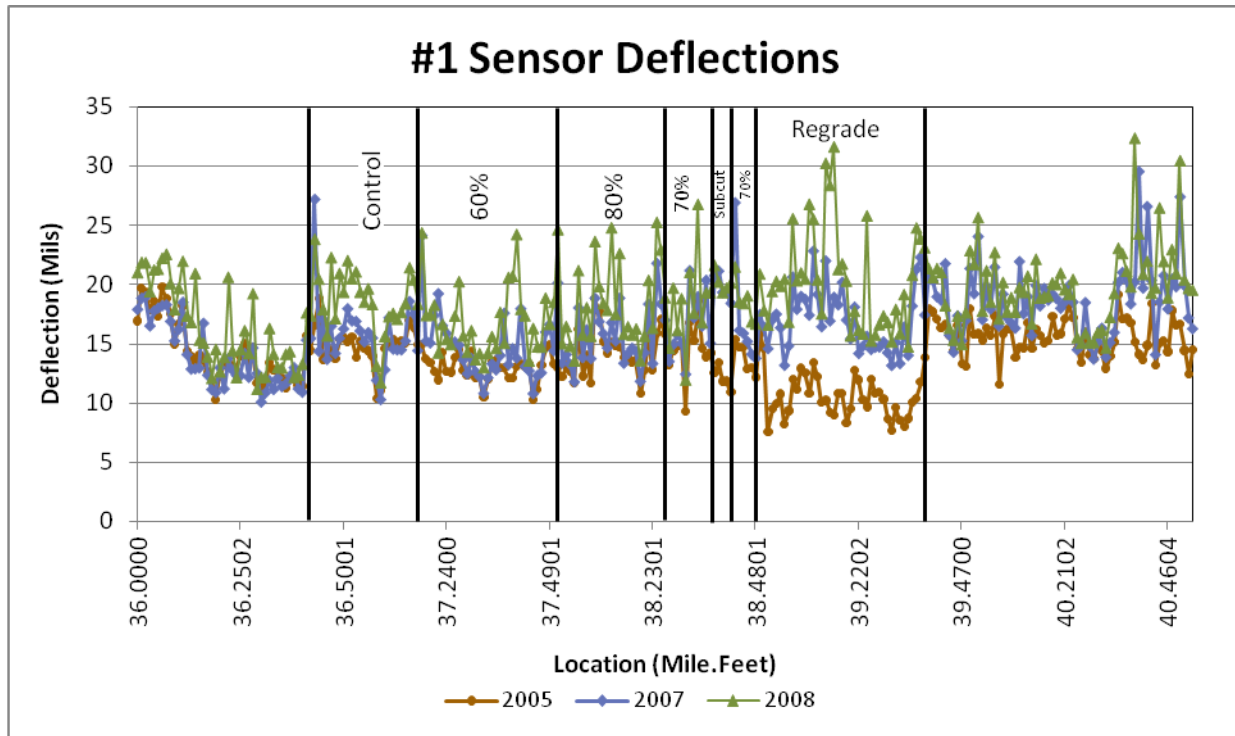


Figure 3

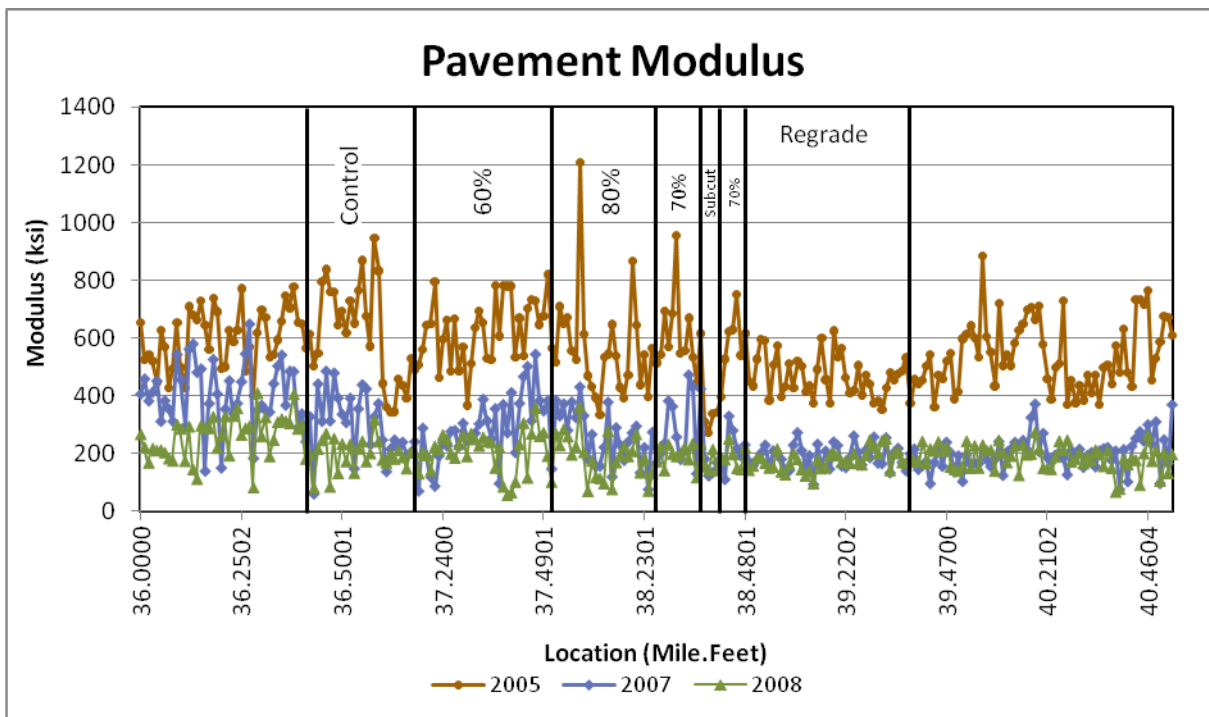


Figure 4

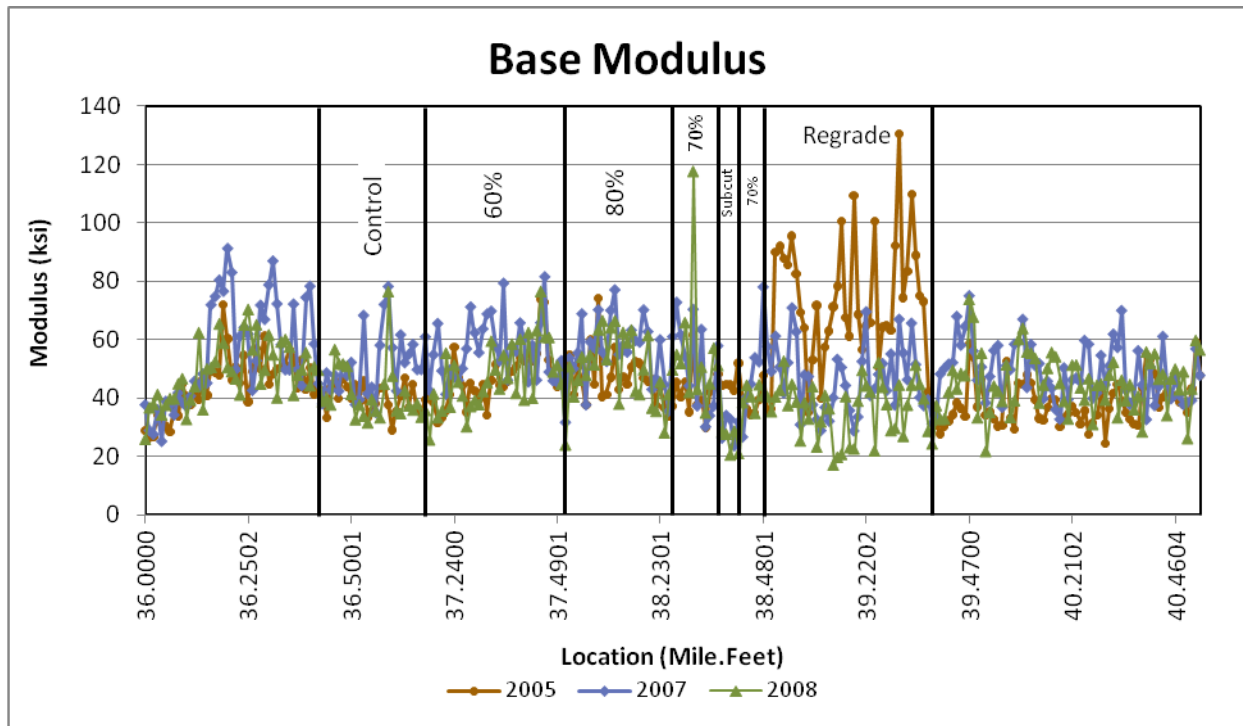


Figure 5

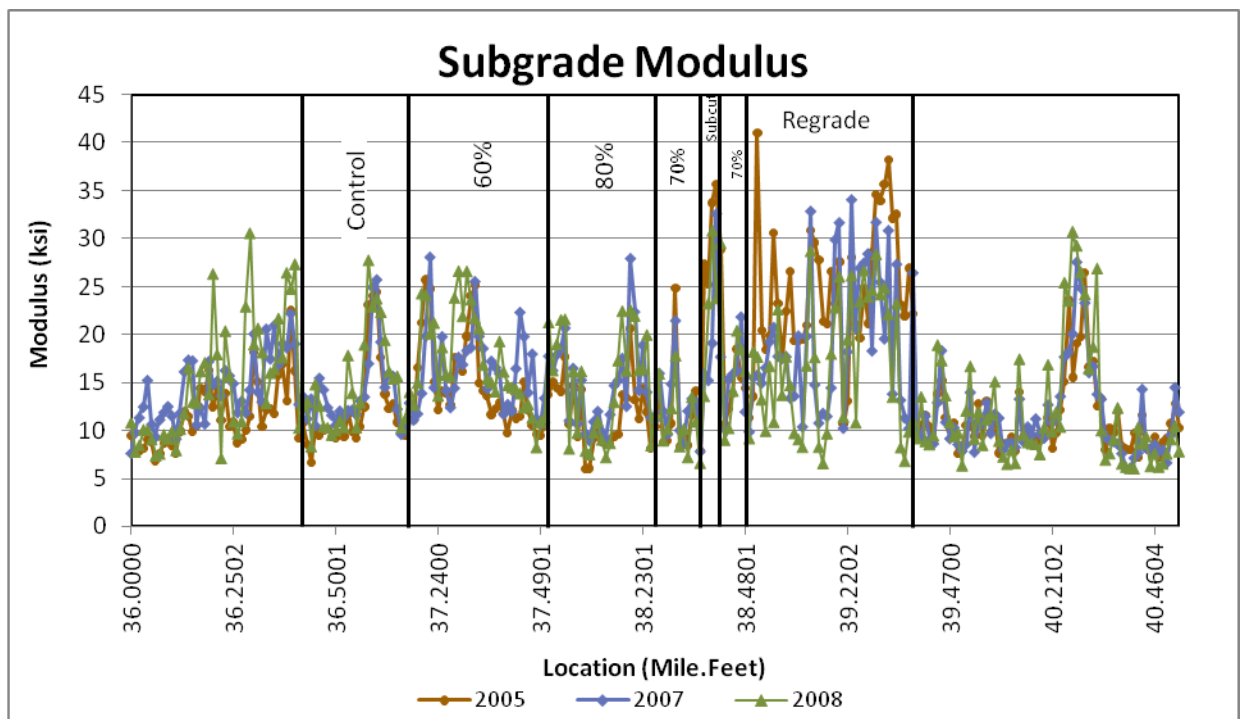


Figure 6

Segment	FWD Data from Control and Test Segments											
	#1 Sensor Deflection			Pavement Modulus			Base Modulus			Subgrade Modulus		
	2005	2007	2008	2005	2007	2008	2005	2007	2008	2005	2007	2008
Control	14.68	15.31	18.63	620.50	307.91	195.94	40.06	51.64	42.08	12.35	14.10	14.52
60%	12.92	14.44	17.07	629.93	284.84	204.34	47.64	55.53	46.69	14.61	16.33	17.32
70%	14.34	16.64	18.45	600.10	261.46	194.58	40.74	50.72	50.56	12.49	13.47	12.39
80%	14.20	15.46	18.20	562.63	256.78	188.13	46.77	56.88	50.60	11.70	14.59	14.47
Subcut	12.07	19.80	20.24	333.27	157.35	168.46	45.67	29.50	25.38	30.18	20.1	24.20
Regrade	10.23	16.76	20.32	472.18	189.44	175.79	73.44	46.71	36.20	25.88	19.81	16.72

Table 9

### Ride Data

Ride data was collected in 2005 with the Light-Weight Profiler (LWP). The data is reported as the International Roughness Index (IRI). The ride data was collected in both directions in 2005. Ride data was collected by the 'Pathways Van' in 2008 in the east bound direction and in 2009 in the west bound direction. Table 10 below shows the average IRI for the control section and each test section.

Figures 7, 8, 9, and 10 are a graphical representation of the IRI data that has been collected thus far. There doesn't appear to be a significant difference in the IRI between the test segments and control segments. There does appear to be a significant bump in the 60% salvaged HBP section in the west bound direction. It also appears that there may be a rough transition across both lanes at the boundary of the 70% salvage HBP segment and the Subcut segment.

Average IRI				
Location	West Bound		East Bound	
	2005	2009	2005	2008
Control (RP 36 to RP 37.5)	36.5	37.2	35.7	39.9
60% (RP 37.5 to RP 38)	36.2	41.2	35.7	33.7
80% (RP 38 to RP 38.5)	34.8	37.2	40.4	37.2
70% (RP 38.5 to RP 39) [less subcut]	41.7	43.4	37.7	41.0

Table 10

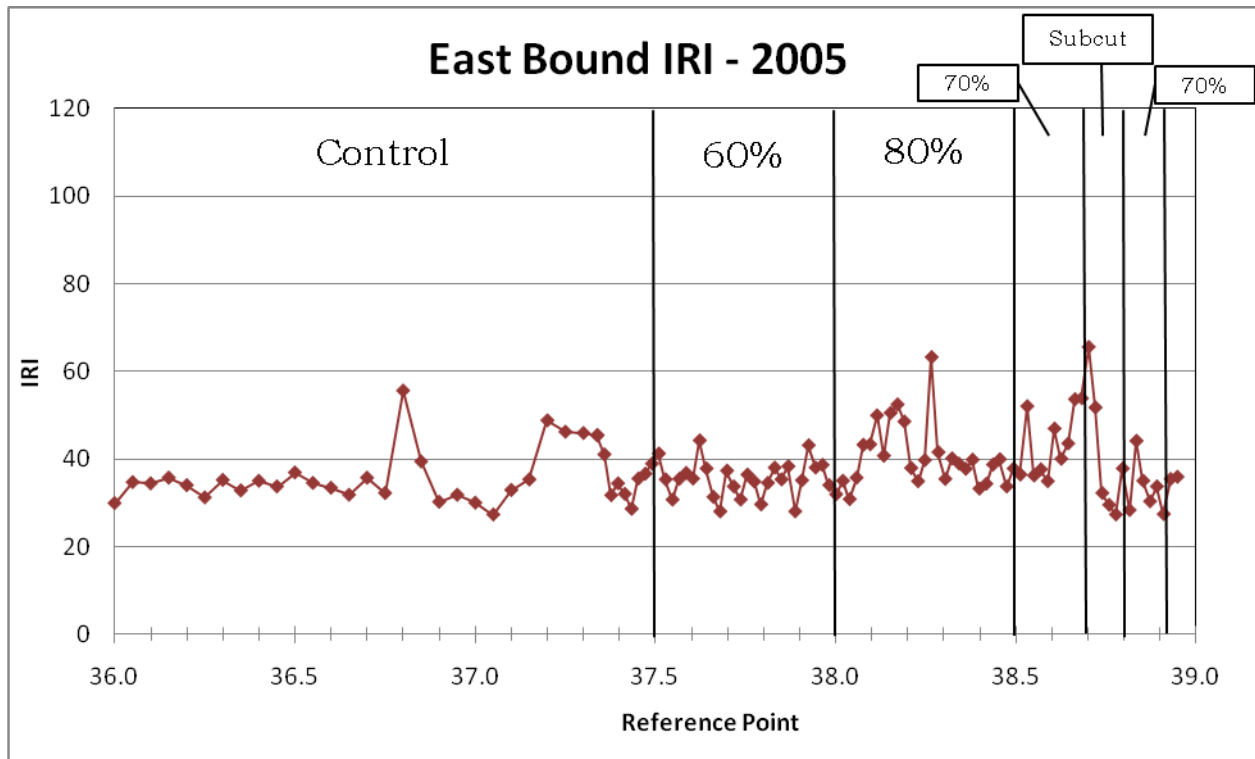


Figure 7

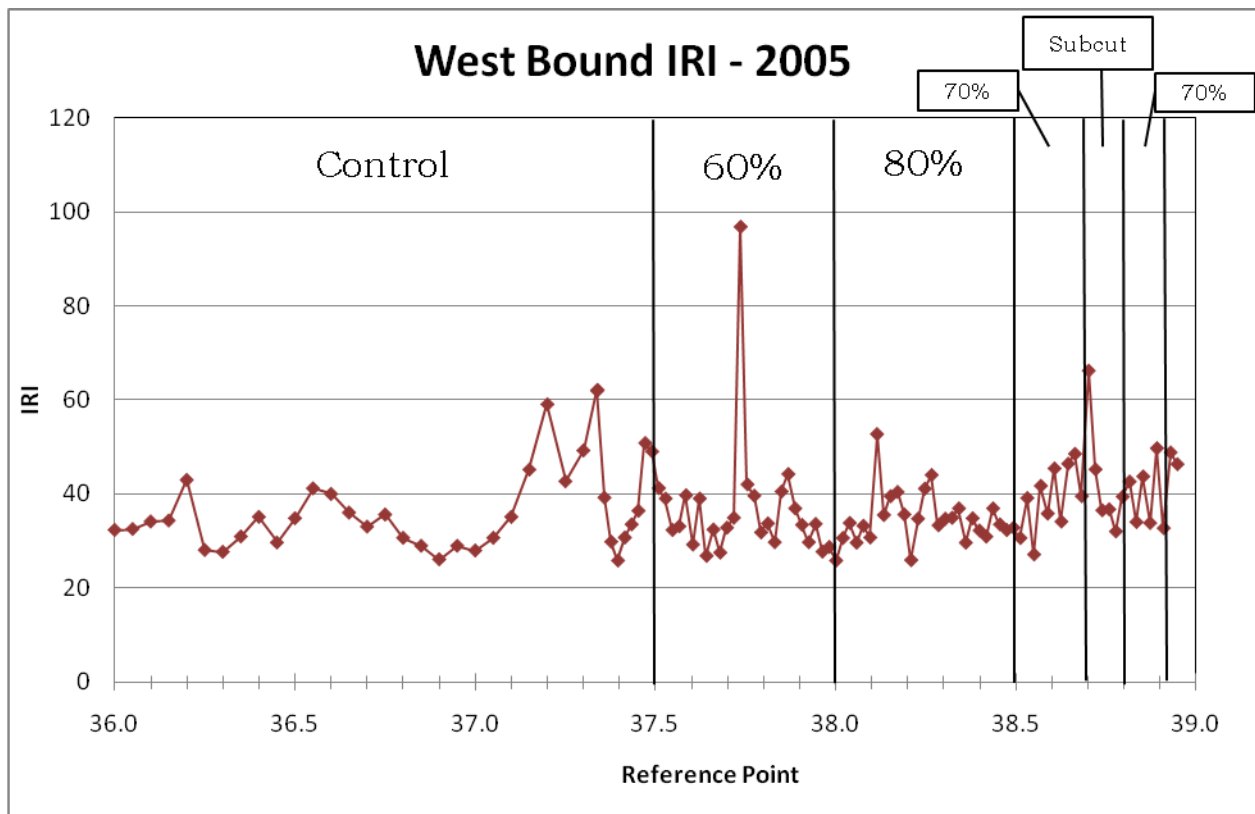


Figure 8

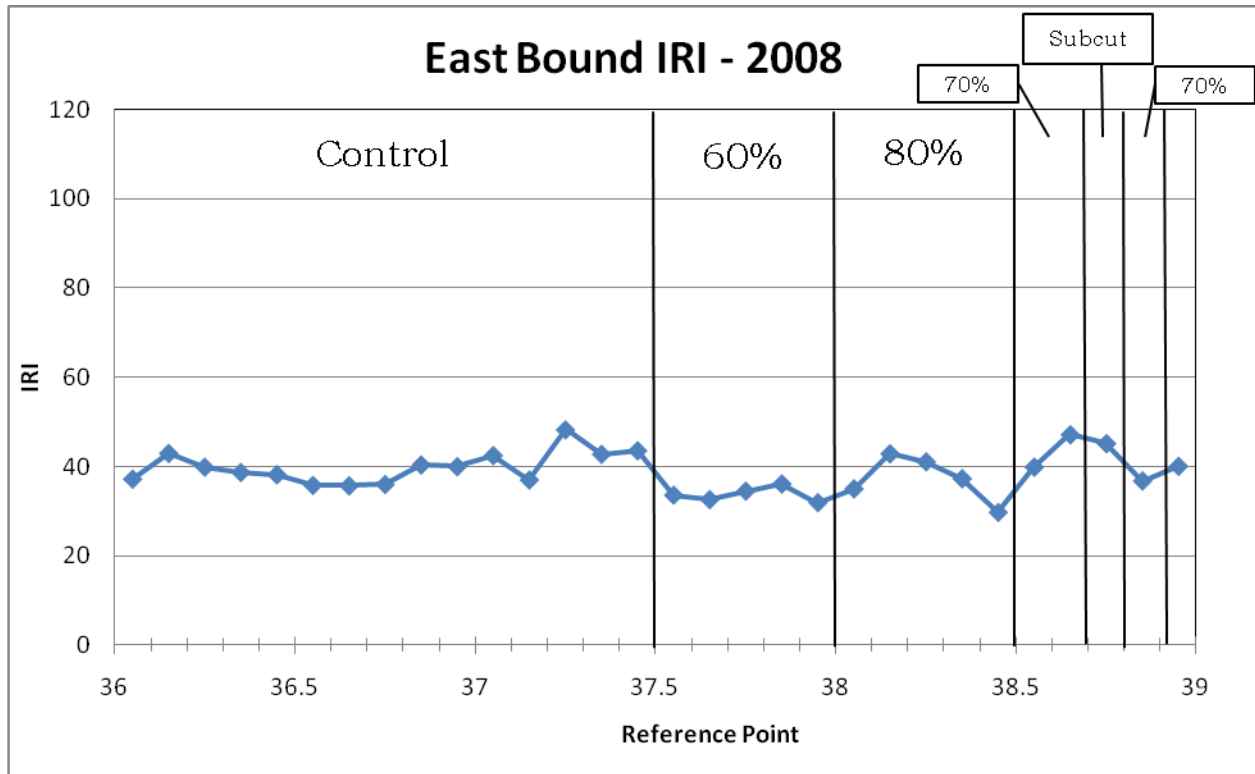


Figure 9

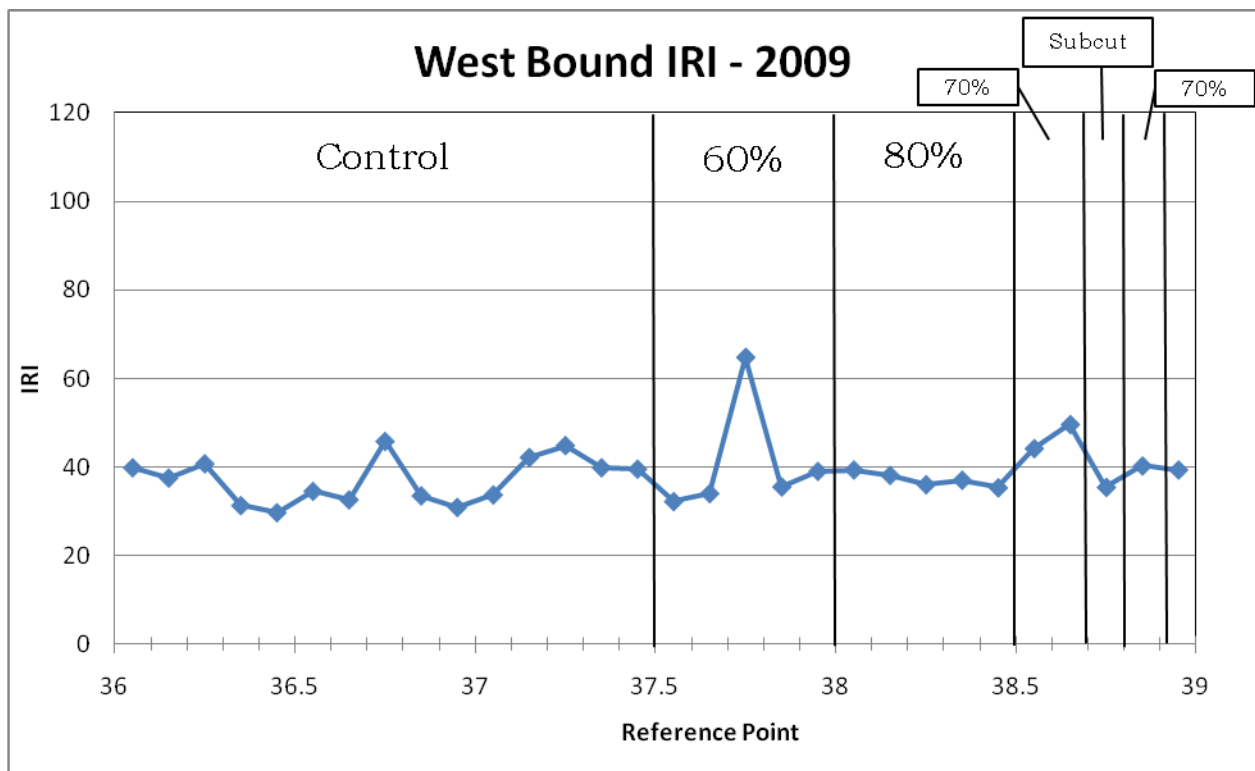


Figure 10

## **Maintenance Costs**

At this time the only maintenance work performed on this roadway was a slurry seal in 2009. The unit cost of this work was bid at \$38,777 per mile.

## **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.

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. An adjacent ½ mile long segment, designed to contain 50% salvaged HBP, will act as the control for this project. 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 significant 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 no obvious visual differences between the test segments and the control segment. All sections show minimal rut depth and transverse cracking. All sections have intermittent longitudinal cracks, primarily in the outside wheel paths, ranging from 5ft to 20ft in length. The control and test segments were tested with a FWD for pavement moduli and a LWP for ride. There were no major differences in the pavement moduli or ride between the different test segments.

The control and test segments will continue to be monitored. Data will continue to be collected for distress, rutting, ride, and subgrade strength. The maintenance operations will be monitored to compare the maintenance costs of the test segments to the control segment.