NORTH DAKOTA
DEPARTMENT OF TRANSPORTATION

MATERIALS AND RESEARCH DIVISION

Experimental Study ND 2002-02

Performance of HBP vs. PCC Pavement

Fifth Evaluation

Project NH-8-013(030)380

June, 2013

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 — YEAR: 2002 - NUMBER: 02 — SURF:
	CONSTRUCTION PROJ NO	8 — NH-8-013(030)380
	LOCATION	28 — Richland County
	EVALUATION FUNDING	48 — 1 HP&R; 2 x CONSTRUCTION; 3 DEMONSTRATION; 4 IMPLEMENTATION
	NEEP NO.	49
	PROPRIETARY FEATURE?	51 — Yes; X No
SHORT TITLE	TITLE 52	Performance of HBP Vs. PCC Pavement
THIS FORM	DATE 000	MO. June -- YR. 2013
	REPORTING	1 INITIAL; 2 X ANNUAL; 3 FINAL
KEY WORDS	KEY WORD 1	145 Asphalt pavement
	KEY WORD 2	167 Concrete pavement
	KEY WORD 3	189 Performance
	KEY WORD 4	211 Shoulders
	UNIQUE WORD	233
	PROPRIETARY FEATURE NAME	255
CHRONOLOGY	Date Work Plan Approved	3/2002 (277)
	Date Feature Constructed:	11/2002 (281)
	Evaluation Scheduled Until:	11/2012 (285)
	Evaluation Extended Until:	11/2017 (289)
	Date Evaluation Terminated:	(293)
QUANTITY AND COST	QUANTITY OF UNITS (ROUNDED TO WHOLE NUMBERS)	297
	UNITS	305 — 1 LIN. FT; 2 SY; 3 SY-IN; 4 CY; 5 TON; 6 LBS; 7 EACH; 8 LUMP SUM
	UNIT COST (*Dollars, Cents*)	306
AVAILABLE EVALUATION REPORTS	CONSTRUCTION	315
	PERFORMANCE	X
	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

All three segments of the completed roadway show increased distress since the 2010 evaluation.

The "Pathways Van" data shows that there has been some loss of ride quality from initial construction. The HBP segment 1 has the highest IRI but is not far behind the concrete segments 1 and 2.

With the cost of the chip seal, the HBP Segment 1 has the highest maintenance costs and the PCC section with HBP shoulders has the next highest. HBP had the lowest cost of initial construction and PCC pavement with HBP shoulders had the next lowest initial cost. PCC pavement with PCC shoulders had the highest initial cost.

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Performance of HBP vs. PCC Pavement
ND 2002-02

Purpose and Need

The use of Portland Cement Concrete (PCC) pavement or Hot Bituminous Pavement (HBP) is determined by such factors as highway classification, whether it is rural or in an urban area, subgrade properties in certain cases and most importantly - traffic. Typically, in areas with high ESALs, such as interstates and urban areas, PCC Pavement has been the preferred alternative when these areas are reconstructed.

Within the past decade, there have been changes in pavement design methods and impr**o**ved material properties that are intended to increase pavement performance. NDDOT desires to collect current information comparing the performance of PCC Pavement and HBP based on design methods and material properties currently in use by NDDOT.

A typical asphalt section is 12” to 18” of aggregate base and 4” to 6” of asphalt. A typical concrete section is 4” of aggregate base and 4” of permeable base with edge drains or 8” of aggregate without edge drains, and 9” to 11” of concrete.

Objective

The objective is to compare the performance of HBP versus PCC Pavement based on current design methods and material properties.

Scope

For comparison, a section of ND Highway 13 was reconstructed with HBP and PCC pavement sections. Three different pavement sections were designed and constructed using current NDDOT practices. Segment 1 is HBP with HBP shoulders. Segment 2 is doweled PCC pavement with HBP shoulders. Segment 3 is doweled PCC pavement with PCC shoulders.

Construction of the three segments will be evaluated for relative cost, quality of the finished pavement, and for ease of construction. Thereafter, the project will be evaluated every two years for a minimum period of ten years.

The biennial evaluation will include maintenance costs, visual inspections, and data collected with the NDDOT “Pathways Van”. Data collected from visual inspection will include: distresses (e.g. cracks, ruts, & etc.), pavement & shoulder condition, and observed ride quality. The “Pathways Van” is a high-speed profiler that will collect the following data: International Roughness Index (IRI), rut depth, distress score, Ride Index, and Public Ride Perception Index (PRPI).

Project History

Location

The HBP and PCC pavement sections were constructed as part of project NH-8-013(030)380. This project was the reconstruction of the westbound roadway of ND Highway 13, a four-lane, divided highway that is classified as an interregional corridor. The project extends 8.9 miles from I-29 to the west city limits of Wahpeton, ND. It is in a rural area with some industrial facilities on the east end of the project. Refer to Figure 1 for the project location map and also the segment locations.

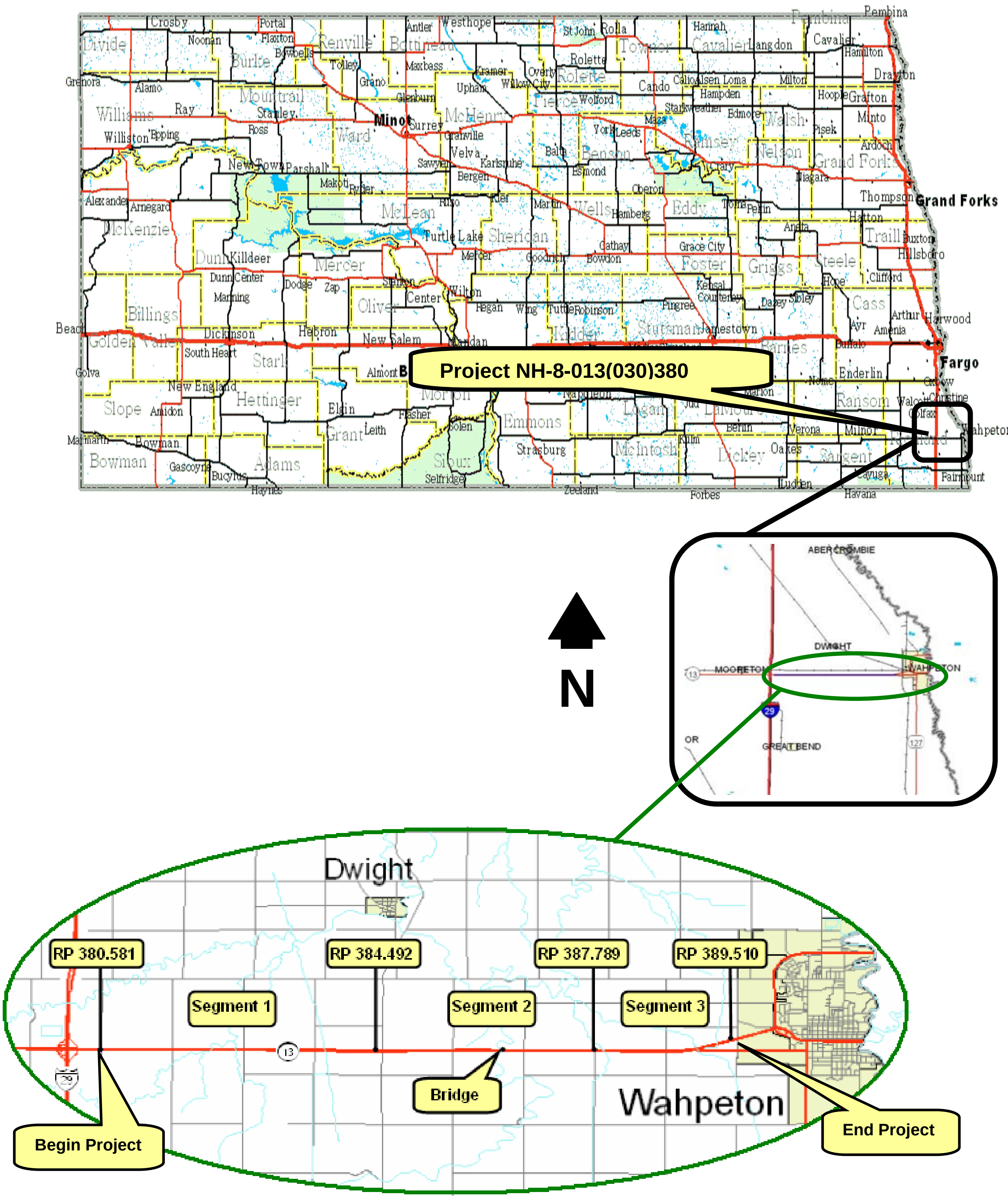

Figure 1 - Project location.

Traffic

The 2000 one-way traffic used for the design is shown in Table 1.

Year	Passenger Car	Trucks	Total	30^{TH} Max Hr	Flex. ESALs	Rigid ESALs
2000	2,275	375	2,650	275	475	800

Table 1, Traffic

Design

Each of the three pavement sections was designed and constructed with 2002 NDDOT design procedures. The 1997 standard specifications manual was used on this project. Current NDDOT pavement thickness design practice uses Darwin 3.01 software and is in accordance with *AASHTO Guide for Design of Pavement Structures 1993*. The doweled PCC pavement was designed for a 30 year life and the HPB was designed for a 20 year life which follows current NDDOT guidelines. The doweled PCC pavement segments include edge-drains and the HBP segment does not.

Because of uniformly poor soil conditions, the entire project was subcut an additional 12" and a type S2 separation fabric was installed. Typically, PCC pavement sections are not designed with a sub-base but the PCC pavement segments in this project have a 12" Class 3 aggregate sub-base due to the subcut. The additional 12" of aggregate resulting from the subcut is included with the 16" of base required by the HBP design for this traffic. The three pavement sections are presented in Table 2.

Segment	Stationing	Length	Sub-base	Base	Pavement	Shoulders
1	20095+00 to 20301+18	3.905 Miles	16"-Class 3	8"-Salvaged Material	8"-Class 33 HBP	8"-Class 33 HBP
2	20301+18 to 20475+08	3.294 Miles	12"-Class 3	4"-Salvaged Material + 4"-Permeable	9"-Doweled PCC	4"-Class 27 HBP
3	20475+08 to 20566+47.7	1.731 Miles	12"-Class 3	4"-Salvaged Material + 4"-Permeable	9"-Doweled PCC	9"-PCC

Table 2, Pavement Sections

Construction

Project NH-8-013(030)380 was initiated to remedy the poor condition of the existing surface of the roadway. The existing roadway was reconstructed and turning lanes were added. This project did not change the roadway's original horizontal or vertical alignment. As part of this project, two structures were replaced; a bridge at RP 386.299 was replaced with a new bridge and a bridge at RP 387.788 was replaced with a box culvert.

Construction began April 4, 2002 and the roadway was opened November 13, 2002. Progressive Contractors Inc. (PCI) from Saint Michael, Minnesota was the prime contractor and also paved the PCC pavement. Gowan Construction Inc. from Oslo, Minnesota was responsible for salvaging the existing pavement, grading, and placing the aggregate base. Bituminous Paving Inc. (BPI) from Ortonville, Minnesota was responsible for paving the HBP. The Project Engineers, representing NDDOT, were Lyle Landstrom and Randy Kirkevold from the Fargo District

Many centerline pipes were replaced as part of this project. New centerline pipes on this project were constructed with a tapering depth of aggregate that was intended to minimize differential settlement.

Because of poor soil conditions, this entire project was subcut 12" and a type S2 separation fabric was installed. Extremely soft areas were subcut an additional 12" and a type R1 reinforcement fabric was installed. Soft areas were found by observing rutting of the subgrade caused by the passing of a large water truck used on this project. The fabric specifications are in Appendix D.

There was a problem maintaining enough slope in the edge-drains in the area of left turn lanes. In these areas the median is narrow and the ditch is very shallow. Because of the shallow ditch it was difficult to get a proper slope in the edge-drain for drainage. During construction it was discovered that the edge-drains at RP 384.621, RP 386.620, and RP 387.632 were not draining properly and that the base was becoming saturated. These edge-drains were reworked to improve drainage but the Project Engineers suspect that the edge-drain at RP 387.632 still does not drain properly.

BPI paved the HBP in Segment 1 on September 11, 2002. The 8” of HBP was placed in 3 lifts; a 3” leveling course, a 3” intermediate course, and a 2” wearing course. PG 58-34 asphalt cement was used in the wearing course and PG 58-28 was used in the bottom two courses. Class 33 aggregate was used in all courses.

During construction, some portions of the leveling course became cracked and rutted. These portions of the leveling course were milled and repaved before the intermediate course was paved.

There were some repairs made to the wearing course. Construction traffic caused some pavement damage on the east end of the HBP segment. This area was milled and repaved. Because of paving irregularities, another small area of wearing course was milled and repaved. This area includes the driving lane and the outside shoulder.

Construction Cost Estimate

The cost per mile of each pavement type is presented in Table 3 below. Only costs for construction of the pavement sections are included in this estimate. The quantities used for this estimate are the quantities given in the project plans and have not been adjusted to the actual quantities as constructed. The unit prices are from the selected bidder's bid.

Segment	Cost Per Mile
1-HBP	$539,871.80
2-PCC/HBP shoulders	$687,273.10
3-PCC/PCC shoulders	$741,110.03

Table 3, Construction Costs

Evaluation

Post-Construction Inspection-2003

Pavement Condition

Materials and Research personnel visited the completed roadway on January 29, 2003 with Randy Kirkevold. The roadway showed no distresses and was in excellent condition. Randy Kirkevold remarked that there were areas on some left turn lanes that may collect water and these areas may require correction in the future.

The PCC pavement had some obviously lighter colored areas caused by grinding of the pavement for smoothness. Some of the tining of the pavement appeared shallow. The observed ride of both the PCC pavement segments was smooth.

The HBP had some construction joints from repairs made to the wearing course during construction. The passing lane had one construction joint and the driving lane had three construction joints. The observed ride of the HBP was smooth but the construction joints were noticeable when driven over.

The roadway was also visited during the spring on April 9, 2003. Several new dips had formed in the HBP section where culverts passed under the road. The dips were quite noticeable. No change was noticed in the PCC pavement.

Maintenance Costs

The maintenance costs recorded in 2003 for the roadway were approximately $700, which only occurred in Segment 3. Segment 1 and 2 had no recorded maintenance costs. See Appendix A for more information on maintenance costs.

Roadway Profile

The roadway profile was recorded by the pathways van and it was found that the IRI for Segment 1 was 39.3, IRI for Segment 2 was 42.1, and the IRI for Segment 3 was 44.5. See Appendix B for a graph of the roadway profile.

Skid Testing

There was no skid testing completed during the post-construction evaluation.

First Evaluation-2004

Pavement Condition

The first visual evaluation was conducted on September 13th, 2004. The roadway was in excellent condition and the ride was good. The dips over culverts, that were noticed in the spring of 2003, were gone except for one. There was a noticeable dip at a culvert near the west end of the project in the HBP section. This culvert was not replaced during the construction of this project.

It was apparent that maintenance forces had sealed the cracks within the project limits. The greatest use of crack sealant was in the PCC pavement section with HBP shoulders. The sealant had been used to seal the joint between the PCC and HBP shoulder. Also, there were some transverse cracks in the HBP shoulder that had been routed and sealed. Almost all of these transverse cracks were over edge-drain outlet pipes. There were no sealed transverse or longitudinal cracks in the HBP section. Crack sealant had been used on the joints of the HBP left turn lanes in all of the segments.

No transverse cracks were noticed in the HBP section. No cracks or distresses were noticed in the PCC pavement. A summary of the pavement condition can be found in Table 4 in the summary.

Maintenance Costs

The maintenance costs recorded in 2004 for the roadway were approximately $2,750 for Segment 1 (compared to $700 in 2003), $3,250 for Segment 2, and $1,500 for Segment 3. Over 99% of the 2004 total maintenance costs were classified as "Rubber Fill Costs." This was the cost of sealing (and routing when necessary) cracks and joints with a sealant. A summary of the maintenance costs can be found in Table 7 in the summary and Appendix A has more information on maintenance costs.

Roadway Profile

The roadway profile was recorded by the pathways van and it was found that the IRI had increased from the 2003 evaluation for all three segments. Segment 1 increased from 39.3 to 63.1, Segment 2 increased from 42.1 to 53.1, and Segment 3 increased from 44.5 to 55.1. A summary of the profile can be found in Table 6 in the summary and Appendix B has a graph of the roadway profile.

Skid Testing

The Montana DOT performed skid testing on the roadway in 2004. This testing was performed according to ASTM E-274 with a ribbed tire. The Montana DOT performed the 2004 testing at a test speed of 50 mph. The average skid number for Segment 1 was 46.5, Segment 2 was 43.1, and Segment 3 was 37.9. A summary of the skid testing can be found in Table 8 in the summary and additional information on the skid testing can be found in Appendix C.

Second Evaluation-2006

Pavement Condition

The second visual evaluation was conducted on November 15th, 2006. It was apparent that the HBP within the project had been chip sealed and that any cracks in the HBP would not be visible. The PCC had no visible changes from the previous evaluation.

The ride in all three sections was good except for several dips at culverts. Most notable was the box culvert at RP 387.783 at the beginning of Segment 3. The roughness at this location can be seen in the IRI graph in Appendix B Chart 2. A summary of the pavement condition can be found in Table 4 in the summary.

Maintenance Costs

The NDDOT reported maintenance costs for each mile of road that it maintained until 2005. In 2005, the HBP portions of Segment 1 and Segment 2 were chip sealed as part of project SNH-8-013(036)379. CRS-2P emulsified asphalt and Class 41 aggregate were used for the chip seal. The cost of aggregate and asphalt for each segment was based on bid price and design calculations in the project plans. The cost of contract bond, mobilization, and traffic control was calculated by dividing the total cost for the project by the segment's portion of the length of the project. Costs for pavement marking paint and tape were not included. The portion of the project cost calculated for Segment 1 was $75,081 and Segment 2 was $18,536.

The NDDOT reported maintenance costs for each mile of road that it maintained until 2005. As a result, there are no maintenance costs recorded in 2006. A summary of the maintenance costs can be found in Table 7 in the summary and Appendix A has more information on maintenance costs.

Roadway Profile

The roadway profile was recorded by the pathways van and it was found that the IRI had increased from the 2004 evaluation for Segments 1 and 3 but the IRI decreased from the 2004 evaluation for Segment 2. Segment 1 increased from 63.1 to 68.7, Segment 2 decreased slightly from 53.1 to 52.6, and Segment 3 increased from 55.1 to 58.1. The decrease in the IRI in Segment 2 can possibly be attributed to deveating from the previous path which causes a change in the IRI. A summary of the profile can be found in Table 6 in the summary and Appendix B has a graph of the roadway profile.

Skid Testing

The Montana DOT performed skid testing on the roadway for the 2006 evaluation. This testing was performed according to ASTM E-274 with a ribbed tire. The Montana DOT performed the 2004 testing at a test speed of 50 mph but they changed their standard test speed to 40 mph for the 2006 testing. Because of this change, values from 2004 cannot be directly compared to 2006 values. All future testing will be at a standard test speed of 40 mph. The average skid number for Segment 1 was 43.3, Segment 2 was 50.1, and Segment 3 was 46.9. A summary of the skid testing can be found in Table 8 in the summary and additional information on the skid testing can be found in Appendix C.

Third Evaluation-2008

Pavement Condition

The third evaluation was conducted November 4, 2008. Segment 1 had noticeable wear in the chip seal which was installed in 2005. A majority of the wear in the chip seal is occurring in the wheel path. Materials and Research could not physically measure any rutting using a seven foot metal straight edge. Rutting was checked every half mile throughout Segment 1.

Segment 2 did not show any distresses on the PCC. The asphalt shoulders were starting to show some distress near an implement dealership. Other than the shoulder showing some distress Segment 2 had no other visible distresses.

Photo 1 – Asphalt shoulder near implement dealership at transition between Segments 2 and 3.

Segment 3 had no visible distresses and the IRI was also fairly consistent for this section. A summary of the pavement condition can be found in Table 4 in the summary.

Maintenance Costs

The NDDOT reported the maintenance costs for each mile of road up until 2005. As a result, there were no maintenance costs recorded for the 2008 evaluation. A summary of the maintenance costs can be found in Table 7 in the summary and Appendix A has more information on maintenance costs.

Roadway Profile

The roadway profile was recorded by the pathways van in 2007 and 2008.

2007 Profile:

The roadway profile was recorded by the pathways van in 2007 and 2008. From the 2007 profile, it was found that the IRI had decreased from the 2006 evaluation for all three of the segments. Segment 1 decreased from 68.7 to 67.5, Segment 2 decreased from 52.6 to 50.9, and Segment 3 decreased from 58.1 to 52.1. A summary of the profile can be found in Table 6 in the summary and Appendix B has a graph of the roadway profile.

2008 Profile:

From the 2008 profile recorded by the pathways van, it was found that the IRI decreased slightly from the 2007 data for Segment 1 and increased for Segments 2 and 3. Segment 1 decreased from 67.5 to 67.4, Segment 2 increased from 50.9 to 58.0, and Segment 3 increased from 52.6 to 64.0. A summary of the profile can be found in Table 6 in the summary and Appendix B has a graph of the roadway profile.

Skid Testing

The Montana DOT performed skid testing in 2007 according to ASTM E-274 with a ribbed tired at 40 mph as done in the 2006 evaluation. The average skid number of each section increased from the 2006 evaluation. The skid in Segment 1 increased from 43.3 to 49.8, from 50.1 to 51.6 in Segment 2, and from 46.9 to 50.3 in Segment 3. A summary of the skid testing can be found in Table 8 in the summary and additional information on the skid testing can be found in Appendix C.

Fourth Evaluation-2010

Pavement Condition

The fourth evaluation was conducted October 5, 2010. Segment 1 had noticeable wear in the chip seal which was installed in 2005. A majority of the wear in the chip seal is occurring in the wheel path. Materials and Research physically measured rutting using a seven foot metal straight edge. Rutting in the wheel path measured 1/16th to 1/8th of an inch and was checked every half mile throughout Segment 1. There were also 12 transverse cracks in Segment 1.

Photo 1: Rutting in a wheel path in the driving lane of Segment 1.

Segment 2 has a noticeable dip in the shoulders on each side of the box culvert located in this segment. It has two new transverse cracks near the transition from Segment 3 to Segment 2. The asphalt shoulders have settled approximately ½ inch throughout the section. A longitudinal crack is located 800’ east of the Wild Rice Bridge in Segment 2.

Photo 2 – Settling of the asphalt shoulders in Segment 2.

Segment 3 has one new transverse crack at station 20550+45 which was sealed. 4 small corner breaks and 3 edge line breaks have developed.

Photo 3: Distress located in Segment 3.

A summary of the pavement condition can be found in Table 4 in the summary.

Maintenance Costs

The NDDOT reported the maintenance costs for each mile of road up until 2005. As a result, there were no maintenance costs recorded for the 2010 evaluation. A summary of the maintenance costs can be found in Table 7 in the summary and Appendix A has more information on maintenance costs.

Roadway Profile

From the 2010 profile recorded by the pathways van, it was found that the IRI increased from the 2008 data for Segment 1 and decreased for Segments 2 and 3. Segment 1 increased from 67.4 to 70.7, Segment 2 decreased from 58.0 to 55.8, and Segment 3 decreased from 64.0 to 61.1. A summary of the profile can be found in Table 6 in the summary and Appendix B has a graph of the roadway profile.

Skid Testing

There was no skid testing performed for the 2010 evaluation. A summary of the skid testing can be found in Table 8 in the summary and additional information on the skid testing can be found in Appendix C.

Fifth Evaluation-2012

Pavement Condition

The fifth evaluation was conducted January 9, 2013. Segment 1 had noticeable wear in the chip seal which was installed in 2005. A majority of the wear in the chip seal is occurring in the wheel paths in both the driving lane and passing lane. Materials and Research physically measured rutting using a six foot metal straight edge every half mile throughout Segment 1. Rutting was observed in the driving lane, and there was a difference in the rutting from the right wheel path to the left wheel path. The rutting in the right wheel path ranged from 1/8th to 1/4th of an inch and the rutting in the left wheel path ranged from zero to 1/8th of an inch. Similar to the 2010 evaluation, there were also 12 transverse cracks observed in Segment 1.

Photo 1: Rutting in a right wheel path in the driving lane of Segment 1.

Segment 2 has a noticeable dip in the shoulders on each side of the box culvert located in this segment as in the 2010 evaluation. It has two transverse cracks near the transition from Segment 3 to Segment 2 as in 2010. The asphalt shoulders have settled approximately ½ inch throughout the section. One new longitudinal crack was observed about 900' east of the Wild Rice Bridge, along with the longitudinal crack observed in the 2010 evaluation. There was also one new transverse crack located near the east end of the Wild Rice Bridge in Segment 2. There was a HBP turning lane approximately at RP 386.6 that had settled about 3/4th of an inch below the PCC roadway, see photos 2 and 3.

Photo 2 – Settling of the asphalt shoulders in Segment 2

Photo 3 – Settling of the asphalt turning lane in Segment 2

Segment 3 had the one sealed transverse crack as observed in 2010. There were also 5 edge line breaks and 5 small corner breaks observed throughout the section. At a turning lane located approximately at RP 388.4 it was observed that there is a new unsealed longitudinal crack spanning approximately 300' over the 330' turn lane.

Photo 4 – Longitudinal crack in turning lane in Segment 3.

A summary of the pavement condition can be found in Table 4 in the summary.

Maintenance Costs

The NDDOT reported the maintenance costs for each mile of road up until 2005. As a result, there were no maintenance costs recorded for the 2012 evaluation. A summary of the maintenance costs can be found in Table 7 in the summary and Appendix A has more information on maintenance costs.

Roadway Profile

From the 2012 profile recorded by the pathways van, it was found that the IRI increased from the 2010 data for all three of the segments. Segment 1 increased from 70.7 to 72.5, Segment 2 increased from 55.8 to 57.8, and Segment 3 increased from 61.1 to 63.6. A summary of the profile can be found in Table 6 in the summary and Appendix B has a graph of the roadway profile.

Skid Testing

There was no skid testing performed for the 2012 evaluation. A summary of the skid testing can be found in Table 8 in the summary and additional information on the skid testing can be found in Appendix C.

Summary

Pavement Condition

All three segments of the completed roadway are showing some distresses since construction. Segment 1 has noticeable wear in the chip seal which was installed in 2005. A majority of the wear in the chip seal is occurring in the wheel paths in both the driving lane and passing lane. It was observed in 2010 that there were 12 sealed transverse cracks in the segment and this was also observed in the 2012 evaluation. No rutting was observed in the segment until the 2012 evaluation. The rutting occurring was in the driving lane and was different from the right wheel path to the left wheel path. The rutting in the right wheel path ranges from 1/8th to 1/4th of an inch and the rutting in the left wheel path ranges from zero to 1/8th of an inch.

Segment 2 has a noticeable dip in the shoulders on each side of the box culvert located in this segment which was the same as the 2010 evaluation. It has two transverse cracks near the transition from Segment 3 to Segment 2 as observed in 2010 and one new transverse crack located right before Wild Rice Bridge. The asphalt shoulders have settled approximately ½ inch throughout the section which was the same as the 2010 evaluation. One sealed longitudinal crack is located 800' east of the Wild Rice Bridge as observed in 2010 and one new sealed longitudinal crack is located 900' east of the Wild Rice Bridge. It was also observed in the 2012 evaluation that there is a turning lane approximately at RP 386.6 that had settled about 3/4th of an inch below the roadway.

In Segment 3 there is one sealed transverse crack as observed in 2010. It was observed in 2012 that there are 5 edge line breaks and 5 small corner breaks in segment 3, compared to 4 corner breaks and 3 edge line breaks in 2010. The 2012 review noted there was a new unsealed longitudinal crack spanning approximately 300' feet of the 330' turning lane located at approximately RP 388.4.

The table below is a summary of the distresses observed for the different segments of roadway over the course of the evaluation periods:

Section	2004	2006	2008	2010	2012
1 (HBP)	Transverse=N/A Longitudinal=N/A Other=N/A	Transverse=N/A Longitudinal=N/A Other=N/A	Transverse=N/A Longitudinal=N/A Other=N/A	Transverse=12 Longitudinal=N/A Other=N/A	Transverse=12 Longitudinal=N/A Other=N/A
2 (PCC/HBP shoulders)	Transverse=N/A Longitudinal=N/A Other=N/A	Transverse=N/A Longitudinal=N/A Other=N/A	Transverse=N/A Longitudinal=N/A Other=N/A	Transverse=2 Longitudinal= 1 Other=N/A	Transverse=3 Longitudinal=2 Other=N/A
3 (PCC/PCC shoulders)	Transverse=N/A Longitudinal=N/A Other=N/A	Transverse=N/A Longitudinal=N/A Other=N/A	Transverse=N/A Longitudinal=N/A Other=N/A	Transverse=1 Longitudinal=N/A Other=7	Transverse=1 Longitudinal=1 Other=10

Table 4, Distress Summary

Updated traffic data was collected from 2004, 2007 and 2010 and is shown below in Table 5 for each test segment:

	2000		2004		2007		2010	
Segment	**Flex. ESALs**	**Rigid ESALs**	**Flex. ESALs**	**Rigid ESALs**	**Flex. ESALs**	**Rigid ESALs**	**Flex. ESALs**	**Rigid ESALs**
1	475	800	405	680	320	530	325	545
2	475	800	360	600	320	530	325	545
3	475	800	295	490	270	455	-	-

Table 5, Traffic Data

The factors used to calculate the flexible and rigid ESALs from the number of vehicles are lower than those used for 2000 traffic. As a result, the updated traffic for 2004, 2007, and 2010 has fewer ESALs than the 2000 traffic.

Roadway Profile

The NDDOT Pathways Van collects data on this roadway annually. For most years the average IRI and distress scores are shown below in Table 6. The IRI graph for the 2012 data is included in Appendix B Chart 1.

	Segment 1						
	2002	**2004**	**2006**	**2007**	**2008**	**2010**	**2012**
IRI	39.3	63.1	68.7	67.5	67.4	70.7	72.5
Distress Score	99	99	96	97	95	97	-
	Segment 2						
	2002	**2004**	**2006**	**2007**	**2008**	**2010**	**2012**
IRI	42.1	53.1	52.6	50.9	58	55.8	57.8
Distress Score	99	99	98	98	98	97	-
	Segment 3						
	2002	**2004**	**2006**	**2007**	**2008**	**2010**	**2012**
IRI	44.5	55.1	58.1	52.6	64	61.1	63.6
Distress Score	99	99	98	98	98	97	-

Table 6: Distress and IRI averages for each test segment.

The “Pathways Van” data shows that there has been loss of ride quality from initial construction. The HBP Segment 1 has the highest IRI followed by the concrete in Segment 3 and the best ride quality is the concrete in Segment 2. The decrease in the IRI could be attributed to deviation from the previous path in the driving lane while profiling or conditions of the roadway varied from year to year. There has been little change in the IRI in the concrete Segments 2 and 3 since 2008 but the IRI in the asphalt section in Segment 1 continues to increase.

Maintenance Costs

The NDDOT reported the maintenance costs for each mile of road that it maintained until 2005. These mile long sections begin and end at reference points. Because the limits of all of the test segments are between reference points, the segments of maintenance cost data either overlap two test segments or are partially outside the project limits. Appendix A, Chart 1 shows the total maintenance costs per mile for 2003 and 2004.

Maintenance costs that were in two test segments (or were partially outside the project limits) were divided between the two segments based on where the split occurred. For example, 49.2% of the maintenance costs for Mile 384 were attributed to Segment 1 and 50.8% were attributed to Segment 2. The cost of the 2005 chip seal project was also included. The total costs per segment were totaled and then divided by the segment length for the estimated average. Table 7 shows the estimated average maintenance costs per mile.

Maintenance Costs per mile for each Segment

	Segment 1*	Segment 2*	Segment 3
Maintenance Costs/Mile	$19,921.10*	$6,666.02*	$534.47

Table 7, Maintenance Costs per Mile

* Cost of Chip seal is included.

With the cost of the chip seal, the HBP Segment 1 has the highest maintenance costs and the PCC section with HBP shoulders has the next highest. HBP had the lowest cost of initial construction and PCC pavement with HBP shoulders had the next lowest initial cost. PCC pavement with PCC shoulders had the highest initial cost.

Skid Testing

The Montana DOT performed skid testing in 2004, 2006 and 2007. This testing was performed according to ASTM E-274 with a ribbed tire. The Montana DOT performed the 2004 testing at a test speed of 50 mph but they changed their standard test speed to 40 mph for the 2006 and 2007 testing. Because of this change, values from 2004 cannot be directly compared to 2006 or 2007 values. The average skid number of each section is shown below and the individual readings are shown in Appendix C, Chart 3.

Section	2004	2006	2007
	Average	Average	Average
1 (HBP)	46.5	43.3	49.8
2 (PCC/HBP shoulders)	43.1	50.1	51.6
3 (PCC/PCC shoulders)	37.9	46.9	50.3

Table 8, Skid Testing Results

From the results shown above, the skid resistance has decreased as time has passed. This could be attributed to common wear on the pavement surface and changes in roadway conditions.

Results from this ongoing study indicate:

- The pavement condition is continuing to deteriorate over time. Distresses in the roadway for all three segments have increased since construction. The IRI of the roadway has also increased since construction for all three segments.
- With the cost of the chip seal, the HBP Segment 1 has the highest maintenance costs and the PCC section with HBP shoulders has the next highest. The HBP has the lowest initial cost and PCC pavement with HBP shoulders has the next lowest initial cost. PCC pavement with PCC shoulders has the highest initial cost.
- Skid testing of the roadway surface show that the skid resistance has decreased overtime.

An evaluation will be conducted in 2014 to continue to monitor the performance of the three segments.

Appendix A: Maintenance Costs

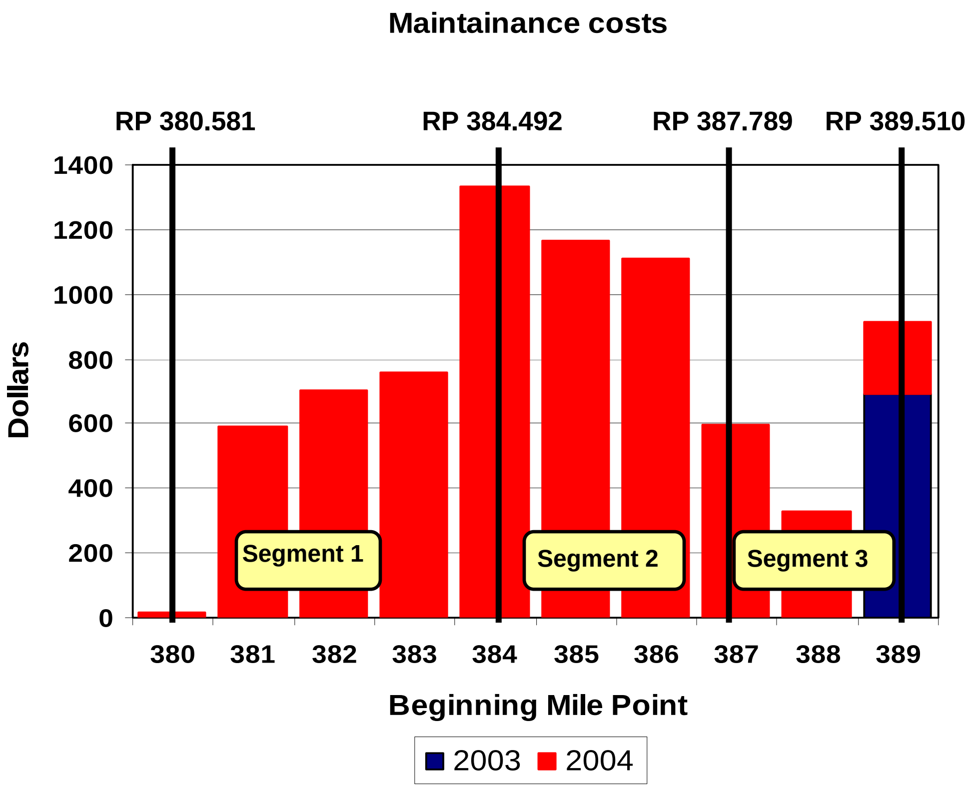

Chart 1, Maintenance Costs

*** Cost of Chip seal not included in chart 1**

Maintenance Costs per mile for each Segment

	Segment 1	Segment 2	Segment 3
Maintenance Costs/Mile	$19,921.10*	$6,666.02*	$534.47

* Cost of Chip seal is included.

Table 9, Maintenance Costs

Appendix B: Pathways Van IRI Graph

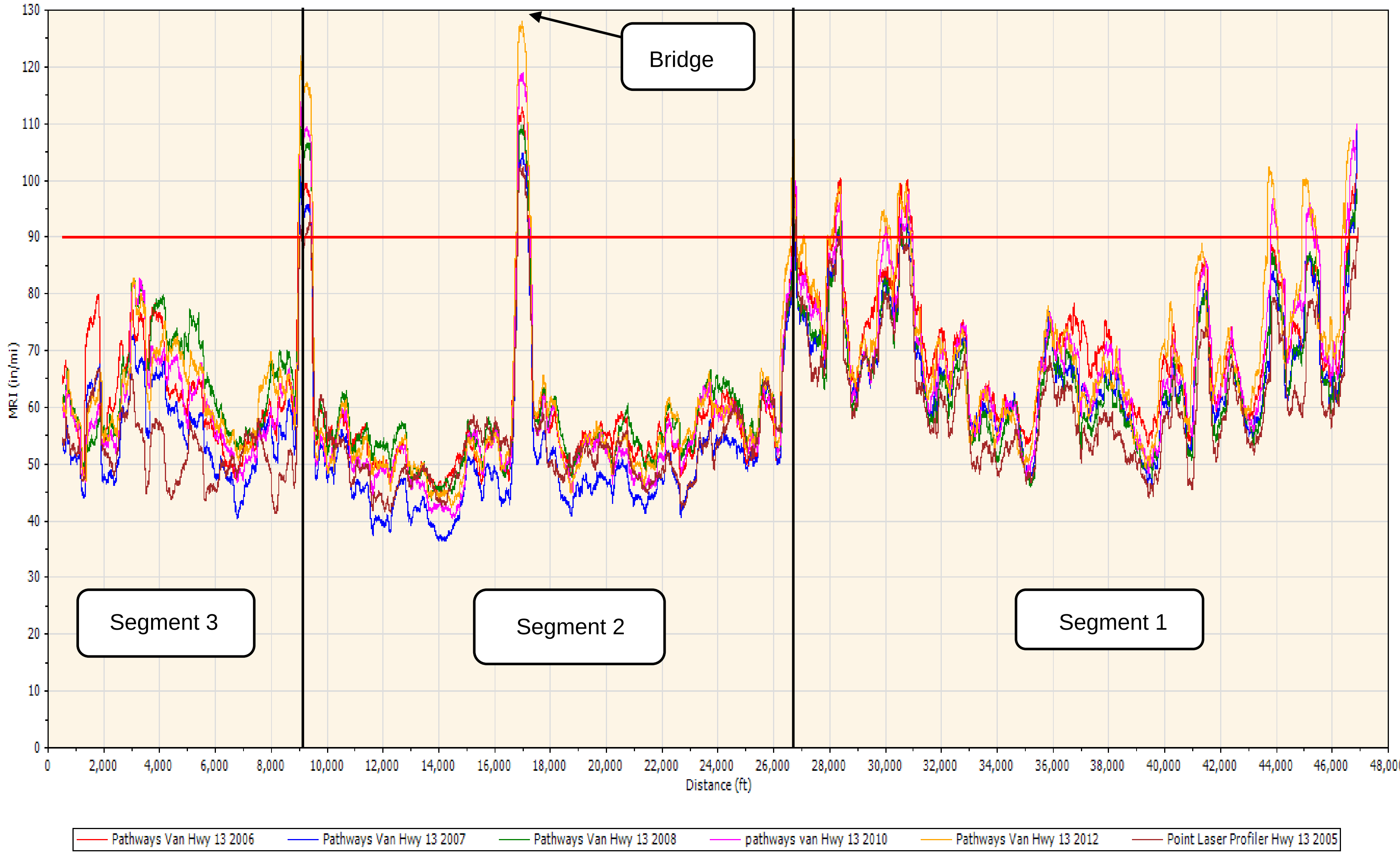

Chart 2, Graph of Profile Data

Appendix C: Skid Testing Results

Average Skid Testing Results for each Segment

Section	2004	2006	2007
	Average	Average	Average
1 (HBP)	46.5	43.3	49.8
2 (PCC/HBP shoulders)	43.1	50.1	51.6
3 (PCC/PCC Shoulders)	37.9	46.9	50.3

Table 10, Skid Testing Results

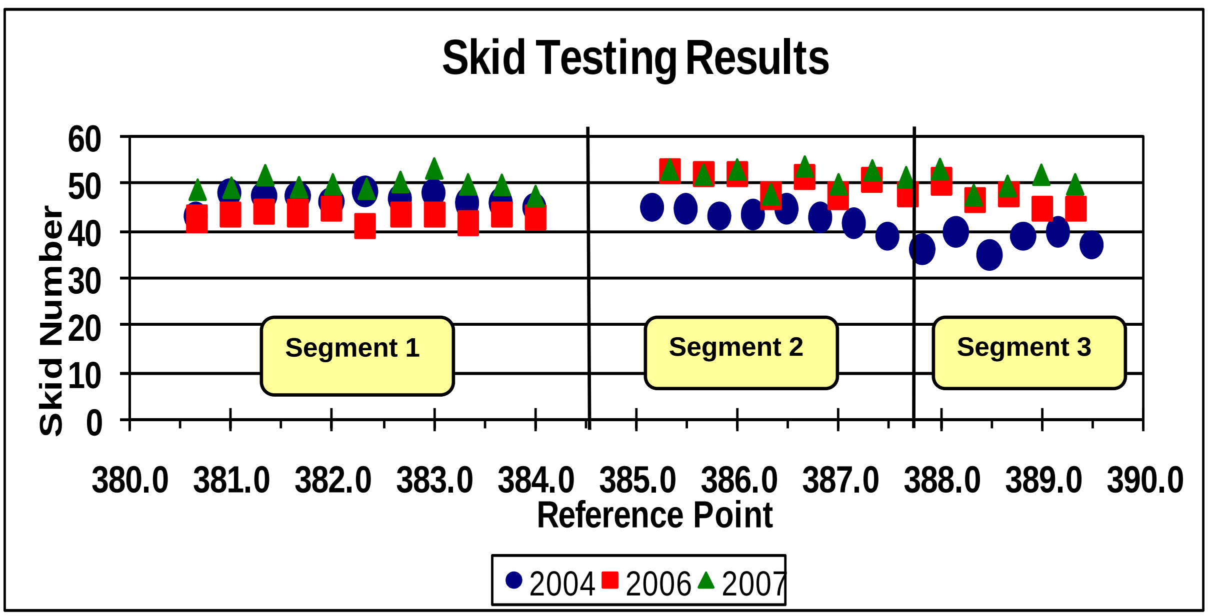

Chart 3, Skid Testing Results

Appendix D: Geotextile Fabric Specifications

Geotextile Fabric Specifications

		Geotextile Fabric Type	
		Separation[(2)]	Reinforcement
Geotextile Property	Test Method	S2	R1
Grab Tensile Strength[1)], lbs., min.	ASTM D-4632	180	N/A
Grab Tensile Strength(1), lbs./in., min., Wide Width Method	ASTM D-4595	N/A	270
Grab Tensile Elongation, % max.	ASTM D-4595	N/A	15
Trapezoid Tear Strength lbs., min. (any direction)	ASTM D-4533	N/A	100
Puncture Strength lbs., min.	ASTM D-4833	N/A	100
AOS less than mm, (greater than US STD. Sieve)	ASTM D-4751	.125-0.425 (40-120)	0.600 (30)
Permittivity, sec.$^{-1}$, min.	ASTM D-4491	0.7	0.05
Ultraviolet Degradation % min. @ 150 Hrs., min.	ASTM D-4355	70	70
Sewn-Seam Strength, lbs.	ASTM D-4632	160	N/A
Sewn-Seam Strength, lbs./in.	ASTM D-4884	N/A	240

(All values represent minimum roll values. Test results from any sample shall meet or exceed the minimum values listed.)

(1) Weakest principal direction.
(2) Separation Fabrics shall be nonwoven.