Manitoba and Minnesota SPS-5 Projects
15-Year Ranking of Treatments

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Abstract

Under the auspices of the Long Term Pavement Performance (LTPP) program eight SPS-5 overlay sections were constructed in Manitoba in 1989 and Minnesota in 1990. In addition to a control section the variables included mix design (virgin or recycled materials), overlay thickness (50 or 125 mm), and type of surface preparation (minimum or extensive). Over the past 15 years these sites have been monitored to evaluate and compare the pavement performance.

The pre-rehabilitation condition record of the Manitoba test site was that it was rough with fatigue and block cracking evident. The predominant distress of the pre-rehabilitation condition of the Minnesota site was recorded as severe depressed transverse cracks. As much of the original amount of cracking has reflected through the applied bituminous overlays, none of the design options have outperformed the others in preventing or reducing the severity of reflective cracking.

This paper concludes that the SPS-5 study has demonstrated that given pavements in the original condition of these two test sites, the use of the more expensive options of milling, thicker overlays, and virgin bituminous material have not resulted in significant pavement performance gains. Thus the lowest cost design alternatives (minimal surface preparation, thin overlay, and RAP in HMA mixture) would be chosen as the most cost-effective overlay design options.

Key Words: Asphalt Overlay, Milling, Reflective Cracking, RAP

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Introduction & Background

The US Strategic Highway Research Program (SHRP) Long-Term Pavement Performance (LTPP) program began the Specific Pavement Study (SPS-5) "Rehabilitation Techniques for Hot Mix Asphalt Pavements" experiment with the 1989 construction of the Brokenhead River test site in Manitoba. The following year the Minnesota Department of Transportation (Mn/DOT) constructed another SPS-5 site on US 2 west of Bemidji. These two sites are situated approximately 300 km apart.

Each location contained nine 500-foot test sections, with the Minnesota site containing an additional three sections with experimental variables of interest. The SPS-5 experiment uses the following variables for its eight core test sections in addition to a control section:

- Use of virgin and recycled hot mix asphalt overlay materials
- Overlay thickness of 50 mm (2 in) and 125 mm (5 in)
- Type of surface preparation (minimum and extensive); minimum preparation includes crack filling and overlay, while extensive preparation includes milling and crack repair before overlay

Table 1 shows a list of the study variables for each section along with the shorthand descriptions used to identify them under the present study. Figures 1 and 2 show a layout of the Minnesota and Manitoba test sections, respectively.

For full details on the materials and construction of the test sections the reader is asked to reference a previously completed report (1) that can be accessed at http://www.mrr.dot.state.mn.us/research/MnROAD_Project/MnRoadReports/MnRoadOnlineReports/2000-31.pdf or a published paper by Watson et al (2).

Both Minnesota and Manitoba transportation agencies have cooperatively shared data and analysis efforts to evaluate and compare the performance of the two sites. The Bemidji site has now been scheduled for rehabilitation in 2006; therefore a final review of the performance of both of the sites is herein undertaken. This paper is intended to focus on the 15-year performance summary.

Table 1. SPS-5 Test Section Identification

LTPP ID	Surface Preparation	Asphalt Mix Type	Overlay Thickness (mm)
1 (C)	None – Control Section		
2 (U50R)	None	Recycled	50
3 (U125R)	None	Recycled	125
4 (U125V)	None	Virgin	125
5 (U50V)	None	Virgin	50
6 (M50V)	Milled	Virgin	50
7 (M125V)	Milled	Virgin	125
8 (M125R)	Milled	Recycled	125
9 (M50R)	Milled	Recycled	50
559 – MN	Tight Blade	Virgin Mn/DOT	65
560 – MN	Mill Transverse Cracks	Virgin Mn/DOT	65
561 – MN	Tight Blade	Virgin SHRP	38

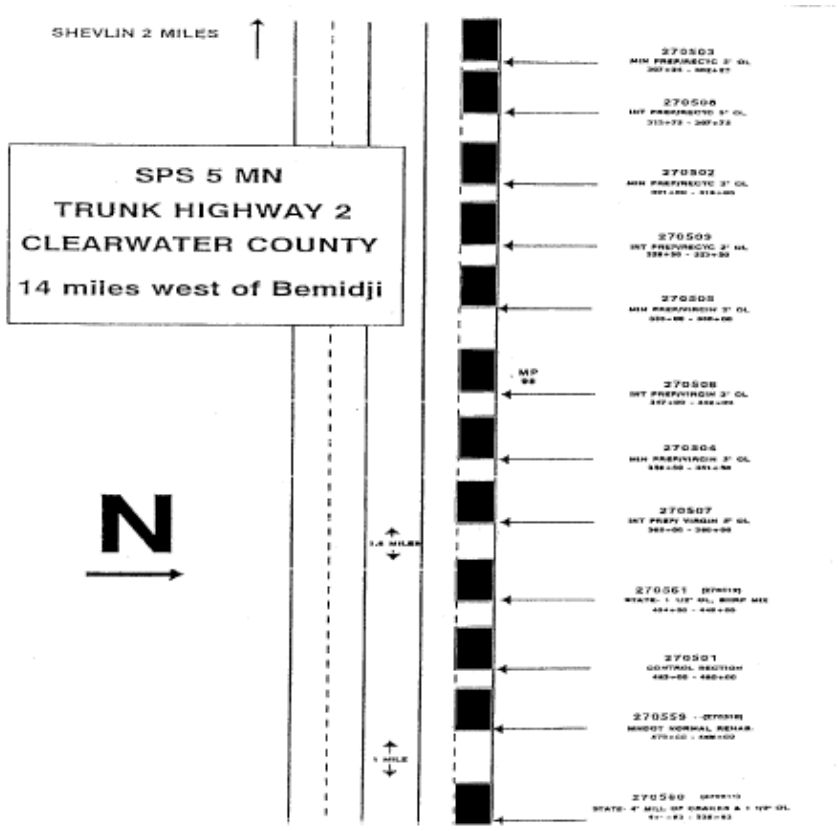

Figure 1. Minnesota SPS-5 Test Section Layout

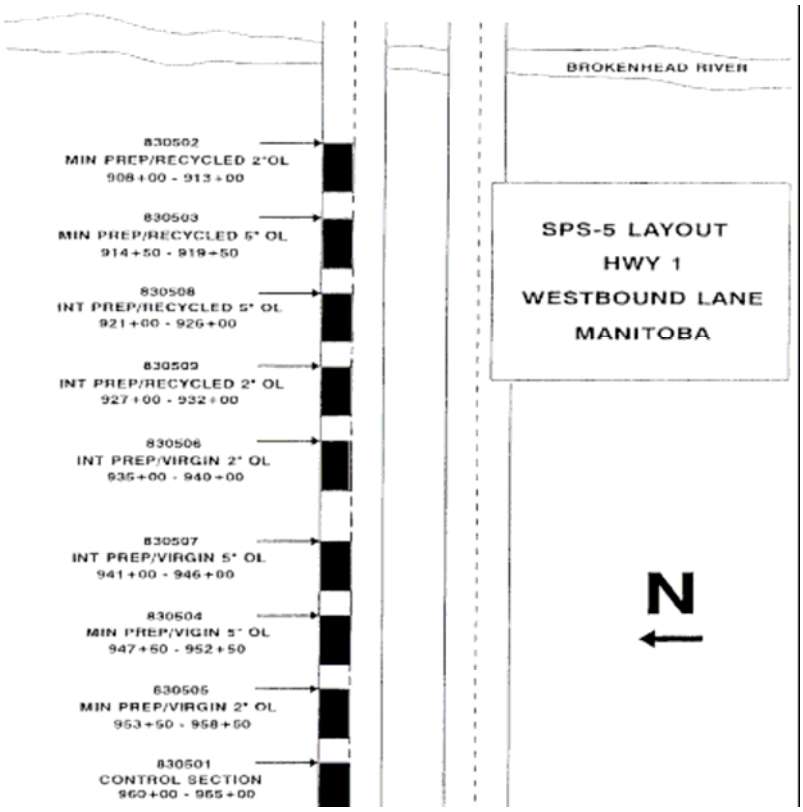

Figure 2. Manitoba SPS-5 Test Section Layout

Test Section Pavement Performance

A visual survey of both test sites by the authors occurred on September 14-15, 2005. For the Brokenhead River test site, it was noted that the surface rideability was quite smooth. A great deal of fatigue and block cracking was observed. Several sections displayed ruts from dual tires in the wheelpaths. The Bemidji test site had little fatigue cracking or rutting evident, but the transverse cracks were depressed causing excessive roughness over the cracks resulting in poor ride.

The data in the following sections was obtained from the LTPP online database (3). Data is available through 2004 for each section.

Roughness

Table 2 shows a summary of the ride quality of the test sections in 2004. The roughness or rideability of the test sections is quantified using the International Roughness Index. The IRI is calculated from a summary of the longitudinal profile that is measured annually for the test sections by LTPP using a non-contact profilometer. The IRI is then used to calculate a Present Serviceability Rating (PSR) used by Mn/DOT. It is interesting to note that for 50-mm overlays the Manitoba site was rougher than its counterpart in Minnesota, and that for 125-mm overlays the Minnesota site was rougher than its counterpart in Manitoba.

Table 2. 2004 IRI and PSR Measurements

	Minnesota		Manitoba	
Section	**IRI (m/km)**	**PSR**	**IRI (m/km)**	**PSR**
1 (C)	3.26	1.90		
2 (U50R)	1.54	3.08	2.17	2.60
3 (U125R)	1.89	2.80	1.39	3.22
4 (U125V)	1.84	2.85	1.54	3.08
5 (U50V)	1.58	3.05	2.35	2.47
6 (M50V)	1.52	3.11	2.35	2.47
7 (M125V)	1.40	3.20	1.16	3.43
8 (M125R)	1.48	3.14	1.12	3.47
9 (M50R)	1.58	3.05	1.86	2.83

Figure 3 shows a typical plot of the roughness progression over time (Section U125R is shown). For each of the sections monitored, the roughness values remained fairly constant until 1994. Two years of data are missing, and then the IRI began to increase rapidly starting in 1997. The Minnesota sections show an initial decrease in IRI after rehabilitation and an apparent surface

treatment in 2000. The IRI for each section continues to increase to this day. The 125-mm overlays were applied in one more lift than the 50-mm overlays, resulting in significantly lower roughness values. The milled sections have lower roughness than the minimal surface preparation sections. Similar virgin and recycled mixtures had similar roughness values.

The control section shows the worst ride by far, with IRI values approaching 3.5 m/km. There is very little difference in IRI values across the 8 treatment sections in Minnesota, ranging from 1.4 to 1.9 (a larger range was seen in the Manitoba sections). The roughness on the Bemidji site is largely attributed to the cupped transverse cracks, which will be addressed in a later section.

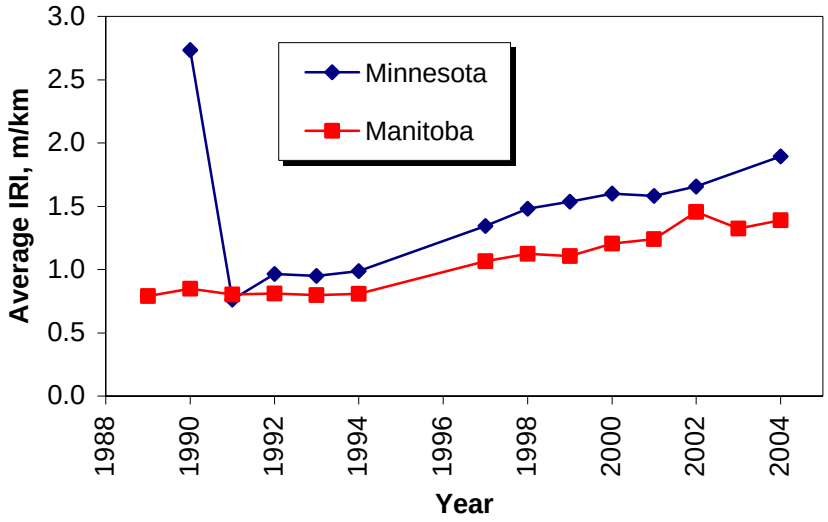

Figure 3. Typical Roughness Progression (Section U125R)

The Mn/DOT district in which the SPS-5 sites are located uses a structural rating (SR) threshold of 2.8 to program their projects. Mn/DOT has counted cracks since the beginning of the project and has perceived a range of years for when the sections reached the SR threshold (see Table 3). For many years Section M125R showed the highest pavement performance until it recently dropped to the target value.

Table 3. SR Data from Minnesota Sites

Section	Years to Reach SR = 2.8
1 (C)	Unknown
2 (U50R)	10
3 (U125R)	14
4 (U125V)	10
5 (U50V)	7
6 (M50V)	8
7 (M125V)	Has not reached 2.8
8 (M125R)	15
9 (M50R)	13
559	14
560	Unknown
561	Unknown

Rutting

Transverse profiles have been measured annually on the test sections by the LTPP raters using dipstick equipment. Figure 4 shows the measured rut depths for each section in 2004. Besides the control section, all of the Minnesota test sections have rut depths of less than 3 mm (1/8 in). The Manitoba sections have rut depths ranging from 5 to 10 mm (1/2 to 3/8 in). The rut depths on the Manitoba sections have progressed steadily over time to their current values. In Manitoba the sections with milled surfaces have shown greater rut depths than those with minimal surface preparation. In 3 of 4 cases the sections containing virgin materials rutted more than those with RAP, which indicates that the stiffer binder in the RAP increases the rutting resistance of the mix. The results are not conclusive in terms of whether or not thickness affects the rut resistance of the pavement.

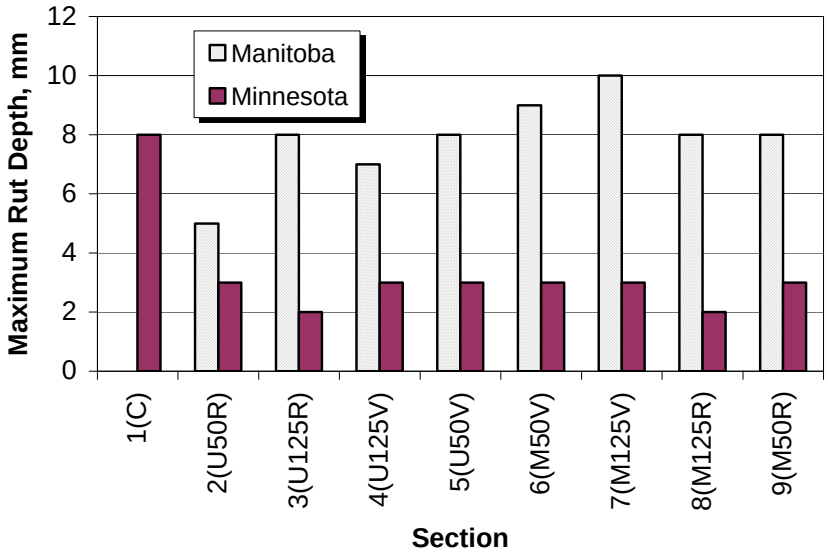

Figure 4. 2004 Rut Depth Measurements

Transverse Cracking

Figure 5 shows the total length of transverse cracks (all severities) for each test section. The Minnesota sections show much less variation in total crack length than the Manitoba sections. For both sites the control section showed the least amount of transverse cracking. In general the thicker overlays had more cracking than the thinner overlays, and the milled sections had more cracks than those with minimal surface preparation. For the Minnesota sections, in 3 of 4 cases the virgin mixes had less cracking than the recycled mixes, even though the virgin mixes used a stiffer asphalt binder.

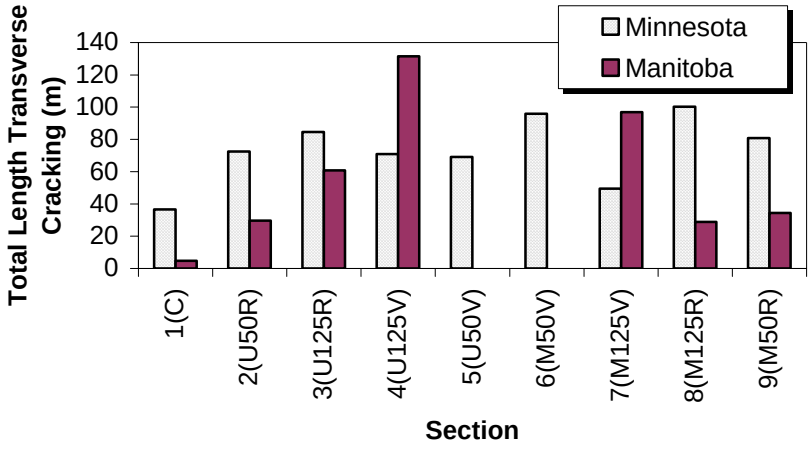

Figure 5. 2004 Total Transverse Crack Length Comparison

Longitudinal Cracking

Figure 6 shows the total length of longitudinal cracking (all severity levels) in each section. Again there was more variability in the Manitoba sections than in the Minnesota sections. The amount of surface preparation prior to the overlay had little effect on the length of longitudinal cracking. In Minnesota the virgin mixes showed more cracking than the recycled mixes, while the Manitoba sections showed mixed results. In Manitoba the thicker overlays had more cracking than the thinner overlays, while the Minnesota sections showed mixed results.

Fatigue/Block Cracking

Figure 7 shows the total area (all severity levels) of both fatigue and block cracking for the Manitoba sections. As expected, the 50-mm overlays showed much more fatigue and block cracking than the 125-mm overlays. The amount of surface preparation prior to the overlay made little difference in the amount of cracking. The recycled mixes showed more fatigue cracking than the virgin mixes, while the mix type had mixed effects on block cracking. No fatigue or block cracking was present on the Minnesota sections, which is likely due to the combination of a thicker original pavement structure and fewer traffic loadings.

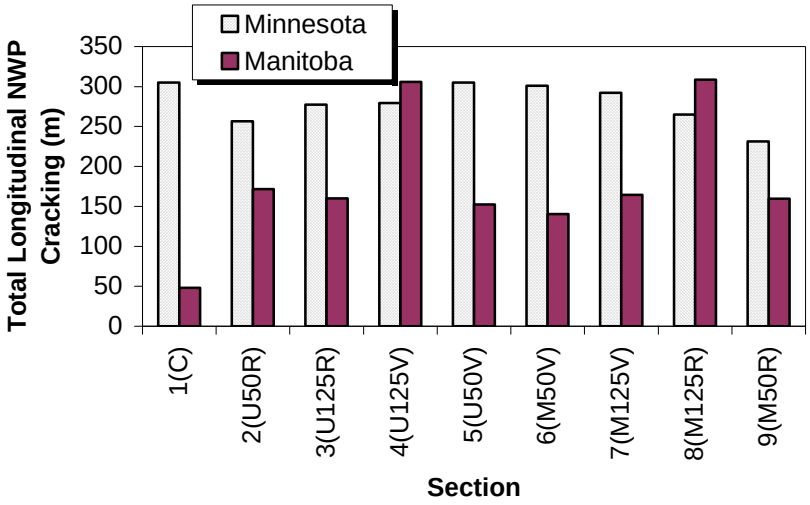

Figure 6. 2004 Total Longitudinal Crack Length Comparison

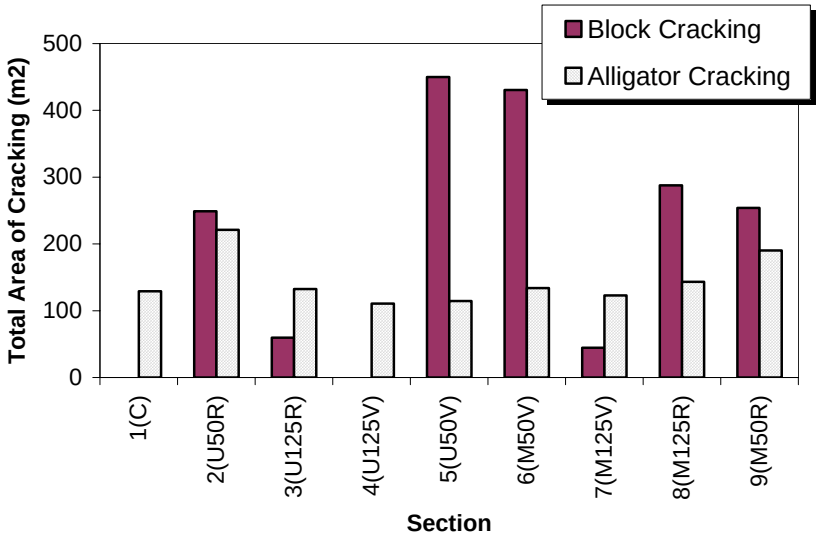

Figure 7. 2004 Fatigue and Block Cracking in Manitoba

Summary and Conclusions

The pre-rehabilitation (1989) condition record of the Brokenhead River test site was that it was rough with fatigue and block cracking evident. As much of the original amount of cracking has reflected through the applied bituminous overlays, none of the design options have outperformed the others in preventing reflective cracking. Therefore the least-cost, most simple alternative is the logical choice for the most cost-effective asphalt overlay design option.

The predominant distress of the pre-rehabilitation (1989) condition of the Bemidji site was recorded as severe depressed transverse cracks. The severity of these depressed transverse cracks has triggered the rehabilitation set to occur in 2006. Similar to the Manitoba SPS-5, none of the design options have significantly outperformed the others in terms of preventing or reducing the severity of the depressed transverse cracks. Therefore the lowest cost asphalt overlay design option would be the most cost-effective on this site as well.

For a time, the level of service on some overlay sections was higher than others, which does provide some benefit to the agency as well as the driving public. However, this performance gap has closed over 15 years to where the pavement sections are more or less performing equally.

The relative performance of each of the design options may also be compared to its counterpart on the other site. This comparison must take into account that the pavement structure is much thinner on the Brokenhead River test site, even though it has had approximately 3 times the number of ESALs compared to the Bemidji site.

The asphalt mix designs and design thicknesses used on both test sites were successful in limiting high severity rutting and roughness from occurring.

This research concludes that the SPS-5 study has demonstrated that given pavements in the original condition of these two test sites, the use of the more expensive options of milling, thicker overlays, and virgin bituminous material have not resulted in significant pavement performance gains. Thus the lowest cost design alternatives would be chosen as the most cost-effective overlay design options.

References

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