

# Performance of SPS-1 Project in Kansas

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## ABSTRACT

The Long-Term Pavement Performance (LTPP) SPS-1 experiment entitled “Strategic Study of Structural Factors for Flexible Pavements” was developed to determine and evaluate the factors affecting the performance of flexible pavements. The experimental design was aimed at determining the effects of following specific pavement design features: (1) base type, (2) base thickness, (3) pavement thickness, and (4) in-pavement drainage systems. The SPS-1 experimental project in Kansas, constructed in 1993, was located in the eastbound driving lane of US-54, a major rural arterial. The experiment consisted of 12 standard SPS-1 sections, 1 Kansas DOT (KDOT) control section, and 5 supplemental sections. The service life of these sections was estimated by KDOT to be from 2 to 120 years. However, because of premature distresses, some sections were rehabilitated in 1996 and 1997. This paper discusses causes of premature distresses on some sections and the performance of other sections.

**Key words: flexible pavements—SPS-1—rutting**

## **INTRODUCTION**

The Long-Term Pavement Performance (LTPP) program within the Strategic Highway Research Program (SHRP) was aimed at determining the effects of various design features and environmental and material performance by recording performance and construction data for a large number of in-service and new pavement sections. The LTPP program was divided into two subprograms, General Pavement Studies (GPS), representing pavements that used material and structural design practices in the United States and Canada from the 1960s to the 1980s; and Specific Pavement Studies (SPS), representing performance and specific structural factors of interest in the 1990s.

The SPS-1 project, “Strategic Study of Structural Factors for Flexible Pavements,” was designed to determine and evaluate factors affecting the performance of flexible pavements (FHWA 1993). The experiment examines the effects of climatic region, subgrade soil (fine or coarse), and traffic rate (as covariate) on pavement sections incorporating different levels of structural factors. These factors include drainage (presence or lack), asphalt concrete (AC) surface thickness (4 in. and 7 in.); base type (dense-graded untreated aggregate and/or dense-graded asphalt-treated), and base thickness (8 in. and 12 in. for undrained sections; and 8 in., 12 in., and 16 in. for drained sections). The design stipulated a traffic loading level in the study lane in excess of 100,000 equivalent single axle loads (ESALs) per year (FHWA 1993). This paper examines the performance of the SPS-1 project in Kansas, which incorporated some of the above factors for a particular soil type and traffic.

## **THE SPS-1 PROJECT IN KANSAS**

### **Project Layout and Description of Test Sections**

The SPS-1 project in Kansas, constructed in 1993, is located in the eastbound driving lane of US-54 in Kiowa County. The experiment consisted of 12 SPS-1 standard sections, 1 KDOT control section, and 5 supplemental sections, as shown in Figure 1. The project involved construction of a new two-way asphalt-surfaced roadway, offset from the original alignment by approximately 50 feet. The sections were laid out on the base type and surface layer thickness criteria (Johnson 1994). Three KDOT supplemental sections were constructed first, followed by the KDOT control section. Six sections with dense-graded aggregate base (DGAB) were built next, followed by six sections with asphalt-treated base (ATB). Two KDOT supplemental sections with asphalt surfacing over dense-graded aggregate base were placed last. The permeable asphalt-treated base (PATB), designed to provide in-pavement drainage, was placed on six sections (SHRP #4 to SHRP #9). These sections also had a drainage blanket and longitudinal drains. Longitudinal drain was also provided for KDOT Sections 1 and 2. The KDOT control section did not have any base and was built directly over fly ash-treated subgrade.

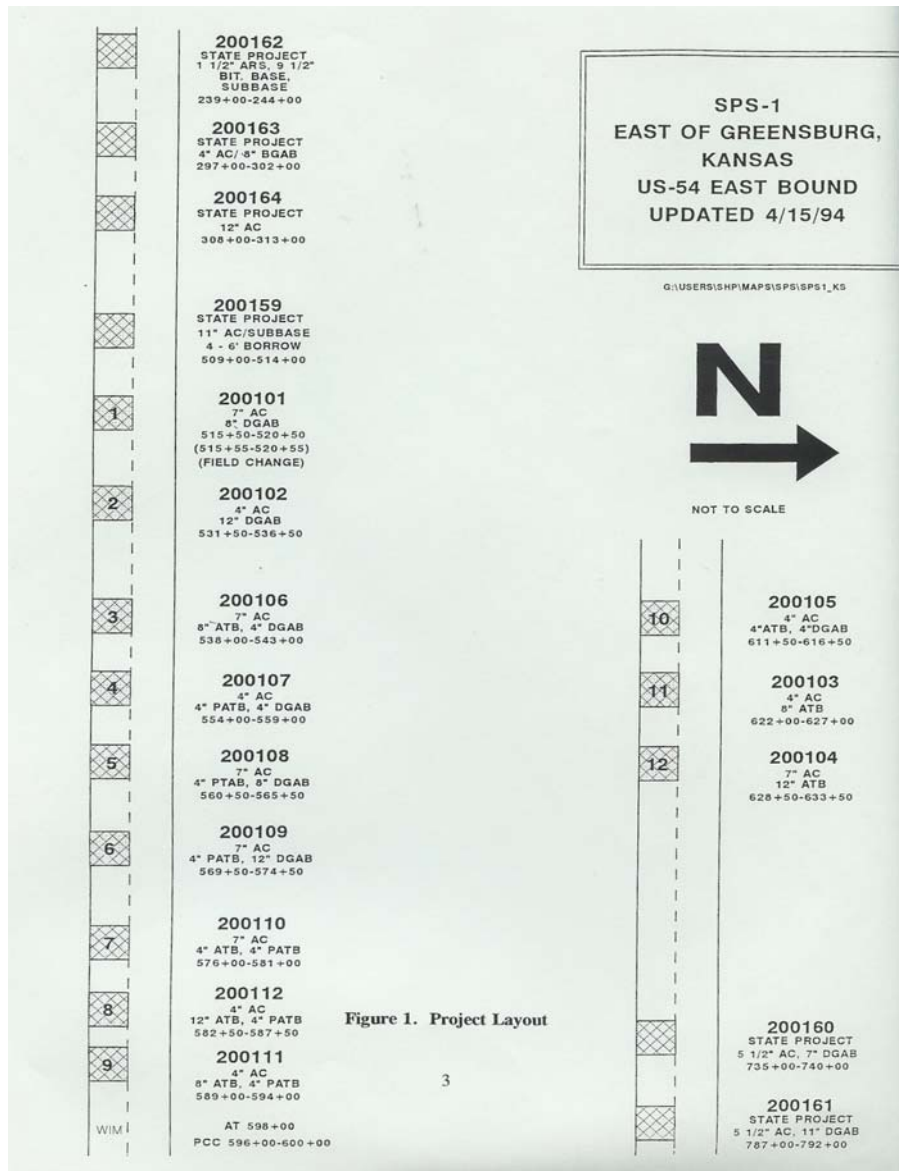


Figure 1. Project Layout

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Figure 1. Kansas SPS-1 project layout

Table 1 summarizes the design features and section attributes of the SPS-1 project in Kansas. As mentioned earlier, the sections were built with varying base types (DGAB, ATB, or PATB) and with or without longitudinal drains. The thicknesses of the asphalt mixture surface and base courses were also varied. The sections had dense-graded asphalt mixtures designed by the Marshall method on most sections. Three sections (KDOT #3, #5, and #6) had asphalt-rubber mixtures in the asphalt base and/or surface courses. The total asphalt layer thickness varied from 4 in. to 11 in. for the KDOT sections and 4 in. to 7 in. for the SHRP test sections.

### Traffic

The annual average daily traffic (AADT) of US-54 was 5,000 with 28% trucks in 1993. The AADT decreased to 4,648 with 22% trucks in 1996, then increased to 5,006 with 30% trucks in 2000. The calculated ESALs decreased from 230,000 in 1993 to 73,000 in 1996, then increased to 351,000 in 2000. The applied cumulative ESALs up to 1996 and 2000 were 670,000 and 1,937,000, respectively.

**Table 1. Section attributes of the SPS-1 project in Kansas**

Section no.	Layer thickness (in.)	Drainage type	Design life (years)	Construction year	Rehabilitation year
KDOT #3	1.5"ARS/9.9"BM-2C/6"FASB	No sub.	10	1993	1996
KDOT #5	1.5"ARS/2.5"ARB/8"DGAB/6"FASB	No sub.	13	1993	1996
KDOT #6	1.5"ARS/2.5"ARB/8"BM-2C/6"FASB	No sub.	20	1993	1996
SPS-1 CS	2"BM-1B/8.8"BM-2C/6"FASB	No sub.	10	1993	1997
SHRP #1	7.6"BM-1B/8.5"DGAB/6"FASB	No sub.	13	1993	1996
SHRP #2	4"BM-1B/12.3"DGAB/6"FASB	No sub.	4.5	1993	1996
SHRP #3	7.3"BM-1B/7.3"ATB/4"DGAB/6"FASB	No sub.	87	1993	
SHRP #4	4.1"BM-1B/4.1"PATB/3.7"DGAB/6"FASB	B	6.5	1993	1996
SHRP #5	7.6"BM-1B/3.6"PATB/7.9"DGAB/6"FASB	B	20	1993	
SHRP #6	7"BM-1B/3.6"PATB/11.9"DGAB/ /6"FASB	B	120	1993	
SHRP #7	7"BM-1B/3.8"ATB/3.9"PATB/6"FASB	B	36	1993	
SHRP #8	5"BM-1B/12"ATB/3.6"PATB /6"FASB	B	95	1993	
SHRP #9	4"BM-1B/8.5"ATB/3.6"PATB /6"FASB	B	39	1993	
SHRP #10	3.9"BM-1B/3.8"ATB/4.1"DGAB/6"FASB	No sub.	2	1993	
SHRP #11	3.6"BM-1B/7.7"ATB/6"FASB	No sub.	28	1993	
SHRP #12	6.8"BM-1B/12.1"ATB/6"FASB	No sub.	47	1993	
KDOT #1	1.5"BM-1B/4"BM-2C/7"DGAB/GG/6"FASB	L	10	1993	1997
KDOT #2	1.5"BM-1B/4"BM-2C/11"DGAB/6"FASB	L	10	1993	1997

**Table 1 Key**

**Drainage type** No sub.: no sub-drainage layer  
 B: drainage blanket with long drains  
 L: longitudinal drains

**Layer type** ARS: asphalt rubber surface      DGAB: dense graded aggregate base  
 BM-1B: dense graded surface mix      PATB: permeable asphalt treated base  
 BM-2C: dense graded base mix      GG: geogrid, engineering fabric  
 ARB: asphalt rubber base      FASB: fly ash-stabilized base  
 ATB: asphalt treated Base      SPS-1 CS: KDOT control section

## Construction Overview

Project construction started in the fall of 1992 with the required removals and utility relocations. The preparation of base and subbase courses was scheduled to begin in May 1993. However, the project was delayed due to weather conditions (rain) (Johnson 1994).

### *Preparation and Compaction of Subgrade*

Fly ash was introduced into the subgrade, which was sandy silt, to dry out the soil. Class C fly ash was mixed into the upper six inches of the soil at a target application rate of 8% by weight. Compaction was achieved through moisture-density relationships. This provided uniform material with uniform thickness along the test section and ensured that the compaction specifications were met for forming a stable working platform.

### *Base Layer*

As mentioned earlier, two base types were used for the SPS-1 project: undrained (unstabilized and stabilized) and drained (stabilized). The undrained bases were relatively impermeable layers consisting of DGAB and/or ATB. Segregation or degradation of materials during placement of DGAB was controlled and the quality of in-place density was monitored. Low-viscosity asphalt cement was used to prime the surface of the DGAB in the test sections where a permeable ATB layer was placed over DGAB. The ATB layer was constructed to control elevations and minimize surface irregularities. Low-viscosity asphalt cement was also used to tack the ATB layer before placing the surface course.

The drainable base layers incorporated a permeable layer (PATB) with edge drains to permit water to drain out of the pavement structure. The PATB mixture, with relatively open gradation, was central plant-mixed, hot-laid, and contained 2% to 2.5% asphalt with the same grade as that used in a hot-mix asphalt (HMA) surface course. Edge drains were installed in the shoulders of the pavement sections with PATB. Both inside and outside edge drains were constructed for crowned pavements, while only one edge drain was required for the cross-sloped pavements. The PATB was used as a backfill in the edge drain trench. Transverse collector sub-drains were located in the transition zones between the drained and undrained sections whenever there was a longitudinal slope.

### *Hot-Mix Asphalt Concrete*

The asphalt concrete surface mixtures were designed to meet the specifications provided by the Marshall mix design method. Most of the SHRP and KDOT sections had a KDOT BM-1B mixture (1/2-in. nominal maximum aggregate size [NMAS]) as the surface course and a KDOT BM-2C (3/4-in. NMAS) as the base course. Table 2 shows the details of these mixtures and Figure 2 shows the gradations.

The BM-2C mixture was designed with 75 blows of a Marshall hammer. The design asphalt content was 4.25% (AC-10). The mixture had 15% CS-1A (1 1/2-in. NMAS), 21% CS-1D (3/4-in. NMAS), 39% limestone screening (CS-2C, 1/4-in. NMAS) and 25% sand and sand gravel. The specifications required 50% of the coarse aggregates be crushed. The design gradation provided 75% crushed materials. As shown in Figure 2, the mixture has a dense gradation.

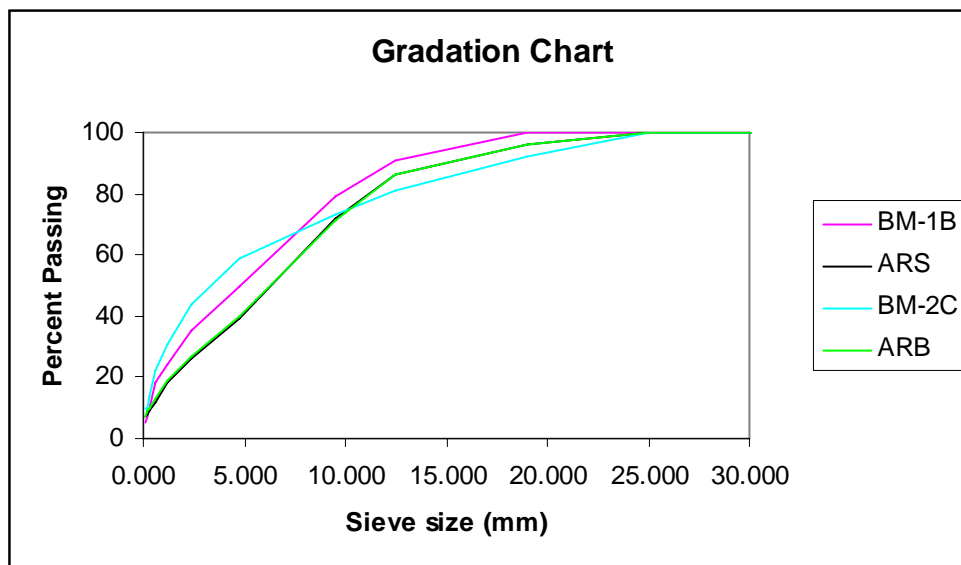
The BM-1B mixture was also designed by the Marshall method, but with 50 blows. This mixture had 4.75% (AC-10) design asphalt content. The blend consisted of 35% CS-1D (3/4-in. NMAS), 16% CS-1K (3/8-in. NMAS), 24% limestone screening (CS-2C, 1/4-in. NMAS) and 25% sand and sand gravel. The

specifications required 75% of the coarse aggregates be crushed. The design gradation provided 75% crushed materials. As shown in Figure 2, this mixture is also dense-graded.

The gradations for the asphalt rubber base (ARB) and asphalt rubber surface (ARS), also shown in Figure 2, are similar to those for BM-2C and BM-1B, respectively. The target asphalt rubber contents for the ARB and ARS mixtures were 7.5% and 9.9%, respectively.

**Table 2. Hot-mix asphalt mixture design details**

Mixture/aggregate blend properties	BM-1B		BM-2C	
	Required	Design	Required	Design
Asphalt content (%)	-	4.75	-	4.25
Air voids (%)	3-5	3.12	3-5	3.15
VMA (%)	KDOT Zone II	11.4	KDOT Zone II	9.26
VFA (%)	65-80	72	65-80	65.9
Stability (lbs)	750+	2402	1500+	3490
Density (cft)	-	148	-	148.7
Filler-to-binder ratio	-	1.48	-	1.66
Crushed aggregates	75% min	75%	50% min	75%



**Figure 2. Blend gradations of the hot-mix asphalt mixtures**

## PERFORMANCE EVALUATION OF THE TEST SECTIONS

As early as in 1995, some test sections were experiencing premature failure. The predominant distresses reported were rutting followed by fatigue cracking.

### Rutting

Rutting is a longitudinal depression in the wheel paths of the pavement surface that develops gradually with increasing load repetitions. Rutting can result from the permanent deformation in any or all of the pavement layers and subgrade. Three types of rutting were considered in the evaluation of the SPS-1 test sections: densification or one-dimensional consolidation; plastic/shear flow of HMA materials from

wheel loads; and mechanical deformation or subsidence in the base, subbase, or subgrade, accompanied by distress patterns at the surface when the mix is too stiff or rigid.

Soon after construction was completed, two sections with an ARS, KDOT #3 and KDOT #5, started to show the first signs of rutting (Gisi and Dietz 1997). The severity of rutting varied from section to section. Sections SHRP #1 (7.6-in. BM-1B/8.5-in. DGAB), SHRP #2 (4-in. BM-1B/12.3-in. DGAB), SHRP #4 (4.1-in. BM-1B/4.1-in. PATB/3.7-in. DGAB), KDOT #1 (1.5-in. BM-1B/4-in. BM-2C/7-in. DGAB/GG), and KDOT #2 (1.5-in. BM-1B/4-in. BM-2C/11-in. DGAB) were experiencing one-dimensional consolidation (densification)-type of rutting. This may indicate rutting in any or all layers of the sections.

Sections KDOT #1 (1.5-in. BM-1B/4-in. BM-2C/7-in. DGAB/GG) and KDOT #2 (1.5-in. BM-1B/4-in. BM-2C /11-in. DGAB) had rutting in the wheel paths with ride quality in some areas being affected. Sections KDOT #3 (1.5-in. ARS/9.9-in. BM-2C), KDOT #5 (1.5-in. ARS/2.5-in. ARB/8-in. DGAB), and KDOT #6 (1.5-in. ARS/2.5-in. ARB/8-in. BM-2C), which are the KDOT asphalt rubber sections, had consolidation as well as lateral movement of asphalt mixture materials (shear displacement).

Some of the rutting in section KDOT #3 (1.5-in. ARS/9.9-in. BM-2C) was due to densification of the ARS on the wheel path, but not all was associated with it. Hot weather during the summer also contributed to rutting on this section. Rutting in section KDOT #6 (1.5-in. ARS/2.5-in. ARB/8-in. BM-2C) was due to an unstable base and ARS densification in the wheel paths. Some of the rutting in sections SHRP #1 (7.6-in. BM-1B/8.5-in. DGAB) and SHRP #2 (4-in. BM-1B/12.3-in. DGAB) was due to asphalt mixture densification on the wheel paths, and some of the rutting in SHRP #2 (4-in. BM-1B/12.3-in. DGAB) was attributed to poor subgrade compaction. These sections were repaired primarily by milling and overlay (mill 4 inches and inlay with 4 inches of BM-2). Figures 3 through 10 show the measured rut depth trends on some of the sections up to 1996.

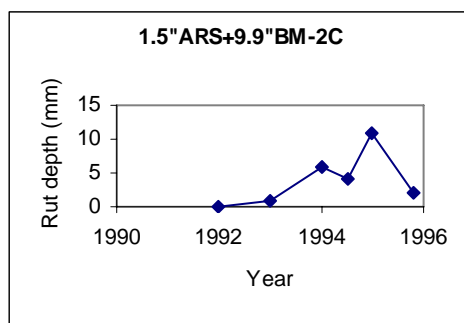


Figure 3. Rutting on section KDOT #3

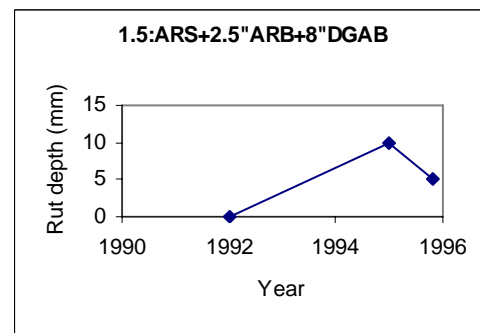


Figure 4. Rutting on section KDOT #5

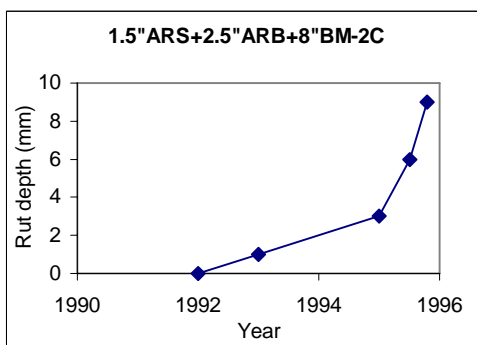


Figure 5. Rutting on section KDOT #6

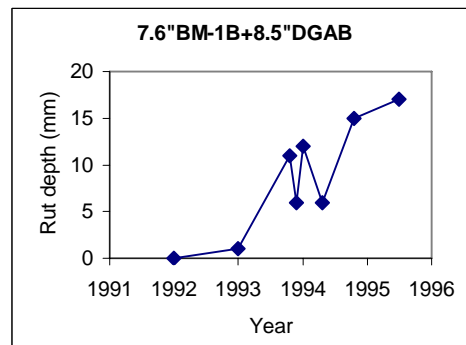


Figure 6. Rutting on section SHRP #1

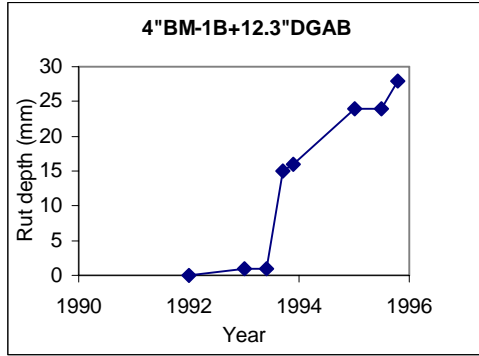


Figure 7. Rutting on section SHRP #2

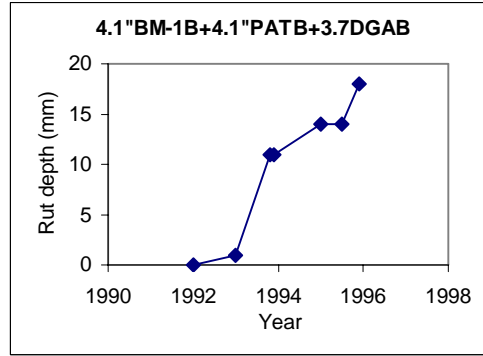


Figure 8. Rutting on section SHRP #4

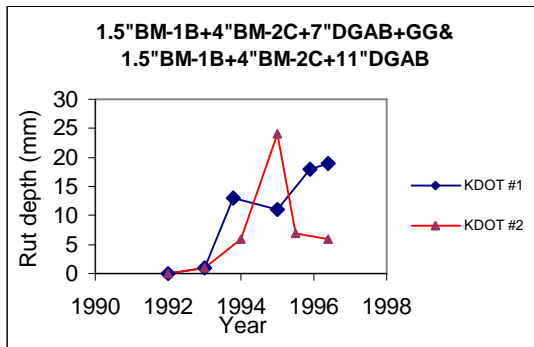


Figure 9. Rutting on section KDOT #1 & #2

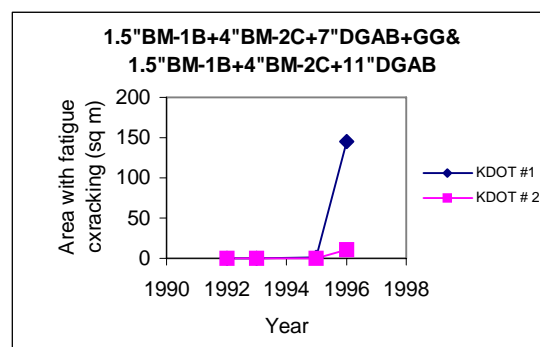


Figure 10. Fatigue cracking on section KDOT #1 & #2

## Cracking

Sections KDOT #1 (1.5-in. BM-1B/4-in. BM-2C/7-in. DGAB/GG) and KDOT #2 (1.5-in. BM-1B/4-in. BM-2C/11-in. DGAB) were observed to have major cracking problems. The DGAB fines appeared through the cracks in the ruts. These sections had indicated rutting failure and cracking. Laboratory testing on the cores showed that the rutting in section KDOT #1 (1.5-in. BM-1B/4-in. BM-2C/7-in. DGAB/GG) was due to unstable surface and base layers. KDOT #1 and KDOT #2 were milled up to four inches and inlaid with a BM-2 mix in 1997. A three-inch BM-2 overlay was then placed on both sections.

Sections SHRP #1 (7.6-in. BM-1B/8.5-in. DGAB), SHRP #2 (4-in. BM-1B/12.3-in. DGAB), and SHRP #4 (4.1-in. BM-1B/4.1-in. PATB/3.7-in. DGAB) indicated rutting as well as map or alligator cracking. Section SHRP #2 (4-in. BM-1B/12.3-in. DGAB) had one-inch-deep ruts in both wheel paths in 1996. It was suggested that a four-inch mill and inlay be used if the deterioration continued. The deficiencies mentioned above were summarized by the KDOT Geotechnical Unit in Table 3.

Sections KDOT #3 (1.5-in. ARS/9.9-in. BM-2C) and KDOT #5 (1.5-in. ARS/2.5-in. ARB/8-in. DGAB) were milled and overlaid in December of 1995. Test sections KDOT #6 (1.5-in. ARS/2.5-in. ARB/8-in. BM-2C), SHRP #1 (7.6-in. BM-1B/8.5-in. DGAB), SHRP #2 (4-in. BM-1B/12.3-in. DGAB), and SHRP #4 (4.1-in. BM-1B/4.1-in. PATB/3.7-in. GAB) showed signs of rutting along with block cracking and were repaired in the summer of 1996.

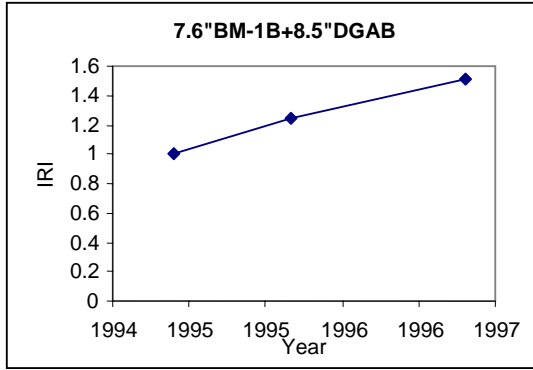
Most of the sections that experienced premature distresses by 1996 had a design life of more than 10 years (Table 1) except for section SHRP #2 (4-in. BM-1B/12.3-in. DGAB), which had an estimated life of 4.5 years. The whole SPS-1 project was overlaid with a one-inch BM-1T overlay in the fall of 2000.

**Table 3. Assessment of deficiencies for SHRP and KDOT sections (Gisi and Dietz 1997)**

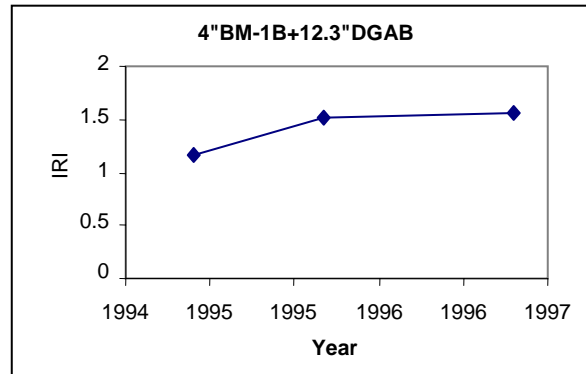
<b>Test section</b>	<b>Deficiencies</b>
SPS-1 control section	Minor rutting, longitudinal cracking in middle of the lane, map cracking near the west end of the west bound lane
SHRP #1 (7.6-in. BM-1B/8.5-in. DGAB)	Milled 4 inches, inlaid 4 inches (BM-2) in 1996; no visible distresses
SHRP #2 (4-in. BM-1B/12.3-in. DGAB)	Milled 4 inches, inlaid 4 inches (BM-2) in 1996; no visible distresses in 1997
SHRP #3 (7.3-in. BM-1B/ 7.3-in. ATB/4-in. DGAB)	Map cracking in the wheel paths
SHRP #4 (4.1-in. BM-1B/ 4.1-in. PATB/ 3.7-in. DGAB)	Milled 4 inches, inlaid 4 inches (BM-2) in 1996; no visible distresses in 1997
SHRP #5 (7.6-in. BM-1B/3.6-in. PATB/ 7.9-in. DGAB)	Minor rutting and map cracking in the wheel paths
SHRP #6 (7-in. BM-1B/3.6-in. PATB/ 11.9-in. DGAB/)	Minor rutting and map cracking in the wheel paths
SHRP #7 (7-in. BM-1B/3.8-in. ATB/ 3.9-in. PATB)	Minor rutting and map cracking in the wheel path
SHRP #8 (5"BM-1B/12"ATB/3.6PATB)	Map cracking in the wheel paths
SHRP #9 (4-in. BM-1B/ 8.5-in. ATB/3.6-in. PATB)	0.5-in. rutting and map cracking in the wheel paths
SHRP #10 (3.9-in. BM-1B/ 3.8-in. ATB/4.1-in. DGAB)	1.0-in. rutting and map cracking in the wheel paths
SHRP #11 (3.6-in. BM-1B/7.7-in. ATB)	Map cracking in the wheel paths
SHRP #12 (6.8-in. "BM-1B/12.1-in. ATB)	Map cracking in the wheel paths
KDOT #1 (1.5-in. BM-1B/4-in. BM-2C/ 7-in. DGAB/GG)	1.5-in. rutting, map cracking in wheel paths; surface staining, and maintenance patching has been done; scheduled for milling, inlaying, and overlaying in summer 1997
KDOT #2 (1.5-in. BM-1B/ 4-in. BM-2C/11-in. DGAB)	1-in. rutting, map cracking in wheel ruts, longitudinal cracking, surface staining; minor maintenance patching has been done; scheduled for milling, inlaying, and overlaying in summer 1997
KDOT #3 (1.5-in. ARS/9.9-in. BM-2C/ 8- in. DGAB)	Milled 4 inches, inlaid 4 inches (BM-2) in 1995; rutting is beginning to appear
KDOT #5 (1.5-in. ARS/2.5-in. ARB/ 8-in. DGAB)	Milled 4 inches, inlaid 4 inches (BM-2), overlaid 3 inches
KDOT #6 (1.5-in. ARS/2.5-in. ARB/ 8-in. BM-2C)	Milled 4 inches, inlaid 4 inches (BM-2) in 1996; no visible distresses

**International Roughness Index**

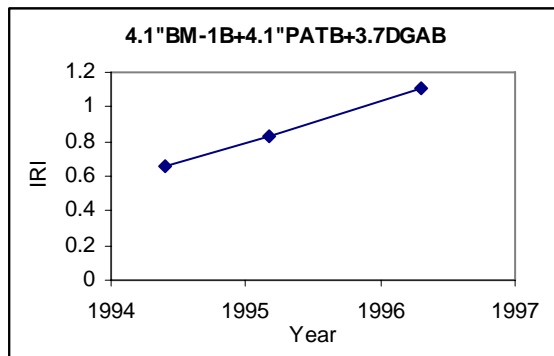
The ride quality of the test sections was assessed by the International Roughness Index (IRI) values. Test sections with thicker and/or treated base layers had slightly lower IRI values than those with thin and/or untreated base layers. Figures 11 to 17 show the measured IRI values up to 1997.



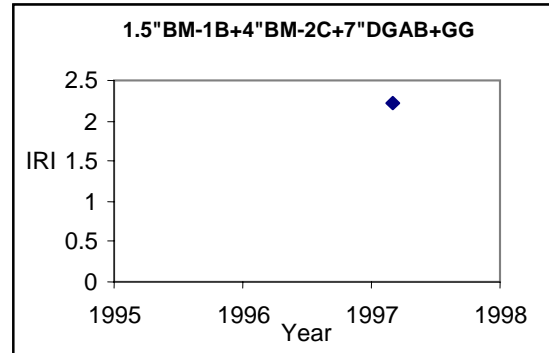
**Figure 11. IRI on section SHRP #1**



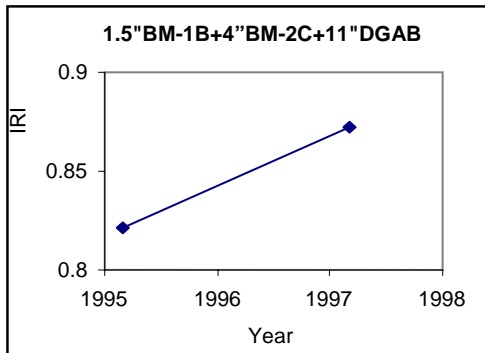
**Figure 12. IRI on section SHRP #2**



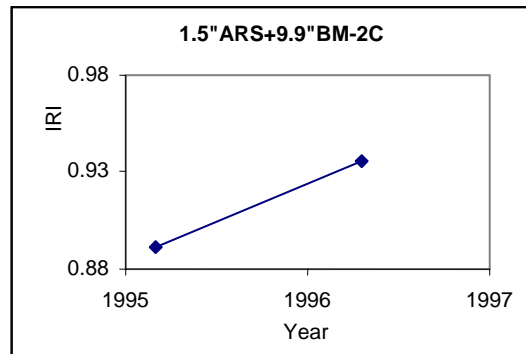
**Figure 12. IRI on section SHRP #4**



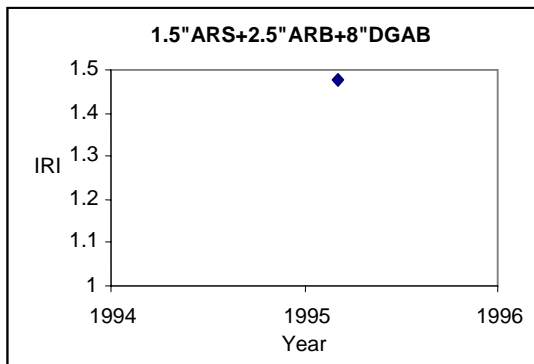
**Figure 13. IRI on section KDOT #1**



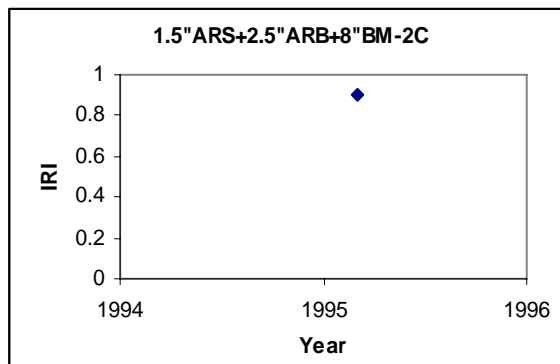
**Figure 14. IRI on section KDOT #2**



**Figure 15. IRI on section KDOT #3**



**Figure 16. IRI on section KDOT #5**



**Figure 17. IRI on section KDOT #6**

## ASSESSMENT OF OBSERVED DEFICIENCIES

### Field and Laboratory Measurements

#### *Field Measurements*

A rut-depth survey was done in January of 1996 with a rod and level. Cores from the inner and outer wheel paths were also retrieved. The falling weight deflectometer (FWD) tests were carried out on sections KDOT #1 (1.5-in. BM-1B/4-in. BM-2C/7-in. DGAB/GG) and KDOT #2 (1.5-in. BM-1B/4-in. BM-2C /11-in. DGAB) in March 1997 (Gisi and Dietz 1997). DARWin 3.0 software was used to backcalculate the effective pavement and subgrade resilient moduli using the 1993 AASHTO design guide algorithms. The deflections obtained at both the outer wheel path (OWP) and the mid-lane path (MLP) locations were analyzed.

For section KDOT #1 (1.5-in. BM-1B/4-in. BM-2C/7-in. DGAB), the subgrade modulus at the OWP (5,330 psi) was somewhat lower than that at the MLP location (6,750 psi). The effective pavement modulus at the OWP location (43,740 psi) was more than 50% lower than that at the MLP location (78,230 psi). Thus, the effective structural number ( $SN_{eff}$ ) at the OWP location was much lower than that at the MLP location (1.98 vs. 2.41). On section KDOT #2 (1.5-in. BM-1B/4-in. BM-2C/11-in. DGAB), the backcalculated subgrade moduli at both locations were comparable (6,960 psi and 7,100 psi). The effective pavement moduli (93,170 psi and 87,100 psi) were also comparable, as were the effective structural numbers (3.37 vs. 3.29). It is to be noted that the geogrid in section KDOT #1 (1.5-in. BM-1B/4-in. BM-2C/7-in. DGAB/GG) was assumed to be equivalent to 4 inches of DGAB in the original design. The distress survey and FWD test results do not appear to support this assumption.

From the FWD analysis, it was determined that section KDOT #1 (1.5-in. BM-1B/4-in. BM-2C/7-in. DGAB/GG) would require an additional 6 inches of hot mix asphalt overlay to support the traffic (2,962,000 ESALs) for the next ten years and section KDOT #2 (1.5-in. BM-1B/4-in. BM-2C/11-in. DGAB) would require an additional 2 inches for the same time period.

#### *Physical Properties*

The density and permeability tests conducted on the cores retrieved from the test sections were used to analyze the void characteristics. Test results showed that the density was greater in the wheel path than outside of the wheel paths. This indicates that there were fewer air voids in the wheel path, and shear flow of asphalt materials might be responsible for this. Density comparisons were also used to measure rutting resulting from densification of AC material. The amount of rutting from the laboratory cores showed slightly lower rutting potential when compared to the transverse roadway profiles obtained from the rod-and-level survey.

#### *Mechanical Tests*

Stability tests were performed after the permeability tests. Cores with low permeability were remixed and compacted to the nearest field density by the Corps of Engineers Gyratory Testing Machine (GTM). The GTM results are useful for identifying mixtures susceptible to localized shear failure or lateral movement of hot-mix asphalt material. A gyratory stability index (GSI) was measured from the plot of the compaction curve by empirically relating the number of revolutions required to reproduce the in-place density. If the GSI value exceeds one, the mix is unstable on the rich side of the compaction curve, and progressive rutting would occur under hot weather conditions. The results showed that the ARB mix in section KDOT #5 (1.5-in. ARS/2.5-in. ARB/8-in. DGAB) and the BM-1B and BM-2C mixes in section

KDOT #1 (1.5-in. BM-1B/4-in. BM-2C/7-in. DGAB) were unstable and might have contributed to rutting on these sections.

Gradation tests were run on the DGAB materials for sections KDOT #1 (1.5-in. BM-1B/4-in. BM-2C/7-in. DGAB) and KDOT #2 (1.5-in. BM-1B/4-in. BM-2C/11-in. DGAB). The results showed that the materials have similar gradations and that they fall well within the required DGAB specifications. However, material passing the No. 200 sieve lies near the maximum percent passing of the grading band.

On both KDOT #1 and KDOT #2, the tensile strength ratios (TSR) determined from the modified Lottman tests on the cores were initially found to be very low for the BM-2C mixes (42% for KDOT #1 and 30% for KDOT #2). The cores were then reheated and recompact to densities comparable to the core densities and the tests were rerun. For the recompact BM-2C mixes, the TSR was 57% corresponding to 57% saturation, which was lower the required minimum value. The TSR for BM-1B was 78.9%, which is slightly lower than the minimum 80% required for the Superpave mixes. Therefore the surface mix BM-1B indicated non-susceptibility to stripping, while the base mix BM-2C might be susceptible to stripping.

## **LTPP EVALUATION OF KANSAS SPS-1 PROJECT**

The LTPP program recently published a report on the initial evaluation of all SPS-1 projects (Von Quintus and Simpson, 2003). The report contains the following findings related to the performance of the SPS-1 project in Kansas:

- The excessive moisture in the subgrade caused problems throughout the project. The contractor had difficulty compacting the material to proper density. Fly ash was used to stabilize the subgrade. This resulted in sections not having uniform, homogeneous platforms.
- The elevation survey indicated that all sections except SHRP #7, SHRP #10, and SHRP #12 had thickness deviations of more than 0.24 in. (6 mm).
- On average, sections with unbound aggregate base layers were found to have higher rut depths, while those with ATB layers had the lowest.
- Some sections had high IRI values immediately after construction because of fine-grained subgrade soil and construction difficulties.
- Sections with unbound aggregate layers had slightly more fatigue cracking than those with ATB.
- Sections with a thick HMA surface layer exhibited a greater average area of fatigue cracking than did the companion sections with a thin HMA surface layer.

## **CONCLUSION**

The results of this study show that rutting failure on most sections in the Kansas SPS-1 project can be attributed to a deficiency in the mixtures. Cracking was also observed on some of the sections that failed due to excessive rutting. Some valuable conclusions can be drawn from this study:

- The SPS-1 project faced construction difficulties due to excessive moisture in the subgrade and subbase. Variable densities were obtained for those layers.
- Although traffic is known to be a major contributor to pavement failure, the traffic data for these sections indicates that the failures that occurred in some of the sections by 1995 had very little to do with traffic.
- The asphalt rubber mixtures performed very poorly. The asphalt rubber sections rutted immediately after construction, and rutting severity increased rapidly during the first three years. These sections were the first ones to be rehabilitated.
- Most of the sections with dense-graded aggregate bases experienced premature distresses. The sections with ATB layers had lower measured rut values than those with DGAB. The HMA

pavements with aggregate base layers had slightly more fatigue cracking than those with ATB layers. The HMA pavements with thicker base layers are smoother than those with thin layers.

- BM-1B and BM-2C were reported as unstable mixes and BM-2C did not provide good moisture resistance. Furthermore, the geogrid used in one section did not make any significant difference, compared to a companion section without it.
- Most sections, which had in-pavement drainage, did not experience premature failure within the first three years of evaluation, compared to the failed sections without in-pavement drainage. These sections were smoother with less fatigue cracking and lower rut depths.
- The test sections with thick HMA surface layer exhibited a greater average area of fatigue cracking than did the companion sections with thin HMA surface layers.

## REFERENCES

- Federal Highway Administration. 1993. *Specific Pavement Studies: Construction Guidelines for Experiment SPS-1; Strategic Study of Structural Factors for Flexible Pavement*. McLean, VA: Long-Term Pavement Performance Division, Turner-Fairbank Highway Research Center.
- Gisi, A. and J. M. Dietz. 1997. *Report of Pavement Investigation 54-49 K-3196-01, Kansas SPS-1 Experimental Project, US-54 East Greensburg, Kiowa County*. Topeka, KS: Geotechnical Unit, Bureau of Materials and Research, Kansas Department of Transportation.
- Johnson, A.M. 1994. *SPS-1 Construction Report, US-54 Near Greensburg, Kansas, Sections 200101 to 200164*. St. Paul, MN: Braun Intertec Corp.
- Von Quintus, H.L. and A.L. Simpson. 2003. *Structural Factors for Flexible Pavements - Initial Evaluation of the SPS1 Experiment*. Final Report FHWA-RD-01-166. McLean, VA: Research Development and Technology Division, Federal Highway Administration, Turner-Fairbank Highway Research Center.