15-Year Performance of SPS-2 Project in Kansas

Taslima Khanum, E.I.T.[1]
Mustaque Hossain, Ph.D., P.E.[2]
Andrew J. Gisi, P.E.[3]
Daba S. Gedafa, E.I.T.[4]

Abstract

The Long Term Pavement Performance (LTPP) SPS-2 experiment was designed to study the structural factors, such as drainage, base type, concrete strength, thickness, and lane width for rigid pavements. The SPS-2 experiment section in Kansas, constructed in 1992, is a jointed, dowelled plain concrete pavement. The experiment consisted of twelve standard SPS-2 sections and one Kansas Department of Transportation (KDOT) supplemental/control section. 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 surface deflections. Performance parameters analyzed in this study included IRI, faulting, cracking (combined longitudinal and transverse crack lengths), and joint load transfer efficiency (LTE). The results show that the project has performed very well to date. Most sections are smooth, crack free, and have negligible faulting. The load transfer efficiency of the sections has been good too. The drainable sections with permeable asphalt treated base have performed the best. These sections were built smoother and remained so after 15 years of service. The section with low PCC slab thickness (203-mm) and low concrete design strength (3.8-MPa) on dense graded aggregate base has performed the worst. The combination of high slab thickness and high concrete strength tends to mask the effect of base on pavement performance. The KDOT supplemental/control section with thick slab (305-mm) over dense graded, Portland cement-treated base has also performed very well. Statistical analysis of IRI and LTE data also supports these conclusions.

Introduction

The Strategic Highway Research Program (SHRP) was initiated in 1987 in order to improve performance of highway pavements and bridges. A 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. The LTPP national database was established later and is now being updated periodically with the performance monitoring data collected from those selected pavement sections.

---

[1] CalTrans District 4, 111 Grand Avenue, Oakland, CA 94623
[2] Prof., Dept. of Civil Eng., 2118 Fiedler Hall, Kansas State University, Manhattan, KS 66506
[3] Materials and Research Center, Kansas Dept. of Transportation, 2300 Van Buren, Topeka, KS 66611

[4] Ph.D. Candidate, Dept. of Civil Eng, 2118 Fiedler Hall, Kansas State University, Manhattan, KS 66506. Tel: 785-532-5862, Fax: 785-532-7717, Email: daba@ksu.edu

The LTPP program was divided into two sub programs: the General Pavement Studies (GPS), representing pavements that used materials and structural design practices in US and Canada from 1960's to 1980's; and the Specific Pavement Studies (SPS) providing performance and specific structural factors of interest in the 1990's. The SPS-2 experiment entitled, "Strategic Study of Structural Factors for Rigid Pavements" was developed to study the structural factors affecting the performance of rigid 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. This paper presents the analysis of performance of the SPS-2 project in Kansas with respect to (a) Drainage and (b) Base type. Comparison with a supplemental/control section designed by the Kansas Department of Transportation (KDOT) has also been made. Statistical analysis of roughness and joint load transfer efficiency has also been done.

Kansas SPS-2 Project Layout and Test Sections

The Kansas SPS-2 project was constructed in 1992 and is located in the westbound driving lane of Interstate 70 near Abilene. The project involved reconstruction of an existing 4-lane divided interstate highway (Johnson 1993). The roadway consisted of - two 3.7-m lanes; a 3.1-m tied outer shoulder; and a 1.2-m inner shoulder in the westbound direction. This SPS-2 experiment included 12 standard sections and one supplemental/control section of KDOT as shown in Table 1. Each section is 152.4-m long and there are transitions of varying length in between the sections.

The sections incorporated two different slab thicknesses (203 and 279 mm), two concrete strength classes (design modulus of rupture of 3.8- and 6.2-MPa at 14-day), three base types (permeable asphalt-treated base, PATB; Lean Concrete Base, LCB; dense graded aggregate base, DGAB) and two lane widths (3.7-and 4.3-m). As shown in Table 1, most of the 6.2-MPa flexural concrete did not fulfill the 14-day strength requirements. The 28-day strength criteria were fulfilled with an average of 6.4-MPa. Calcite cemented sandstone was used for the sand portion in 6.2-MPa mix to help increase the flexural strength. The results showed this mix gained strength slowly may be due to calcite cemented sandstone. Table 1 shows design and actual Portland Cement Concrete (PCC) slab thicknesses. There is some variation in the thickness. The actual PCC slab thickness was used for subsequent analysis. The KDOT supplemental/control section consists of a 305-mm PCC slab over 150-mm dense graded Portland cement treated base (PCTB). The 14-day design modulus of rupture for this section was 4.1-MPa.

Subgrade soils were silty clay and defined as fine grained by LTPP. Since this project involved reconstruction of an existing concrete highway, the top subgrade layer was reworked and recompacted after incorporating existing granular subbase and shoulder material. Construction was difficult due to wet climate (Johnson 1993). Thus a Class C fly ash was added to dry out and stabilize the wet subgrade. As a result, all sections now have 150-mm fly ash-modified subgrade.

The project was initially classified to be in the dry-freeze zone of the LTPP program. Later it was reassigned to the wet-freeze zone since the annual precipitation at this site (81.3 -cm/year) was greater than 50.8-cm/year for the LTPP dry-freeze zone. The freezing index was 259 ^{o}C-days.

The base year Annual Average Daily Traffic (AADT) on this section was 13,750 with 21.4% trucks. The estimated 40-kN Equivalent Single Axle Load (ESAL) in the SPS-2 lane was

1,300,678 during base year with a total of 26,013,550 40-kN ESALs over the 20-year design period.

Table 1. Kansas SPS-2 test section details

Test Section No.	SHRP ID	Base*	Slab Thickness (mm)		14-Day Concrete Strength (MPa)		Lane Width (m)	Drainage
			Design	Actual	Design	Actual		
KDOT Suppl.	KDOT Control	6” PCTB 6”Mod. Fly ash	305	310	4.1	4.3	3.7	Undrained
KDOT 1	200209	4” PATB 4” DGAB	203	216	3.8	4.3	3.7	Drained
KDOT 2	200210	4” PATB 4” DGAB	203	211	6.2	6.4	4.3	Drained
KDOT 3	200211	4” PATB 4” DGAB	279	254	3.8	4.0	4.3	Drained
KDOT 4	200212	4” PATB 4” DGAB	279	231	6.2	6.0	3.7	Drained
KDOT 5	200208	6” LCB	279	282	6.2	5.9	3.7	Undrained
KDOT 6	200207	6” LCB	279	257	3.8	4.0	4.3	Undrained
KDOT 7	200205	6” LCB	203	206	3.8	4.8	3.7	Undrained
KDOT 8	200206	6” LCB	203	198	6.2	5.7	4.3	Undrained
KDOT 9	200202	6” DGAB	203	208	6.2	5.5	4.3	Undrained
KDOT 10	200201	6” DGAB	203	198	3.8	4.2	3.7	Undrained
KDOT 11	200204	6” DGAB	279	290	6.2	5.4	3.7	Undrained
KDOT 12	200203	6” DGAB	279	284	3.8	4.1	4.3	Undrained

* PCTB: dense graded Portland cement-treated base; PATB: permeable asphalt-treated base; LCB: Lean Concrete Base; DGAB: dense graded aggregate base

Layout and Construction

The test sections were laid out starting at the west end of the project and according to the base type as shown in Figure 1. Lane width and surface thickness were not considered. The KDOT supplemental/control section was first, followed by those with PATB over DGAB (KDOT Sections 1, 2, 3 and 4). The sections with LCB were placed next (KDOT Sections 5, 6, 7 and 8). The last sections are those containing DGAB (KDOT Sections 9, 10, 11 and 12). The construction of the test sections started in June 1992 and completed in July 1992. The project was opened to traffic on August 13, 1992 (Johnson 1993).

Table 2 shows the mix design details. Type II cement was used in all mixes. The cement content varied from 1478.7 kg/m^3 for LCB to 4568.6 kg/m^3 for the 6.2-MPa mixture. All mixtures, including lean concrete base and paving concrete, used 70% natural sand and 30% crushed stone. Crushed limestone was used in LCB and in the 3.8-MPa concrete mix. The 6.2-MPa mix had calcite-cemented sandstone for the coarse aggregate part to help in increasing the flexural strength. The design water-cement ratios for the LCB, 3.8- and 6.2-MPa mixes were 1.0, 0.5 and 0.35, respectively (Johnson 1993). The mixes were air-entrained and a water-reducing admixture was used in the 6.2-MPa mix.

The construction of the project was fairly uneventful except for the fact that the PATB layer was placed too thick but was trimmed to the required thickness (Johnson 1993). Compaction of PATB was problematic too. Post-construction coring and flexural beam tests showed that most sections had concrete that exceeded the design strength as shown in Table 1. The strength gain over the design strength was most significant for the 3.8-MPa mixture.

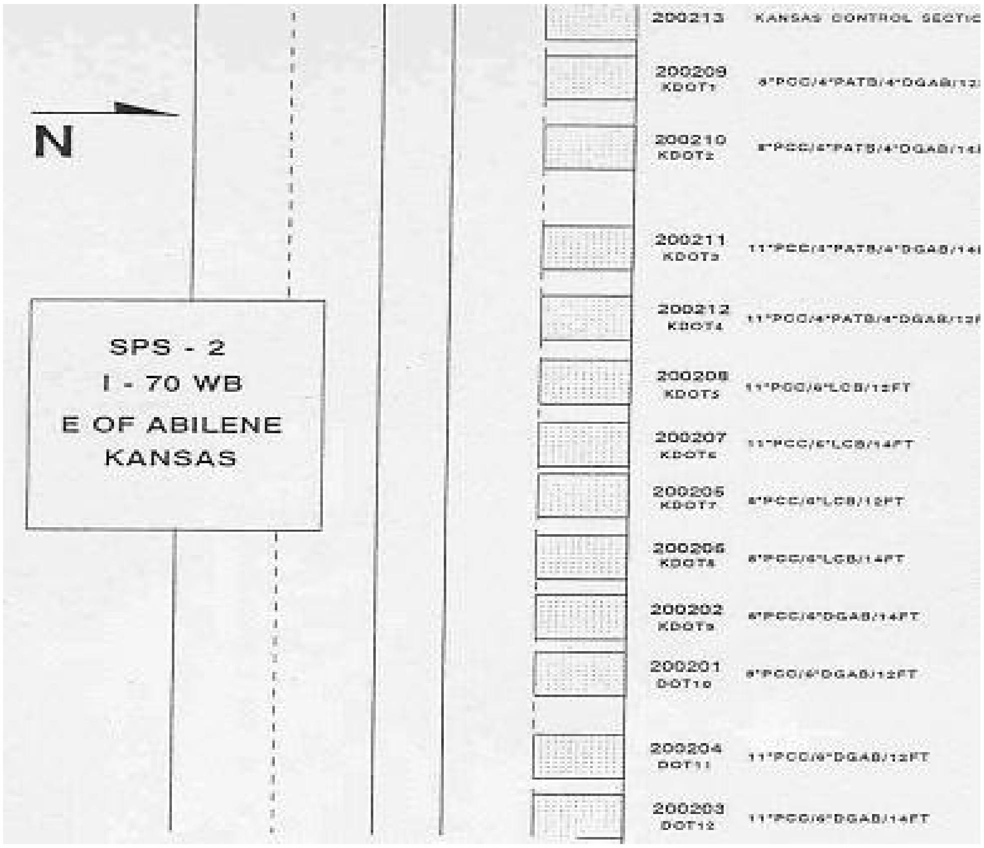


Figure 1. Lay out of SPS-2 sections

Table 2. SPS-2 mix design data

Feature	Lean Concrete Base	3.8 MPa Concrete	6.2 MPa Concrete
Strength Requirement	3.5-5.2 MPa comp. (7-day cure)	3.8 $\pm$ 0.4 MPa flex. (14-day cure)	6.2 $\pm$ 0.7 MPa, flex. (14-day cure)
% Air/ Air Ent. admix	4-9%	73.7 gm	218.3 gm
Slump required	25–75 mm	44.5 $\pm$19 mm	44.5 $\pm$19 mm
Cement Type	II	II	II
Cement Content (kg/m^3)	1478.7	2819.6	4568.6
Water Content (kg/m^3)	1484.0	1409.8	1595.3
Coarse Agg. Content (kg/m^3)	4923.7	4722.3	7149.7
Fine Agg. Content (kg/m^3)	11495.7	10976.3	7139.1
Unit Wt. (kg/m^3)	2169.1	2230.1	2290.9

Performance Monitoring, Data Analysis and Results

The Kansas SPS-2 project has been monitored by the LTPP program since its construction. A Toledo Model 930 high speed Weigh-In-Motion system was installed to provide automatic high-speed weighing, classifying, and traffic data collection. The test sections have carried 6.6-million ESAL's from 1992 to 2000 and no data could be obtained from the LTPP data base from 2000 to 2008. The truck traffic had been lower than that anticipated during the design process. Performance monitoring of these sections included annual measurements for ride quality (International Roughness Index, IRI) since 1992, faulting measurements since 1999, cracking measurements since 1993, and the Falling Weight Deflectometer (FWD) testing since 1992. All performance data used in this study were retrieved online from Datapave release 21 of January 2007. This version of Datapave contains the following data elements for the key performance measures: (a) IRI, every year since 1992 and up to 2004 and 2006; (b) Faulting for 1999 and 2001 to 2003; (c) Cracking for 1993, 1996, and 1999 to 2003; and (d) FWD deflection data for every other year since 1992 and up to 2005. From the wheel-path FWD deflection data, joint load transfer efficiency (LTE) values were computed for all sections. Thus performance parameters analyzed in this study included IRI, faulting, cracking (combined longitudinal and transverse crack lengths), and joint LTE corresponding to the design features incorporated in the experiment. Statistical analysis has been done to determine the significant difference of IRI and LTE over the years and for different base types. Change of IRI over time has also been investigated.

Figure 2 shows the average initial IRI for the sections in the SPS-2 project. The project was opened to traffic on August 13, 1992 and roughness data was taken on August 14, 1992 on all sections except on KDOT supplemental/control section and KDOT 10 (200201). KDOT 1 (200209) was the smoothest and KDOT 8 (200206) was the roughest initially. This shows that the initial roughness did not depend on the lane width, PCC thickness and strength as evident in Figure 2.

Figure 3 (a) shows the IRI history of the sections with 3.7-m lane width, 3.8-MPa design strength, and 203-mm PCC slab thickness. The figure compares the ride quality of the sections KDOT 1 (PATB), KDOT 10 (DGAB) and KDOT 7 (LCB). It is clear that the drained PATB section (KDOT 1) remained smoother than the undrained sections for the analysis period. The drained PATB section also was the smoothest after construction. The DGAB section (KDOT 10) is progressively becoming rougher than the LCB section (KDOT 7) with common design features mostly due to cracking. The section had a large amount of cracking in 2000 (22.8-m of longitudinal and transverse cracks) and was repaired. For 3.7-m lane width, thicker PCC slab (279-mm) and higher slab strength (6.2-MPa), the section with DGAB (KDOT 11) was the smoothest, PATB was next and LCB was the roughest as shown in Figure 3 (b). It appears that LCB performed the worst among all base types. Faulting on all sections till 2003 was minimal.

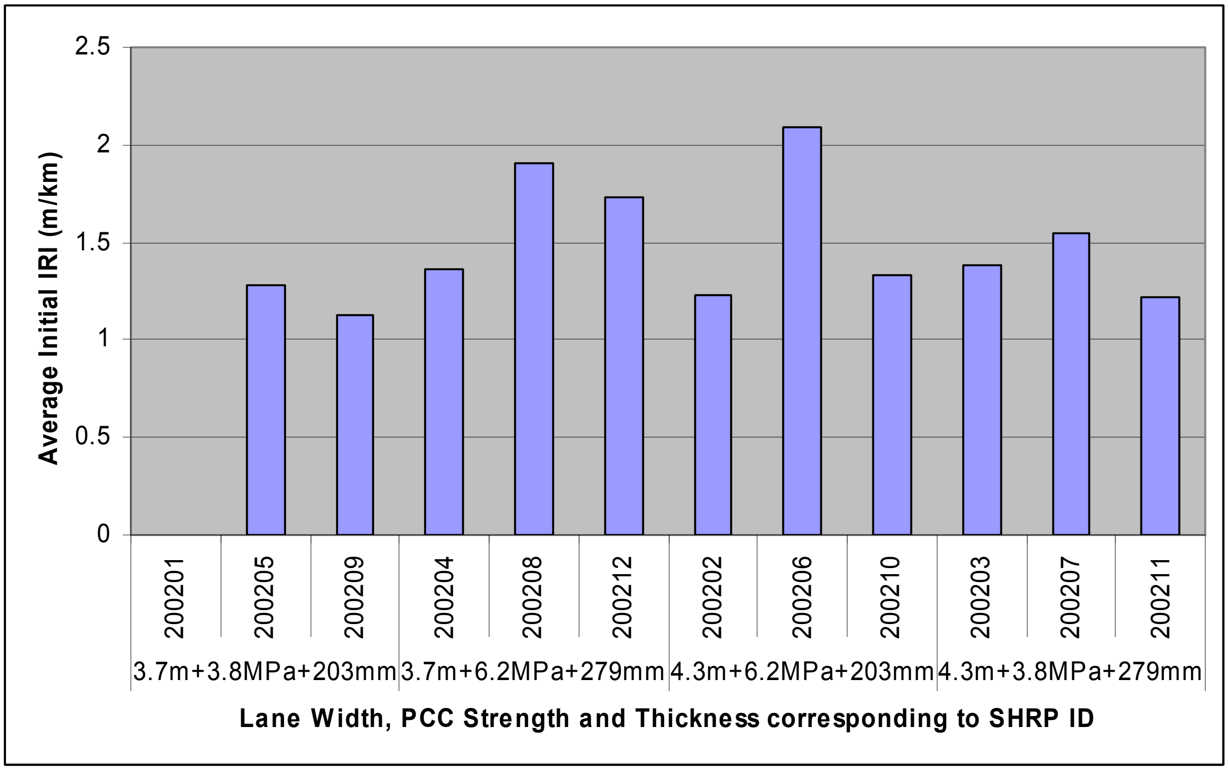


Figure 2. Average Initial IRI for SPS-2 Project

Figure 3 (c) shows the IRI progression on the sections with 4.3-m lane width, 6.2-MPa design strength, and 203-mm PCC slab thickness. The sections are KDOT 2 (PATB), KDOT 9 (DGAB) and KDOT 8 (LCB). The section with the DGAB base (KDOT 9) showed the smallest increase in roughness, whereas the section with LCB had the largest. However, KDOT 9 (DGAB) had some longitudinal and transverse cracking. No cracking was observed on the other sections till 2003. The increased roughness with LCB is also evident for the section with 4.3-m lane width, 3.8-MPa concrete design strength, and 279-mm PCC slab thickness as shown in Figure 3 (d). For these design features, the section with PATB (KDOT 3) was the smoothest initially after construction and remained so over time. Only the sections with DGAB showed some cracking. Faulting on all sections was also minimal till 2003.

Figure 4 shows the typical LTE versus time relationships for the sections with 3.7-m lane width, 3.8-MPa concrete design strength, and 203-mm PCC slab thickness. The LTE values appear to be good for all sections considering the guidelines suggested by the 1993 AASHTO Design Guide (AASHTO 1993). As expected, the sections with stabilized bases showed higher LTE values than the sections with DGAB except in 2005. The trends are similar for other SPS-2 sections with different design features. Some fluctuations have been observed in the LTE values over the years because of the time/temperature variations during FWD testing. The higher the test temperature, the higher was the LTE values. The LTE values in August 1992 were higher than the LTE values in December 1992.

Considering all four performance measures- roughness, faulting, cracking and load transfer efficiency (LTE), the drained sections with PATB have performed the best thus far.

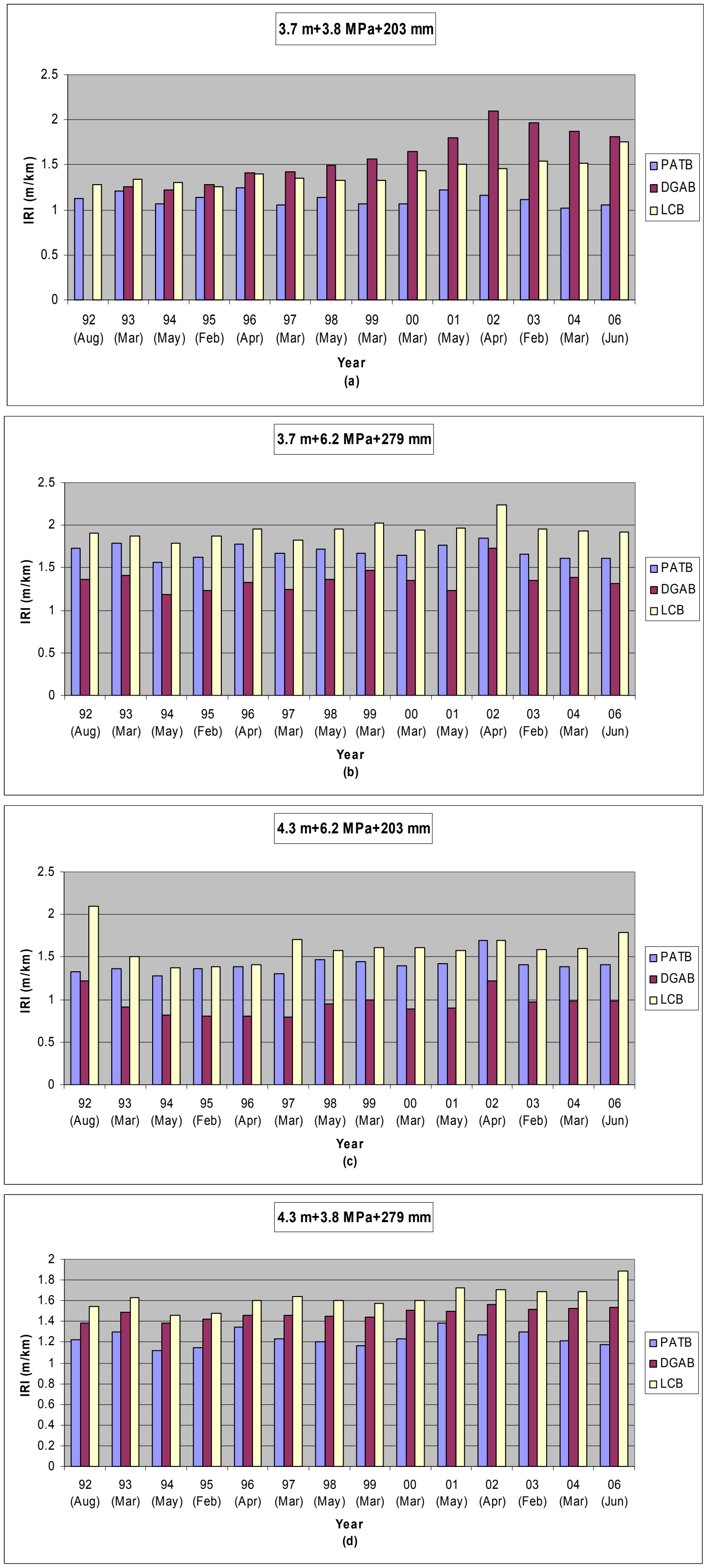


Figure 3. Change of IRI with time for the drained and undrained sections

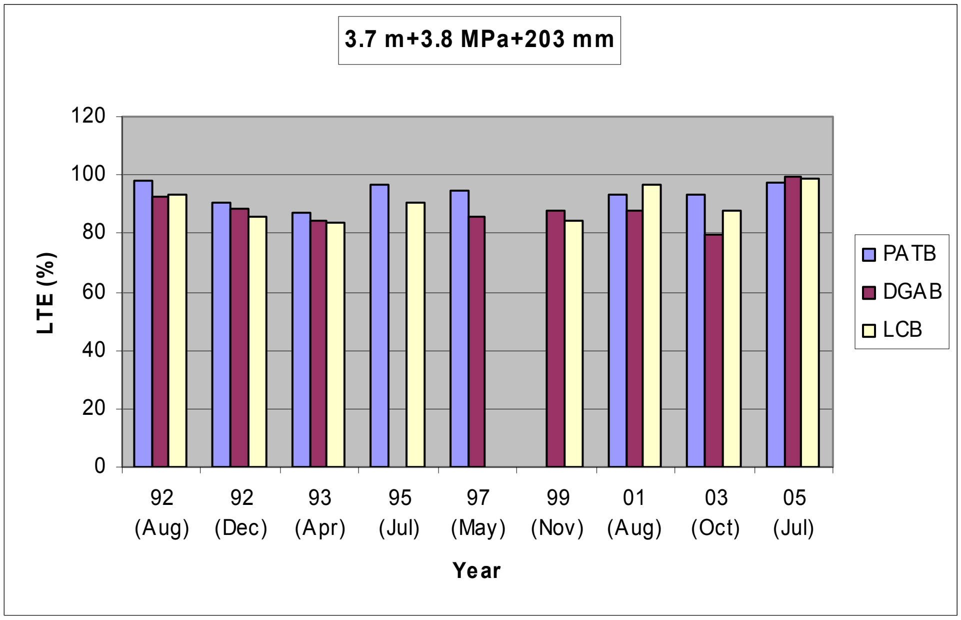


Figure 4. Change of LTE values with time

Base Type

PATB vs. LCB: Figures 5(a) through 5(d) show the comparison of IRI values on the sections with stabilized bases (PATB and LCB). The figures clearly show that for most design feature combinations, the sections with PATB have outperformed the sections with LCB. The sections with PATB were also built smoother initially. For widened lane (4.3-m) and high strength sections, the IRI values are somewhat comparable but for all other design features, the sections with PATB are much smoother. It is to be noted that LTE values for some years are missing on some sections because no FWD tests at the joints were done during those years. On a few sections, LTE values were computed to be more than 100% indicating locked joints and were ignored during comparison.

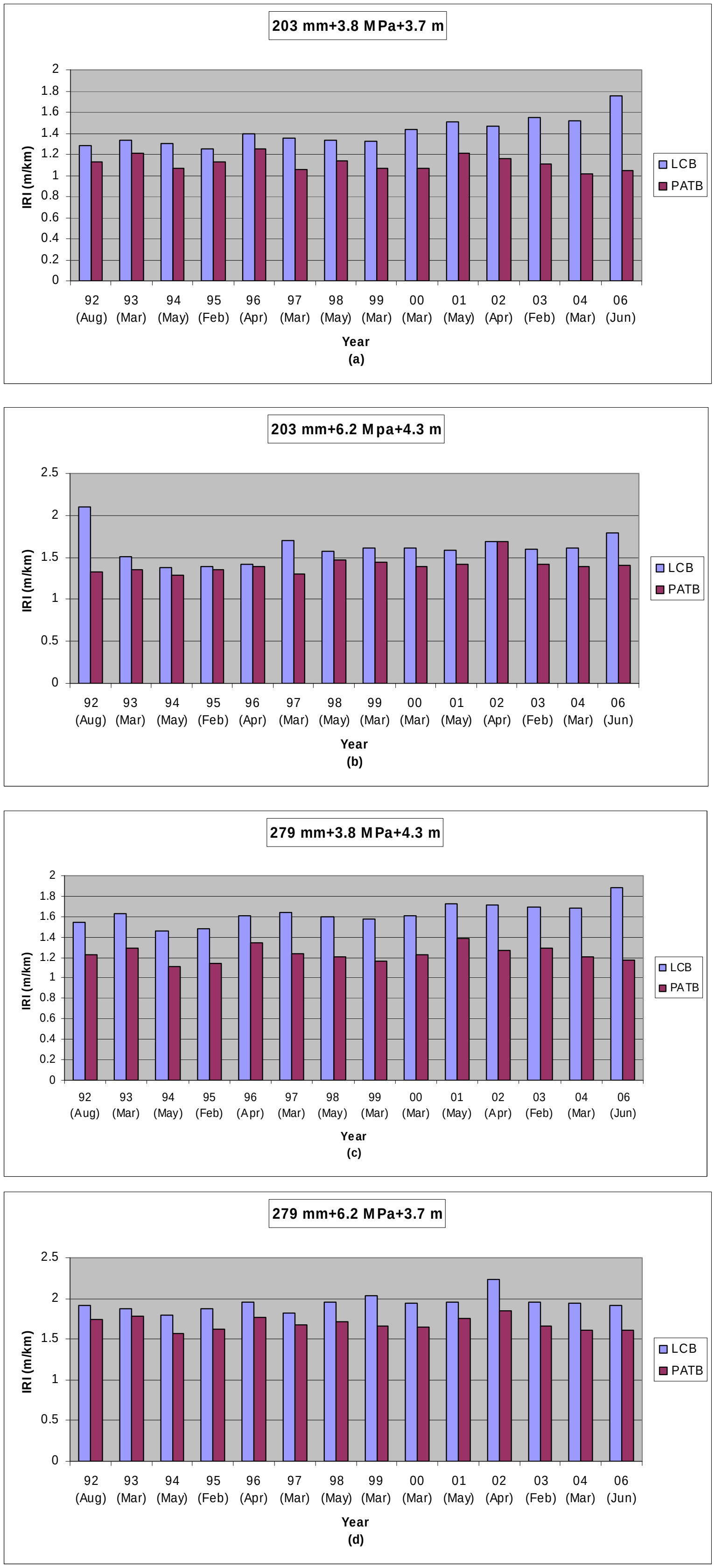


Figure 5. Change in IRI with time for the sections with stabilized bases

Faulting is negligible on all sections. The PATB sections for 3.7-m lane width, 3.8-MPa concrete design strength and 203-mm PCC slab thickness and for 3.7-m lane width, 6.2-MPa concrete design strength and 279-mm slab thickness showed some cracking but the amount is very small (0.5-m in 2003). For 3.7-m lane width, 3.8-MPa concrete design strength and 203-mm PCC slab thickness, and for 4.3-m lane width, 6.2-MPa concrete design strength and 203-mm PCC slab thickness, the sections with PATB also show higher LTE values with time than the sections with LCB as shown in Figures 6(a) and 6(b), respectively. The only exception was in 2005. For other design features, both sections have shown comparable LTE values during recent years (Figures 6(c) and 6(d)). Based on the time-series trends of the performance measures in this study, the sections with PATB have outperformed those with LCB.

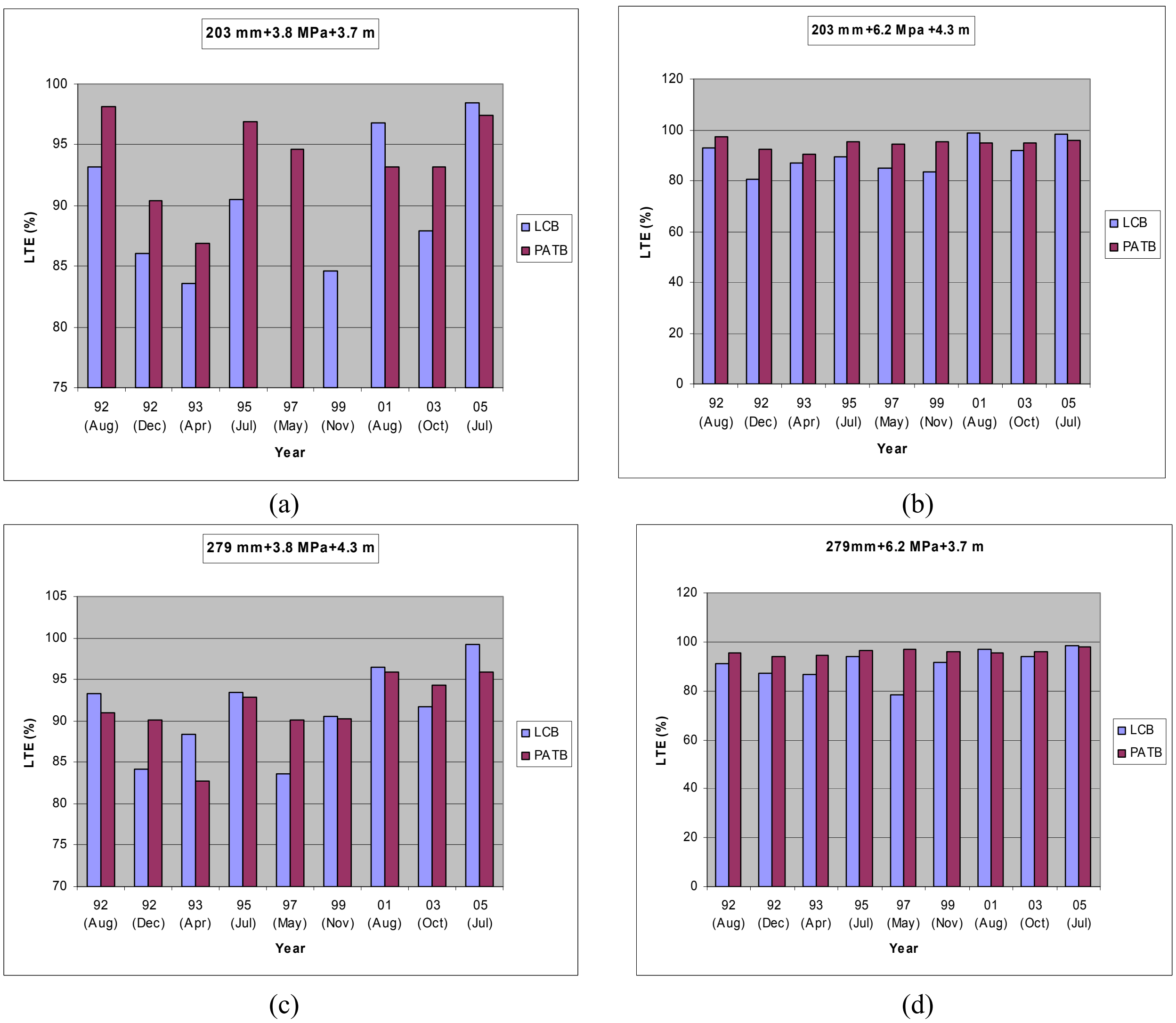


Figure 6. Change of LTE with time for the sections with stabilized base

LCB vs. DGAB: Figure 7 shows IRI for 3.7-m lane width, 3.8-MPa concrete design strength and 203-mm PCC slab thickness. The section with DGAB has become rougher than the section with LCB. As mentioned earlier, this section with DGAB had considerable amount of cracking and was repaired recently. For all other design features, the sections with LCB have higher IRI than the sections with DGAB. The differences have become more prominent recently. Again, faulting amount has been very low on all sections, but since 2001, the section with DGAB and widened lane (4.3-m) has developed some negligible amount of cracking. No cracking has been observed on the section with DGAB, high strength and high thickness. It appears that the effect of base layer is masked by higher PCC slab strength and thickness. The LTE values on the sections with DGAB have been lower than those with LCB over the years (Figures 8(a) through 8(d)). However, the LTE values, in general, are good as per AASHTO (1993) recommendations.

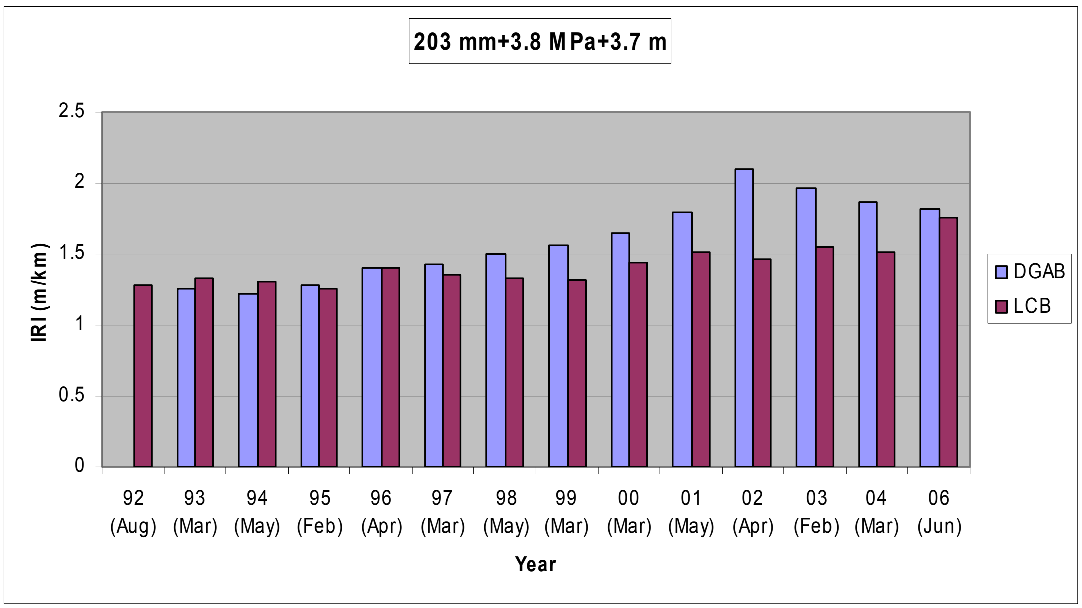
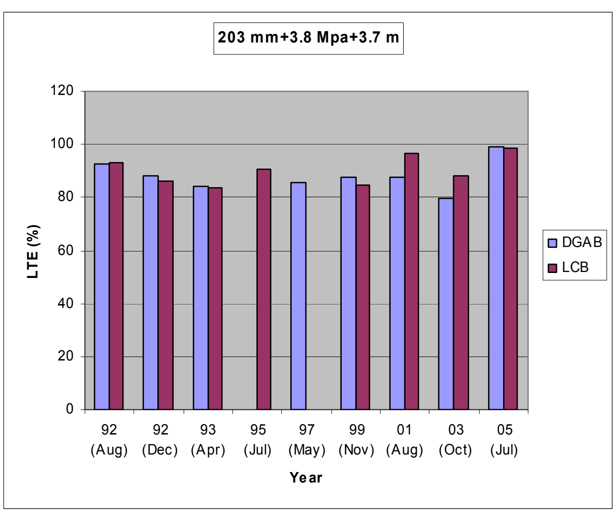
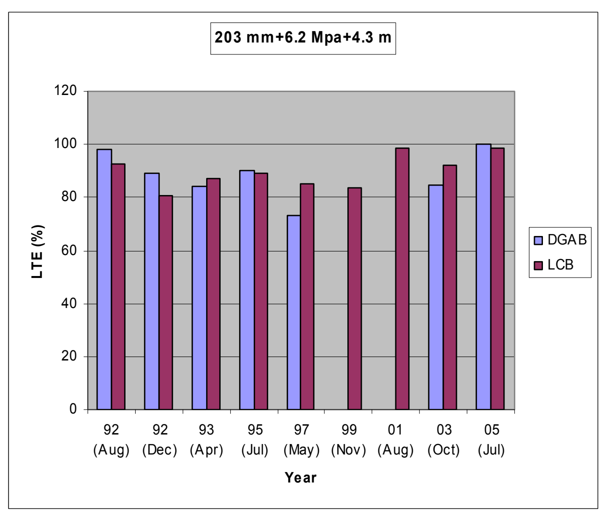


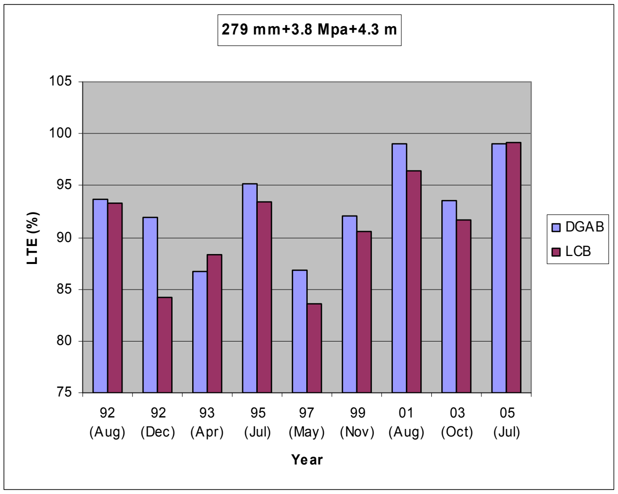
Figure 7. Comparison of IRI values for the sections with DGAB and LCB

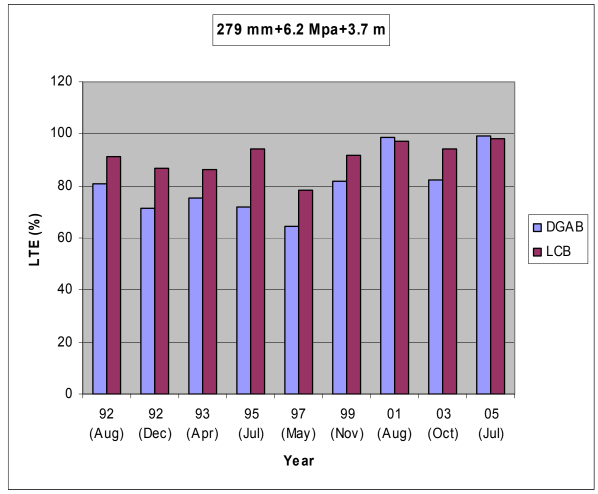


(a)



(b)





(c) **(d)**

Figure 8. Comparison of LTE values with time for the sections with DGAB and LCB bases

Control section vs. DGAB: As mentioned earlier, the KDOT supplemental/control section consists of a 305-mm thick PCC slab over 150-mm dense graded Portland cement (PCTB) treated base. The performance of this section has been compared with the four sections with DGAB base (DGAB-1 [KDOT 10], DGAB-2 [KDOT 9], DGAB-3 [KDOT 12], and DGAB-4 [KDOT 11]). Comparison with LCB and PATB has not been reported in this paper.

Figure 9 shows the change of IRI values with time for the sections with the DGAB base and the KDOT supplemental/control section with the stabilized base. It is evident that the section (KDOT 9) with the widened lane (4.3-m) and 6.2-MPa concrete design strength has remained the smoothest with time. However, this section also showed some cracking (Figure 10) and had been repaired.

The joint load transfer efficiency values of different sections with DGAB base were also compared with that for the KDOT supplemental/control section with PCTB as shown in Figure 11. As expected, the KDOT supplemental/control section had very good (greater than 80%) LTE values with time. However, all sections have shown good load transfer efficiencies for most of the time. LTE values for sections KDOT 9 (DGAB-2) and KDOT 11 (DGAB-4) have shown very high fluctuations with time.

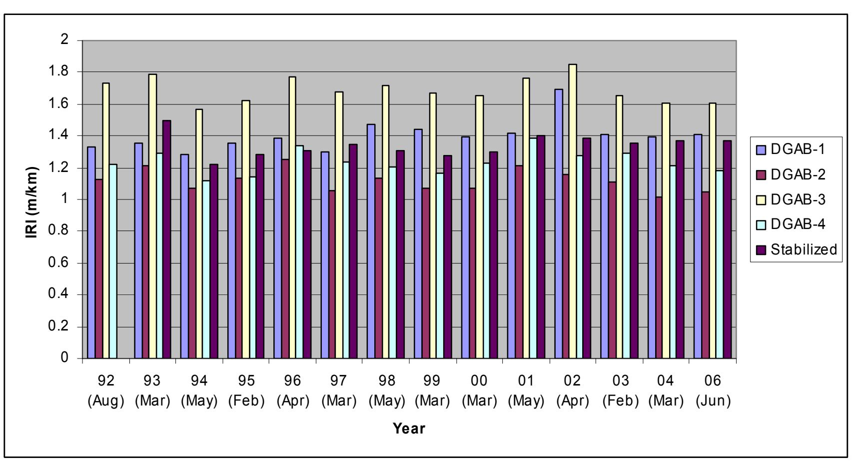


Figure 9. Change in IRI with time for the Control section

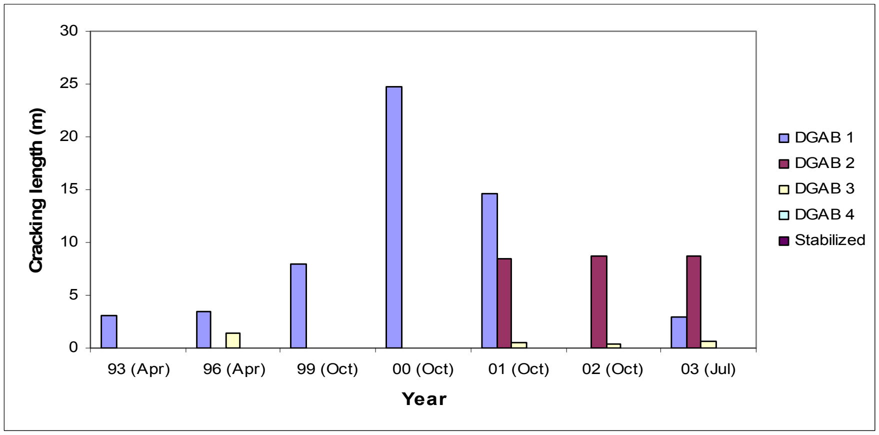


Figure 10. Cracking on the sections with DGAB base

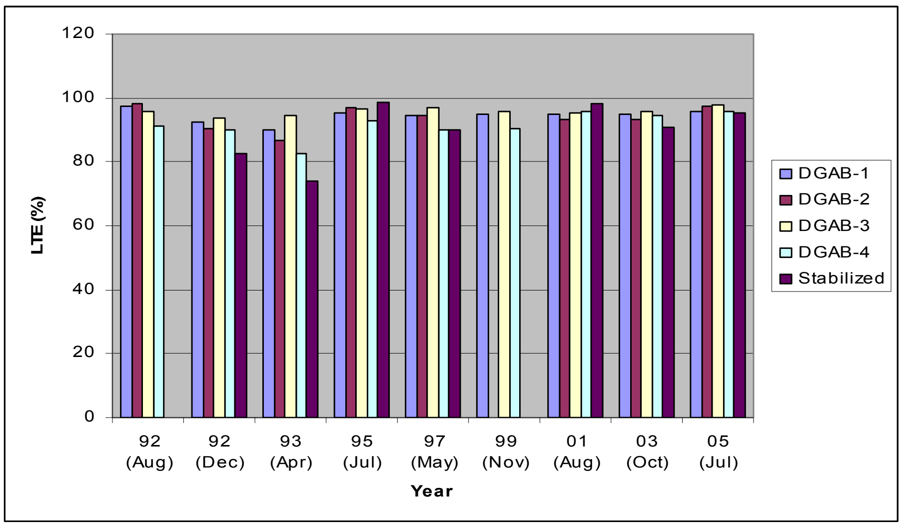


Figure 11. Change in LTE with time for the Control section

Statistical Analysis

Statistical analysis has been done for IRI and LTE using SAS. Contrast option in proc GLM has been used to determine the significant difference of IRI and LTE over years. The assumptions that residuals should be normally distributed and have a constant variance have not been violated in this study. Buch et al. (2005) also found that there was no serious violation of the assumptions while analyzing SPS-2 data. Significant difference tests for the sections with different base layers during same year were also done for IRI and LTE. A 5% significance level was used for all analysis.

Table 3 (a) shows the significant difference test results for IRI over the years using 1992 as the base year for all sections except KDOT 10 and KDOT supplemental/control section. IRI of KDOT 7 in 1992 was significantly different from IRI during all other years. Other sections have at least one year (up to the seventh year) that has statistically similar IRI to that in 1992. This shows the higher smoothness levels retained by almost all sections of this experiment.

Significant difference test results for LTE's over the years are summarized in Table 3 (b). The LTE's in August 1992 have been used as the base year data. The LTE's in August 1992 are significantly different from the ones in December 1992 mainly due to the difference in test temperature. The LTE's in August 1992 are statistically similar to the LTE's in all other years for KDOT 4. In general, LTE's in August 1992 are significantly different from the LTE's during other years.

Table 4(a) tabulates the significant difference test results for IRI's during the same years for different base types corresponding to same slab thickness, concrete strength, and lane width. IRI is significantly different during all years for sections with 279-mm PCC slab thickness, 6.2-MPa concrete strength and 3.7-m lane width and sections with 279-mm PCC slab thickness, 3.8-MPa concrete strength and 4.3-m lane width. In general, smoothness performance of the sections with different base types is significantly different.

Table 4(b) tabulates the significant difference test results for LTE's for the sections with different base layers. As mentioned earlier, LTE information is missing during some years in which FWD data was not taken or it was more than 100% indicating locked joint. In general, LTE performance is statistically similar for the sections with 279-mm PCC slab thickness, 3.8-MPa concrete strength and 4.3-m lane width. The LTE value of PATB base is significantly different from that of DGAB base during all years except 2005 for sections with slab thickness of 279-mm, PCC strength of 6.2-MPa and lane width of 3.7-m.

Changes in IRI as a Function of Time: Linear regression using proc REG option in SAS has been done with time (year) as an independent variable and IRI as a dependent variable. Two time periods have been considered separately: 1992-2002 and 1992-2006. The first case has been considered since there was a change in trend in 2002 and the second case included all data available to date. Null hypothesis that slope (β_1) is zero has been used in both cases. The results are shown in Table 5. The two cases have shown different results for KDOT 1, KDOT 3 and KDOT 4. However, for most sections, there is a linear relationship between time and IRI.

Table 3. Significant Difference Test

		Dec. 92	93	94	95	96	97	98	99	00	01	02	03	04	05	06
(a) For IRI Over Years																
3.7m+3.8MPa+203mm	200201															
	200205		No	No	No	No	No	No	No	No	No	No	No	No		No
	200209		No	Yes	Yes	No	No	Yes	Yes	Yes	No	Yes	Yes	No		No
3.7m+6.2MPa+279mm	200204		Yes	No	No	Yes	No	Yes	No	Yes	No	No	Yes	Yes		No
	200208		No	No	No	Yes	No	Yes	Yes	No	No	No	No	No		No
	200212		No	No	No	Yes	No	Yes	No	No	Yes	No	No	No		No
4.3m+6.2MPa+203mm	200202		No	No	No	No	No	No	No	No	No	Yes	No	No		No
	200206		Yes	Yes	Yes	No	No	Yes	Yes	No	No	No	No	No		No
	200210		Yes	No	Yes	No	Yes	No	No	No	No	No	No	No		No
4.3m+3.8MPa+279mm	200203		No	Yes	Yes	No	No	No	No	No	No	No	No	No		No
	200207		No	No	No	Yes	No	Yes	Yes	No	No	No	No	No		No
	200211		No	No	No	No	Yes	Yes	No	Yes	No	No	No	Yes		No
(b) For LTE Over Years																
3.7m+3.8MPa+203mm	200201	Yes	No		NA		No		Yes		Yes		No		Yes	
	200205	No	No		Yes		NA		No		Yes		Yes		Yes	
	200209	No	No		Yes		No		NA		No		No		Yes	
3.7m+6.2MPa+279mm	200204	No	Yes		No		No		Yes		No		Yes		No	
	200208	No	No		Yes		No		Yes		No		Yes		No	
	200212	Yes	Yes		Yes		Yes		Yes		Yes		Yes		Yes	
4.3m+6.2MPa+203mm	200202	No	No		Yes		NA		NA		No		No		Yes	
	200206	No	Yes		Yes		No		No		Yes		Yes		Yes	
	200210	No	No		Yes		Yes		Yes		Yes		Yes		Yes	
4.3m+3.8MPa+279mm	200203	Yes	No		Yes		No		Yes		Yes		Yes		Yes	
	200207	No	Yes		Yes		No		Yes		Yes		Yes		Yes	
	200211	Yes	No		Yes		Yes		Yes		No		No		No	

Note: Yes = Similar, No = significantly different @ 5% significance level; NA=not applicable.

Table 4. Significant Difference Test Results for the Sections with Different Base Layers

		Aug. 92	Dec. 92	93	94	95	96	97	98	99	00	01	02	03	04	05	06
(a) For IRI																	
3.7m+3.8MPa+ 203mm	PATB Vs DGAB		NA	Yes	No	No	No	No	No	No	No	No	No	No	No		No
	PATB VS LCB		No	No	No	No	No	No	No	No	No	No	No	No	No		No
	DGAB VS LCB		NA	Yes	No	No	Yes	No	No	No	No	No	No	No	No		No
3.7m+6.2MPa+ 279mm	PATB Vs DGAB		No	No	No	No	No	No	No	No	No	No	No	No	No		No
	PATB VS LCB		No	No	No	No	No	No	No	No	No	No	No	No	No		No
	DGAB VS LCB		No	No	No	No	No	No	No	No	No	No	No	No	No		No
4.3m+6.2MPa+ 203mm	PATB Vs DGAB		No	No	No	No	No	No	No	No	No	No	No	No	No		No
	PATB VS LCB		No	No	No	No	Yes	No	No	No	No	No	Yes	No	No		No
	DGAB VS LCB		No	No	No	No	No	No	No	No	No	No	No	No	No		No
4.3m+3.8MPa+ 279mm	PATB Vs DGAB		No	No	No	No	No	No	No	No	No	No	No	No	No		No
	PATB VS LCB		No	No	No	No	No	No	No	No	No	No	No	No	No		No
	DGAB VS LCB		No	No	No	No	No	No	No	No	No	No	No	No	No		No
(b) For LTE																	
3.7m+3.8MPa+ 203mm	PATB Vs DGAB	No	Yes	Yes	NA		No		NA		Yes		No		Yes		
	PATB VS LCB	No	Yes	Yes	No		NA		NA		Yes		Yes		Yes		
	DGAB VS LCB	Yes	Yes	Yes	NA		NA		Yes		No		Yes		Yes		
3.7m+6.2MPa+ 279mm	PATB Vs DGAB	No	No	No	No		No		No		No		No		Yes		
	PATB VS LCB	Yes	No	No	Yes		No		Yes		Yes		Yes		Yes		
	DGAB VS LCB	No	No	No	No		No		No		Yes		No		Yes		
4.3m+6.2MPa+ 203mm	PATB Vs DGAB	Yes	Yes	Yes	Yes		No		NA		NA		No		Yes		
	PATB VS LCB	No	No	Yes	Yes		No		No		No		Yes		Yes		
	DGAB VS LCB	No	No	Yes	Yes		No		NA		NA		No		Yes		
4.3m+3.8MPa+ 279mm	PATB Vs DGAB	Yes	Yes	Yes	Yes		Yes		Yes		Yes		Yes		No		
	PATB VS LCB	Yes	No	Yes	Yes		Yes		Yes		yes		Yes		No		
	DGAB VS LCB	Yes	No	Yes	Yes		Yes		Yes		Yes		Yes		Yes		

Note: Yes = Similar, No = significantly different @ 5% significance level; NA=not applicable.

Table 5. Change in IRI as a function of time

Test Section No.	SHRP ID	$H_0 : \beta_1 = 0$	
		1992-2002	1992-2006
KDOT Control	KDOT Control	Yes	Yes
KDOT 1	200209	Yes	No
KDOT 2	200210	No	No
KDOT 3	200211	No	Yes
KDOT 4	200212	No	Yes
KDOT 5	200208	No	No
KDOT 6	200207	No	No
KDOT 7	200205	No	No
KDOT 8	200206	Yes	Yes
KDOT 9	200202	Yes	Yes
KDOT 10	200201	No	No
KDOT 11	200204	No	No
KDOT 12	200203	No	No

Note: Yes = no linear relation between time and IRI; No = there is a linear relation between time and IRI @ 5% significance level

LTPP Evaluation of Kansas SPS-2 Project

The LTPP program published a report on initial evaluation and analysis of all SPS-2 projects using performance data up to year 2000 (Jiang and Darter 2005). The study found that the Kansas SPS-2 project is in good shape. The following findings related to the SPS-2 project in Kansas have been found in the report:

(1) Designed versus constructed: In general, good. The key deviations from the LTPP guidelines are:

- mean slab thickness values for five sections are more than ½ inch higher than the designed value.
- mean 14-day flexural strength values for the lower strength concrete are more than 10 percent above the design values.
- construction difficulties and deviations are relatively minor.

(2) Data availability – Excellent overall.

- site condition data are good except for deficient traffic data and missing automatic weather station data.
- only 66 percent of the cores have been tested.
- good monitoring data except for deficient faulting data are available.

Conclusions

The 15-year performance of Kansas SPS-2 project has been analyzed in this study with respect to the design features, drainage and base type. Based on this study, the following conclusions can be drawn:

- The Kansas SPS-2 project has performed very well to date. Most sections are smooth, crack free, and have negligible faulting. The load transfer efficiency of the sections has been good too.

- The drainable sections with permeable asphalt treated base have performed the best. These sections were built smoother and remained so after almost 15 years of service.

- The sections with lean concrete base have not performed well in terms of smoothness although they have maintained very good load transfer efficiencies.

- The section with smaller slab thickness (203-mm) and low design concrete strength (3.8-MPa) on dense graded aggregate base has performed the worst.

- The combination of high slab thickness and high design concrete strength tends to mask the effect of base on pavement performance.

- The KDOT supplemental/control section with a thick PCC slab (305-mm) over dense graded Portland cement treated base has also performed very well.

- The smoothness performance (in terms of IRI) is significantly different for the sections with different base types.

- The LTE values of the sections with PATB bases are significantly different from that of the sections with DGAB bases for almost all years when the PCC slab thickness is 279-mm, concrete strength is 6.2-MPa and lane width is 3.7-m.

- In general, there is a linear relationship between time and IRI.

References

AASHTO (1993). *AASHTO Guide for Design of Pavement Structures*. AASHTO, Washington, DC.

Buch, N., Chatti, K., Haider, S. W., Pulipaka, A., Lyles, R. W., and Gilliland, D. (2005). "Statistical challenges presented by the SPS-2 experiment and data." *Proc., 8th Int. Conf. on Concrete Pavements*, Colorado Springs, Colo., 149–166.

Jiang Y. J. and Darter, M.I. (2005). *Structural Factors for Jointed Plain Concrete Pavement:SPS-2 - Initial Evaluation and Analysis.* Final Report. FHWA-RD-01-167, Office of Engineering Research and Development, Federal Highway Administration, McLean, Virginia, April.

Johnson, A.M. (1994). *SPS-1 Construction Report, US-54 Near Greensburg, Kansas, Sections 200101 to 200164.* Braun Intertec Corp., St. Paul, Minnesota.

SHRP (1990). *Specific Pavement Studies: Preliminary Construction Guidelines for Experiment SPS-2; Strategic Study of Structural Factors for Rigid Pavements.* Strategic Highway Research Program, Washington, D.C.