20-year Performance of SPS-2 Sections in North Dakota and Wisconsin

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Abstract

The Long Term Pavement Performance (LTPP) Specific Pavement Studies (SPS-2) experiment was designed to study the structural factors, such as drainage, base type, concrete strength, slab thickness, and lane width for rigid pavements. The SPS-2 experiment sections in North Dakota and Wisconsin, constructed in 1994, are jointed, dowelled plain concrete pavement. SPS-2 sections in North Dakota and Wisconsin are considered as sister sections since they were built in the same year. The experiment consisted of six and eight supplemental sections in North Dakota and Wisconsin, respectively in addition to 12 standard SPS-2 sections. These sections have been monitored by the LTPP program since construction. Performance monitoring included measurements for ride quality (International Roughness Index, IRI), faulting, cracking, and load transfer efficiency based on surface deflections. The main objective of the study is to compare 20-year performance of SPS-2 sections in North Dakota and Wisconsin. Performance parameters analyzed in this study included IRI, faulting, load transfer efficiency, cracking, spalling, scaling, and pumping. The results show that the sections have performed well to date. Most of the sections are smooth, crack free, and have negligible faulting. Thinner sections (203 mm) over dense graded aggregate base and lean concrete base are the smoothest in North Dakota and Wisconsin, respectively. Thinner sections (203 mm) over lean concrete base and permeable asphalt treated base are the roughest in North Dakota and Wisconsin, respectively. The effect of base type on the smoothness of thicker sections is not clear. Thinner sections (203 mm) are smoother than thicker sections for the same base type in general except a Wisconsin section with thicker slab (279 mm) and a higher flexural strength (6.2 MPa) over permeable asphalt treated base.

Introduction

The Strategic Highway Research Program (SHRP) was initiated in 1987 in order to improve performance of highway pavements and bridges. As part of this national research effort, the Long Term Pavement Performance (LTPP) program was aimed at determining the effects of various designs, environmental, and material performance through monitoring a large number of in-service pavement sections (Khanum et al. 2008). The Specific Pavement Studies 2 (SPS-2) project, titled Strategic Study of Structural Factors for Jointed Plain Concrete Pavements, was designed as a controlled field experiment that focuses on the study of specific design features (structural factors) for doweled jointed plain concrete pavements (SHRP 1990). The experimental design was aimed at determining the effects of the following specific pavement design features: (1) In-pavement drainage system, (2) Base type, (3) Concrete strength, (4) Pavement thickness, and (5) Lane width. The effects of site conditions (e.g., subgrade soil, traffic, climate, and their interactions) were also considered. The SPS-2 experimental plans were originally designed to incorporate project sites in all four LTPP climatic regions (dry freeze, wet freeze, dry no-freeze, wet no-freeze) and on both fine-grained and coarse-grained subgrades. This requirement made it possible to cover a large

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inference space of the continental United States. A major effort was made by SHRP, State highway agencies (SHAs), and the Federal Highway Administration (FHWA) to identify appropriate SPS-2 sites and to construct all the sections according to their original experimental design (Jiang and Darter 2005).

The SPS-2 projects were constructed between 1992 and 1997 (with one site completed in 2000) *(Jiang and Darter 2005)*. This study is based on SPS-2 sections that were built in 1994 in North Dakota and Wisconsin. SPS-2 sections in North Dakota and Wisconsin were designed for dry-freeze and wet-freeze, respectively. A wide range of specific data was collected during construction. Extensive field monitoring data (traffic, profile, cracking) have been collected from these sections over time *(Jiang and Darter 2005).*

Objectives. The main objectives of the study were to determine the effect of base type and slab thickness on the performance of SPS-2 sections in North Dakota and Wisconsin. The performances include: roughness in terms of international roughness index (IRI), faulting, load transfer efficiency, longitudinal and transverse cracking, durability cracking, longitudinal and transverse spalling, scaling, and pumping.

Test Sections

Table 1 shows the test sections that were considered in this study. Three types of bases, dense graded aggregate base (DGAB), lean concrete base (LCB), and permeable asphalt treated base (PATB), were considered. Two different slab thicknesses, 203 mm and 279 mm, were considered. The flexural strengths of concrete slabs were 3.8 MPa and 6.2 MPa. Two lane widths were also considered: 3.66 m (standard lane width) and 4.27 m (wider lane width). SPS-2 sections in North Dakota are located on eastbound Interstate 94 (I-94) near Casselton, North Dakota. The Wisconsin SPS-2 project site is located on the westbound and eastbound lanes of Wisconsin State Highway 29 (STH-29), a rural arterial road, in Marathon County, Wisconsin *(Jiang and Darter 2005).*

Table 1. Test Sections

Section ID	Base Type	Slab Thickness (mm)	Flexural Strength (MPa)	Lane Width (m)
213	DGAB	203	3.8	4.27
214		203	6.2	3.66
215		279	3.8	3.66
216		279	6.2	4.27
217	LCB	203	3.8	4.27
218		203	6.2	3.66
219		279	3.8	3.66
220		279	6.2	4.27
221	PATB	203	3.8	4.27
222		203	6.2	3.66
223		279	3.8	3.66
224		279	6.2	4.27

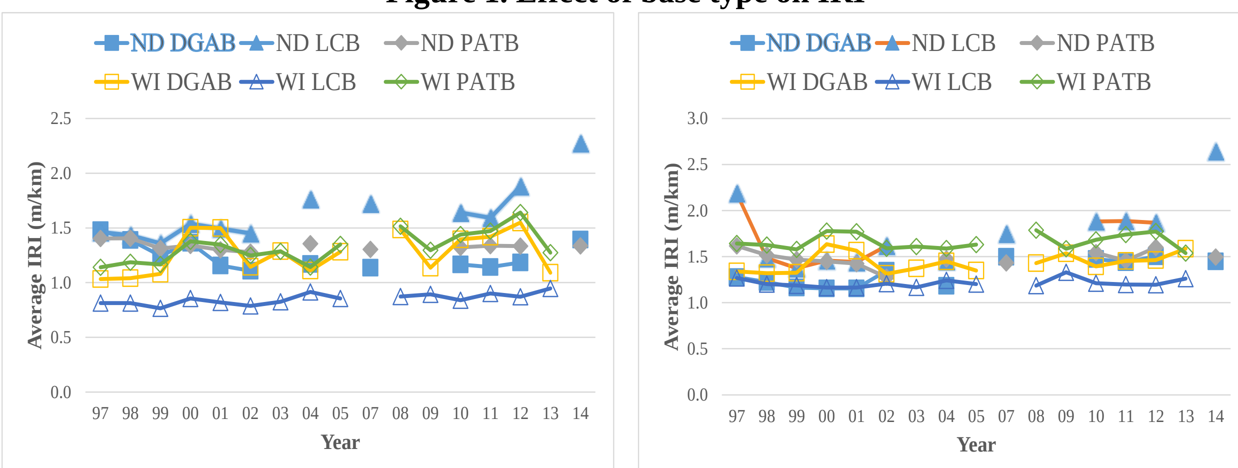
Data Collection

20-year, 1994-2014, data were considered in this study. Roughness in terms of international roughness index (IRI), faulting, deflection, cracking, spalling, scaling, pumping, traffic, and climate data were obtained from LTPP. Data were averaged over a year period. Deflection data was used to determine load transfer efficiency (LTE).

Results and Discussions

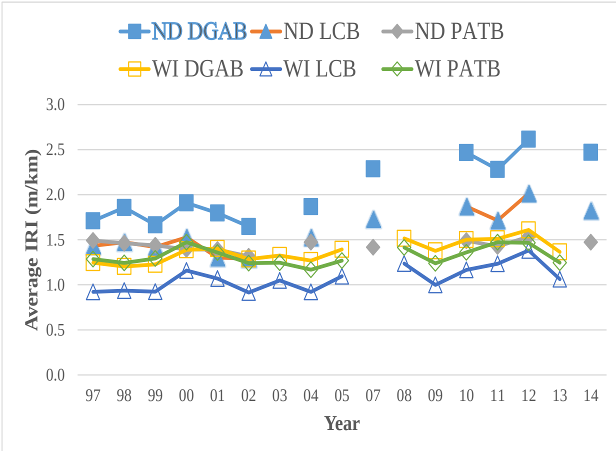
Effect of Base Type on IRI. Concrete sections with LCB are the smoothest and roughest in Wisconsin and North Dakota, respectively for slab thickness of 203 mm, lane width of 4.27 m, and concrete flexural strength of 3.8 MPa as shown in Figure 1(a). International Roughness Index (IRI) varies significantly for sections with DGAB in North Dakota and PATB in Wisconsin. A section with LCB in North Dakota is the roughest at the beginning and end whereas a section with LCB in Wisconsin is the smoothest consistently as shown in Figure 1(b) for 279 mm slab thickness, 3.8 MPa flexural strength, and 3.66 m lane width. A section with LCB base in Wisconsin and DGAB base in North Dakota are the smoothest for a thicker slab thickness (279 mm), narrower lane width (3.66 mm), and lower flexural strength (3.8 MPa) as shown in Figure 1(c). Sections with PATB (279 mm slab thickness, 4. 27 m lane width, and 6.2 MPa flexural strength) are the smoothest and roughest in Wisconsin and North Dakota, respectively as shown in Figure 1(d).

Figure 1. Effect of base type on IRI

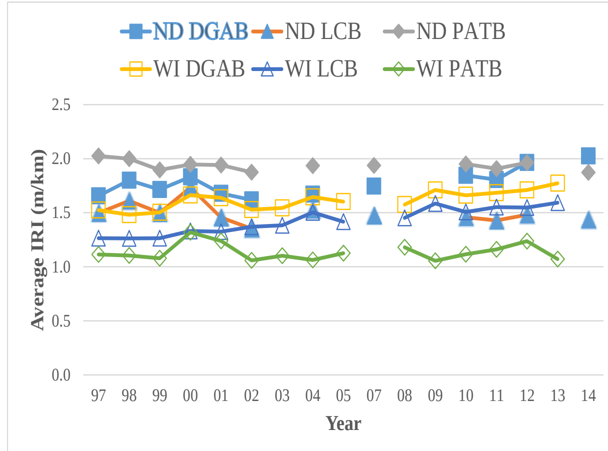


(a) 203 mm, 4.27 m, and 3.8 MPa

(b) 203 mm, 3.66 m, and 6.2 MPa



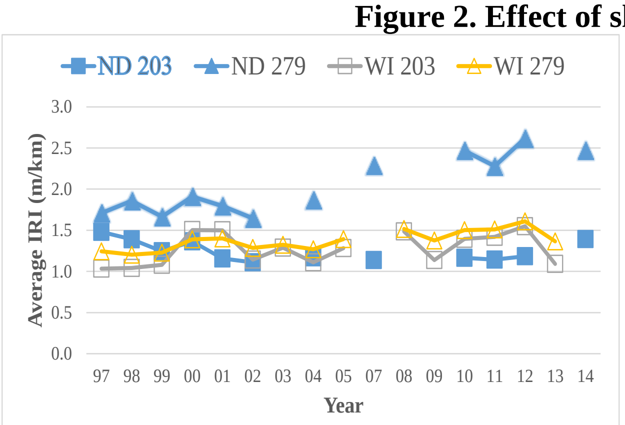
(c) 279 mm, 3.66 m, and 3.8 MPa



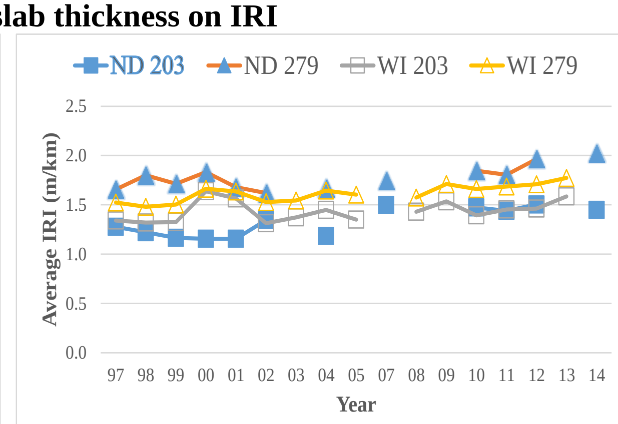
(d) 279 mm, 4.27 m, and 6.2 MPa

Effect of Slab Thickness on IRI. For DGAB bases, thinner sections are smoother than thicker sections irrespective of flexural strength of concrete as shown in Figures 2(a) and (b). For LCB base, thinner sections are smoother than thicker sections in Wisconsin irrespective of flexural strength of the slab, but the trend changes over time for North Dakota sections as shown in Figure 2(c) and (d). Thinner sections with PATB bases are smoother than thicker sections for flexural strength of 3.8 MPa as shown in Figure 2(a). Thicker section is smoother and rougher than thinner section in Wisconsin and North Dakota, respectively for PATB base and higher flexural strength as shown in Figure 2(f). It should be noted that the effect of lane width was not considered in this section and some of the variations could be due to the difference in lane width.

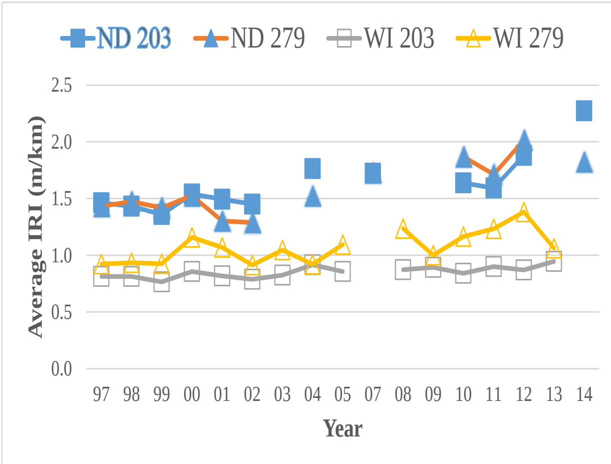
Figure 2. Effect of slab thickness on IRI



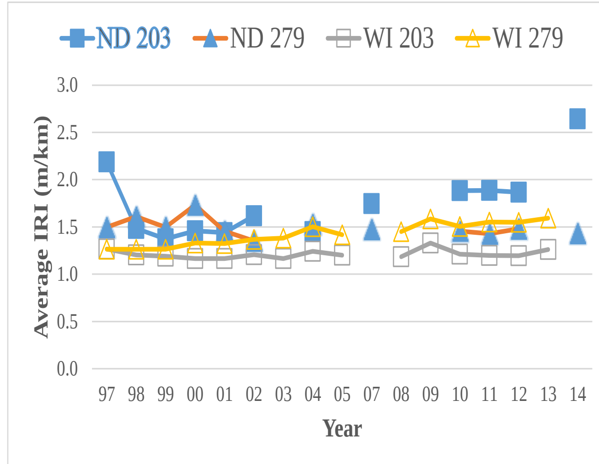
(a) DGAB and 3.8 MPa



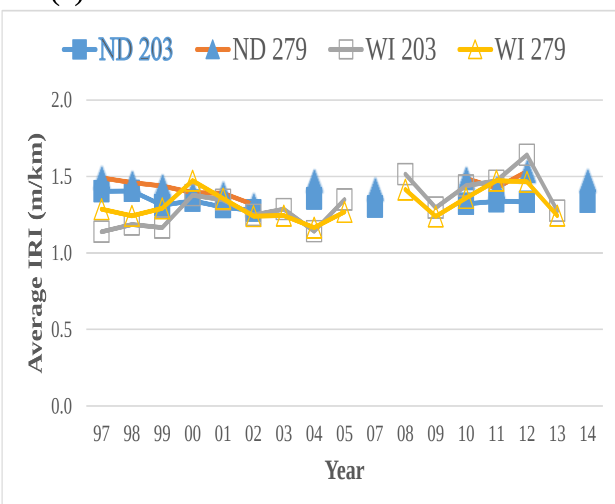
(b) DGAB and 6.2 MPa



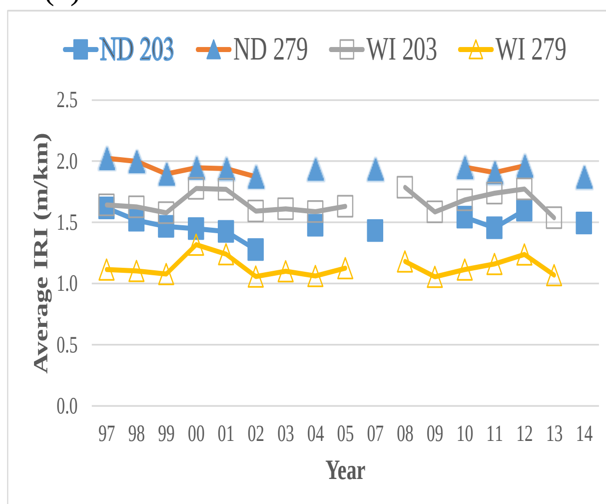
(c) LCB and 3.8 MPa



(d) LCB and 6.2 MPa



(e) PATB and 3.8 MPa



(f) PATB and 6.2 MPa

Effect of Base Type on Edge Faulting. Faulting can result from a combination of factors such as inefficient load transfer at joints, slab pumping, slab settlements, curling, warping, and inadequate base support conditions. Faulting plays a prominent role in pavement surface roughness over time, affecting ride comfort and driver's safety. Moreover, significant joint faulting has an adverse impact on pavement lifecycle costs for maintenance and rehabilitation as well as vehicle operating costs *(FHWA 2006)*. Any slab that is higher on the approach side of the joint registers a positive faulting number. If the slab on the leave side of the joint is higher, then the meter gives a negative reading *(Miller and Bellinger 2003)*. North Dakota sections with LCB bases and flexural strength of 3.8 MPa have positive faulting over the years irrespective of slab thickness and lane width as shown in Tables 2(a) and (c). The effect of other types of bases on edge faulting is not clear since the sign and magnitude changes over time.

Table 2. Effect of Base Type on Edge Faulting

Yr.	ND			WI			ND			WI		
	DGAB	**LCB**	**PATB**	**DGAB**	**LCB**	**PATB**	**DGAB**	**LCB**	**PATB**	**DGAB**	**LCB**	**PATB**
	(a) 203 mm, 4.27 m, and 3.8 MPa						**(b) 203 mm, 3.66 m, and 6.2 MPa**					
94	0.1	0.1	0.3				0	0	0.2			
97	0.2	0.1	0.1									
98				0.3	-0.1	-0.1				-0.5	-0.2	-0.4
99	0.1	0	0				0.2	0	0.1			
00	0.2		0	0.2	-0.2	0	0	0	0.2	-0.5	-0.1	-0.3
01	0.2	0.2	0.3				0.1	0.2	0.3			
02	0	0.2	0.1	0.4	-0.2	-0.5	0.2	0.3	0.2	-0.5	-0.3	-0.3
03	-0.3	0.2	-0.5				0.3	-0.6	0.1			
05				-0.3	-0.4	-0.3					-0.3	-0.8
06	-0.1	0.4	-0.1				-0.1	-0.3	-0.3			
10	1	0.5	-0.1	-0.3	-0.4	-0.3	0.2	0.3	0.4			-0.3
12	0.4	0.1	-0.5	0.1	-0.2	0.1	0.3	-0.1	-0.1	-0.5	-0.4	-0.5
	(c) 279 mm, 3.66 m, and 3.8 MPa						**(d) 279 mm, 4.27 m, and 6.2 MPa**					
94	0.1	0	0				0.6	0	0.5			
97												
98				0	0	0.1				0	0.1	0
99		0.8	0.5					0	0.2			
00	0.5	0.5	0.1	0	0.2	0.2	0.1	-0.3	0	0.2	-0.1	-0.1
01	0.5	0.6	0.1				0.1	-0.2	0.2			
02	0.6	1	0.4	0	0.2	-0.1	0.3	0	0.2	0.1	0.1	0.1
03	0.7	0	0.3				-0.6	-0.7	-0.8			
05				0	0.2	-0.4				-0.4	0	-0.4
06	0.3	0.2	0				0	-0.3	-0.3			
10	0.7	1.9	0.7	-0.1	-0.1		0.2	0.6	-0.2	-0.2	0	-0.1
12	0.4	0.9	0	0.3	0.4	0.2	0.1	0	-0.5	0.3	0.2	0.1

Effect of Base Type on Wheel Path Faulting. Wheel path faulting is positive for LCB section in North Dakota and DGAB and LCB sections in Wisconsin for thinner slab thickness, wider lanes, and lower flexural strength as shown in Table 3(a). Sections with PATB in North Dakota and DGAB and LCB in Wisconsin have positive wheel path faulting for thicker slab, narrower lane, and lower flexural strength as shown in Table 3(c). The effect of base type on wheel path faulting for other sections is not clear since the magnitude and sign changes over the years.

Table 3. Effect of Base Type on Wheel Path Faulting

Yr.	ND			WI			ND			WI		
	DGAB	**LCB**	**PATB**	**DGAB**	**LCB**	**PATB**	**DGAB**	**LCB**	**PATB**	**DGAB**	**LCB**	**PATB**
	(a) 203 mm, 4.27 m, and 3.8 MPa						**(b) 203 mm, 3.66 m, and 6.2 MPa**					
94	0	0.2	0.2				0.2	0.3	0.1			
97	0	0	0.1									
98				0	0	0.1				0	0	-0.2
99	0.2	0.2	0				0	0	0			
00	0.6		0.5	0.2	0	0	0.2	0	0.3	-0.1	0	0
01	0.2	0.2	0.6				0.4	0.2	0.4			
02	0.3	0.4	0.1	0.1	0.1	-0.2	0.2	0.2	0	0	0	-0.2
03	-0.3	0.6	0.2				0.4	-0.1	0.2			
05				0.2	0.1	0				-0.5	-0.3	-0.5
06	0.2	0.1	0.1				0	-0.1	-0.1			
10	1.5	1.2	0.6	0.1	0	0	0.5	0.4	0.7	-0.4	-0.2	0
12	1	0.5	-0.2	0.4	0.1	0.3	0.2	0.1	0	0	-0.1	0.1
	(c) 279 mm, 3.66 m, and 3.8 MPa						**(d) 279 mm, 4.27 m, and 6.2 MPa**					
94	-0.5	0.2	0				0.2	0.1	0.2			
97												
98				0	0	0				0.1	0	0
99		0.6	0.1					-0.1	0.1			
00	0.5	0.5	0.1	0.1	0.1	0	0.1	0	0	0	0.1	0
01	0.5	0.5	0.2				0	0.1	0.1			
02	0.5	0.9	0.3	0	0.1	-0.1	0.1	0.1	0	0.1	0	0
03	0.7	-0.4	0.2				-0.1	-0.3	-0.1			
05				0.1	0.2	-0.1				-0.1	-0.1	0
06	0.3	0.4	0.1				0	0	0.1			
10	1.6	2.5	1	0	0	-0.4	0.2	1.1	0.3	0	0	0
12	0.5	1.5	0.2	0.2	0.3	0.2	0.1	0.3	0	0.3	0.1	0.1

Effect of Base Type on LTE. The effect of base type on load transfer efficiency (LTE) is not clear since the values are very high in general irrespective of base type as shown in Table 4. Majority of LTE values are greater than 100% indicating locked joints.

Table 4. Effect of Base Type on LTE

Yr.	**ND**			**WI**			**ND**			**WI**		
	DGAB	**LCB**	**PATB**	**DGAB**	**LCB**	**PATB**	**DGAB**	**LCB**	**PATB**	**DGAB**	**LCB**	**PATB**
	(a) 203 mm, 4.27 m, and 3.8 MPa						**(b) 203 mm, 3.66 m, and 6.2 MPa**					
94	99	100	100				99	99	100			
95	103	98	98				98	100	102			
98				102	97	100				99	100	103
99	99	100	104				100	100	100			
00				101	98	98				100	113	80
01	100	94	100				100	98	100			
02				103	102	101				103	100	102
03	106	102	107				100	100	100			
04				104	101	100				103	99	100
10	111	91	105	104	101	103	102	100	102	106	100	103
	(c) 279 mm, 3.66 m, and 3.8 MPa						**(d) 279 mm, 4.27 m, and 6.2 MPa**					
94	100	100					99	98	101			
95	102	96					102	100	102			
98			97	100	100	97				96	101	100
99	101	102					101	99	103			
00			102	100	96	102				97	98	95
01	100	100					101	102	100			
02			104	102	98	104				103	102	101
03	102	106					105	111	108			
04			100	100	94	100				105	100	101
10	99	98	104	104	103	104	104	93	99	103	102	105

Effect of Slab Thickness on LTE. The effect of slab thickness on LTE is not clear since LTE values are consistently high irrespective of slab thickness as shown in Table 5. The effect of lane width on LTE was not considered.

Cracks. Longitudinal, transverse, and durability cracking have been considered. They are discussed separately.

Longitudinal Cracks: Section 217 (LCB base, 203 mm slab thickness, 3.8 MPa flexural strength, and 4.27 m lane width) has shown longitudinal cracks at all severity levels (low, medium, and high). Sections 215, 216, 218, 219, 222, and 224 have also shown minor low severity longitudinal cracks except 224 that also shows medium severity longitudinal cracks in North Dakota. Only two sections, 218 (LCB base**,** 203 mm slab thickness, 6.2 MPa flexural strength, and 3.66 m lane width and 222 (PATB base, 203 mm slab thickness, 6.2 MPa flexural strength, and 3.66 m lane width), have shown low severity longitudinal cracks in Wisconsin. The result in Table 6 shows SPS-2 sections in North Dakota developed more longitudinal cracks than the sections in Wisconsin.

Table 5. Effect of Slab Thickness on LTE

Yr.	ND		WI		ND		WI	
	203	279	203	279	203	279	203	279
	(a) DGAB and 3.8 MPa				(b) DGAB and 6.2 MPa			
94	99	100			99	99		
95	103	102			98	102		
98			102	100			99	96
99	99	101			100	101		
00			101	100			100	97
01	100	100			100	101		
02			103	102			103	103
03	106	102			100	105		
04			104	100			103	105
10	111	99	104	104	102	104	106	103
	(c) LCB and 3.8 MPa				(d) LCB and 6.2 MPa			
94	100	100			99	98		
95	98	96			100	100		
98			97	100			100	101
99	100	102			100	99		
00			98	96			113	98
01	94	100			98	102		
02			102	98			100	102
03	102	106			100	111		
04			101	94			99	100
10	91	98	101	103	100	93	100	102
	(e) PATB and 3.8 MPa				(f) PATB and 6.2 MPa			
94	100	99			100	101		
95	98	101			102	102		
98			100	97			103	100
99	104	101			100	103		
00			98	102			80	95
01	100	99			100	100		
02			101	104			102	101
03	107	105			100	108		
04			100	100			100	101
10	105	100	103	104	102	99	103	105

Table 6. Longitudinal Cracks

Year	ND										WI	
	215	216	217	217	217	218	219	222	224	224	218	222
	L	L	L	M	H	L	L	L	L	M	L	L
1994	0	0	0	0	0	0	0	0	0	0		
1997			9.7	0	0							
1998											0	0
1999	0	0	13.1	13.1	0	0	0	0	9	0		
2000	0	0	8.5	34.5	0	3.8	0	0	8	0	0	0
2001	0	0	10.3	41	0	8.9	0	0	9	0		
2002	0.8	0.6	46.1	13	4.5	14.1	0	0	0	0	0	0
2003	0	0	3.7	38.4	33	10.1	0	0	0	7.4		
2004											0	0
2005											0	0
2006	0	0	19.5	50.8	17	10.4	0	0	0	6		
2010	0	0	13.8	53	0	17.9	0.3	0	0	8.8	0.3	1.1
2012	1	0	6	63.5	0	27.9	1.4	3.8	0	8.8	0.6	1.9

Transverse Cracks. Table 7 shows that only SPS-2 sections in North Dakota developed transverse cracking. All the sections have LCB base. Section 217 (LCB base, 203 mm slab thickness, 3.8 MPa flexural strength, and 4.27 m lane width) shows transverse cracking at all severity levels (low, medium, and high).

Durability Cracking. Only section 217 (LCB base, 203 mm slab thickness, 3.8 MPa flexural strength, and 4.27 m lane width) in North Dakota developed minor durability cracking.

Table 7. Transverse Cracks

Year	ND				
	217			219	220
	L	M	H	L	L
1994	0	9.6	0	0	0
1997	0	3.7	6		
1999	2.8	8.6	0	0	0
2000	6.9	4.3	0	0	0
2001	4.1	4.3	4.3	0	0
2002	6.6	4.3	0	0	0
2003	3	1.2	11.7	1.2	0.6
2006	1.4	4.3	5.3	1.2	0.6
2010	0	0	0	0	0.3
2012	8	0	0	0	0.5

Spalling. The effects of base type on longitudinal and transverse spalling were considered.

Longitudinal Spalling. Sections in Wisconsin developed more low severity longitudinal spalling than sections in North Dakota as shown in Table 8. The effect of base type on longitudinal spalling is not clear since the extent varies over the years. Medium and high severity longitudinal spalling are insignificant and the results have not been included for brevity.

Table 8. Low Severity Longitudinal Spalling

Yr.	ND			WI			ND			WI		
	DGAB	LCB	PATB	DGAB	LCB	PATB	DGAB	LCB	PATB	DGAB	LCB	PATB
	(a) 203 mm, 4.27 m, and 3.8 MPa						(b) 203 mm, 3.66 m, and 6.2 MPa					
94	0	0	0				0	0	0			
97	0	0	0									
98				2.5	0	0				11.9	14	0
99	3	2.8	0				0.7	0.4	0			
00	0	0	0	0	0	0	0	0	0	11.8	4.3	2.6
01	0	0	0				0	0	0			
02	0	0	0	0	0	0	1.5	0	0	11	4.3	2.6
03	0	6.9	0				1.5	18.5	11.8			
04				0	0	8				32.3	13.3	0.4
05				0.2	30.8	43.2				65.2	18	6.4
06	0	0	0				1.2	0	0			
10	0	0	0	15.9	96.5	63.3	0	0	0	87.5	46	39
12	36	17.1	7.5	17.2	55.5	55.8	32.4	58.9	15	84.8	28.2	39
	(c) 279 mm, 3.66 m, and 3.8 MPa						(d) 279 mm, 4.27 m, and 6.2 MPa					
94	0	0	0				0	0	0			
97												
98				6.1	16.7	0				0	0	31
99	0	0	0				0	0	0			
00	0	0	0	11.9	10.8	2.6	0	0	0	0	0	23
01	0	0	0				0	0	0			
02	0	0	0	11.9	10.8	2.6	0	0	0	0	0	23
03	0.6	3.2	11.8				3.6	0.1	0			
04				23.4	14.9	0.4				0	2.5	64
05				17.7	13.9	6.4				0.7	4	77
06	0	0	0				0	0	0.6			
10	0	0	0	37.4	21.1	38.7	0	0	0	45.1	41.7	142
12	38.4	42.9	15	45.5	13.4	38.7	22.2	88.3	5.5	12.3	36.3	152

Transverse Spalling. Sections in Wisconsin developed more low severity transverse spalling than sections in North Dakota as shown in Table 9. The extent of low severity transverse spalling is the highest in a section with LCB base, 203 mm slab thickness, 6.2 MPa flexural strength, and 3.66 m lane width as shown in Table 9(b). Medium severity transverse spalling are insignificant and the results have not been included for brevity.

Table 9. Low Severity Transverse Spalling

Yr.	**ND**			**WI**			**ND**			**WI**		
	DGAB	**LCB**	**PATB**	**DGAB**	**LCB**	**PATB**	**DGAB**	**LCB**	**PATB**	**DGAB**	**LCB**	**PATB**
	(a) 203 mm, 4.27 m, and 3.8 MPa						**(b) 203 mm, 3.66 m, and 6.2 MPa**					
94	0.1	0	0				0.2	0.2	0			
97	0.7	0.9	0									
98				0	0	0				0.5	0.5	0
99	0	0	0				0	0	0			
00	0	0	0	0	0	0	0	0	0	0	0.4	0.5
01	0	0	0				0	0	0			
02	0	0	0	0	0	0	0	0	1.3	0	0.4	0.5
03	0	0	0				0	0.6	0.6			
04				0	0.5	0.5				4.1	19.7	8
05				0	1.5	0.6				5.8	20.2	7.9
06	0	1	0				0	1.8	2.4			
10	0	0	0	0.5	2.4	0.6	0	0	2.4	10.2	26.3	9.1
12	0	0	1.1	0.5	2.5	3.3	0.4	0.5	1.9	9.7	25.5	10.4
	(c) 279 mm, 3.66 m, and 3.8 MPa						**(d) 279 mm, 4.27 m, and 6.2 MPa**					
94	0.2	0.4	0.1				0.2	0.1	0.5			
97												
98				2.2	0	0				0	0	0
99	0	0	0				0	0	0			
00	0	0	0	0	0	0	0	0	0	0	0	0
01	0	0	0				0	0	0			
02	0	0	0	0	0	0	0	0	0	0	0	0
03	0	0	0				0	0.5	0.5			
04				1.7	0	0.8				0	0	0
05				2.3	0	0.8				2	0	0
06	0	0	0				1.1	1.2	0.5			
10	0	0	0	4.1	1.4	0.9	0	0.5	1.4	2	0	1
12	0	0	0	8.4	1.5	0.9	0.5	0.5	2.6	1.5	0	1

Pumping. Only two sections in North Dakota, 217 (LCB base, 203 mm slab thickness, 3.8 MPa flexural strength, and 4.27 m lane width) and 218 (LCB base, 203 mm slab thickness, 6.2 MPa flexural strength, and 3.66 m lane width), had low severity pumping problems. The results have not been included for brevity.

Scaling. Only one section, 222 (PATB base, 203 mm slab thickness, 6.2 MPa flexural strength, and 3.66 m lane width), developed a minor scaling both in North Dakota and Wisconsin. The results have not been included for brevity.

Traffic Data Comparison. One way average annual daily traffic (AADT) and average annual daily truck traffic (AADTT) are higher on SPS-2 sections in North Dakota than in Wisconsin as shown in Table 10. Equivalent single axle load (ESAL) on SPS-2 sections in both states is very close for all practical purposes. This shows that traffic may not be the main reason for the difference in SPS-2 section performances in North Dakota and Wisconsin.

Table 10. Comparison of Traffic Data

Year	EASL		One Way AADT		One Way AADTT	
	ND	WI	ND	WI	ND	WI
1994	364		4913		705	
1995	382		5040		740	
1996	409		5140		805	
1997	401	386	5280	3146	825	502
1998	405	445	5435	3272	835	594
1999	454	447	5350	3036	888	580
2000	460	452	5850	3157	900	603
2001	511	470	5300	3283	1000	627
2002	521	489	5353	3415	1010	652
2003	527	509	5407	3551	1020	679
2004	532	529	5461	3693	1030	706
2005	537	550	5515	3841	1041	734
2006	543	572	5570	3995	1051	763
2007	548		5626		1062	
2008	553		5682		1072	

***Climate Data Comparison*.** SPS-2 sections in North Dakota and Wisconsin were designed for dry-freeze and wet-freeze zones, respectively. Mean annual temperatures in Wisconsin are slightly higher than those in North Dakota as shown in Table 11. Mean annual precipitations in Wisconsin is also higher than the ones in North Dakota in general. SPS-2 sections in North Dakota got more than expected precipitations. There have been more freeze-thaw days in Wisconsin than in North Dakota. Climate might have contributed to the differences in the performances of SPS-2 sections in North Dakota and Wisconsin.

Table 11. Comparison of Climate Data

Year	Mean Annual Temperature (ºC)		Mean Annual Precipitation (inches)		Freeze-thaw (Days)	
	ND	WI	ND	WI	ND	WI
1994	4.8	5.8	30.1	28.7	84	102
1995	4.8	5.7	22.2	39.6	72	89
1996	3	4.2	23.1	34.0	70	94
1997	4.6	5.3	28.1	29.0	73	104
1998	6.9	7.8	29.8	32.9	79	96
1999	6.9	6.5	22.1	27.7	100	107
2000	5.5	5.8	33.5	36.6	62	88
2001	6.2	6.6	24.5	31.7	73	102
2002	5.8	6.4	19.6	36.4	112	129
2003	5.6	5.7	19.1	30.1	63	101
2004	5.2	5.6	24.8	34.3	105	106
2005	6.4	6.5	29.6	28.8	76	85
2006	6.8	7	19.9	33.3	99	121
2007	5.7	6.5	24.2	29.0	60	77
2008	4	4.8	31.1	29.6	72	80
2009	4.1	5.3	23.9	33.1	65	91
2010	5.7	7.3	28.7	42.0	48	82
2011	5.3	6	32.4	34.6	84	90
2012	7.5	8	19.0	28.1	92	108

Conclusions

The following conclusions can be made based on the results of this study:

- Thinner sections (203 mm) over dense graded aggregate base and lean concrete base are the smoothest in North Dakota and Wisconsin, respectively.
- Thinner sections (203 mm) over lean concrete base and permeable asphalt treated base are the roughest in North Dakota and Wisconsin, respectively.
- The effect of base type on the smoothness of thicker sections is not clear.
- Thinner sections (203 mm) are smoother than thicker sections for the same base type in general except a Wisconsin section with thicker slab (279 mm) and a higher flexural strength (6.2 MPa) over permeable asphalt treated base.
- The effect of base type on faulting and load transfer efficiency is not clear.
- Cracks are more prevalent on North Dakota sections in general, with lean concrete base in particular whereas spalling is more prevalent in Wisconsin sections in general, with lean concrete base in particular.
- Only two sections with lean concrete base had pumping problems in North Dakota.
- Only one section with permeable asphalt treated base had minor scaling issues in both states.
- The differences in performances in both states may not be due to the difference in traffic since equivalent single axle load (ESAL) is very close for practical purposes.

- Some of the differences in performances may be due to the differences in climate: lower temperature in North Dakota, and higher precipitation and freeze-thaw days in Wisconsin.

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