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LTPP Data Analysis: Effectiveness of Maintenance and Rehabilitation Options

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Submitted by:

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Author Acknowledgments

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Summary of Findings

NCHRP Project 20-50(03/04) was conducted to assess the relative performance of different pavement maintenance and rehabilitation treatments, including the influence of pretreatment condition and other factors on treatment effectiveness. The data used in this study were drawn from the Long-Term Pavement Performance Studies' SPS-3 (flexible pavement maintenance), SPS-5 and GPS-6B (flexible pavement rehabilitation), and SPS-6 and GPS-7B (rigid pavement rehabilitation) experiments.

In terms of roughness, rutting, and fatigue cracking, the most effective of the maintenance treatments in the SPS-3 core experiment has been the thin overlay treatment, followed by the chip seal treatment, and then the slurry seal treatment. The thin overlay treatment was the only one of the four SPS-3 maintenance treatments to produce an initial (albeit small) reduction in roughness, and the only one of the four to have a significant effect on long-term roughness, relative to the control sections. For rougher pavements, however, there was some evidence that chip seals and slurry seals also had some effect on long-term roughness, rutting, and cracking, relative to the control sections. Crack seals did not have any significant on long-term roughness, rutting, or fatigue cracking.

Overall, overlay thickness and preoverlay roughness level were the two factors that most influenced the performance of asphalt overlays of asphalt pavements in the SPS-5 experiment, with respect to roughness, rutting, and fatigue cracking. The 5-inch overlays have outperformed 2-inch overlays with respect to roughness, rutting, and fatigue cracking. Overlay mix type (virgin versus recycled) and preoverlay preparation (with or without milling) have had slight and inconsistent effects. The average initial postoverlay IRI of an asphalt overlay of an asphalt pavement, in both the SPS-5 and GPS-6B experiments, was found to be 0.98 m/km. However, both data sets show a slight but statistically significant tendency for asphalt pavements overlaid when rougher to have somewhat more initial roughness after overlay than asphalt pavements overlaid when smoother.

The rutting data from the SPS-5 and GPS-6B experiments indicate that on average, about 6 mm of rutting develops in the first year or so after placement of an asphalt overlay of an asphalt pavement. This is presumably due to compaction of the mix by traffic, and appears to be independent of the overlay thickness, mix type, preoverlay preparation, and preoverlay rutting level.

Overall, the rigid pavement rehabilitation treatments in the SPS-6 experiment could be from most to least effective in the following order: 8-inch overlay of cracked/broken and seated pavement, 4-inch overlay (of either intact or cracked/broken and seated pavement, with or without sawing and sealing of joints, and with either minimal or intensive preoverlay repair), concrete pavement restoration with diamond grinding, and concrete pavement restoration without diamond grinding. Concrete pavement restoration with diamond grinding yielded an initial posttreatment IRI of 1.05 m/km on average, whereas restoration without diamond grinding yielded no benefit in terms of IRI, and in fact tended to leave the pavement rougher than before.

Concrete pavement rehabilitation with an asphalt overlay yielded a slightly better IRI, 1.00 m/km, almost exactly the same as that of asphalt overlays of asphalt pavements. Unlike the asphalt overlays of asphalt pavements in the SPS-5 and GPS-6B experiments, however, the asphalt overlays of concrete pavements in the SPS-6 and GPS-7B experiments did not demonstrate any correlation between preoverlay IRI and initial postoverlay IRI. In the long term, both restoration and overlay treatments reduced long-term roughness, rutting, and cracking levels, compared to the control sections, but the restored test sections are approaching the control sections in condition faster than are the overlay sections.

As with asphalt overlays of asphalt pavements, much of the rutting that occurs in asphalt overlays of concrete pavements in the first twelve years or so of service develops within the first year or so. In both the SPS-5 and SPS-6 experiments, however, the long-term rutting data are so erratic that analysis of long-term trends is problematic.

No significant difference in long-term cracking performance was detected between minimal versus intensive preoverlay preparation, nor between sections without versus with sawed and sealed joints, nor between four-inch overlays with sawed-and sealed joints versus those over cracked/broken and seated pavements, nor between four-inch versus eight-inch overlays of cracked/broken and seated pavements.

Chapter 1

Introduction

What is pavement maintenance? What is pavement rehabilitation? For the purposes of this report, **maintenance** is defined as preservation of pavement condition, safety, and ride quality. **Rehabilitation** is defined as a structural or functional enhancement that produces substantial extensions in service life, by substantially improving pavement condition and ride quality. Maintenance and rehabilitation are two different objectives. To describe them as two separate groups of techniques blurs the distinction between them, because many techniques are used for both maintenance and rehabilitation.

What effects do maintenance and rehabilitation treatments have on pavement performance? Many millions of dollars are spent on pavement maintenance and rehabilitation every year in the United States. Yet we still are not able to quantify very well the initial and long-term effects of different maintenance and rehabilitation treatments on pavement performance.

The common definition of pavement performance is the serviceability history of the pavement.[1] Performance may be quantified by the area under the curve of serviceability versus time or traffic.[2] This is illustrated in Figure 1. For the purpose of life-cycle cost analysis of pavement design, maintenance, or rehabilitation alternatives, it is important to be able to estimate the performance of the different alternatives under consideration.

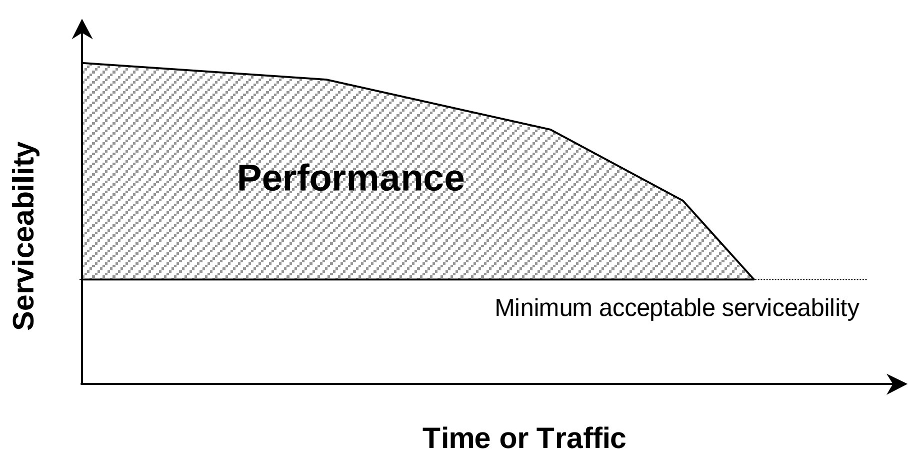

Figure 1. Pavement performance quantified by the area under the serviceability curve.

The following issues related to the effects of maintenance and rehabilitation were studied in NCHRP Project 20-50(03/04):

- The relative effectiveness of different maintenance and rehabilitation treatments in producing immediate improvements in pavement condition,
- The relative effectiveness of different maintenance and rehabilitation treatments in producing long-term changes in pavement condition, and
- The influence of climate, traffic level, pretreatment structural capacity, and pretreatment condition on the effectiveness of different maintenance and rehabilitation treatments.

Research Objectives

The specific objectives of NCHRP Project 20-50(03/04) were the following:

(1) To identify, based on the data available from the LTPP studies, the pre-maintenance and pre-rehabilitation conditions that influence the performance (as measured by distress) of each maintenance and rehabilitation option, and

(2) To determine, based on LTPP data, the relative performance of the different maintenance and rehabilitation options.

The research deals with rehabilitation of flexible and rigid pavements and maintenance of flexible pavements. It does not address maintenance of rigid pavements. The specific LTPP experiments relevant to this study were SPS-3 (flexible pavement maintenance), SPS-5 and GPS-6B (flexible pavement rehabilitation), and SPS-6 and GPS-7B (rigid pavement rehabilitation). For the three SPS experiments mentioned, the research was confined to analysis of data from the core experimental sections, that is, not including agency supplemental sections. The data used in this research were the data available, at all quality levels, in LTPP data release 11.5, dated 13 June 2001.

It was not an objective of this research study to estimate the typical lives of the different maintenance and rehabilitation treatments used in the these experiments, nor to develop performance prediction models for the treatments. Indeed, such activities were explicitly excluded from the scope of this study. The focus of this research is on the relative effectiveness of the different maintenance and rehabilitation treatments, and the influence of pretreatment condition and other factors on the relative effectiveness of the treatments.

The most effective treatment is not always the most cost-effective treatment. It was not an objective of this research study to identify which maintenance or rehabilitation treatments are likely to be most cost-effective at different times in a pavement's life (i.e., at different condition levels). Such an assessment cannot be based on condition data alone, but rather should be based on an analysis of condition data together with with predicted performance of different maintenance and rehabilitation alternatives, and the life-cycle costs of those alternatives.

Organization of this Report

The research conducted for NCHRP Project 20-50(03/04) is described in this report in the following sequence:

- Chapter 1 – Introduction and research approach.
- Chapter 2 – Flexible pavement maintenance effectiveness.
- Chapter 3 – Flexible pavement rehabilitation effectiveness
- Chapter 4 – Rigid pavement rehabilitation effectiveness,
- Chapter 5 – Conclusions.
- Appendix A – Supporting material for analysis of flexible pavement maintenance effectiveness.
- Appendix B – Supporting material for analysis of flexible pavement rehabilitation effectiveness.
- Appendix C – Supporting material for analysis of rigid pavement rehabilitation effectiveness.

References Chapter 1

[1] W. N. Carey and P. E. Irick, "The Pavement Serviceability – Performance Concept, *Highway Research Bulletin* No. 250, 1960.

[2] Huang, Y. H., *Pavement Analysis and Design*, copyright 1993, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, page 427.

Chapter 2

Flexible Pavement Maintenance Effectiveness

Description of LTPP Experiment SPS-3

The SPS-3 experiment was designed to assess the performance of different flexible pavement maintenance treatments, relative to the performance of untreated control sections. The experiment design was developed by the Texas Transportation Institute, under SHRP Highway Operations contracts.[3] The core SPS-3 experiment consists of a control section and four maintenance treatments, listed in Table 1. Agency supplemental test sections are also present at several SPS-3 sites. These are additional test sections for study of maintenance treatments of interest to the participating highway agency.

Table 1. SPS-3 core experimental sections.

Test section number	Treatment
310	Thin overlay
320	Slurry seal
330	Crack seal
340	Control
350	Chip seal

The thin overlays were nominally 1.5 inches thick. These overlays were placed by the state and provincial highway agencies, using their own asphalt concrete mixes and their own crews. The slurry seals and chip seals were placed by four contractors, one in each of the four LTPP regions. The material specifications were the same for all four regions, but a different source was used for each region. The material used for crack sealing was the same for all sites in all regions, but the installation procedures varied. Four different installation crews, one in each region, applied the crack sealant.

Thus, for the crack seals, the installation crews varied by region. For the slurry seals and chip seals, both the materials and installation crews varied by region. For the thin overlays, both the materials and installation crews varied by state or province.

SPS-3 experiments were placed at 81 sites in the United States and Canada, in 1990 and 1991. Their locations are illustrated in Figure 2.† Location data for the SPS-3 sites are given in Table 2.

Figure 2. SPS-3 locations.

Every SPS-3 site is located adjacent to a GPS-1 or GPS-2 test section, and is linked to this GPS site in the LTPP database. Thirty of the 81 SPS-3 sites have no control (340) test section; at these sites, the linked GPS site serves as the control. Those 30 GPS sections that serve as controls for SPS-3 sites are indicated in bold italics in Table 2.

† All maps in this report were printed using Microsoft ® Streets and Trips 2001, copyright © 1988-2001 Microsoft Corp. and/or its suppliers.

Table 2. SPS-3 location data.

SHRP ID	State	Linked GPS	County	Nearby city or town	Route	Latitude	Longitude
01A300	AL	014125	Montgomery	Montgomery	SR 152	32.42	86.24
01B300	AL	011019	Washington	Sunflower	US 43	31.35	88.03
01C300	AL	014155	Houston	Clayhatchee	US 84	31.24	85.57
04A300	AZ	***041036***	Mohave	Kingman	US 93	35.71	114.47
04B300	AZ	***041021***	Mohave	Kingman	I-40	35.16	113.68
04C300	AZ	041017	Pima	Kingman	I-19	31.77	111.04
04D300	AZ	***041016***	Santa Cruz	Nogales	I-19	31.64	111.06
05A300	AR	***053071***	Benton	Springdale	US 71	36.27	94.15
06A300	CA	061253	Butte	Chico	SR 32	39.77	121.73
08A300	CO	081053	Delta	Grand Junction	US 50	38.70	108.03
08B300	CO	***082008***	Bent	Las Animas	US 50	38.09	103.19
12A300	FL	***129054***	Nassau	Yulee	SR 200	30.62	81.63
12B300	FL	***123997***	Clay	Hibernia	US 17	30.09	81.71
12C300	FL	***124154***	Volusia	Edgewater	SR 442	28.95	80.94
16A300	ID	***161020***	Jerome	Twin Falls	US 93	42.74	114.44
16B300	ID	***161021***	Jefferson	Idaho Falls	US 20	43.65	111.93
16C300	ID	***161010***	Jefferson	Idaho Falls	I-15	43.68	112.12
17A300	IL	171003	Clinton	Aviston	US 50	38.62	89.63
17B300	IL	171002	Stevenson	Freeport	US 20	42.32	89.61
18A300	IN	181028	Spencer	Dale	I-64	38.20	87.02
19A300	IA	196150	Sac	Pettis	SR 196	42.35	94.96
20A300	KS	201005	Franklin	Ottawa	SR 68	38.62	95.25
20B300	KS	201010	Ford	Ford	US 400 *	37.64	99.75
21A300	KY	211010	Owsley	Booneville	SR 11	37.48	83.71
21B300	KY	211034	Barren	Glasgow	Cumb Pkwy	36.99	85.97
24A300	MD	241634	Worcester	Salisbury	SR 90	38.37	75.26
26A300	MI	261013	Montcalm	Howard City	US 131	43.44	85.49
26B300	MI	261012	Mecosta	Big Rapids	US 131	43.71	85.53
26C300	MI	261001	Clare	Harrison	SR 61	44.03	84.92
26D300	MI	261010	Genesee	Thetford Center	SR 57	43.18	83.66
27A300	MN	271016	Beltrami	Bimidji	US 71	47.52	94.91
27B300	MN	276251	Beltrami	Bimidji	US 2	47.46	94.91
27C300	MN	271028	Otter Tail	Frazee	US 10	46.68	95.67
27D300	MN	271019	Mille Lacs	Princeton	US 169	45.59	93.60
28A300	MS	***281802***	Covington	Collins	US 84	31.70	89.42
29A300	MO	291005	Miller	Bagnell	US 54	38.25	92.60
29B300	MO	291002	Cole	Stringtown	SR 3	38.53	92.34

Table 2. SPS-3 location data (continued).

SHRP ID	State	Linked GPS	County	Nearest city or town	Route	Latitude	Longitude
30A300	MT	***301001***	Judith Basin	Geyser	US 87	47.24	110.47
31A300	NE	311030	Furnas	Arapahoe	US 6	40.31	99.84
32A300	NV	***321021***	Washoe	Reno	SR 650	39.56	119.76
32B300	NV	327000	Elko	Wendover	I-80	40.88	114.25
32C300	NV	***322027***	Elko	Wells	I-80	40.99	114.43
36A300	NY	361643	Washington	Fort Ann	US 4	43.44	73.46
36B300	NY	361644	St. Lawrence	Cranberry Lake	SR 3	44.25	74.77
40A300	OK	404087	Jackson	Altus	US 62	34.64	99.29
40B300	OK	***401015***	Seminole	Seminole	SR 3E/US377 *	35.19	96.67
40C300	OK	***404088***	Kay	Tonkawa	US 60	36.69	97.27
42A300	PA	421605	Northumberland	Milton	SR 147	41.00	76.83
42B300	PA	421597	Tiogo	Nelson	SR 49	41.97	77.24
47A300	TN	***473101***	Cannon	Auburntown	SR 96	35.94	86.12
47B300	TN	***473075***	De Kalb	Cookeville	SR 56	36.07	85.74
47C300	TN	***471023***	Anderson	Lake City	I-75	36.19	84.10
48A300	TX	481094	Bexar	Helotes	SR 16	29.60	98.71
48B300	TX	481069	Kaufman	Crandall	US 175	32.62	96.43
48D300	TX	***482172***	Mitchell	Westbrook	I-20	32.36	100.99
48E300	TX	481183	Garza	Southland	US 84	33.33	101.52
48F300	TX	483579	Van Zandt	Canton	SR 19	32.62	95.85
48G300	TX	***481169***	Rusk	Henderson	SR 322	32.20	94.80
48H300	TX	481050	Grimes	Stoneham	SR 105	30.35	95.92
48I300	TX	483559	Walker	Huntsville	SR 30	30.70	95.64
48J300	TX	481122	Wilson	Elmendorf	US 181	29.24	98.25
48K300	TX	489005	Bexar	Helotes	SR 1560	29.52	98.72
48L300	TX	483769	El Paso	El Paso	US 62	31.80	106.26
48M300	TX	483749	Duval	Freer	US 59	27.93	98.56
48N300	TX	483739	Kenedy	Sarita	US 77	26.98	97.80
48Q300	TX	483865	Mills	Mullin	US 84	31.57	98.67
49A300	UT	***491004***	Garfield	Spry	US 89	38.03	112.36
49B300	UT	***491017***	Sevier	Sevier	US 89	38.57	112.26
49C300	UT	***491006***	Sanpete	Gunnison	SR 28	39.19	111.84
51A300	VA	511023	Prince	Petersburg	I-95	37.02	77.39
53A300	WA	***531008***	Spokane	Spokane	US 195	47.56	117.39
53B300	WA	***531501***	Douglas	Waterville	US 2	47.65	120.07
53C300	WA	***531801***	Clark	Washougal	SR 14	45.57	122.31
56A300	WY	***561007***	Park	Cody	US 14 *	44.50	108.92

Table 2. SPS-3 location data (continued).

SHRP ID	State	Linked GPS	County	Nearest city or town	Route	Latitude	Longitude
56B300	WY	***567775***	Sweetwater	Eden	SR 28	42.00	109.63
83A300	MB	831801	–	Griswold	TCH 1 *	49.77	100.54
87A300	ON	871620	–	Coldwater	400	44.65	79.65
87B300	ON	871622	–	Bracebridge	11	45.11	79.31
89A300	PQ	891021	–	Champlain	40	46.46	72.42
90A300	SK	906420	–	Whitewood	9	50.17	102.30
90B300	SK	906405	–	Plunkett	TCH 16 *	51.90	105.31

* Route numbers are believed to be correct as shown here and incorrect in LTPP database release 11.5.

Climate Characterization

The climatic distribution of the SPS-3 sites was determined by extracting the latitude and longitude for each site from the LTPP database, searching the National Oceanic and Atmospheric Administration (NOAA) database for the weather station nearest the SPS-3 site, and extracting the 30-year average annual precipitation and average annual temperature for the weather station. These data are provided in Appendix A. The distribution of SPS-3 sites with respect to average annual precipitation and temperature is illustrated in Figure 3.

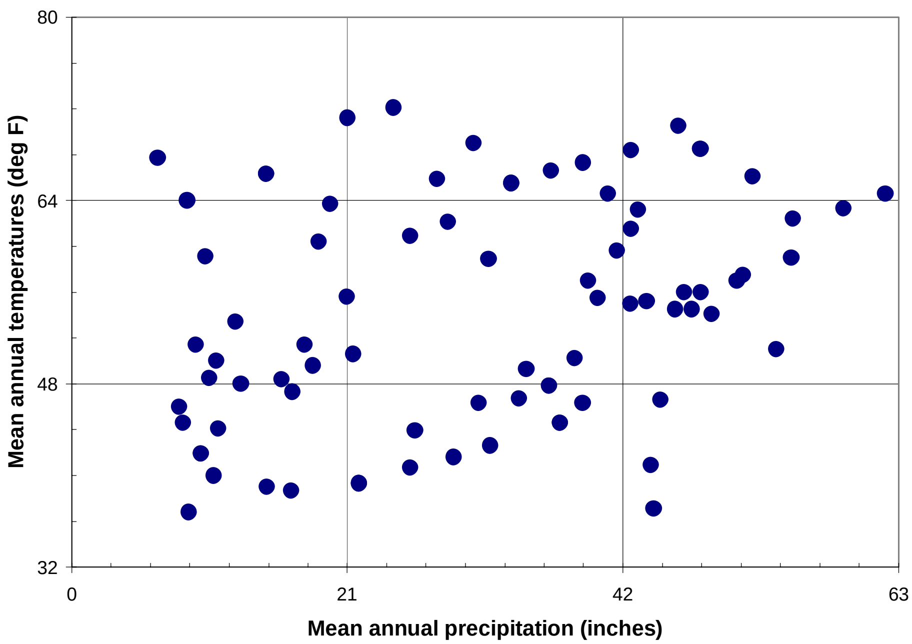

Figure 3. Distribution of SPS-3 sites with respect to precipitation and temperature.

Figure 3 illustrates the precipitation and temperature values used to define "low," "medium," and "high" levels for each:

Average annual precipitation:	Low = Less than 21 inches
	Medium = 21 to 42 inches
	High = More than 42 inches
Average annual temperature:	Low = Less than 48 °F
	Medium = 48 to 64 °F
	High = More than 64 °F

These levels were selected based on examination of the temperature and precipitation ranges covered by all five of the LTPP experiments addressed in this study (SPS-3, SPS-5, SPS-6, GPS-6B, and GPS-7B). The SPS-3 experiment covers the ranges fairly well. The categorization of each site by is also listed in Appendix A.

Test Section Layouts and Pavement Structures

The station limits, layer thicknesses, and material types for each of the SPS-3 test sections and linked GPS sections were extracted from the SPS_PROJECT_STATIONS and TST_L05B data tables in the LTPP database. The thicknesses in the TST_L05B table represent the LTPP regional data collection centers' best estimates of the as-constructed layer thicknesses and materials.

Specifically in the case of the SPS-3 sections, the asphalt concrete layer thicknesses were determined from cores, whereas the thicknesses and materials of the underlying layers were taken to be the same as in the linked GPS section. The test section layout and pavement layer data are given in Appendix A. An example is shown in Figure 4. Note that in this particular example, there is no 340 section; the linked GPS section serves as the control.

Station (m)	Section	Construction Number = 1: AC Thicknesses		Base: Thickness	Base: Type	Subbase: Thickness	Subbase: Type	Subgrade Type	CN = 2: AC Thicknesses	
0 – 152	531008 GPS	3.4		3.1	GB (304)	9.8	GS (304)	SS (257)	1.7 3.9	
152 – 320										
320 – 472	53A320 SlS	3		3.1	GB (304)	9.8	GS (304)	SS (257)	0.2 (72) 2.5	
472 – 503										
503 – 655	53A330 CrS	3.4		3.1	GB (304)	9.8	GS (304)	SS (257)	3.4	
655 – 747										
747 – 899	53A350 ChS	2.8		3.1	GB (304)	9.8	GS (304)	SS (257)	0.2 (71) 2.8	
899 – 960										
960 – 1,113	53A310 ThO	2.5		3.1	GB (304)	9.8	GS (304)	SS (257)	1.8 2.9	

Figure 4. Example SPS-3 pavement structure information.

Structural Characterization

The structures of the SPS-3 pavements at the start of the experiment were characterized using the available layer thickness and materials data, and using deflection data. The as-constructed layer thicknesses and material types were used to calculate a pretreatment Structural Number for each SPS-3 test section. The following structural coefficients were used for this purpose:

Asphalt concrete:	0.44
Treated base:	0.22
Granular base :	0.14
Treated subbase:	0.16
Granular subbase:	0.11

Two deflection-based measures of the pavements' structures were evaluated as well:

- Mean maximum deflection, normalized to 9000 pounds and 68°F; and
- Mean Area Under the Pavement Profile (AUPP), normalized to 9000 pounds and 68°F.

The definition and calculation of AUPP are illustrated in Figure 5. This or any of several other basin curvature parameters may be used to estimate the strain in the asphalt concrete layer, which in turn may be used to estimate the remaining fatigue life of the pavement.

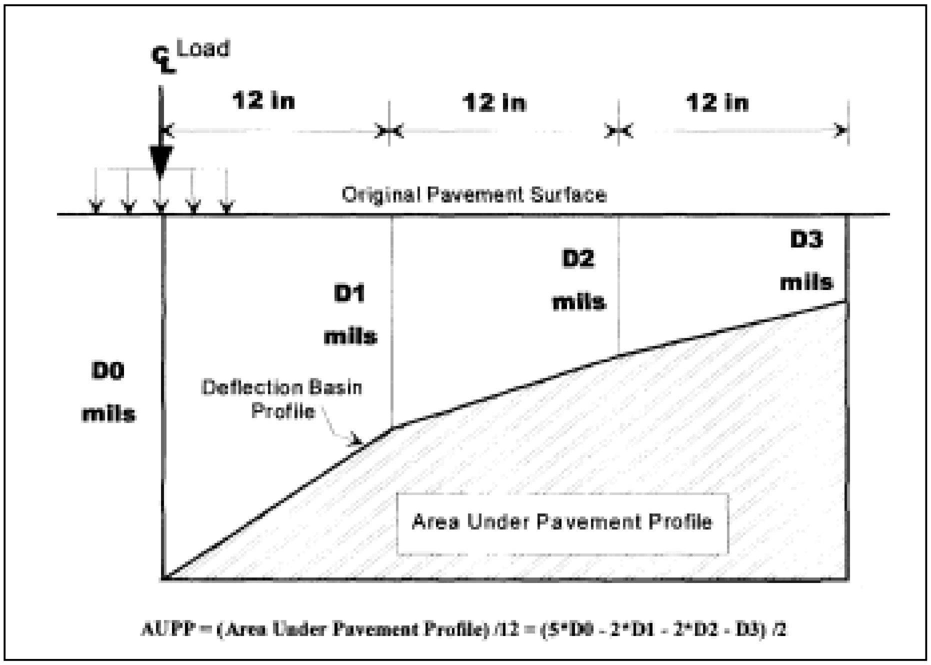

Figure 5. Illustration and calculation of Area Under Pavement Profile (AUPP).[4]

To calculate the mean maximum deflection and AUPP for each SPS-3 site, the following deflection data items were retrieved from the LTPP database:

- Testing dates and times,
- Testiing paths,
- Applied loads,
- Deflection sensor configurations,
- Air and pavement surface temperatures, and
- Asphalt mix temperatures and the times and depths of measurement.

For the purpose of comparing the structures of different asphalt pavements tested at different temperature, it is necessary to adjust the deflections to a single reference temperature. To accomplish this, first, for each test section and each deflection testing date, an equation was developed for middepth asphalt mix temperature as a function of testing time. These equations were used to assign a midddepth asphalt mix temperature to every deflection basin in that test section on that date.

The deflection-based parameters determined as described here are not truly “pretreatment” values, because many SPS-3 sites were not deflection tested until sometime shortly after the treatment date. Therefore, the control section (340) deflection data were used whenever possible for structural capacity determination. When suitable data were not available for the control section (e.g., either deflection measurements or asphalt mix temperature measurements were lacking, or when the control section is a linked GPS site with a pavement structure different than that of the SPS-3 site), data from the crack seal (330) section were used, or if suitable data for that section were also unavailable, data from the slurry seal (320) section were used. In a very few cases, none of the nonoverlay test sections at a site had available the deflection and temperature data needed to determine the AUPP value at the start of the experiment.

Next, regression equations developed for the temperature adjustment factor TAF described in the 1993 *AASHTO Guide*[5] (see Figures 5.6 and 5.7 in Part III of the *Guide*) were used to adjust each deflection basin’s maximum deflection (d_0) to 68°F. This approach to adjustment for temperature has the practical advantage that it uses the measured asphalt mix temperature directly, without the added variation that would result from estimating mix temperature from surface or air measurements from the testing day or previous days.

Strictly speaking, temperature also affects the other deflections used in the calculation of AUPP, but the magnitudes of these adjustments would be very small. For the purposes of determining AUPP values for comparing the SPS-3 pavement structures, it was considered sufficient to adjust only the maximum deflection.

Mean d_0 and AUPP values were determined using deflections measured in the wheelpath at the 9000-pound target load level. Wheelpath deflections were used, rather than midlane deflections, to better reflect the effect of past traffic on remaining structural capacity. The same deflections were used to calculate deflection basin AREA values, using the traditional four-sensor AREA definition. Note that AUPP is not normalized with respect to the magnitude of maximum deflection to eliminate the effect of load level, as is AREA. Thus, for the purpose of comparing d_0 and AUPP values for different locations, the deflections used need to be normalized to a reference load level. In this analysis, deflections measured at load levels close to the 9000-pound target load level were normalized to 9000 pounds for use in calculation of AUPP and AREA.

Examination of the SN calculations and deflection results yielded the following observations:

- Maximum deflection and AUPP are strongly correlated, as shown in Figure 6.
- Neither maximum deflection nor AUPP correlates very well to deflection basin AREA. This latter parameter is a measure of the relative stiffness of the pavement structure's stiffness versus the foundation's stiffness.
- Neither maximum deflection nor AUPP correlates very well to SN calculated from layer thicknesses and assumed structural coefficients. This should not be too surprising, for at least two reasons. First, SN calculated from layer thicknesses and material properties does not reflect the effect of past traffic, whereas AUPP and maximum deflection, calculated from wheelpath deflections, ostensibly do. Second, SN applies to the pavement layers above the subgrade, whereas AUPP and maximum deflection are influenced by the stiffness of the subgrade as well.

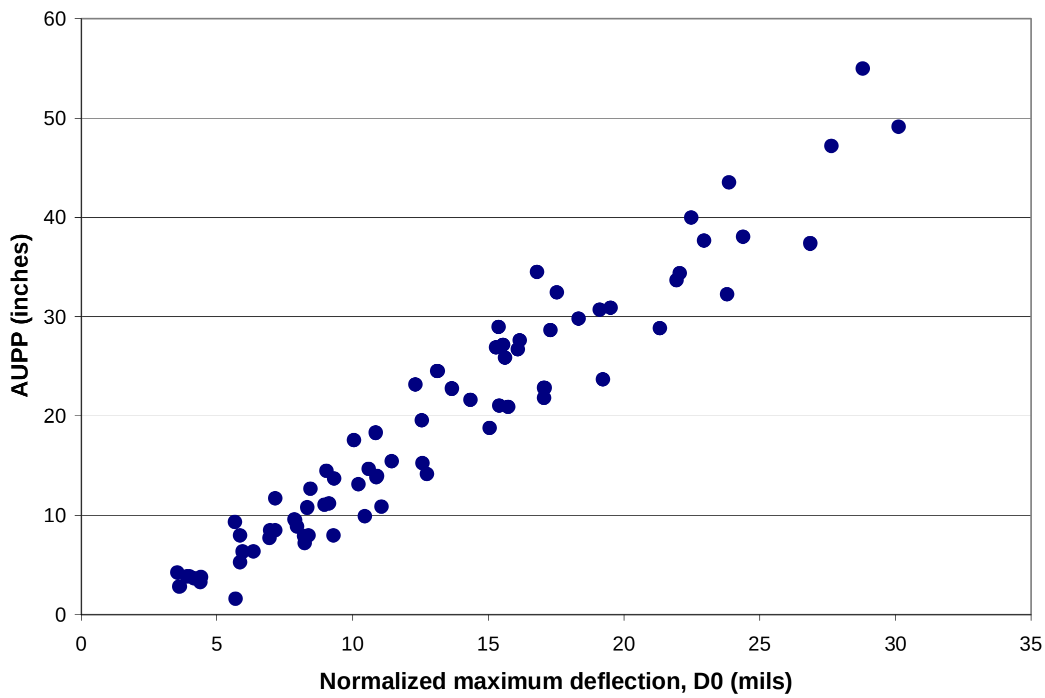

Figure 6. Maximum deflection versus AUPP, SPS-3 sites.

Based on examination of cumulative frequency distributions of maximum deflection and AUPP for the SPS-3 sites, the following maximum deflection values and AUPP values were used to define “weak,” “medium,” and “strong” levels of pavement structure. Note that for both parameters, these levels apply to deflections normalized to 9000 pounds and 68°F.

Mean maximum deflection:	Weak = More than 16 mils
	Medium = 8 to 16 mils
	Strong = Less than 8 mils
AUPP:	Weak = More than 24 inches
	Medium = 8 to 24 inches
	Strong = Less than 10 inches

Traffic Characterization

The 18-kip-equivalent single-axle (ESAL) levels at the SPS-3 sites were determined by extracting the following data from the LTPP database:

- Historical estimates of ESALs for years prior to the start of the SPS-3 experiment, from the TRF_HIST_EST_ESAL data table;
- ESAL estimates obtained from traffic monitoring during the experiment, from the TRF_MON_EST_ESAL data table; and
- Axle load distributions obtained from traffic monitoring during the experiment, from the TRF_MONITOR_AXLE_DISTRIBUTION data table.

ESALs were calculated for the years in which axle load distribution data were available, using the number of axles reported in each load range in the distribution, and load equivalency factors calculated as a function of Structural Number (determined as described previously). For years during the experiment in which axle load distribution data were not available, ESAL estimates from TRF_MON_ EST_ESAL table were used if available.

In a few cases, linear interpolations of annual ESALs were necessary for years in which no axle load distribution or ESAL data were available. It was also necessary in a few cases to extrapolate a year or two before or after the years for which data were available. A growth rate of 5 percent was used for these extrapolations.

The annual ESAL levels calculated for the year 1990 are shown by SPS-3 site in Appendix A. The cumulative frequency distribution of 1990 annual ESAL levels is shown in Figure 7. The annual traffic level in 1990 was fairly low for nearly all of the SPS-3 sites: less than about 50,000 ESALs for 33 percent of the sites, and less than about 150,000 ESALs for 67 percent of the sites.

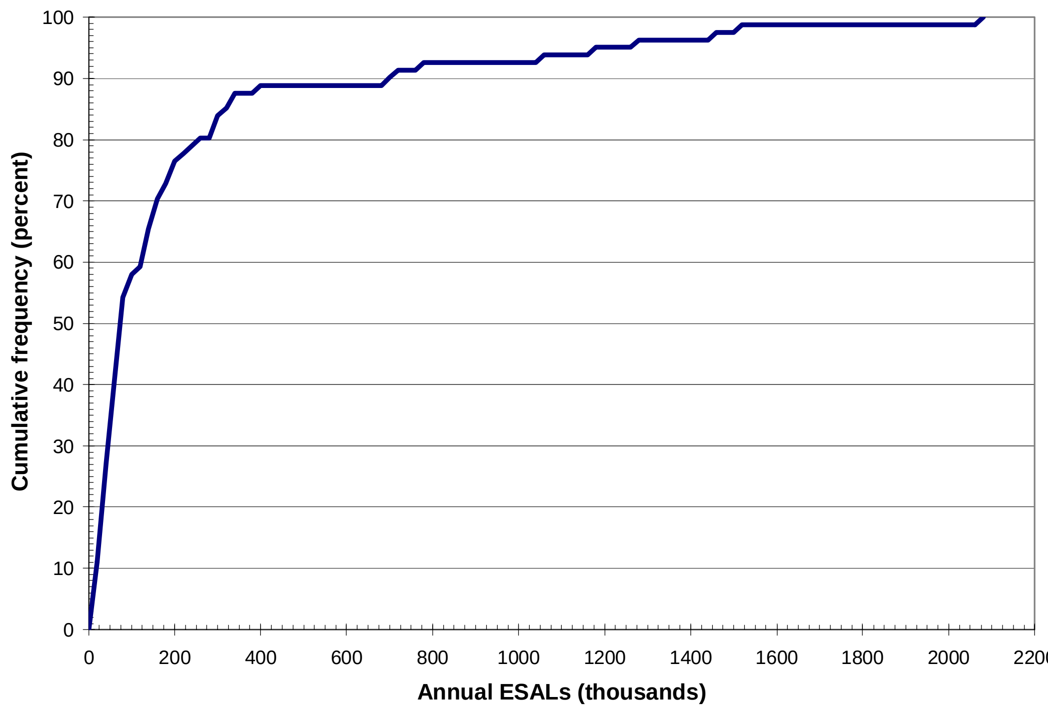

Figure 7. Cumulative frequency distribution of 1990 annual ESAL levels at SPS-3 sites.

It appears to be inadvisable, however, to categorize the SPS-3 sites with respect to the ESALs (or any other traffic parameter) in a given year, because of the weight that this puts on the importance of the data for that year being accurate. Consider two examples: the Minnesota SPS-3 site 27A300, and the Indiana SPS-3 site, 18A300. The ESAL levels determined for these two sites, for each year for which data are available, are shown in Tables 3 and 4 respectively. The word “average” is used in the annual ESAL column because the values shown in Tables 3 and 4 represent the average of the values reported in the database for some of the sections at the SPS-3 site, plus the linked GPS site (in most cases, the exact same values). The source of the ESAL information is also shown for each year.

In the case of the Minnesota site, a reasonable sequence of ESAL values is drawn from the three sources (historical ESAL estimates, monitoring ESAL estimates, and ESALs calculated from axle load distribution data). The annual ESAL level in 1990, the year of the start of the SPS-3 experiment, appears to be a reasonably good indicator of future ESAL levels at this site.

Table 3. Example annual ESAL data, Minnesota site 27A300.

Year	Average ESALs (thousands)	Source
1976	15	TRF_HIST_EST_ESAL
1977	15	TRF_HIST_EST_ESAL
1978	15	TRF_HIST_EST_ESAL
1979	14	TRF_HIST_EST_ESAL
1980	11	TRF_HIST_EST_ESAL
1981	17	TRF_HIST_EST_ESAL
1982	25	TRF_HIST_EST_ESAL
1983	26	TRF_HIST_EST_ESAL
1984	27	TRF_HIST_EST_ESAL
1985	25	TRF_HIST_EST_ESAL
1986	21	TRF_HIST_EST_ESAL
1987	22	TRF_HIST_EST_ESAL
1988	23	TRF_HIST_EST_ESAL
1989	25	TRF_HIST_EST_ESAL
1990	23	TRF_MON_EST_ESAL
1991	32	TRF_MON_EST_ESAL
1992	35	TRF_MONITOR_AXLE_DISTRIBUTION
1993	34	TRF_MONITOR_AXLE_DISTRIBUTION
1994	45	TRF_MONITOR_AXLE_DISTRIBUTION
1995	40	TRF_MONITOR_AXLE_DISTRIBUTION
1996	35	TRF_MONITOR_AXLE_DISTRIBUTION
1997	50	TRF_MONITOR_AXLE_DISTRIBUTION

In the case of the Indiana site, however, a noticeable drop in annual ESALs occurs when the data source changes from historical to monitored ESAL estimates, and a more dramatic drop occurs when the source changes from monitored ESAL estimates to ESALs calculated from axle load distribution data.

Table 4. Example annual ESAL data, Indiana site 18A300.

Year	ESALs (thousands)	Source
1975	685	TRF_HIST_EST_ESAL
1976	729	TRF_HIST_EST_ESAL
1977	773	TRF_HIST_EST_ESAL
1978	801	TRF_HIST_EST_ESAL
1979	770	TRF_HIST_EST_ESAL
1980	743	TRF_HIST_EST_ESAL
1981	1,602	TRF_HIST_EST_ESAL
1982	1,637	TRF_HIST_EST_ESAL
1983	1,684	TRF_HIST_EST_ESAL
1984	1,835	TRF_HIST_EST_ESAL
1985	1,928	TRF_HIST_EST_ESAL
1986	2,483	TRF_HIST_EST_ESAL
1987	2,673	TRF_HIST_EST_ESAL
1988	2,767	TRF_HIST_EST_ESAL
1989	2,946	TRF_HIST_EST_ESAL
1990	2,067	TRF_MON_EST_ESAL
1991	2,091	TRF_MON_EST_ESAL
1992	1,277	interpolated
1993	463	TRF_MONITOR_AXLE_DISTRIBUTION
1994	395	TRF_MONITOR_AXLE_DISTRIBUTION
1995	615	TRF_MONITOR_AXLE_DISTRIBUTION
1996	535	interpolated
1997	456	TRF_MONITOR_AXLE_DISTRIBUTION
1998	259	TRF_MONITOR_AXLE_DISTRIBUTION

Regardless of what might be the explanation for the discrepancies, does the annual ESAL level in 1990 appear to be a good indicator of future ESAL levels at this site? It is very hard to say, and the same is true for many other sites. This is why it appears to be inadvisable to categorize the SPS-3 sites with respect to the ESALs (or any other traffic parameter) in a given year.

It also appears to be inadvisable to place great confidence in accumulated ESAL quantities calculated from the available annual data. For the purpose of analyzing the long-term effects of SPS-3 maintenance treatments on pavement performance, the accumulated ESALs from the dates of initial posttreatment profile and distress measurement to the dates of the most recent measurements were also calculated for each test section at each SPS-3 site. These accumulated ESAL estimates are provided in Appendix A. The accuracy of these accumulated ESAL estimates should, however, be viewed with caution.

Pretreatment Condition

The pretreatment International Roughness Index (IRI), rutting, and cracking levels in the SPS-3 test sections were determined using the last measurement of each of these parameters prior to treatment. Pretreatment data are most available for IRI (59 of 81 sites, or 73 percent). Most of the SPS-3 pavements had little roughness at the time of treatment. For 33 percent, the IRI was less than 1.05 m/km; for 68 percent the IRI was less than 1.4 m/km.

Pretreatment data are much less available for cracking (21 of 81 sites, or 26 percent) and least available for rutting (11 of 81 sites, or 14 percent). Thus, attempting to describe the range of SPS-3 sites with respect to pretreatment condition, particularly pretreatment distress, using the available pretreatment data would fail to describe most of the sites.

The relationship of pretreatment condition to long-term treatment effectiveness has been examined wherever possible, i.e., for those test sections with pretreatment condition data available.

Construction Problems and Deviations

At more than 40 percent of the SPS-3 sites, some problem or deviation occurred with the application of one or more of the maintenance treatments.[3] These construction deviations are listed in Table 5. Most of the problems were related to the chip seal treatment.

SPS-3 Performance Findings from Previous Studies

Damage Modeling Approach Proposed in Original Experiment Design

The approach to SPS-3 performance modeling proposed by the developers of the SPS-3 experiment design was development of one or more damage models.[3] Such models express some aspect of pavement performance (e.g., development of a given type of distress or other performance measure) in terms of a damage index between 0 and 1.

Table 5. SPS-3 construction problems and deviations.[3]

SHRP ID	State	Linked GPS	Problem or Deviation
04A300	AZ	***041036***	Lost chip seal (350).
04B300	AZ	***041021***	Some chip loss (350).
08A300	CO	081053	Some chip loss (350).
08B300	CO	***082008***	Chip seal (350) overlaid due to subgrade failure.
16B300	ID	***161021***	Some chip loss (350).
16C300	ID	***161010***	Some chip loss (350).
17B300	IL	171002	State DOT crack sealed the control (340) section sometime between 10/90 and 6/91.
18A300	IN	181028	Premature failure of slurry seal (320) because of rainy weather after placement. Traffic allowed on section too soon, caused rutting in wheel paths.
20B300	KS	201010	Alligator cracking in slurry seal section (320) will need to be patched (2/92).
30A300	MT	***301001***	Lost chip seal (350).
32A300	NV	***321021***	State chip seals (supplementals) overlaid.
32B300	NV	327000	Minor chip loss (350).
32C300	NV	***322027***	All treatments overlaid between June and September 90.
36A300	NY	361643	Chip seal (350) lost some aggregate immediately. Snowplows have damaged except for wheelpaths.
36B300	NY	361644	Chip seal (350) lost some aggregate immediately. Snowplows have damaged except for wheelpaths.
40A300	OK	404087	Thin overlay (310) not placed.
42A300	PA	421605	Chip seal (350) lost some aggregate immediately. Intermittent damage.
42B300	PA	421597	All treatments placed by state forces. No slurry seal (320) placed.
47A300	TN	***473101***	Chip seal (350) lost aggregate in first 300-400 ft of test section lane. Original surface is open-graded friction course. Will be taken out of service 4/92.
48D300	TX	***482172***	Diluted fog seal on control (2172) and crack seal (330) sections.
48E300	TX	481183	Crack seal (330) required patching for safety reasons.
48I300	TX	483559	Chip seal (350) Lost some aggregate following construction, then stabilized. Cold weather before and during construction.
48N300	TX	483739	Failure of slurry seal (320) near end of test section, caused by problems during construction. Crack seal section (330) required patching of alligator cracking for safety reasons.
48Q300	TX	483865	Chip seal (350) losing agregate. Fog sealed 11/20/90.
49A300	UT	***491004***	Considerable chip loss (350).
49B300	UT	***491017***	Considerable chip loss (350).
49C300	UT	***491006***	Considerable chip loss (350).
51A300	VA	511023	Chip seal (350) losing aggregate. Crack seal (330) pulling out of a number of cracks.

Table 5. SPS-3 construction problems and deviations (continued).[3]

SHRP ID	State	Linked GPS	Problem or Deviation
53A300	WA	***531008***	Lost chip seal (350).
53B300	WA	***531501***	Lost chip seal (350).
56A300	WY	***561007***	Lost chip seal (350).
56B300	WY	***567775***	Lost chip seal (350).
87A300	ON	871620	Province not happy with treatments. All treatments overlaid except slurry (320) and thin overlay (310).
87B300	ON	871622	Chip seal (350) deleted because of construction problems.
89A300	PQ	891021	Chip seal (350) lost some aggregate immediately. Snowplows have caused damage except in wheelpaths.

An S-shaped curve has upper and lower horizontal asymptotes, and is well suited for measures of performance that can be expressed in this manner (e.g., percent of wheelpath area cracked, portion of allowable serviceability loss that has occurred). The general form of such a model is the following:

$$g = \exp\left[-\left(\rho / W \right)^{\beta} \right] \qquad \text{(Eqn. 1)}$$

where g = the damage index
W = accumulated traffic or age
ρ = parameter for the expected traffic or time to failure
β = parameter for the shape of the performance trend

This model form was used to develop the original AASHO flexible and rigid pavement performance models,[6,7] which are still embedded in the design equations in the 1993 *AASHTO Guide*.[5] In the context of the AASHTO models, the damage index g is the ratio of the actual serviceability loss (initial serviceabilty minus actual serviceability) to maximum allowable serviceability loss (initial serviceability minus failure serviceability, 1.5). In the AASHTO models, both ρ and β are functions of the applied load (axle type and magnitude) and the pavement design.

The report on the SPS-3 experiment design proposed the development of a basic damage model for the performance of the control sections in the SPS-3 experiment, as a function of design, materials, soils, climate, and traffic rate variables. The relative effectiveness of different maintenance treatments on improving performance could hypothetically then be expressed as adjustments to the parameters which define the shape of the S-shaped curve in the basic performance model.[3] Variations on the basic model form could reflect the following potential effects of a maintenance treatment:

- Delaying initiation of a distress,
- Achieving an immediate improvement in pavement condition by reducing the quantity of a distress without significantly affecting the rate of occurrence of the distress, and/or
- Changing the rate of occurrence of a distress.

Reference 3 identified structural adequacy as a factor in the SPS-3 experiment design, and defined it as the ratio of in-place Structural Number to required Structural Number. This factor does not, however, appear to enter into the originally proposed approach to modelling SPS-3 maintenance effectiveness.

Reference 3 describes some efforts to apply this analysis approach to early performance data from the SPS-3 experiment. These efforts were hampered by data availability problems and the short times in which the treatments had been in service. The researchers estimated that it would be five to ten years from the time of treatment application before the effects of the maintenance treatments on pavement performance could be assessed.

Five-Year Evaluation of SPS-3 Performance by Expert Task Groups

In the summer and fall of 1995, four Expert Task Groups (ETGs), one in each LTPP region, visited and evaluated a total of 57 SPS-3 sites.[8] The ETG members used a 0-10 scale (e.g., 0-2 = “very poor,” 8-10 = “very good”) to give consensus ratings to the overall pavement condition independent of treatment, the overall condition of the treatments, the overall effectiveness of the treatments, and the appropriateness of the treatments.

According to Reference 8, the SPS-3 maintenance treatments were judged by the ETGs to have exhibited somewhat better performance than the control sections in the first five years of service. This was judged to be more true of the thin overlay and chip seal treatments than the slurry seal and crack seal treatments.

A 1999 TRB paper[9] attributed the following conclusions to the 1995 report on the Expert Task Groups’ site evaluations of SPS-3:

- Sections with preventive maintenance treatments generally outperformed control sections.
- Treatments applied to pavements in good condition have shown good results.
- Traffic level and pavement structural adequacy did not appear to affect performance.

There does not, however, appear to be any indication in Reference 8 that either traffic level or structural adequacy were taken into consideration in the ETGs' evaluations. This leaves some question as to the basis of the statement in Reference 9 that "the early message from this [SHRP SPS-3] research is that preventive maintenance treatments are effective on high-volume roads."

Regression Modeling of SPS-3 Performance

Reference 10 describes efforts made to apply regression analyses to SPS-3 performance data in a 1998 study. The data analyzed included distress, deflection, profile, rut depth, and friction data. Attempts were made to use multiple regression to develop prediction models for cracking, rutting, ride quality, friction, and an index called Pavement Rating Score (PRS).

Reference 10 defines structural adequacy as does Reference 3, as "the actual structural number of the test section divided by structural number requirements to carry the section traffic volume." Whether "actual structural number" is that at the time of construction of the pavement or at the time of application of the maintenance treatment, and in either case, how it is to be determined, is not clear. How the required structural number should be determined, i.e., for what design traffic volume and for what subgrade modulus, drainage, and reliability inputs, is also not clear.

Ultimately, Reference 10 concludes that structural adequacy was not found to have a significant[†] effect on performance of SPS-3 treatments. "That is," the report states, "the pavements with inadequate pavement structure performed as well, or as poorly, as those with adequate structure." Indeed, in several cases, the sections judged structurally adequate deteriorated more rapidly than those judged structurally inadequate.

Reference 10 reports that only the thin overlay treatment achieved a significant immediate reduction in rutting. Analysis of the change in rut depths after five years of service indicated that crack seal sections and thin overlay sections rutted at about the same rate as control sections, slurry seal sections at a slightly slower rate, and chip seal sections at a slightly faster rate. At certain sites in Arizona, chips seals and slurry seals appeared to have accelerated rutting. This

[†] In all of the analyses conducted for the present study, significance is tested at the 95 percent level. In other studies cited, "significant" is the word choice of those studies' authors.

effect was attributed to stripping in the asphalt concrete layer, due to an increase in moisture content in the pavement structure.

Reference 10 reports that thin overlays achieved significant initial reductions in International Roughness Index (IRI), chip seal and slurry seals achieved slight initial reductions, and crack sealing did not initially reduce IRI. Analysis of the change in IRI after five years of service indicated that all of the treatments, including crack sealing, resulted in better smoothness than in the control sections. However, the effect of crack sealing on long-term IRI trends was judged to be difficult to accurately assess after five years of service, given that new cracks did not get sealed, and some sections designated as crack seal treatment sections did not in fact have any cracks.

Deflections measured before treatment, after treatment, and after five years of service were normalized to a fixed load level for analysis purposes, but apparently not adjusted to account for temperature variation. As a result, no conclusions could be drawn about the effects of any of the treatments on either posttreatment deflections or deflections after five years of service.

Survival Modeling of SPS-3 Performance

A survival analysis of SPS-3 sites in the Southern LTPP region was conducted in 1999.[11,12] The objectives of the analysis were to obtain estimates of:

- The life expectancy of each treatment (i.e., the median, or fiftieth percentile, survival time),
- The effect of timing of treatment application on life expectancy (i.e., whether the treatment was applied when the pavement was in good, fair, or poor condition), and
- The benefit of the treatment, in terms of added years of life expectancy due to the treatment, compared to the life expectancy without treatment (i.e., the life expectancy of the control section).

The survival analyses were conducted using the Kaplan-Meier method, which is a nonparametric survival analysis technique. That is, it generates the actual failure probability distribution without attempting to fit the data to any assumed theoretical distribution. Failure probabilities were calculated as a function of age only, not accumulated traffic. Failure was defined as reaching poor condition, defined in terms of severities and quantities of cracking, patching, and bleeding.

The failure probability six years after treatment and the median survival times of the different treatments and the control sections are shown in Table 6. The difference between the fiftieth percentile survival time for the treatment and the fiftieth percentile survival time for the control curve corresponding to the same original condition is an estimate of the added life attributable to the treatment.

Table 6. Results of 1999 Southern region SPS-3 survival analysis.[11]

Treatment	**Original Condition**	**6-Year Failure Probability (%)**	**Average Median Survival Time (Years)**	**Average Median Benefit Compared to no Treatment (Years) ***	**Median Survival Time with No Treatment (Control Sections) ****
Thin Overlay	Good	25	7.5	2.2	5.5
	Fair	30	7.3	4.8	1.5
	Poor	100	2.2	2.5	0
Slurry Seal	Good	48	6.5	2	5.5
	Fair	57	5	3.5	1.5
	Poor	100	2.5	2.5	0
Crack Seal	Good	50	6.5	1	5.5
	Fair	41	7.2	5.7	1.5
	Poor	100	0.75	0.75	0
Chip Seal	Good	25	N/A	N/A	5.5
	Fair	25	N/A	N/A	1.5
	Poor	32	N/A	N/A	0

*Median survival time is the number of years until 50 percent of the sections to which the treatment is applied fail.

**Median benefit compared to no treatment is the number of years a treatment adds to the median survival time compared to no treatment.

Reference 11 states that overall, after six years of service, sections that received maintenance when in poor condition had a probability of failure of 83 percent, whereas those that received treatment when in fair or good condition had probabilities of failure of 38 or 37 percent, respectively. The overall median survival times for thin overlay, slurry seal, and crack seal were 7, 5.5, and 5.1 years, respectively. A median survival time for chip seal could not be determined because fewer than 50 percent of these sections had failed at the time of the analysis.

Nonetheless, chip seals were concluded to have outperformed thin overlay, slurry seal, and crack seal treatments with respect to controlling the reappearance of distress.

Crack Sealing Field Study

In addition to the various SPS-3 performance modelling efforts described above, the findings of a related SHRP field study deserve mention. Reference 13 documents an asphalt pavement crack sealing study conducted under SHRP Project H-106 and the Long-Term Monitoring (LTM) Pavement Maintenance Materials Test Sites project. The study addressed the installation and performance monitoring of 31 different crack treatments (combinations of sealant materials, reservoir configurations, and installation methods such as conventional airblasting versus hot airblasting) at five sites.

The findings from this study are relevant to the crack sealing treatment used in the SPS-3 experiment, because some of the crack sealant reservoir configurations studied resemble those used in the SPS-3 crack sealing sections. In the North Atlantic and North Central regions, a 38-mm-wide by 9.5-mm-deep reservoir was used in the the SPS-3 crack sealing sections. These reservoir dimensions are similar to those of the standard and shallow recessed band-aid treatments (configurations B and C) evaluated in the H-106/LTM study. The 25-mm by 25-mm reservoir size used in the Western region SPS-3 sites is similar to the deep and standard reservoir-and-recess treatments (configurations E and F) evaluated in the H-106/LTM study.

Notable differences in crack treatment performance were noted among the sites surveyed. These differences were attributed to factors such as climate, traffic, pavement type, crack type, and crack spacing, all of which influence the magnitudes of crack movements. When used with using SHRP-specified rubberized asphalt sealants, the standard recessed band-aid configuration (B) exhibited the longest service life, followed very closely by the shallow recessed band-aid configuration (C). The simple band-aid configuration (D) exhibited only about half the service life of these two other treatments.

Reference 13 does not draw any general conclusions comparing the service lives of these configurations and the two configurations (E and F) resembling that used in the Western region SPS-3 sites. These configurations appear to have been used only with 890-SL self-leveling silicone, and were reported to exhibit “mediocre performance and poor cost-effectiveness.” Nonetheless, the report recommended continued field monitoring of this material, citing the sawing of the reservoirs as an important factor in the poor performance observed. The report suggests that better performance could be achieved by routing the reservoir instead of sawing, and adequately recessing the sealant.

Analysis Objectives

The objectives of the analysis of the SPS-3 experiment conducted for the present study are to assess the following:

- The initial effects, if any, of maintenance on the condition of the pavement,
- The long-term effects, if any, of maintenance on the performance of the pavement,
- The influence, if any, of pretreatment condition and other factors on long-term maintenance effectiveness, and
- The relative effectiveness of the different maintenance treatments considered.

With respect to both initial and long-term effects, the analysis aims to determine whether or not the changes in condition that occur in treated test sections are significantly different than the changes that occur in the control sections over the same time intervals.

The pavement condition measures considered are the following:

- Roughness, as expressed by IRI;
- Rutting; and
- Fatigue cracking.

Effects of Flexible Pavement Maintenance Treatment on Roughness

Initial Effects on Roughness

The initial effects of maintenance on roughness are assessed by comparing the last pretreatment IRI measurement with the first posttreatment IRI measurement. The dates of testing used in these comparisons should be the same for all test sections analyzed at a site.

Thus, it may not always be possible to use the first available post-treatment condition measurement for each test section, and it may not always be possible to analyze all of the test sections at a site.

The pretreatment and posttreatment IRI values, as well as the elapsed times between the pretreatment IRI measurement date to the treatment date, and between the treatment date and the posttreatment IRI measurement date, were calculated for each test section used in the short-term IRI analysis. The time lapses are summarized by treatment type in Table 7. The average lapse between pretreatment IRI measurement and treatment ranges from 2 to 3.4 months, depending on treatment type. The average lapse between treatment and posttreatment IRI measurement ranges from 6.4 to 8 months, depending on treatment type.

Table 7. SPS-3 – Distributions of elapsed times between treatment date and pretreatment and posttreatment IRI measurement dates.

Test section number	Treatment	Time from Pretreatment IRI to Treatment (months)			Time from Treatment to Posttreatment IRI (months)		
		min	mean	max	min	mean	max
310	Thin overlay	0.3	3.4	8.7	0.4	6.4	25.3
320	Slurry seal	0.1	2.2	7.5	0.9	7.7	24.8
330	Crack seal	0.1	2.0	7.5	0.9	7.1	24.5
340	Control	0.1	2.4	8.6	0.9	7.3	24.8
350	Chip seal	0.1	2.3	6.9	0.9	8.0	24.5

The most powerful statistical test of SPS-3 treatments' initial effects on pavement condition measures is Dunnett's method for two-sided multiple comparisons with a control (MCC).[14,15,16] Dunnett's method defines a (1-α)% confidence interval for the difference between the observed value in a treated section (or group of sections) and the observed value in the control section (or group of sections).

For example, the core SPS-3 experiment design consists of four maintenance treatments and a control section. Thus, four confidence intervals may be established, one for each treatment other than the control. A significant effect of a treatment on change in condition is inferred if zero is not contained within the confidence interval for that treatment. For any individual SPS-3 site, the (1-α)% confidence interval for the difference between a treated section's change in condition and the control section's change in condition is given by the following equation:

$$(\Delta C_i - \Delta C_c) \pm d_{k,\nu,\alpha/2} \cdot s_p \cdot \sqrt{(1/n_i) + (1/n_c)} \qquad \text{(Eqn. 2)}$$

where ΔC_i	=	change in condition of treated section i
ΔC_c	=	change in condition of control section
d	=	Dunnett's value for two-sided multiple comparisons with a control
k	=	number of treatments, including control
n_i	=	number of observations from which ΔC_i is calculated
n_c	=	number of observations from which ΔC_c is calculated
ν	=	degrees of freedom $= \Sigma (n_j - 1)$, where j is from 1 to k
	=	k (n – 1) when n are equal for all test sections
α	=	significance level
s_p	=	pooled sample standard deviation
	=	square root of overall pooled sample variance s_p^2

The absolute value of Dunnett's d is the solution to the following equation:

$$\int_0^{\infty} \int_{-\infty}^{\infty} [\Phi(z + \sqrt{2}\,|d|\, s_p) - \Phi(z - \sqrt{2}\,|d|\, s_p)]^{k-1}\, d\Phi(z)\, \gamma(s_p) ds_p = 1 - \alpha \qquad \text{(Eqn. 3)}$$

where Φ	=	the standard normal distribution function
z	=	the standard normal variable
γ	=	density of s_p / σ, ratio of sample to population standard deviation

Values of d can be computed by programming the solution of Equation 3, and have also been tabulated.

The correct calculation of the overall pooled variance for use in the above equation is somewhat complicated, but important. First, if the condition values are calculated from multiple measurements (for example, multiple profile runs yielding multiple IRI values), the pooled variance associated with each test section's pretreatment versus posttreatment mean condition values must be calculated. Then, the overall pooled variance, i.e., the weighted average of the test section pooled variance values, is calculated. On the other hand, if the condition values obtained for a given date are not the means of multiple measurements but rather single measurements (e.g., area of alligator cracking), then the appropriate input to the above equation is simple the sample variance of the k treatment condition values.

Two-sided tests are used, rather than one-sided tests, because it is not assumed *a priori* that maintenance treatments always produce beneficial initial or long-term effects on condition. Indeed, some reports that crack sealing may initially increase roughness, for example, suggest that it is important to consider the possibility that a treatment may have a detrimental effect on smoothness.

A multiple comparison analysis is more informative than a one-way analysis of variance (ANOVA) of treatment effects, because an ANOVA would only reveal whether or not at least one significant difference existed among the treatments. It would not reveal which of the treatments had significant effects and which did not.

The MCC analysis is also more powerful than other, more commonly used, multiple comparison tests. For k treatments (including the control), Dunnett's MCC method makes k-1 comparisons, whereas all-pairwise-comparison methods (Tukey, Duncan, etc.) make k (k-1) / 2 comparisons, while all-possible-comparison methods (Scheffé) make k! comparisons. The power of these tests is diminished by the wider confidence intervals needed to encompass such a large set of comparisons, many of which are not of practical interest.

Of the 81 total SPS-3 sites, 59 had data suitable for use in the analysis of initial treatment effects on IRI. Among these reasons for excluding a site from the analysis were: a control section to which some treatment was applied, lack of either a "pretreatment" or a "posttreatment" IRI measurement for the control section ("pretreatment" and "posttreatment" referring here to before and after treatments were applied to the other test sections), or lack of pretreatment measurements for most or all of the treated sections at a site. However, a site was not judged as unsuitable for use if one or two of the four treatment sections did not have suitable data available, as long as the control section did.

Also excluded from the analysis were those test sections identified in Table 5 as having experienced early failure due to unsuccessful construction (mostly chip seals). The other treatments at those sites were used in the analysis if they had suitable data available, as described above.

At several of the SPS-3 sites, the thin overlay treatment was not completed at the same time as the other treatments. The time difference was in most cases small and these small differences were not believed to affect the analysis. If the completion date of the thin overlay treatment was very different than those of the other treatments, the thin overlay was excluded from the analysis.

The initial change in IRI for each section used in the analysis was calculated as the posttreatment IRI minus the pretreatment IRI, so a positive value indicates an increase in IRI (i.e., an increase in roughness), while a negative value indicates a decrease in roughness.

The mean change in IRI was calculated for each core experiment treatment group and the control group. Table 8 shows the results of applying Dunnett's test for two-sided multiple comparisons with the control, to see if the mean change in IRI in any of the treated test section groups is significantly different than the mean change in IRI in the control group. A confidence interval that does not contain zero indicates that the data demonstrate a significant difference. The results indicate that only the thin overlay treatment had a significant initial effect on IRI.

Table 8. Analysis of initial effect of SPS-3 maintenance treatment on IRI.

	Change in IRI (posttreatment – pretreatment), m/km				
	Thin overlay	**Slurry Seal**	**Crack Seal**	**Control**	**Chip Seal**
Treatment mean	-0.191	0.044	0.036	0.026	0.064
Treatment standard deviation	0.531	0.222	0.111	0.094	0.118
Treatment variance	0.282	0.049	0.012	0.009	0.014
n	50	50	49	59	41
n-1	49	49	48	58	40
Pooled variance	0.073				
Pooled standard deviation	0.271				
Degrees of freedom	244				
Dunnett's d for 5,df→∞,0.05	2.442				
Treatment mean – control mean	-0.217	0.018	0.010		0.038
Confidence interval lower limit	-0.687	-0.452	-0.459		-0.420
Confidence interval upper limit	-0.090	0.145	0.138		0.173
Significantly different than control	yes	no	no		no

Another way to see the same results is by looking at the plots of IRI before and after treatment for each treatment group, beginning with the control group. This plot is shown in Figure 8. As would be expected, the best-fit line coincides almost perfectly with the 1:1 line. This suggests that the elapsed time intervals between "pretreatment" and "posttreatment" IRI measurements were sufficiently short that, on average, no change in IRI occurred in the control section group.

The plot for the thin overlay sections, shown in Figure 9, is very different. The average posttreatment IRI is 1.18 m/km, which corresponds to a present serviceability index (PSI) of about 4.26. Although some points are to the left of the 1:1 line (meaning that the IRI initially after overlay was higher than the IRI before overlay), most of the points are to the right of the 1:1 line (the IRI initially after overlay was lower than the IRI before overlay). The overall average effect of the thin overlay treatment was a reduction in IRI of 0.191 m/km, as shown in Table 8.

However, there is a slight but statistically significant upward trend to the posttreatment IRI data for the SPS-3 thin overlays. That is, pavements that were rougher before a thin overlay was placed tended to be somewhat rougher afterwards than pavements that were smoother before placement of a thin overlay. The slope of the best-fit line through the data points in Figure 10 is 0.23. The null hypothesis – that the slope is zero – is rejected, with 95 percent confidence (that is, with 5 percent chance of error) because the calculated F value of 6.48 (the ratio of the regression mean square to the error mean square), exceeds 4.04, the upper 5 percent of an F distribution with 1 and 48 degrees of freedom.

The plot of IRI values before and after application of the slurry seal treatment is shown in Figure 10. The best-fit line has a slightly lower slope than the 1:1 line. Whether or not this is significant may be determined by testing whether or not the slope of the change in IRI (posttreatment IRI – pretreatment IRI), with respect to pretreatment IRI, is significantly different than zero. This slope is –0.24. The null hypothesis – that the slope is zero – is rejected with 95 percent confidence because the calculated F value, 40.34, exceeds 4.04, the upper 5 percent of an F distribution with 1 and 48 degrees of freedom.

Thus, while the overall average initial effect of slurry seal on IRI was not significantly different than the change in IRI that occurred in the control section at the same time, there is a significant difference in effect between pavements that had low IRI values prior to treatment and those that had high IRI values prior to treatment. As Figure 10 illustrates, pavement sections with IRI less than about 1.25 m/km tended to have slightly higher IRI after application of the slurry seal, whereas pavement sections with IRI greater than about 1.5 m/km (what few there are) tended to have slightly lower IRI after application of the slurry seal.

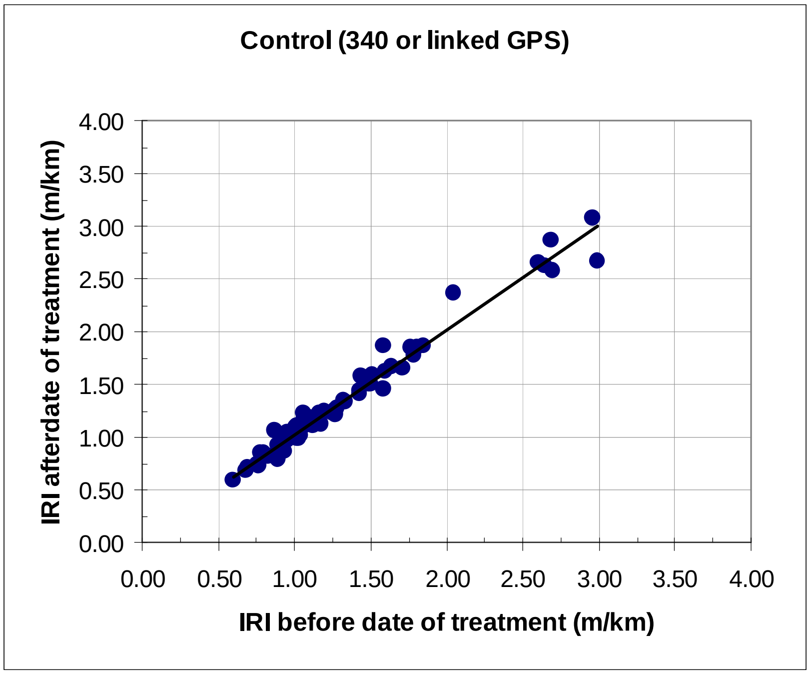

Figure 8. IRI before and after date of treatment, SPS-3 control sections.

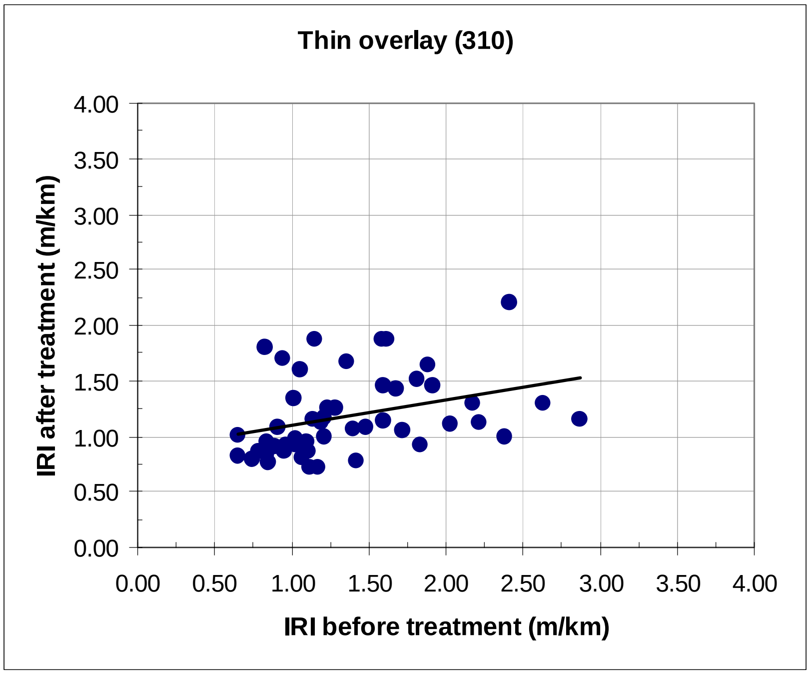

Figure 9. IRI before and after treatment, SPS-3 thin overlay sections.

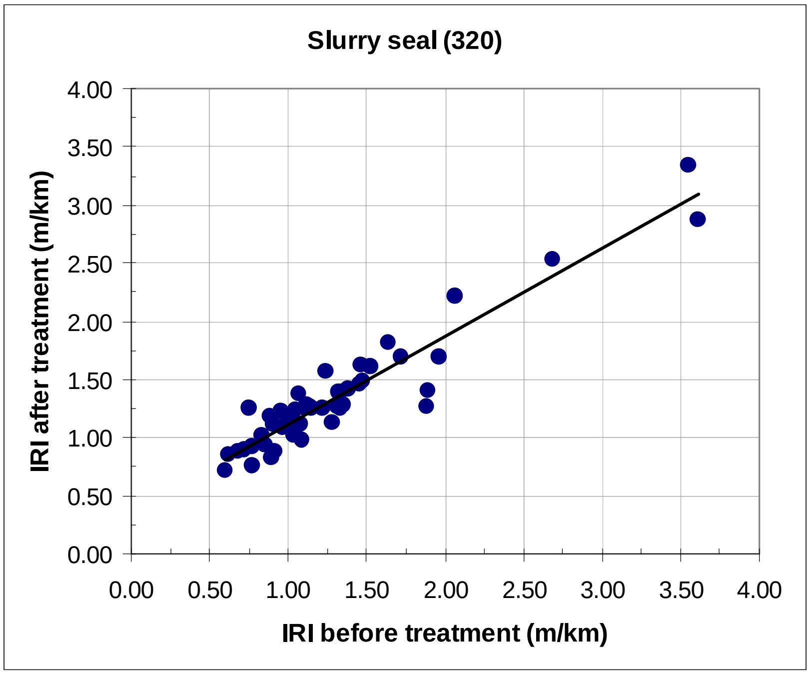

Figure 10. IRI before and after treatment, SPS-3 slurry seal sections.

The plots of IRI values before and after application of the crack seal and chip seal treatments are shown in Figures 11 and 12. In both cases, the best-fit lines almost perfectly coincide with the 1:1 line. This illustrates the results of the statistical tests: the crack seal and chip seal treatments had no initial effect on IRI.

Long-Term Effects on Roughness

The long-term effect of each maintenance treatment on roughness is assessed by analyzing the IRI obtained for each treated section from the most recent profile measurement, compared to the IRI of the control section at the same site.

Of the 81 total SPS-3 sites, 65 had data suitable for use in the analysis of long-term treatment effects on IRI: the 59 sites used in the analysis of initial effects, minus 7 that did not have suitable long-term data (either the control section or the entire site was taken out of service), plus 13 other sites that did (initial posttreatment IRI and long-term IRI data were available, even though pretreatment IRI data were not).

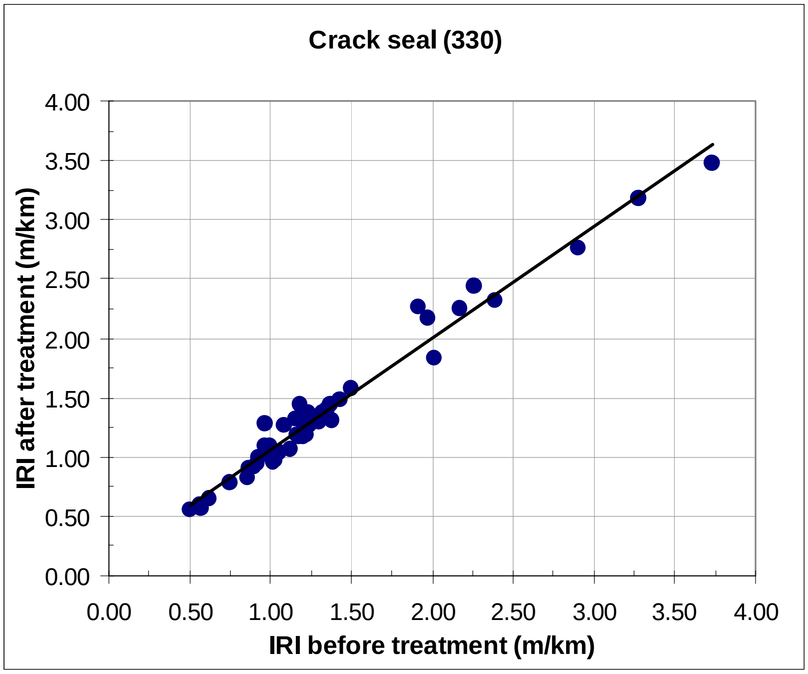

Figure 11. IRI before and after treatment, SPS-3 crack seal sections.

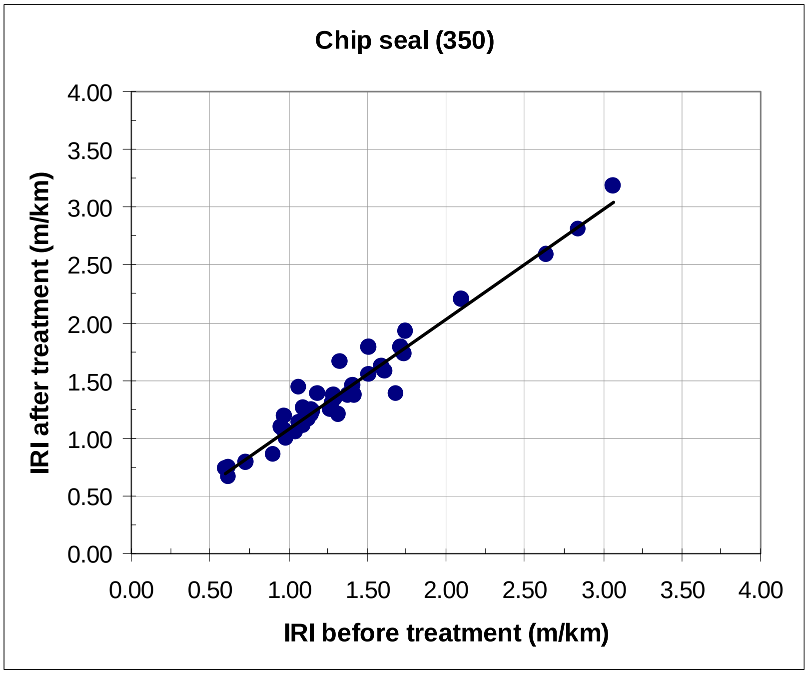

Figure 12. IRI before and after treatment, SPS-3 chip seal sections.

A site was not judged as unsuitable for use if just one or two of the four treatment sections did not have suitable data available, as long as the control section did. As in the analysis of initial effect on roughness, those test sections identified in Table 5 as having experienced early failure due to unsuccessful construction (mostly chip seals) were excluded. The other treatments at those sites were used in the analysis if they had suitable data available. Between 55 and 85 percent of the test sections in the treatment groups were judged to have data suitable for use in an analysis of the long-term effects of maintenance on roughness. The treatment group with the most test sections excluded was the chip seal group.

Dunnett's MCC method or any other test for multiple comparisons among groups is appropriate for analysis of initial effects, but less so for analysis of long-term effects. The reason for this is that over the long term, differences in structural capacity, applied traffic, and age are likely to produce differences in performance among sections receiving the same treatment at different sites. That is, the within-treatment (i.e., site-to-site) variation may be, indeed is likely to be, sufficiently large that it masks any significant between-treatment differences unless it is properly taken into consideration.

Treatment Effect

The first part of the analysis of long-term treatment effects involves testing for significant effects by treatment type, holding constant for age, traffic, climate, etc. This is done by comparing each treated section at a site with the control section at the same site. Rather than compare the means of many sections within different treatment groups, one analyzes the mean difference between each control section and each of the corresponding treated sections. An appropriate statistical test for this purpose is a paired difference test, often referred to as a paired t test.

In an analysis of a long-term effect of a maintenance treatment on IRI, the difference of interest at each site is between the IRI of the treated section, obtained from the most recent profile measurement, and the IRI of the control section, obtained at the same time. Since four comparisons are made (each of the four maintenance treatments versus the control), the significance level, α, of the individual tests should be selected so that $(1 - \alpha)^4$ = the desired overall level of confidence. For four tests to yield a 95 overall level of confidence, the required significance level α is 0.01274. The results of the four paired difference tests are shown in Table 9. These data cover a range of time from 2.0 to 10.4 years, with an average of 6.4 years.

Table 9. Analysis of long-term effect of SPS-3 maintenance treatment on IRI.

	IRI (control versus treatment), m/km			
	Thin overlay	**Slurry Seal**	**Crack Seal**	**Chip Seal**
Mean difference	0.32	0.02	0.02	0.07
n	58	55	57	45
S_D	0.65	0.56	0.44	0.63
$T_{\alpha/2,\ n-1}$	2.57	2.58	2.57	2.60
Confidence interval lower limit	0.10	-0.17	-0.13	-0.18
Confidence interval upper limit	0.54	0.22	0.17	0.31
Significantly different than control	yes	no	no	no

The results indicate that of the four maintenance treatments in the core SPS-3 experiment, only the thin overlays had long-term IRI values significantly different than the corresponding control sections. This is illustrated in Figure 13.

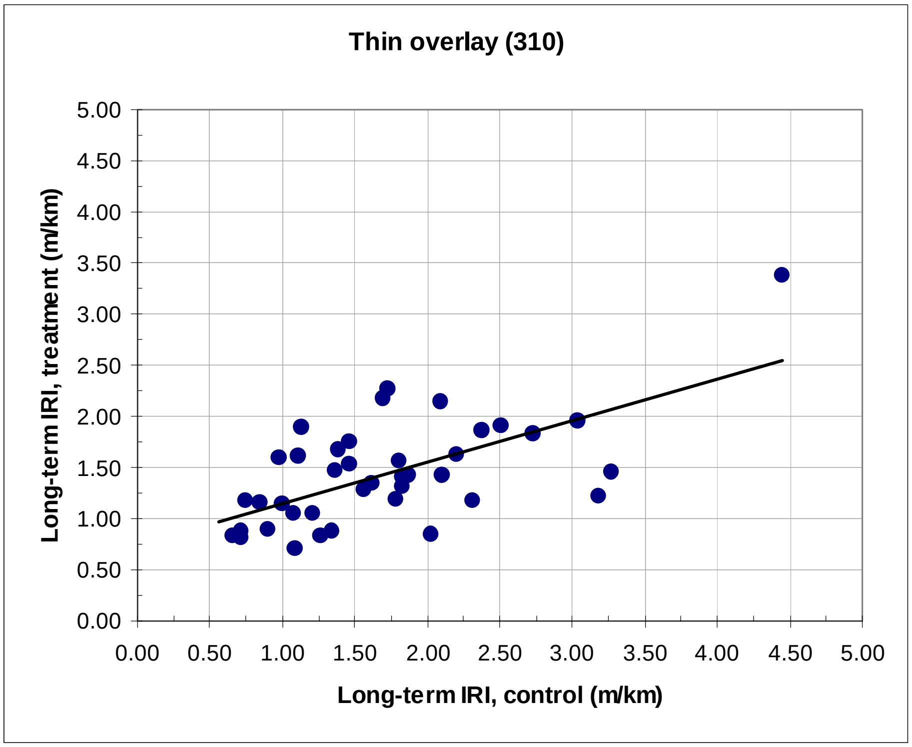

Figure 13. Long-term IRI, SPS-3 thin overlay versus control.

In Figure 13, each point on this graph represents the latest available IRI measurement for a thin overlay section and the IRI measurement for the control section at the same site, on the same date. Below an IRI level of 2.1 m/km, the points are scattered fairly evenly on both sides of the 1:1 line. However, above an IRI level of 2.1 m/km, all of the thin overlay sections have lower IRIs than their corresponding control sections. The slope of the line through the points is thus considerably lower than the 1:1 line.

Plots of the long-term IRI values in the treated sections versus the control sections are shown in Figures 14, 15, and 16 for the slurry seal, crack seal, and chip seal treatments respectively. The second most influential treatment appears to be the chip seal treatment (Figure 16), although the mean difference (0.7 m/km) was not found to be statistically significant.

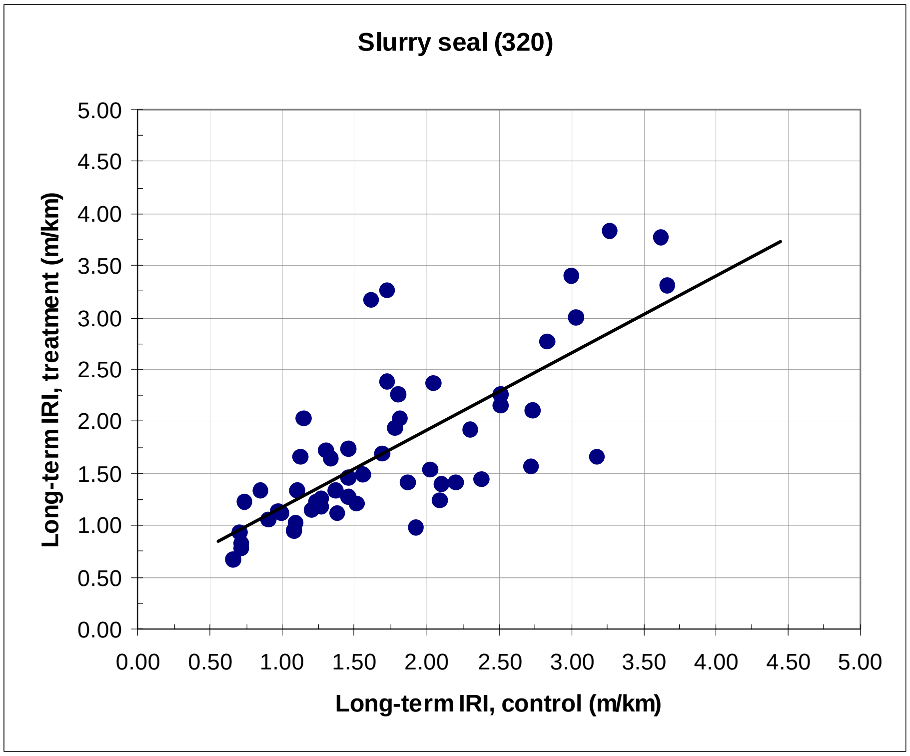

Figure 14. Long-term IRI, SPS-3 slurry seal versus control.

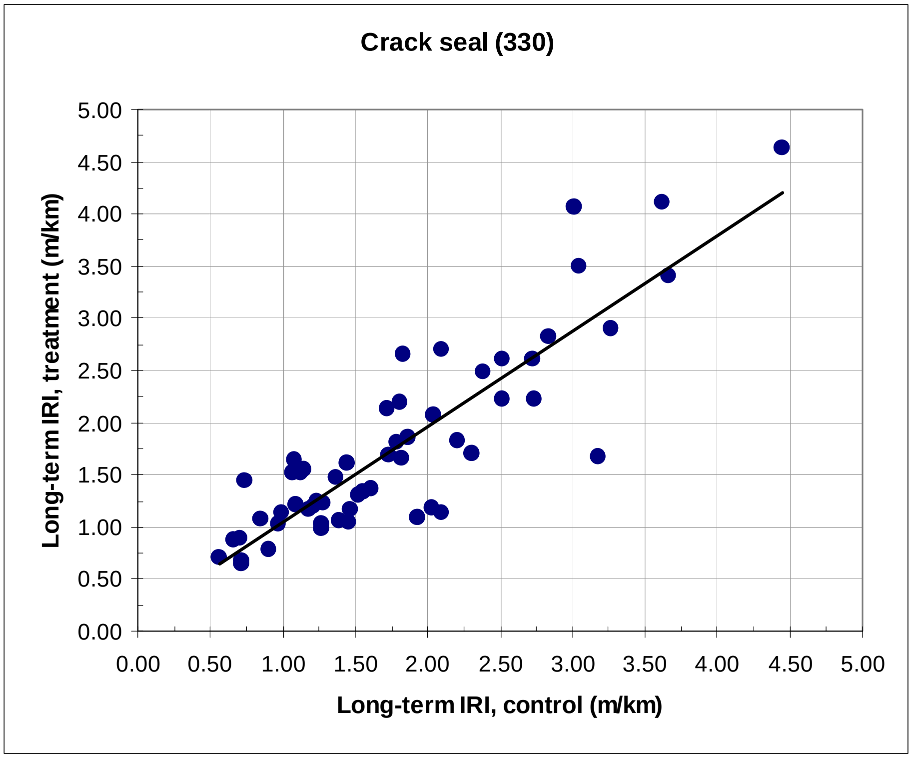

Figure 15. Long-term IRI, SPS-3 crack seal versus control.

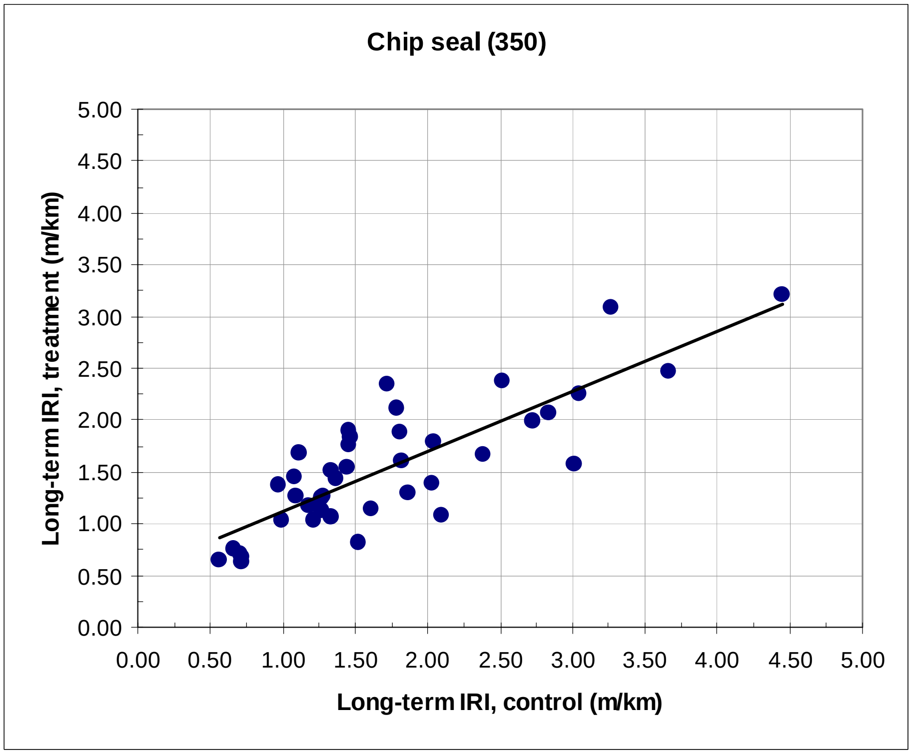

Figure 16. Long-term IRI, SPS-3 chip seal versus control.

The cumulative frequency distributions of long-term IRI are shown for the four treatment groups and the control group in Figure 17. As this plot shows, the median (fiftieth percentile) long-term IRI values are all very close for the slurry seal, crack seal, control, and chip seal group, whereas the median long-term IRI of the thin overlay is slightly less than the rest.

However, looking at not only the fiftieth percentile values but the complete distributions, it appears that not only the thin overlay distribution but also the chip seal distribution are fairly consistently to the left of the control distribution, especially at IRI levels above about 1.75 m/km. The slurry seal and crack seal distributions, on the other hand, follow the control distribution very closely. These results reinforce the impression that the chip seal treatment was the second most effective, after the thin overlay treatment, in reducing long-term roughness.

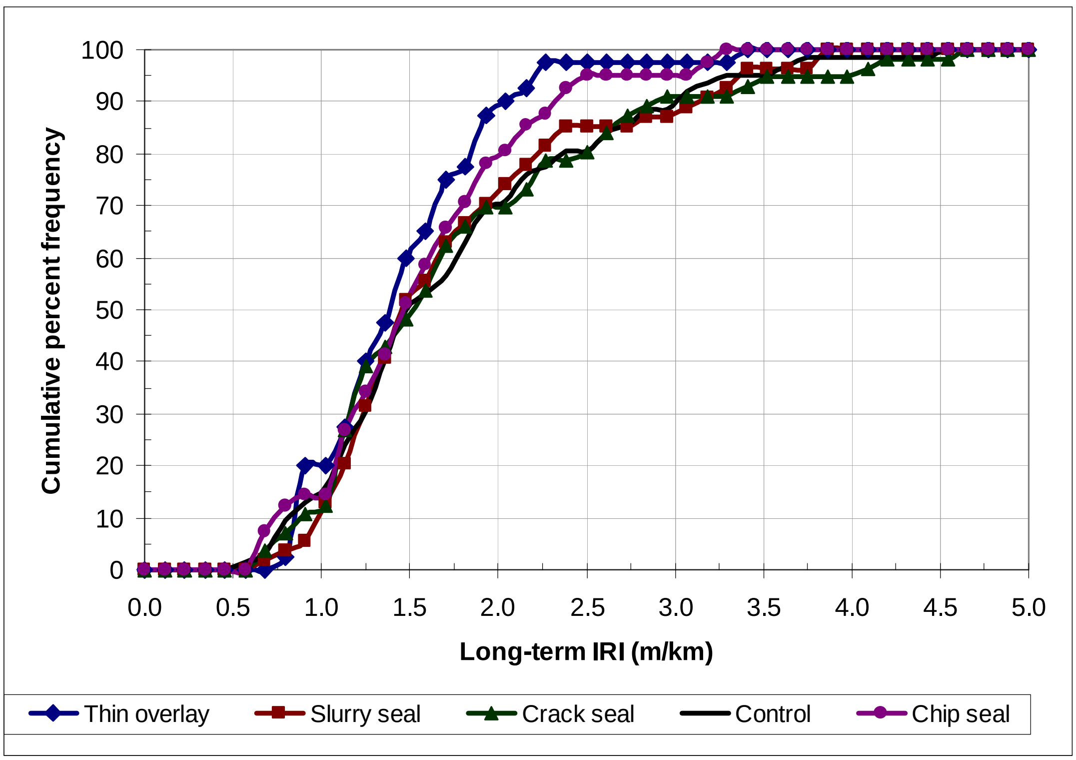

Figure 17. Cumulative frequency distributions of long-term IRI, SPS-3 treatments.

Influence of Other Factors

The second part in the analysis of long-term treatment effects on IRI is to test for significant effects of other factors, i.e., time, traffic, climate, pavement strength, and pretreatment IRI. The steps in this analysis are the following:

1. For each site, the change in IRI in the control section, from the first posttreatment measurement to the most recent measurement, is calculated.

2. For each treated section at the same site, the change in IRI in the treated section at the same site, from the first posttreatment measurement to the most recent measurement, is calculated. Note that the IRI data used should be for dates for which measurements are available for both the control and the treated sections. In a few of the cases where a linked GPS site serves as the control, there a difference of a month or two between the posttreatment measurement dates.

3. The difference between the change in IRI in the control section and the change in IRI in each of the treated sections is calculated for each site.

4. For each treatment type, the slope of the difference calculated in step 3 with respect to each of the factors of interest is analyzed. This may be done with an F test (or equivalently, with a t test). A factor is concluded (with 5 percent chance of error) to have a significant influence on the difference in long-term IRI performance of the control versus the treated section if the calculated F value (the ratio of the regression mean square to the error mean square), exceeds the upper 5 percent of an F distribution with 1 and n-2 degrees of freedom, where n is the number of sites used in the test.

Although testing for significance of factor effects applies a statistical test to the linear regression of performance differences with respect to each of the factors, it does <u>not</u> imply a presumption that those relationships are better described by linear rather than nonlinear regression. In detection of significant factor effects, the question of interest is not whether a linear versus a nonlinear relationship exists, but whether any relationship exists.

The analysis of long-term treatment effects described here represents the first two steps in building models for the effects of maintenance treatments on pavement performance:

- Determining which treatment types significantly affect long-term performance, and
- Determining which factors (traffic, climate, pretreatment condition, etc.), if any, significantly influence how much effect the treatment types have on long-term performance.

Once the significant independent variables have been identified, the next step in the model-building process – which is beyond the scope of this study – would be to select the model form that best reflects the effects of the independent variables, including nonlinear effects and interaction effects, if any.

The results of the F tests for significance of factor effects on the relative long-term IRI performance of the SPS-3 maintenance treatments are summarized in Table 10.

Table 10. Tests for significance of factor effects on relative long-term IRI performance of SPS-3 maintenance treatments.

Treatment		Factor					
		Age	Accumulated ESALs	Normalized maximum deflection	Pre treatment IRI	Average annual precipitation	Average annual temperature
Thin Overlay (310)	n	60	60	57	39	60	60
	Fcalc	0.55	0.70	0.98	0.23	4.20	0.90
	F at 0.05	4.01	4.01	4.02	4.11	4.01	4.01
	Significant?	no	no	no	no	**yes**	no
Slurry Seal (320)	n	58	58	50	43	58	58
	Fcalc	0.10	0.93	0.04	0.08	4.36	0.30
	F at 0.05	4.01	4.01	4.04	4.08	4.01	4.01
	Significant?	no	no	no	no	**yes**	no
Crack Seal (330)	n	60	60	57	41	60	60
	Fcalc	0.04	0.23	2.54	5.88	0.00	2.01
	F at 0.05	4.01	4.01	4.02	4.09	4.01	4.01
	Significant?	no	no	no	**yes**	no	no
Chip Seal (350)	n	44	43	43	35	44	44
	Fcalc	1.55	0.05	1.81	2.61	0.06	0.31
	F at 0.05	4.07	4.08	4.08	4.14	4.07	4.07
	Significant?	no	no	no	no	no	no

Three factor effects, all slight but statistically significant, were detected:

- An effect of annual average precipitation on long-term IRI change with thin overlays,
- An effect of annual average precipitation on long-term IRI change with slurry seals, and
- An effect of pretreatment IRI on long-term IRI change with crack seals.

What does it mean, that on average thin overlays had a significant effect in reducing long-term roughness, as reported earlier, but that no factor effects were found to be significant, with the exception of a slight correlation with precipitation? These are not contradictory findings. From them it may be inferred that the effectiveness of thin overlays in reducing the rate of increase in roughness, relative to the rate in the control sections, was (a) significant, and (b) consistently so across the ranges of the factors studied. The exception to this is the precipitation factor: at sites with more precipitation, the rate of increase in roughness in the control sections exceeded the rate of increase in the thin overlays slightly more than at sites with less precipitation.

Similarly, what does it mean that one significant factor effect was detected for slurry seals and one for crack seals, even though, as reported earlier, on average neither of these treatments had a significant effect in reducing long-term roughness? Again, these are not contradictory statements. From them, it may be inferred that the effectiveness of these two treatment types in reducing the rate of increase in roughness, relative to the rate in the control sections, was (a) negligible, and (b) consistently so across the ranges of the factors studied, with the exception of a slight correlation with precipitation for slurry seals, and pretreatment IRI for crack seals.

Effects of Flexible Pavement Maintenance Treatment on Rutting

Initial Effects on Rutting

The initial effects of maintenance on rutting are assessed by comparing the last pretreatment rutting measurement with the first posttreatment rutting measurement. Unfortunately, this comparison is possible for only about a third of the SPS-3 sites. The main reason for this is the lack of pretreatment rutting data for many of the sites. Some sites or some sections were unsuitable for this analysis for other reasons, described previously in the section on the analysis of the initial effect on IRI.

The results of the analysis of initial effects on the core experiment's maintenance treatments on rutting are shown in Table 11. The change in rutting is calculated as the posttreatment rutting minus the pretreatment rutting, so a positive value for "Treatment mean" indicates an increase in rutting, while a negative value indicates a decrease in rutting. The results indicate that only the thin overlay treatment had a significant initial effect on rutting.

Table 11. Initial effect of SPS-3 maintenance treatment on change in rutting.

	Change in rutting (post – pretreatment), mm				
	Thin overlay	**Slurry seal**	**Crack seal**	**Control**	**Chip seal**
Treatment mean	-3.1	0.0	-0.3	-0.1	-1.0
Treatment standard deviation	6.5	2.8	2.9	2.6	3.2
Treatment variance	41.6	7.7	8.3	6.7	10.0
n	27	33	33	20	31
n-1	26	32	32	19	30
pooled variance	14.5				
Pooled standard deviation	3.81				
Degrees of freedom	139				
Dunnett's d for 5, df→∞,0.05	2.442				
Treatment mean - control mean	-3.1	0.0	-0.3		-1.0
Confidence interval lower limit	-5.8	-2.6	-2.9		-3.7
Confidence interval upper limit	-0.3	2.7	2.4		1.7
Significantly different than control	yes	no	no		no

Long-Term Effects on Rutting

The long-term effects of maintenance treatments on rutting are assessed in the same manner as described previously for IRI. SPS-3 sites that were excluded from the analysis of long-term effects on rutting were those at which all or most of the sections were rehabilitated or taken out of service shortly after treatment application. However, a site was not judged as unsuitable for use if one or two of the four treatment sections did not have suitable data available. Those test sections identified in Table 5 as having experienced early failure due to unsuccessful construction (mostly chip seals) were excluded. The other treatments at those sites were used in the analysis if they had suitable data available.

About 50 percent of the test sections in the thin overlay and slurry seal treatment groups were judged to have data suitable for use in analysis of the long-term effects of maintenance on rutting. About 40 percent of the test sections in the crack seal and chip seal treatment groups had suitable data. The data used in the long-term rutting analysis cover a range of time from 2.0 to 8.1 years, with an average of 4.5 years.

The long-term effect of maintenance treatment type on rutting was analyzed using multiple paired difference tests, as described earlier in the discussion of IRI. The long-term rutting in each treated section was compared to the long-term rutting in the corresponding control section, and the mean differences were tested to determine whether or not they are significantly different than zero. The results are summarized in Table 12.

Table 12. Analysis of long-term effect of SPS-3 maintenance treatment on rutting.

	Long-term rutting (control versus treatment), mm			
	Thin Overlay	**Slurry Seal**	**Crack Seal**	**Chip Seal**
Mean difference	6.7	0.7	1.3	1.2
n	42	43	32	15
S_D	6.3	5.0	5.4	5.1
$T_{\alpha/2, n-1}$	2.61	2.60	2.64	2.85
Confidence interval lower limit	4.1	-1.3	-1.2	-2.6
Confidence interval upper limit	9.2	2.7	3.8	5.0
Significantly different than control	yes	no	no	no

Only in the comparison between the thin overlays and the corresponding control sections was a significant mean difference detected in long-term rutting. Plots of the long-term rutting values in the thin overlay, slurry seal, crack seal, and chip seal sections versus the control sections are shown in Figures 18 through 21 respectively.

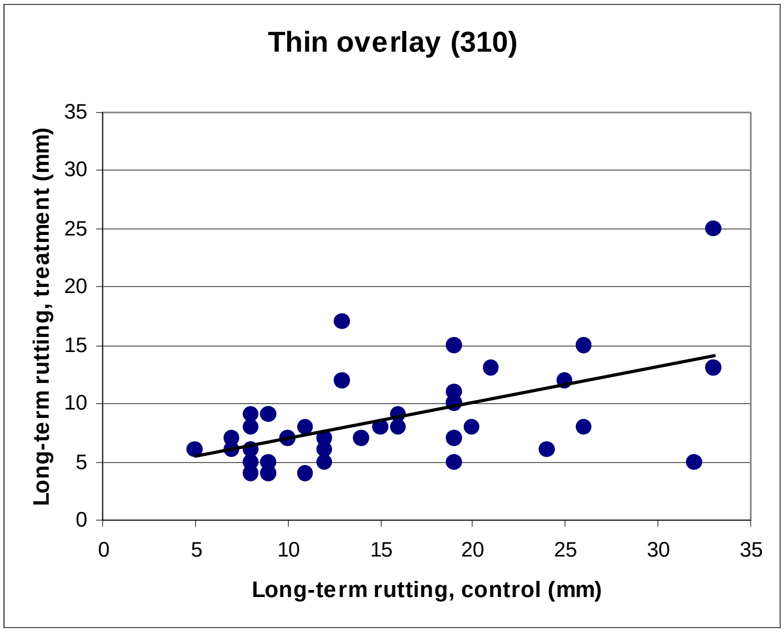

Figure 18. Long-term rutting, SPS-3 thin overlay versus control.

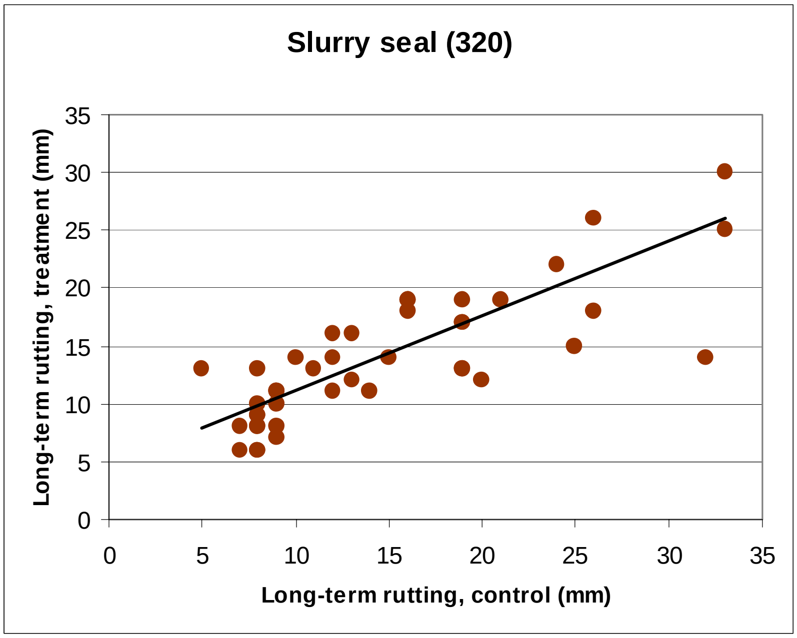

Figure 19. Long-term rutting, SPS-3 slurry seal versus control.

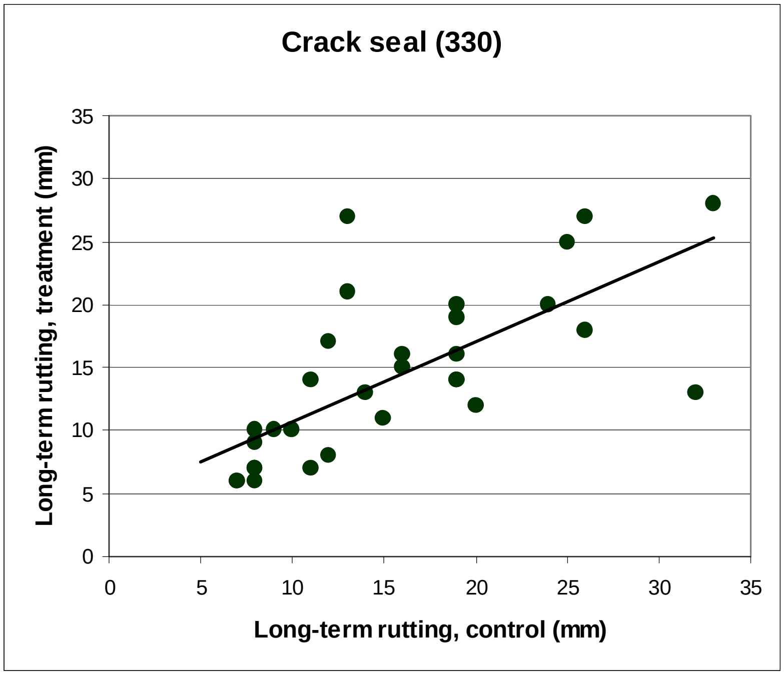

Figure 20. Long-term rutting, SPS-3 crack seal versus control.

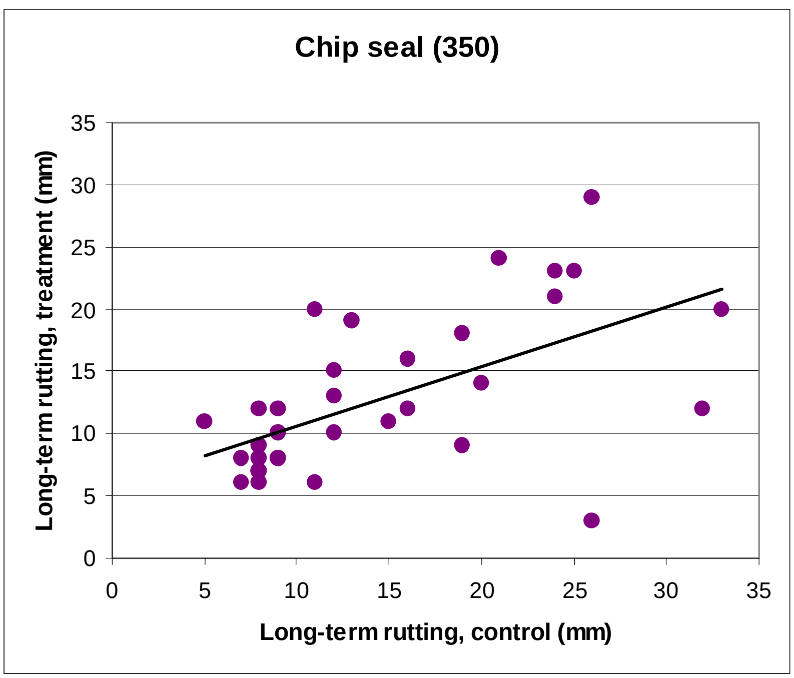

Figure 21. Long-term rutting, SPS-3 chip seal versus control.

The cumulative frequency distributions of long-term rutting are shown for the four treatment groups and the control group in Figure 22. As this plot shows, the thin overlay distribution is clearly to the left of the control and all of the other distributions. At lower rutting levels, the distributions of the other three treatments follow the control distribution fairly closely. However, at rutting levels greater than about 12 mm, the slurry seal, crack seal, and chip seal distributions are also fairly consistently to the left of the control distribution. The frequency distributions reinforce the impression that thin overlays were most effective at reducing long-term rutting, followed by the other three maintenance treatments.

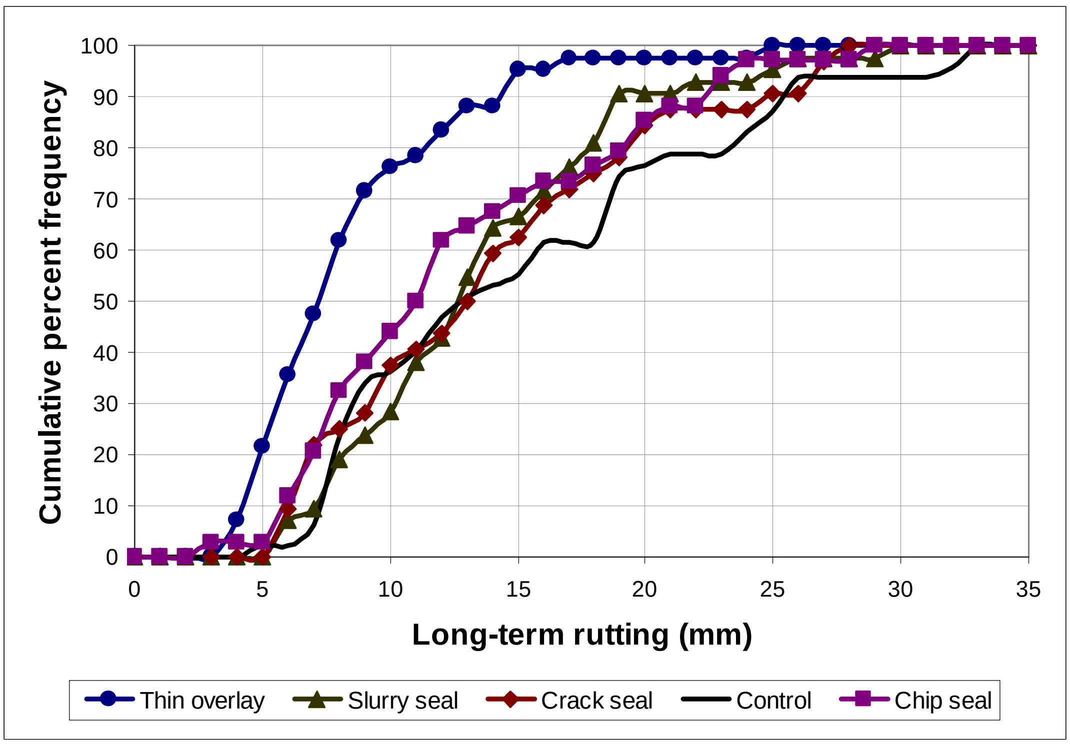

Figure 22. Cumulative frequency distributions of long-term rutting, SPS-3 treatments.

The influence of factors such as climate, traffic, etc., on the effectiveness of SPS-3 maintenance treatments with respect to long-term rutting was analyzed in the same manner as described before for IRI. The results of the F tests for significance of factor effects on the relative long-term rutting performance of the SPS-3 maintenance treatments are summarized in Table 13.

Table 13. Tests for significance of factor effects on relative long-term rutting performance of SPS-3 maintenance treatments.

Treatment		Factor					
		Age	Accumulated ESALs	Normalized maximum deflection	Pre treatment rutting	Average annual precipitation	Average annual temperature
Thin Overlay (310)	n	42	42	40	18	42	42
	Fcalc	12.16	0.07	1.35	0.30	3.68	0.09
	F at 0.05	4.08	4.08	4.10	4.49	4.08	4.08
	Significant?	**yes**	no	no	no	no	no
Slurry Seal (320)	n	43	43	41	14	43	43
	Fcalc	1.27	0.24	1.03	3.28	2.56	0.00
	F at 0.05	4.08	4.08	4.09	4.75	4.08	4.08
	Significant?	no	no	no	no	no	no
Crack Seal (330)	n	32	32	31	7	32	32
	Fcalc	3.76	0.02	1.23	0.46	8.67	0.14
	F at 0.05	4.17	4.17	4.18	6.61	4.17	4.17
	Significant?	no	no	no	no	**yes**	no
Chip Seal (350)	n	34	34	34	12	34	34
	Fcalc	2.57	1.86	0.48	1.51	5.58	0.08
	F at 0.05	4.15	4.15	4.15	4.96	4.15	4.15
	Significant?	no	no	no	no	**yes**	no

Three significant factor effects were detected:

- An effect of age on long-term rutting change with thin overlays,
- An effect of annual average precipitation on long-term rutting change with slurry seals, and
- An effect of annual average precipitation on long-term rutting change with chip seals.

The strongest of these factor effects is the first one listed. Its practical significance is that the difference in rutting between the thin overlay sections and the corresponding control sections was more notable at SPS-3 sites with more years in service.

Effects of Flexible Pavement Maintenance Treatment on Fatigue Cracking

Initial Effects on Fatigue Cracking

The initial effects of maintenance on fatigue cracking are assessed by comparing the percent of the test section area cracked before the treatment with the percent of the area cracked shortly after the application of the treatment.

For the purpose of this analysis, the area of alligator cracking (all severities) was added to the area affected by longitudinal cracking (sealed and unsealed, all severities, wheelpath and nonwheelpath, length times 18 inches or 0.45 m), and this area was divided by the area of the pavement section (typically 556 m^2). Both alligator cracking and longitudinal cracking were considered together, because examination of the survey data indicated that the trends in each may be very erratic from year to year, whereas the sum of the two tends to have a more stable trend. This is believed to be due to variation from year to year in the survey technicians' classification of the distress observed.

It is conceivable that this summation method produces some overestimates of the percent area cracked, in cases when both alligator cracking and longitudinal cracking are located in the same area. Also, the selection of 18 inches as a typical wheelpath width is arbitrary, and different cracked area percentages would be obtained if some other width were assumed. Nonetheless, as will be seen, the initial and long-term effects of maintenance on fatigue cracking are clearly seen using the calculation method described. It should be noted, however, that only about 25 percent of the SPS-3 sites have pretreatment and posttreatment cracking data available for the control section as well as most or all of the treated sections.

A plot of percent area fatigue cracked in the control section before and after the date of treatment of the adjacent sections is shown in Figure 23. In most sections, the cracking recorded shortly after the treatment date is the same or slightly more than that recorded prior to the treatment date. In a few sections, the amount of cracking recorded changed considerably.

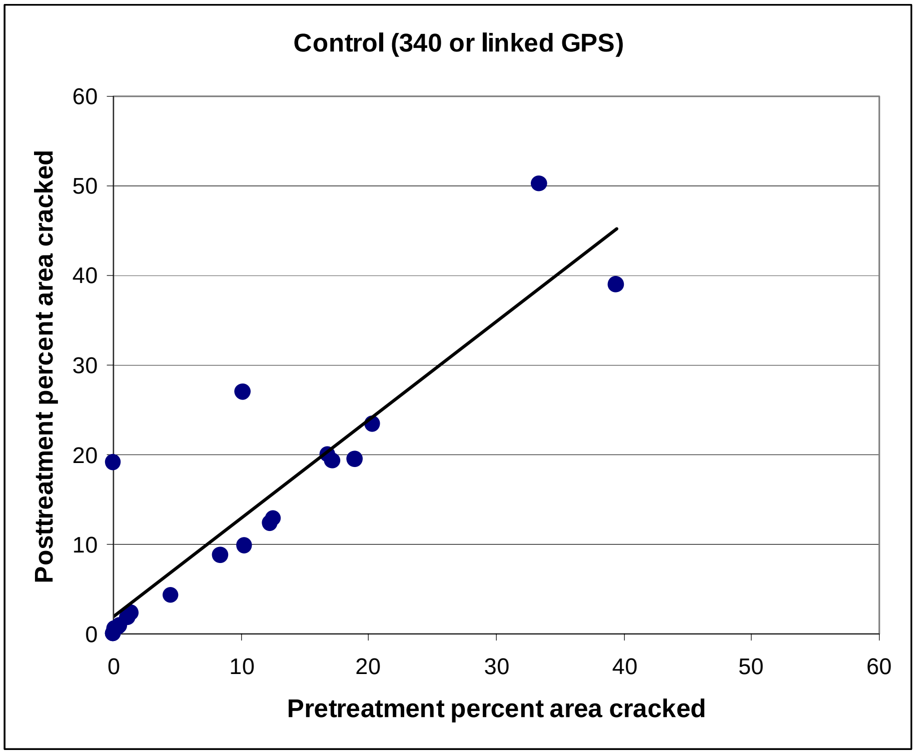

Figure 23. Fatigue cracking before and after treatment date, SPS-3 control sections.

Plots of cracking before and after treatment are shown for the thin overlay sections, slurry seal sections, crack seal sections, and chip seal sections in Figures 24 through 27. It is obvious that cracking immediately after treatment in the thin overlay, slurry seal, and chip seal sections was zero or nearly zero, whereas cracking in the crack seal sections was in nearly every case equal to or greater than the pretreatment cracking level.

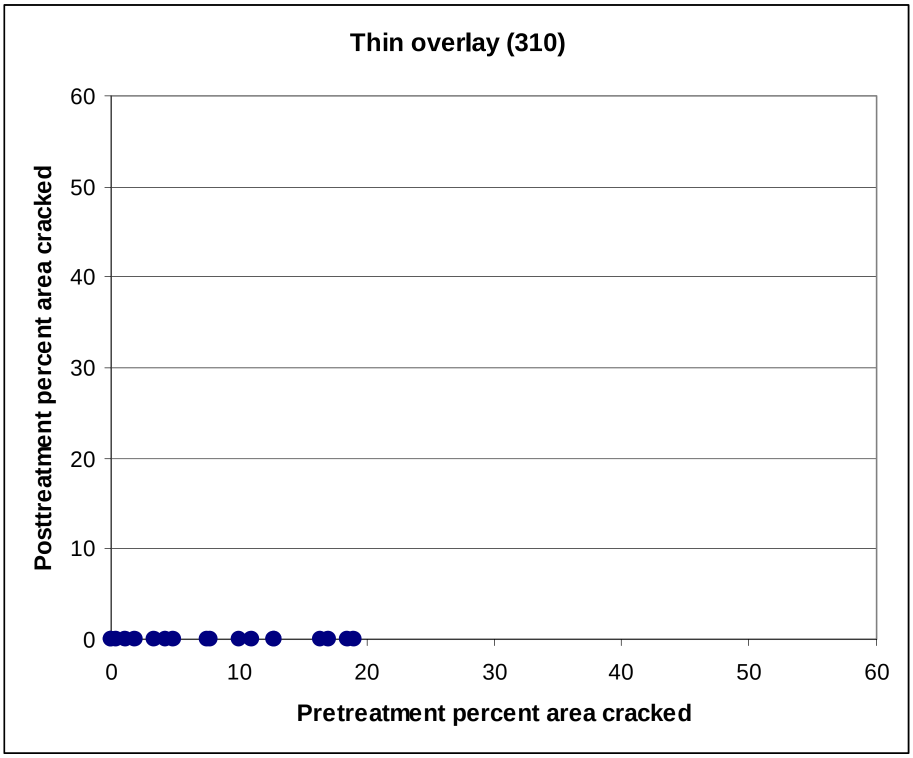

Figure 24. Fatigue cracking before and after treatment, SPS-3 thin overlay sections.

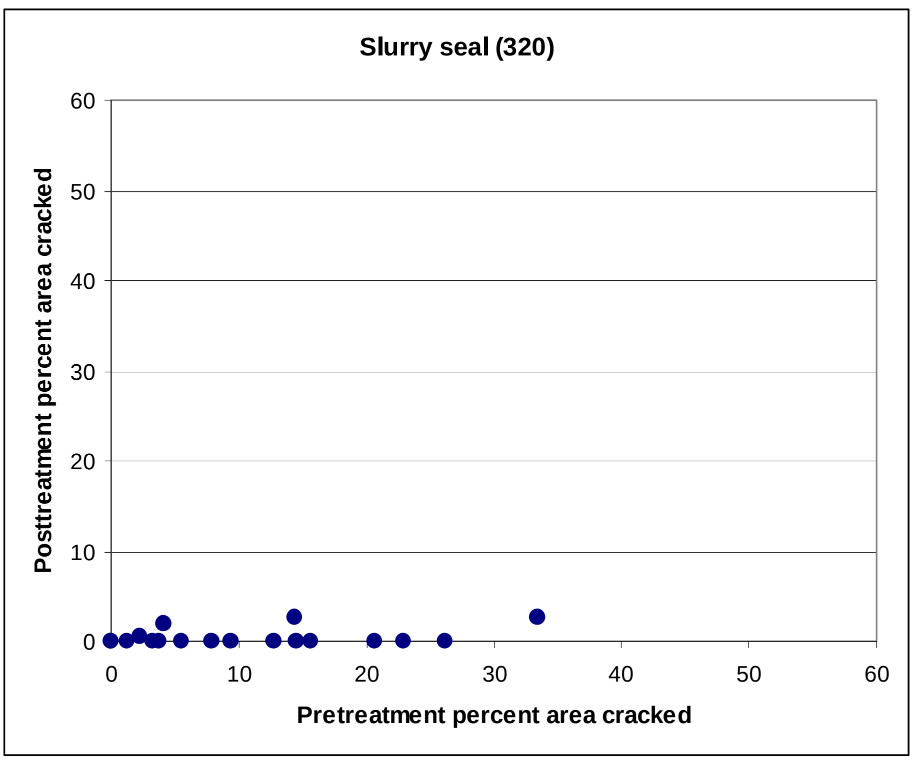

Figure 25. Fatigue cracking before and after treatment, SPS-3 slurry seal sections.

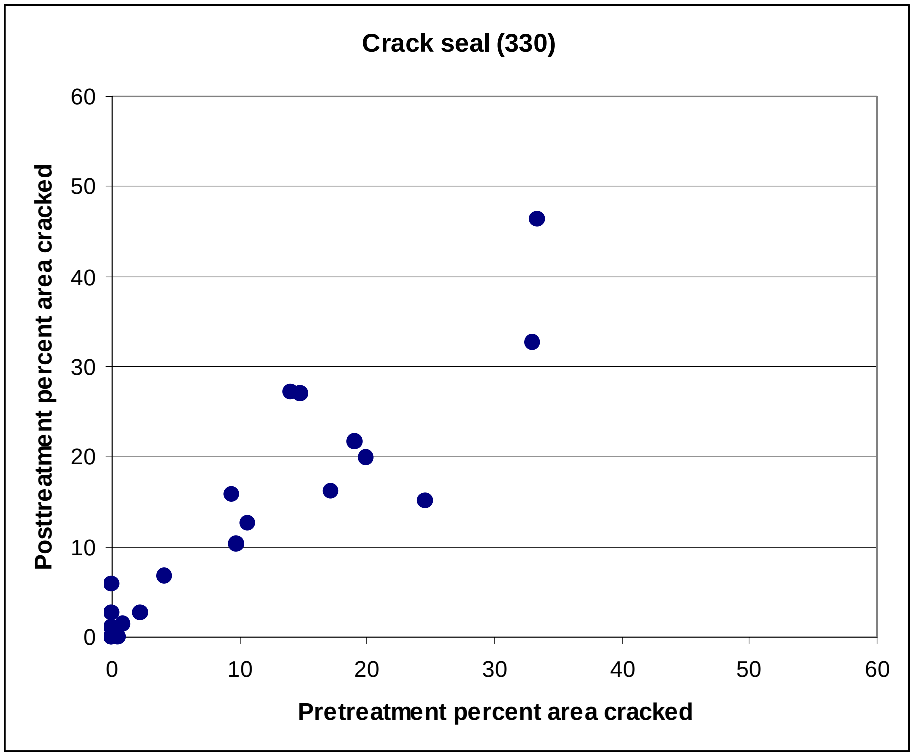

Figure 26. Fatigue cracking before and after treatment, SPS-3 crack seal sections.

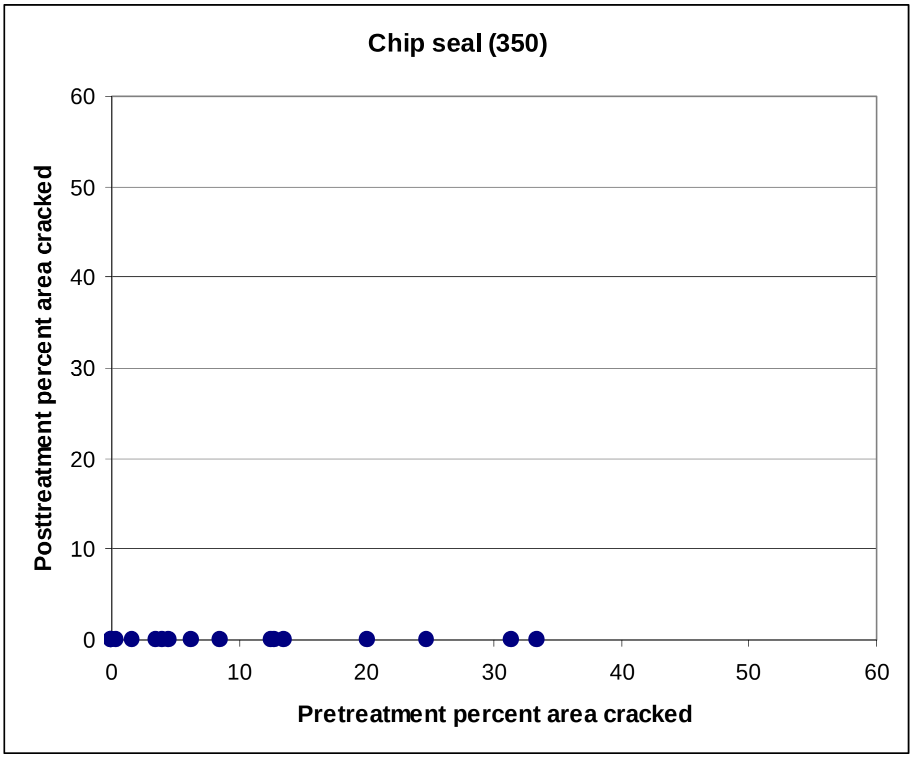

Figure 27. Fatigue cracking before and after treatment, SPS-3 chip seal sections.

These results are as might be expected, since the thin overlay, slurry seal, and chip seal treatments initially obscure the fatigue cracking in the pavement, whereas the crack seal treatment does not obscure the cracks, and in fact may make the cracks more visible to the survey technicians.

Long-Term Effects on Fatigue Cracking

The long-term effects of maintenance on fatigue cracking are assessed by comparing the percent of the test section area cracked, as recorded in the most recent distress survey, with the percent of the corresponding control section cracked, as recorded at the same time.

A plot of percent area fatigue cracked in the thin overlay sections versus their corresponding control sections is shown in Figure 28. The rather remarkable result is that fatigue cracking is fairly consistent among almost all of the thin overlay sections considered in this analysis. The trendline is very close to horizontal, and the average area cracked is 13 percent (according to the calculation method described previously).

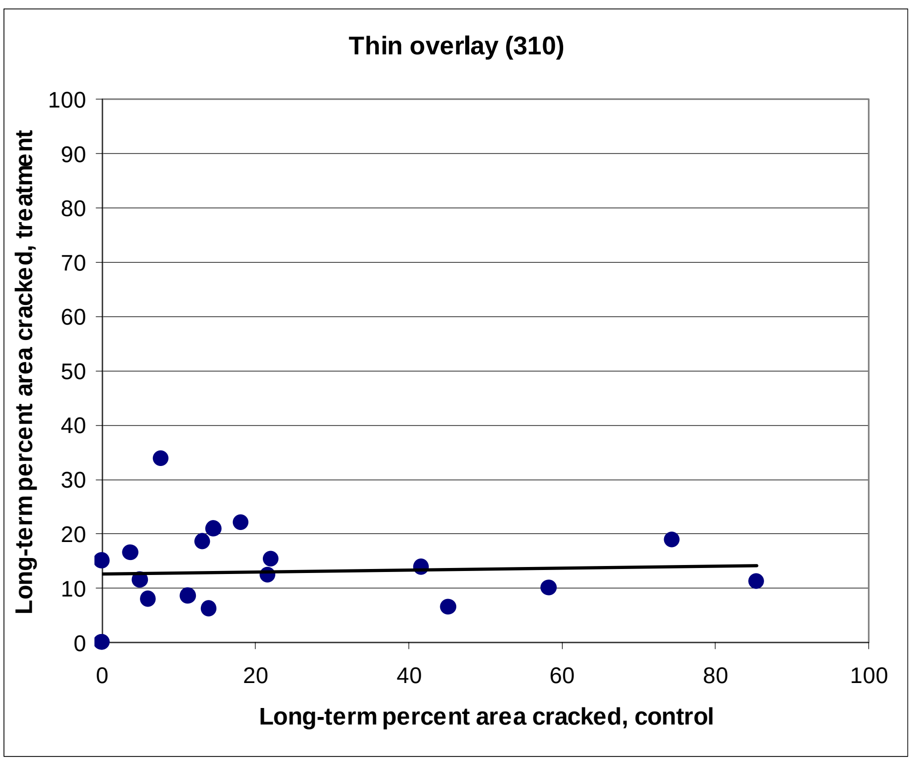

Figure 28. Long-term fatigue cracking , SPS-3 thin overlay versus control.

The effectiveness of the slurry seal treatment, while not as great as that of the thin overlay treatment, is still evident, as shown in Figure 29. At most of the sites, fatigue cracking in the control section exceeds the fatigue cracking in the slurry seal section. There is a more upward trend in the data, however, then there was in the thin overlay data. This suggests that the tendency for fatigue cracking to increase with time is somewhat stronger in the slurry seal sections than in the thin overlay sections.

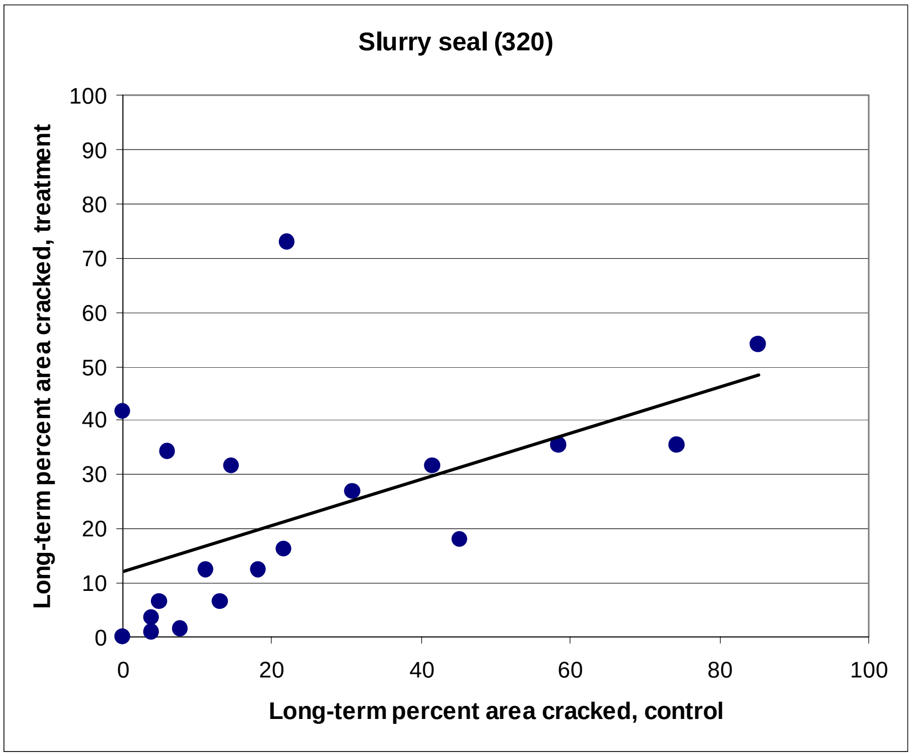

Figure 29. Long-term fatigue cracking , SPS-3 slurry seal versus control.

The situation in the crack seal sections is very different, as Figure 30 shows. For all but a few sections, the fatigue cracking in the crack seal section is greater than in the control section, and in some cases considerably greater. Again, it is conceivable that this is not due to any true adverse effect of crack sealing on the fatigue life of the pavement, but rather (1) the sealing of new cracks (that is, cracks that appeared after the initial treatment date) in some crack seal sections but not in the corresponding control sections, and/or (2) the greater visibility of sealed cracks.

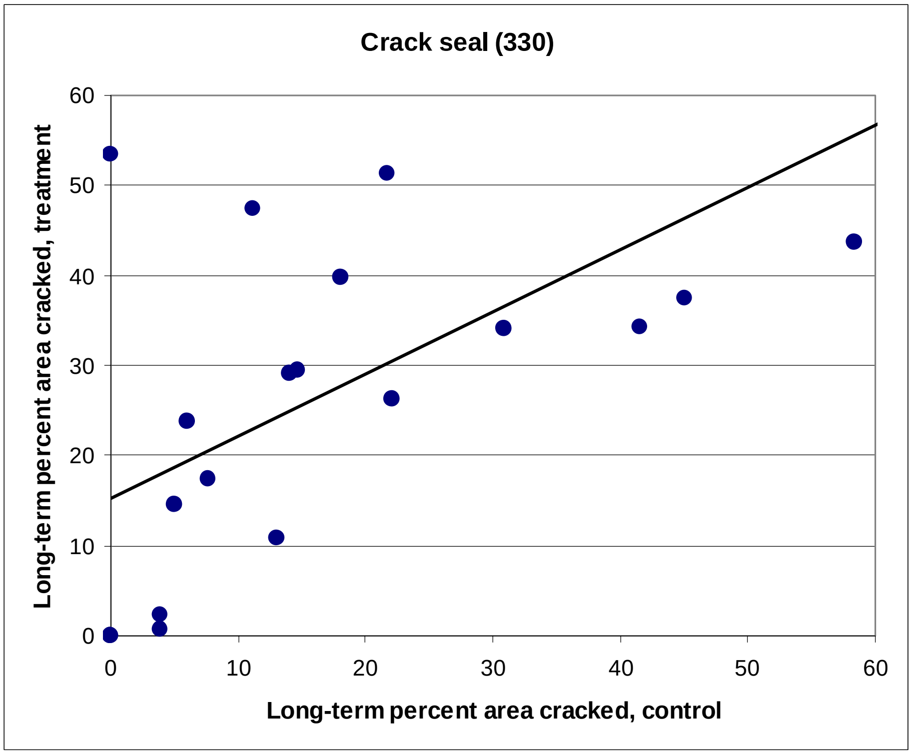

Figure 30. Long-term fatigue cracking , SPS-3 crack seal versus control.

The plot of long-term cracking in the chip seal sections versus the control sections is shown in Figure 31. The slope of the trendline suggests that the effectiveness of the chip seals at retarding the reflection of fatigue cracking is between that of the thin overlay sections and that of the slurry seal sections.

These data cover a range of time from 1.6 to 8.4 years, with an average of 5.9 years. However, a relatively small proportion of SPS-3 sites – just 25 percent – have data suitable for a long-term analysis of cracking. Thus, more detailed analysis of the influence of factor effects seems unwarranted, as any results obtained could not be counted on to reflect most of the SPS-3 experiment.

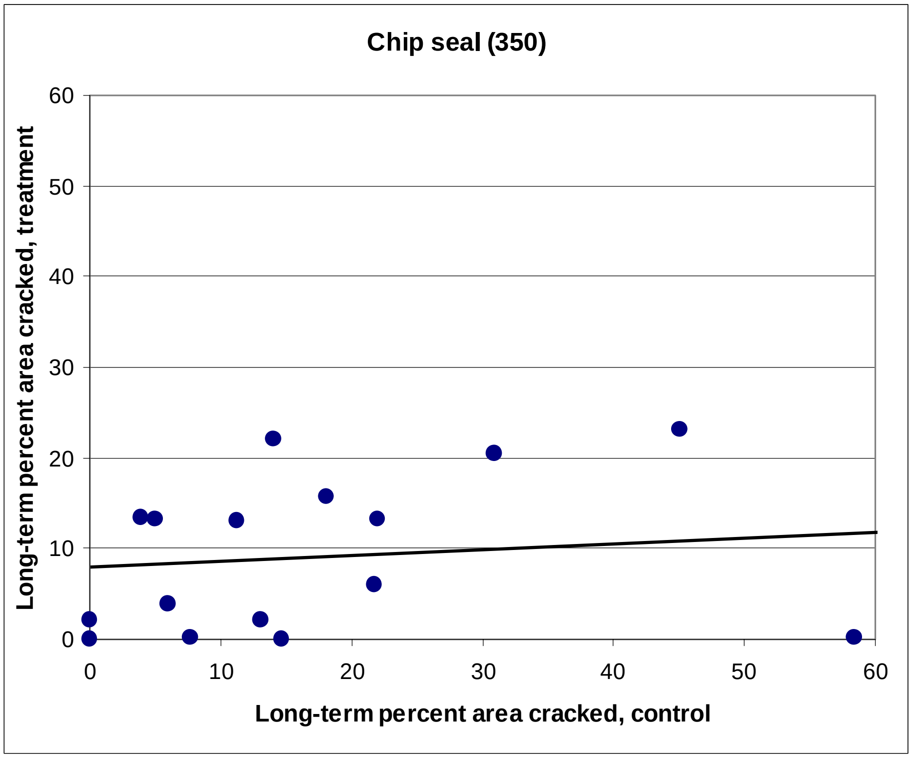

Figure 31. Long-term fatigue cracking , SPS-3 chip seal versus control.

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Chapter 3

Flexible Pavement Rehabilitation Effectiveness

Description of LTPP Experiments SPS-5 and GPS-6B

The SPS-5 experiment was designed to assess the effects of overlay thickness, overlay type, and pavement surface preparation on the performance of asphalt concrete pavements after rehabilitation. The Strategic Highway Research Program's experimental design and research plan for SPS-5 are described in Reference 17.

Each SPS-5 project has nine main experimental sections, listed in Table 14. The numbers shown in the cells are the test section numbers. Section 501 is the unrehabilitated control section. This section can receive routine maintenance over the course of the experiment (e.g., crack sealing, patching, seal coating). Sections 502 through 505 are the "minimal preparation" sections, and received patching and leveling (only for ruts greater than 0.5 inch) prior to overlay. Milling was not done on these sections except to remove an open-graded friction course. Sections 6 through 9 are the "intensive preparation" sections, and received patching, crack sealing, and milling (between 1.5 and 2 inches) prior to overlay. The recycled asphalt overlay mixtures were specified to contain 30 percent recycled material. The specific techniques applied to the test sections, as described in Reference 18, are summarized in Table 15.

Table 14. SPS-5 experimental treatments applied to test sections.

Nominal overlay thickness (inches)	Overlay mix type	Preoverlay preparation		
		None/control	Minimal	Intensive
0	None/control	501		
2	Virgin		505	506
	Recycled		502	509
5	Virgin		504	507
	Recycled		503	508

Table 15. Preoverlay and overlay techniques applied to SPS-5 test sections.

Rehabilitation Treatments	Test Section								
	501	502	503	504	505	506	507	508	509
Asphalt overlay thickness (inches)	0	2	5	5	2	2	5	5	2
Type of mix (V = virgin, R = recycled)	--	R	R	V	V	V	V	R	R
Milling		✔[a]	✔[a]	✔[a]	✔[a]	✔	✔	✔	✔
Patching	✔	✔	✔	✔	✔	✔[b]	✔[b]	✔[b]	✔[b]
Crack sealing	✔					✔[b]	✔[b]	✔[b]	✔[b]
Leveling		✔[c]	✔[c]	✔[c]	✔[c]				
Seal coat	✔[d]								

[a] Milling permitted only to remove open-graded friction course.
[b] Perform after milling as required.
[c] If ruts are ≥ ½ inch.
[d] Not permitted in first year of study.

Eighteen SPS-5 projects have been constructed in the United States and Canada. Their locations are shown in Figure 32. Location data for the SPS-5 projects are given in Table 16.

Figure 32. SPS-5 locations.

Table 16. SPS-5 location data.

SHRP ID	State	Linked GPS	County	Nearby city or town	Route	Latitude	Longitude
010500	AL	014155	Houston	Dothan	US 84	31.24	85.63
040500	AZ		Pinal	Casa Grande	I-8	32.83	112.01
060500	CA		San Bernardino	Barstow	I-40	34.81	116.60
080500	CO		Lincoln	Arriba	I-70	39.28	103.21
120500	FL	121030	Martin	Jupiter	US 1	26.99	80.10
130500	GA		Bartow	Acworth	I-75/US 401*	34.11*	84.73
230500	ME		Penobscot	Argyle	I-95	45.05	68.69
240500	MD		Frederick	Point of Rocks	US 15	39.29	77.53
270500	MN		Beltrami	Solway	US 2	47.52	95.13
280500	MS		Yazoo	Vaughan	I-55	32.84	90.04
290500	MO		Taney	Ridgedale	US 65	36.50	93.23
300500	MT	307066	Sweet Grass	Big Timber	I-90	45.81	110.00
340500	NJ		Monmouth	Shrewsbury	I-195	40.18	74.52
350500	NM		Grant	Wilna	I-10	32.20	108.28
400500	OK		Comanche	Cache	US 62	34.64	98.67
48A500	TX	481069	Kaufman	Gastonia	US 175	32.61	96.42
810500	AB		–	Edson	TCH 16	53.59	116.019
830500	MB		–	Richer	TCH 1	49.66	96.276

* Georgia SPS-5 project's route number and latitude are believed to be correct as shown here and incorrect in LTPP database release 11.5.

Climate Characterization

The climatic distribution of the SPS-5 and GPS-6B sites was determined by extracting the latitude and longitude for each site from the LTPP database, searching the National Oceanic and Atmospheric Administration (NOAA) database for the weather station nearest the SPS-5 or GPS-6B site, and extracting the 30-year average annual precipitation and average annual temperature for the weather station. These data are provided in Appendix B. The distributions of SPS-5 sites and GPS-6B sites with respect to average annual precipitation and temperature are illustrated in Figures 33 and 34 respectively. Not shown in Figure 34, and not considered in the subdivision of the precipitation range, are three GPS-6B sites in Alaska with total annual precipitation in excess of 95 inches.

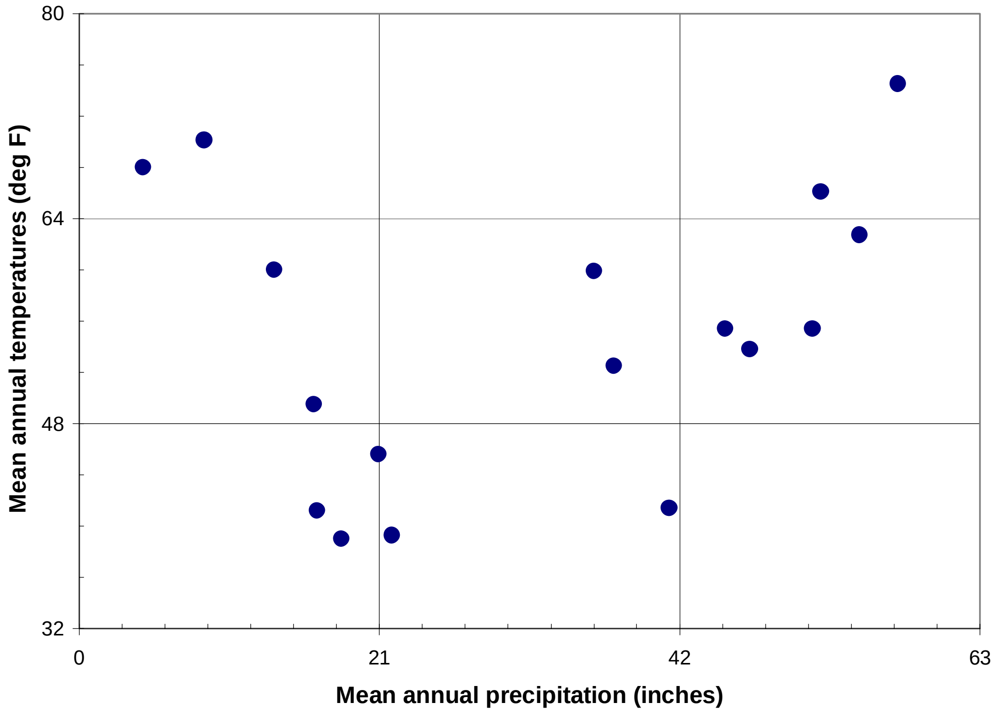

Figure 33. Distribution of SPS-5 sites with respect to precipitation and temperature.

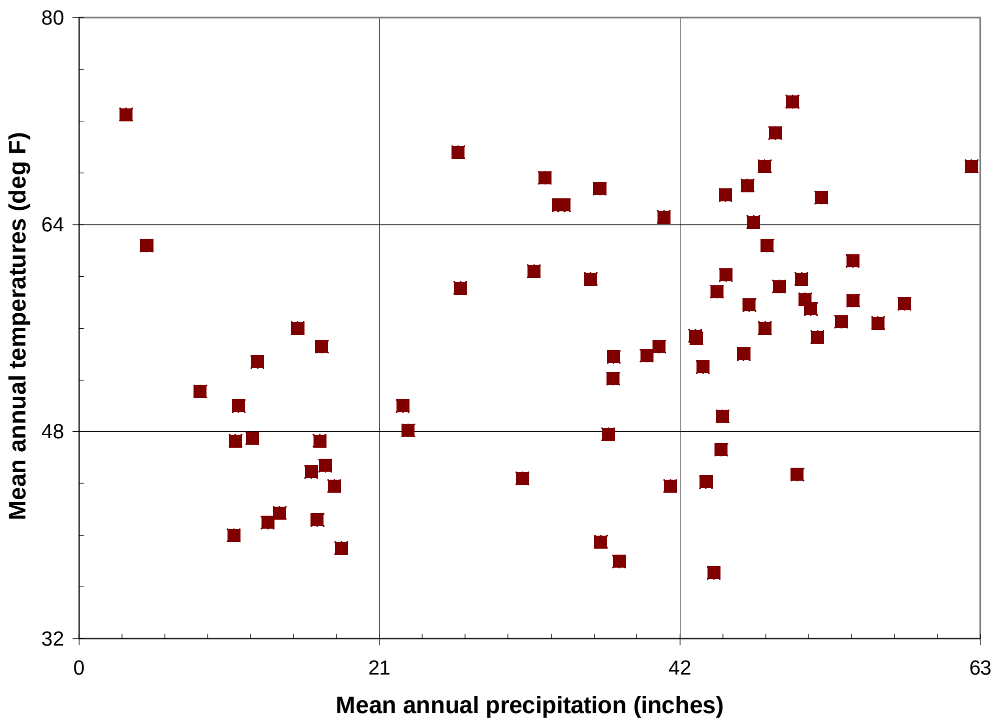

Figure 34. Distribution of GPS-6B sites with respect to precipitation and temperature.

Seven of the nine combinations of low, medium, and high precipitation and temperature ranges defined earlier are covered by the SPS-5 experiment. The climatic distribution of the GPS-6B sites echoes that of the SPS-5 sites.

Test Section Layouts and Pavement Structures

The station limits, layer thicknesses, and material types for each of the SPS-5 test sections and linked GPS sections were extracted from the SPS_PROJECT_STATIONS and TST_L05B data tables in the LTPP database. The thicknesses in the TST_L05B table represent the LTPP regional data collection centers' best estimates of the as-constructed layer thicknesses and materials, from historical records, cores, and rod-and-level surveys. The test section layout and pavement structure data are given in Appendix B. An example is shown in Figure 35.

Structural Characterization

The structures of the SPS-5 pavements at the start of the experiment were characterized using the available layer thickness and materials data, and using deflection data. The as-constructed layer thicknesses and material types were used to calculate a pretreatment Structural Number for each SPS-5 test section, using the same structural coefficients as used for the SPS-3 sites. Temperature- and load-normalized mean maximum deflections and AUPP values were also calculated, by the same procedures used for the SPS-3 sites. However, there are some problematic inconsistencies in availability of measurements (deflections together with mix temperatures) prior to rehabilitation at the SPS-5 sites. Therefore, the results of the analysis of the influence of pretreatment structural capacity on long-term effectiveness of rehabilitation treatments is not presented in this report. The results of the analyses of other factors of potential influence (age, accumulated traffic, climate, and pretreatment IRI or distress) are presented.

Traffic Characterization

The 18-kip-equivalent single-axle (ESAL) levels at the SPS-5 sites were determined in the same way as described in Chapter 2 for the SPS-3 sites. For the purpose of analyzing the long-term effects of SPS-5 rehabilitation treatments on pavement performance, the accumulated ESALs from the dates of initial posttreatment profile and distress measurement to the dates of the most recent measurements were also calculated for each SPS-5 site.

FLORIDA - SPS-5

Station (m)	Section	Original Construction: AC Thickness	Base: Thickness	Base: Type	Subbase: Thickness	Subbase: Type	Subgrade Type	Rehabilitation: AC Thicknesses	
0 – 152	120502	3.1	8.8	GB (303)	15	GS (308)	SS (202)	0.8 (13) 1.8 (13)	1.7
669 – 821	120561	2	8.8	GB (303)	15	GS (308)	SS (202)	1 (13) 2.8 (13)	2.1
945 – 1,098	120503	2.7	9.5	GB (303)	15	GS (308)	SS (202)	3.1 (13) 2.2 (13)	2.3
1,190 – 1,343	120508	2.8	8.8	GB (303)	15	GS (308)	SS (202)	4.4 (13) 2.7 (13)	0.5
1,799 – 1,951	120565	3.1	8.8	GB (303)	15	GS (308)	SS (202)	1.1 (13) 2.2 (13)	2.6 (13) 0.5
2,072 – 2,225	120509	3.2	8.8	GB (303)	15	GS (308)	SS (202)	1 (13) 3.1 (13)	0.7
2,380 – 2,532	120506	2.9	8.8	GB (303)	15	GS (308)	SS (202)	1.1 1.9	1.7
2,620 – 2,773	120566	2.8	8.8	GB (303)	15	GS (308)	SS (202)	1 2.2	2.3 0.3
2,894 – 3,047	120507	2.8	8.8	GB (303)	15	GS (308)	SS (202)	4.5 2.1	0.6
3,169 – 3,321	120504	2.9	8.8	GB (303)	15	GS (308)	SS (202)	1.5 3.6	2.2
3,443 – 3,595	120562	2.7	8.8	GB (303)	15	GS (308)	SS (202)	1 2.6	1.9
3,717 – 3,869	120505	2.9	8.8	GB (303)	15	GS (308)	SS (202)	0.8 1.3	2.2
4,357 – 4,510	120563	3.1	8.8	GB (303)	15	GS (308)	SS (202)	0.9 1.3	0.5
4,631 – 4,784	120564	3.1	8.8	GB (303)	15	GS (308)	SS (202)	0.6 (13) 1.4 (13)	0.6

Figure 35. Example SPS-5 pavement structure information.

These accumulated ESAL estimates are provided in Appendix B. The accuracy of these accumulated ESAL estimates should, however, be viewed with caution.

Pretreatment Condition

The original design of the SPS-5 experiment identified pretreatment condition as a categorical variable to be used in site selection, with a balance of sites in "fair" and "poor" condition to be identified.[17] However, since definitions of "fair" and "poor" levels of pretreatment condition were not established and furnished to the states for use in site selection, pretreatment condition became a quantitative independent variable in the experiment.

The pretreatment International Roughness Index (IRI), rutting, and cracking levels in the SPS-5 test sections were determined using the last measurement of each of these parameters prior to treatment. The relationship of pretreatment condition to long-term treatment effectiveness has been examined wherever possible, i.e., for those test sections with pretreatment condition data available.

Construction Problems and Deviations

At some of the SPS-5 sites, some problem or deviation occurred with the application of one or more of the rehabilitation treatments.[19] These construction problems and deviations are listed in Table 17. Most of these are not serious, although the occurrence of one or more problems at nearly every site is an interesting commentary on the typical problems encountered in asphalt overlay construction. The deviations that are considered of particular significance to this analysis are the rehabilitation activities in what should have been the control section at the California, Colorado, Georgia, Montana, New Mexico, and Manitoba sites. No noteworthy deviations were reported for the Missouri and Oklahoma sites, so they are not listed in Table 17.

GPS-6B Experiment

The GPS-6B experiment consists of asphalt concrete pavements (formerly in the GPS-1 or GPS-2 experiment) that have received a conventional AC overlay at least 1 inch thick. The pavements receive either no pretreatment prior to overlay, or receive maintenance and repair treatment. The LTPP data set used for this analysis included 98 pavement sections belonging to the GPS-6B experiment. Location data for the GPS-6B section are given in Table 18. The locations of the GPS-6B sites are shown in Figure 36.

Table 17. SPS-5 construction problems and deviations.[19]

SHRP ID	State	Problem or Deviation
010500	AL	In section 010507, temperature during laydown was below allowable limit. Longitudinal cracking in both wheelpaths observed after milling. Surface course was delaminated and came up in chunks during milling operation.
040500	AZ	Low temperature behind the paver during placement of first of three lifts was a concern. Calibration of nuclear density gage during testing of second lift was in doubt; the correction applied was later determined to be incorrect. Low stability was noted in the asphalt rubber mix. As much as 1 inch of material was removed by milling in some areas of "minimum restoration" sections. Problems achieving compacted density occurred in left lanes of sections 040504 and 040507.
060500	CA	***The control (501) section was overlaid.*** Segregation of the first lift and mat checking in the overlays was attributed to frequent stops and starts of the paver. Some problems were encountered during compaction of several sections. Several inconsistencies and incomplete work were encountered in the milling operations in sections 060502, 060503, and 060509. Slipping of the paver occurred on supplemental sections 060560 and 060561, resulting in torn reinforcement fabric, which in some areas was removed, but not replaced.
080500	CO	***A rut-level was placed in the control section***, because the severity of rutting was a safety concern.
120500	FL	First 15 m of section 120502 were milled although they should not have been. There was some evidence of segregation in the recycled mix. A 460-mm swath of mix throughout section 120508 was not sufficiently tacked because the spray nozzles of the tack applicator were stuck.
130500	GA	***[Although not noted in Reference 19, the control (501) section failed about a year after the other sections were overlaid. There is no linked GPS section for this site, so effectively there is no control section for this site.]*** The core experimental sections are grouped at the north end (where the subgrade is red sandy silt), and the supplemental sections are grouped at the south end (where the subgrade is crushed gravel). Surface irregularites that could not be removed by compaction occurred during overlay construction in sections 130502 and 130562.
230500	ME	No leveling course was placed on the minimum preparation sections. Cracks that were more then ¾ inch wide were not repaired with patches. In some locations, the overlay thickness was increased to correct both cross slope and rutting.
270500	MN	Some test sections are on fine-grained soils and others are on coarse-grained soils. There is a small town in the middle of the project, with four of the test sections being east of the town and the others being west of the town. This is not anticipated to produce nonuniform traffic.
280500	MS	Construction occurred over a long period of time, primarily because the asphalt concrete production plant had numerous breakdowns and had problems maintaining consistent mix production.

Table 17. SPS-5 construction problems and deviations (continued).[19]

SHRP ID	State	Problem or Deviation
300500	MT	Due to the deterioration of the proposed 300501 control section, the DOT proposed using the neighboring 307066 GPS section as a control. However, this GPS section was milled and overlaid during the same time that the SPS sections were constructed. Thus, ***this project has no control section.***
340500	NJ	Depth of milling in section 340559 could not be measured. Aggregate fracturing occurred at the longitudinal centerline joint and shoulder joint during compaction of both the binder course and the surface course.
350500	NM	***The intended control section 350501 was milled and inlaid.*** In sections 350508 and 350509, the RAP mix was high in air voids, and oil was added to the mix to reduce the air void before placement of the overlay.
480500	TX	Overlay construction was delayed due to rain, mix design problems, and waiting for parts at the plant.
810500	AB	In section 810502, tack coat material was observed bubbling up through surface course lift. Near the middle of section 810505, one of the pneumatic rollers spun its wheels, leaving a slight depression. In section 810509, the inlay that overlaps the shoulder has a 4.6-m crack, 25 mm wide, centered at station 0+25.
830500	MB	***The intended control section 8350501 was overlaid.*** he contractor did not have any recycling experience. The addition of a centerline crown and the milling operation may have resulted in overlay thicknesses to vary by more than 25 mm in some test sections.

Table 18. GPS-6B location data.

SHRP ID	State	County	Nearby city or town	Route	Latitude	Longitude
011001	AL	Lee	Smiths Station	US 280/431*	32.53	85.08
014127	AL	Lauderdale	Rogersville	US 72	34.84	87.36
014129	AL	Coosa	Alexander City	US 280	33.05	86.14
014155	AL	Dale	Dothan	US 84	31.24	85.57
021002	AK	Anchorage	Silvertip	SR 1	60.76	149.24
021004	AK	Anchorage	Anchorage	on or near SR 1*	61.18	149.75
029035	AK	Matanuska-Susitna	Trapper Creek	SR 3	62.42	150.26
062041	CA	Humboldt	Stafford	US 101	40.45	124.05
062051	CA	Napa	Napa	SR 29	38.27	122.30

Table 18. GPS-6B location data (continued).

SHRP ID	State	County	Nearest city or town	Route	Latitude	Longitude
068153	CA	San Luis Obispo	Edna	SR 227	35.21	120.62
068534	CA	Imperial	El Centro	I-8	32.77	115.77
068535	CA	Imperial	El Centro	I-8	32.77	115.52
081047	CO	Rio Blanco	Rangely	SR 64	40.10	108.83
087781	CO	Bent	Las Animas	US 50	38.09	103.18
111400	DC	–	Washington	I-295	38.87	76.99
123997	FL	Clay	Hibernia	US 17	30.09	81.71
124101	FL	Orange	Orlando	SR 528	28.45	81.29
124135	FL	Polk	Crooked Lake Park	27	27.86	81.59
124136	FL	Polk	Crooked Lake Park	27	27.87	81.59
124137	FL	Polk	Crooked Lake Park	27	27.88	81.60
134420	GA	Bryan	Richmond Hill	US 17	31.90	81.36
161007	ID	Twin Falls	Cedar	US 30	42.59	114.70
181037	IN	Spencer	Sand Ridge	SR 66	37.90	87.22
190107	IA	Lee	Jollyville	US 61	40.70	91.25
231009	ME	Lincoln	Nobleboro	US 1	44.06	69.49
231026	ME	Franklin	Wilton	US 2	44.57	70.30
231028	ME	Oxford	Bethel	US 2	44.43	70.80
271016	MN	Beltrami	Bemidji	US 71	47.52	94.91
283093	MS	Jackson	Escatawpa	I-10	30.43	88.67
283094	MS	Jackson	Escatawpa	I-10	30.44	88.63
291010	MO	Pulaski	Waynesville	I-44	37.80	92.23
295403	MO	Dunklin	Senath	US 412	36.12	90.17
295413	MO	Dunklin	Dillman	US 412	36.20	90.09
307066	MT	Sweet Grass	Big Timber	I-90	45.81	110.00
307076	MT	Big Horn	Wyola	I-90	45.12	107.35
307088	MT	Sweet Grass	Big Timber	I-90	45.81	110.00
316700	NE	Phelps	Atlanta	6	40.40	99.44
321030	NV	Clark	Las Vegas	US 95	36.23	115.22
361008	NY	Oneida	Rome	SR 49	43.20	75.42
361011	NY	Onondaga	Syracuse	I-481	43.12	76.05
361643	NY	Washington	Fort Ann	US 4	43.44	73.46

Table 18. GPS-6B location data (continued).

SHRP ID	State	County	Nearest city or town	Route	Latitude	Longitude
371040	NC	Mitchell	Spruce Pine	US 19	35.91	82.06
371802	NC	Granville	Oxford	US 158*	36.32	78.52
404086	OK	Grady	Chickasha	US 81	35.08	97.96
404154	OK	Grady	Rush Springs	US 81	34.75	97.96
404164	OK	Major	Fairview	US 60	36.33	98.48
421605	PA	Northumberland	Milton	SR 147	41.00	76.83
421618	PA	Somerset	Wellersburg	SR 160	39.77	78.91
451025	SC	Greenwood	Greenwood	on or near US 221*	34.25	82.14
469106	SD	Perkins	Summerville	SR 73	45.85	102.18
469197	SD	Jerauld	Lane	SR 34	44.07	98.51
471023	TN	Anderson	Lake City	I-75	36.19	84.10
472001	TN	Dyer	Templeton	I-155/US 51*	36.18	89.23
472008	TN	Gibson	Milan Arsenal	US 45/ SR 43*	35.86	88.75
473101	TN	Canon	Auburntown	SR 96	35.94	86.12
473108	TN	Anderson	Lake City	I-75	36.18	84.00
473109	TN	Maury	Fountain Heights	SR 50	35.53	86.93
473110	TN	McMinn	Riddles Store	SR 68	35.61	84.57
479024	TN	Rutherford	Lascassas	SR 96	35.93	86.24
479025	TN	Cannon	Auburntown	SR 96	35.95	86.10
481039	TX	Ellis	Waxahachie	US 287	32.49	96.82
481093	TX	Atascosa	Campbellton	I-37	28.78	98.31
481111	TX	Lubbock	Lubbock	SR 289	33.53	101.80
481113	TX	Rusk	Mount Enterprise	259	31.96	94.70
481116	TX	Rusk	Mount Enterprise	259	31.89	94.68
481119	TX	Cherokee	Pine Hill	US 79	32.00	95.00
481130	TX	Guadalupe	Seguin	SR 123	29.56	97.94
483669	TX	Angelina	Lufkin	SR 94	31.33	94.79
483729	TX	Cameron	San Benito	US 77/US 83*	26.09	97.58
483835	TX	Brazos	Bryan	US 190/SR 6*	30.73	96.43
483855	TX	Fayette	Lagrange	SR 71	29.90	96.81
483875	TX	Sherman	Lautz	US 287	36.16	102.03
489005	TX	Bexar	San Antonio	SR 1560	29.52	98.72

Table 18. GPS-6B location data (continued).

SHRP ID	State	County	Nearest city or town	Route	Latitude	Longitude
491008	UT	Sevier	Salina	US 89	38.95	111.85
501681	VT	Chittenden	Charlotte	US 7	44.31	73.25
501683	VT	Chittenden	Charlotte	US 7	44.33	73.24
511002	VA	Floyd	Floyd	SR 8	36.96	80.37
511417	VA	Fauquier	Remington	US 17	38.61	77.79
511419	VA	Russell	Smithfield	US 19	36.97	81.92
511423	VA	Wise	Big Stone Gap	US 23	36.85	82.76
512021	VA	Carroll	Brown's Store	US 58	36.73	80.80
531005	WA	Adams	Ritzville	I-90	47.10	118.63
531007	WA	Benton	Paterson	SR 221	46.05	119.60
531008	WA	Spokane	Spokane	US 195	47.56	117.39
541640	WV	Kanawha	Alum Creek	US 119	38.28	81.76
562019	WY	Campbell	Gilette	SR 59	44.16	105.45
567772	WY	Hot Springs	Thermopolis	SR 120	43.67	108.28
811804	AB	–	Edmonton	SR 19	53.34	113.59
811805	AB	–	Calgary	SR 22X	50.91	113.93
836450	MB	–	Richer	TCH 1	49.66	96.31
836451	MB	–	Richer	TCH 1	49.66	96.31
891021	PQ	–	Champlain	SR 40	46.46	72.42
891125	PQ	–	Les Écureuils	SR 40	46.70	71.67
891127	PQ	–	Ste.-Marie	SR 73	46.48	71.04
906405	SK	–	Plunkett	TCH 16*	51.90	105.31
906410	SK	–	Saskatoon	SR 11*	52.06	106.60
906412	SK	–	Saskatoon	SR 11*	52.06	106.62
906420	SK	–	Langbank	SR 9	50.17	102.30

* Route numbers shown here are based on latitude and longitude and may not agree with route numbers in LTPP database release 11.5. TCH stands for Trans-Canada Highway. SR is used for Canadian projects located on the equivalent of state routes in the United States.

Figure 36. GPS-6B locations.

Performance Findings from Previous Studies

Analysis of Trends in Distress, Roughness, and Deflections

An analysis conducted in 1995 to identify any trends in the early performance data from the SPS-5 experiment is described by Daleiden et al.[20] The SPS-5 test sections were evaluated with respect to fatigue cracking, longitudinal cracking in the wheelpath and outside the wheelpath, transverse cracking, and bleeding. Roughness, rutting, and deflections were also evaluated.

The age of the experiment and the amount of data available were identified as the main limitations to analysis of the data available in 1995. Most of the sections were only a few years old at that time, and for many of them, there had been little if any change in condition since rehabilitation. Also, since the sections were not very old, much of the sampling, testing, and monitoring data were in various stages of checking and were not yet available for use in analysis. For example, although SPS projects should have had monitored traffic data since the date of completion of construction, these data were not available at the time that the study described in Reference 20 was conducted. Similarly, climatic data for SPS sites were not yet available, so these data were estimated using climatic data for nearby GPS sites.

The rehabilitation treatments were judged to have improved condition and reduced roughness, compared to the condition and roughness levels prior to rehabilitation. Maximum deflections (under the load plate) were reduced, indicating an increase in load-bearing capacity. Outermost sensor deflections were unchanged, indicating consistency in measured foundation stiffnesses.

Within the first three years after rehabilitation, some recurrence of fatigue cracking, longitudinal cracking, transverse cracking, and rutting was observed in some of the sections. In general, however, it was considered to be too early to attempt to quantify the effects of subgrade type, climate, overlay thickness, or preoverlay preparation on the recurrence of distress.

The early analysis of SPS-5 performance trends described in Reference 20 yielded some observations that the researchers found surprising, including the following:

- An apparent lack of influence of overlay thickness on the recurrence of reflection cracking,
- An apparent lack of influence of climate on the recurrence of postoverlay transverse cracking,
- An apparent lack of influence of preoverlay pavement condition on performance after overlay, and
- An apparent lack of influence of milling on reflection cracking.

Efforts were also made to conduct correlation analyses of the early (through 1995) SPS-5 performance data. The goal of the correlation analyses was to attempt to identify significant factors in any performance trends observed. However, these correlation analyses yielded few results, because of the low levels of distress present in most sections at the time. Although some of the correlation analysis results appeared reasonable, others did not, and overall the correlation analysis results were not considered reliable enough to report.

Analysis of Roughness Before and After Rehabilitation

The results of a 1997 analysis of roughness data from the SPS-5 and GPS-6B experiments are described in References 21, 22, and 23. At the time of the analysis, profile data were available for 11 SPS-5 projects and 37 GPS-6B sections.

The main findings noted in Reference 21 from analysis of the pretreatment and posttreatment IRI data from the SPS-5 experiment are the following:

- No relationship was detected between IRI prior to overlay and IRI after overlay.
- No differences were detected between postoverlay IRIs of pavements that had been milled prior to overlay and postoverlay IRIs of pavements that had not been milled prior to overlay.
- Within a given SPS-5 project, the postoverlay IRI values of the different sections fell within a relatively narrow band, irrespective of the preoverlay IRI values. However, the lower and upper limits of the range of postoverlay IRI values varied from project to project.
- At the time of the analysis, most of the SPS-5 sections had shown little if any change in IRI since rehabilitation.

Of the 37 GPS-6B sections with postoverlay profile data available, 19 sections also had preoverlay profile data available for analysis. For some of the sites, the preoverlay and postoverlay IRI values were very similar. The IRI values before and after overlay for these nineteen sections are shown in Figure 37, in order of increasing overlay thickness. It is speculated in Reference 21 that this may be because the overlay dates in the database for those sections may have been incorrect, and that in fact both the "preoverlay" and "postoverlay" IRI values may have been obtained after the section was overlaid.

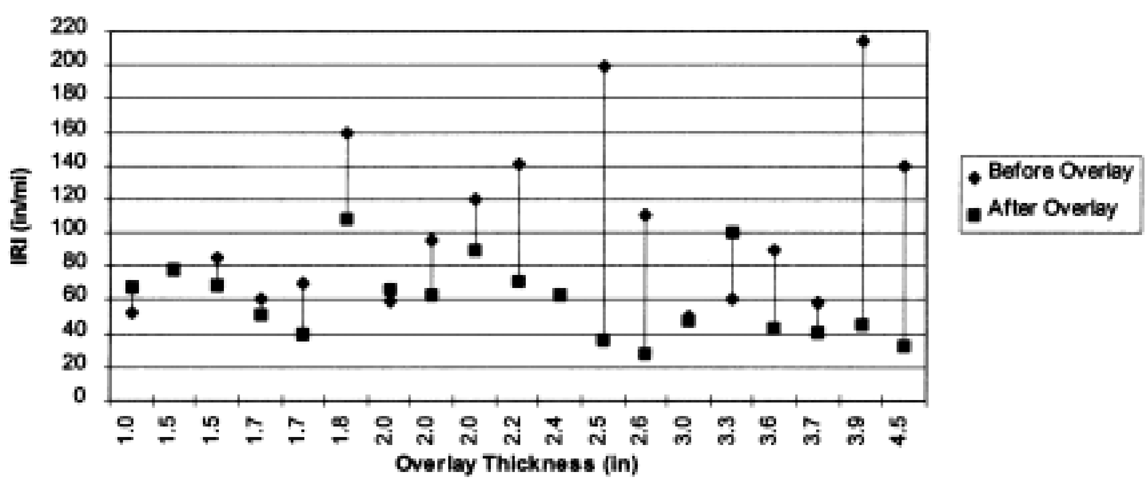

Figure 37. IRI before and after overlay for 19 GPS-6B sections, data as of 1997.[21]

A frequency distribution of the postoverlay IRI values for the 37 GPS-6B projects with profile data available in 1997 is shown in Figure 38. The GPS-6B sections were no more than five years old at the time of the analysis. As these sections had thus far exhibited little if any change in IRI, it was considered too soon to conduct any statistical analysis of IRI trends.

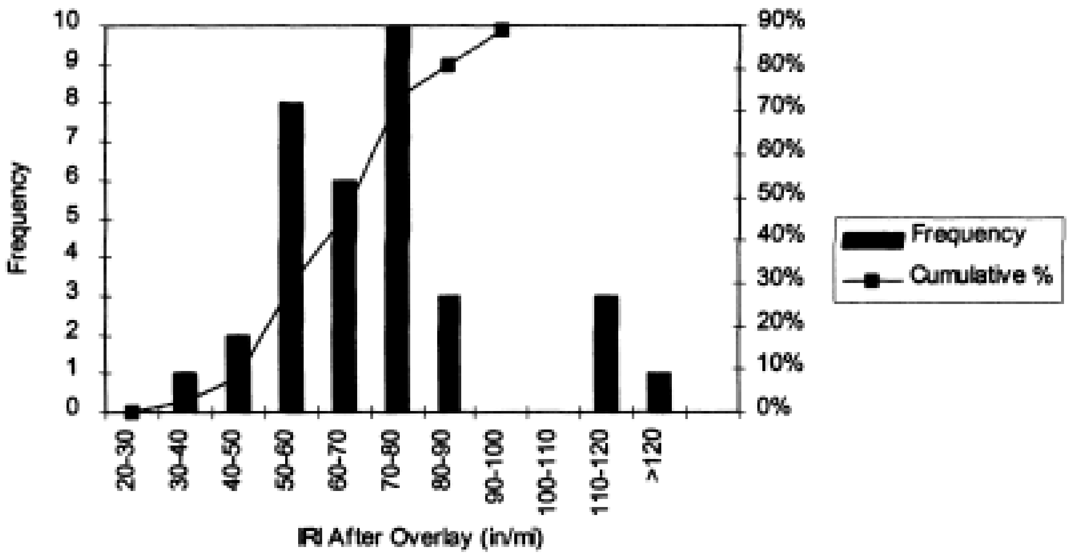

Figure 38. Frequency distribution of postoverlay IRI values for GPS-6B sections, 1997 analysis.[21]

Analysis Objectives

The objectives of the analysis of the SPS-5 and GPS-6B experiments conducted for the present study are to assess the following:

- The initial effects, if any, of overlay rehabilitation on the condition of the pavement,
- The long-term effects, if any, of overlay rehabilitation on the performance of the pavement,
- The influence, if any, of pretreatment condition and other factors on rehabilitation effectiveness, and
- The relative effectiveness of the different overlay treatments considered.

With respect to both initial and long-term effects, the analysis of the SPS-5 experiment aims to assess the changes in condition that occur in treated test sections, compared to the changes that occur in the control sections over the same time intervals. The analysis of the GPS-6B sites supplements the SPS-5 analysis.

In addition to the comparisons with the control sections, the following specific comparisons are of interest in the analyses of long-term effects:

- Minimal versus intensive preoverlay preparation,
- Thin versus thick overlays, and
- Virgin versus recycled mixes.

The pavement condition measures considered are the following:

- Roughness, as expressed by the International Roughness Index (IRI);
- Rutting; and
- Fatigue cracking.

Effects of Flexible Pavement Overlay Rehabilitation on Roughness

Initial Effects on Roughness

IRI Before Overlay

The mean preoverlay IRI values of sixteen of the eighteen SPS-5 sites are given in Table 19, along with estimated PSI values. The following details should be noted:

- The control sections at the California, Colorado, Georgia, Montana, and New Mexico sites are excluded from this IRI analysis because of rehabilitation applied to these sections.
- At the Alabama, Florida, and Texas SPS-5 sites, there is no 501 test section because the linked GPS section serves as the control.
- Preoverlay IRI data are not available for any sections at the Missouri and Manitoba sites.
- Preoverlay IRI data are available for only one test section at the New Mexico site.

Table 19. Mean preoverlay IRI and PSI values by SPS-5 site.

Site	IRI (m/km)	PSI (0–5 scale)
Alabama	1.15	3.76
Arizona	1.85	3.01
California	2.13	2.79
Colorado	1.60	3.25
Florida	1.17	3.73
Georgia	1.02	3.93
Maine	1.23	3.66
Maryland	1.64	3.21
Minnesota	2.70	2.42
Mississippi	2.20	2.74
Missouri	–	–
Montana	1.31	3.56
New Jersey	1.87	2.99
New Mexico	1.74	3.11
Oklahoma	1.83	3.03
Texas	1.53	3.22
Alberta	1.87	3.00
Manitoba	–	–

The PSI values shown throughout this chapter were estimated from the following equation:[24]

$$PSI = 5 - 0.2937\,x^4 + 1.1771\,x^3 - 1.4045\,x^2 - 1.5803\,x \quad \text{(Eqn. 4)}$$

$$x = \log(1 + SV) \quad \text{(Eqn. 5)}$$

$$SV = 2.2704\,IRI^2 \quad \text{(Eqn. 6)}$$

where:

PSI = present serviceability index

SV = 10^6 * population variance of slopes calculated at 1-ft intervals

variance = $\Sigma (Y_i - Y_{mean})^2 / n$

Y_i = individual measured slope

Y_{mean} = mean of measured slopes

n = number of slope measurements

IRI = International Roughness Index, m/km, for a 1-ft sample interval

Note that the above IRI-PSI correlation applies only to flexible pavements. A different correlation is presented in Reference 24 for rigid pavements.

In addition to the sixteen SPS-5 sites listed above, preoverlay IRI data were available for 55 of the 98 total pavement sections belonging to the GPS-6B at the time of this analysis. Summary statistics for preoverlay IRI and PSI for the SPS-5 and GPS-6B experiments are shown in Table 20. The statistics for the two data sets are similar. Note that the PSI statistics are calculated from the distribution of estimated PSI values, not from the IRI statistics.

Table 20. SPS-5 and GPS-6B preoverlay IRI and PSI summary statistics.

	SPS-5		**GPS-6B**	
	IRI (m/km)	**PSI (0-5 scale)**	**IRI (m/km)**	**PSI (0-5 scale)**
Min IRI, Max PSI	0.88	4.11	0.74	4.32
Mean	1.66	3.26	1.74	3.26
Standard deviation	0.54	0.49	0.80	0.67
Median	1.56	3.29	1.54	3.30
Max IRI, Min PSI	3.17	2.18	3.89	1.87
Number of sections	128		55	

The mean preoverlay IRI values of the different SPS-5 treatment groups are given in Table 21, along with the corresponding estimated PSI values. In the case of the control section, the term “preoverlay” refers to profile measurements obtained at the same time as the preoverlay measurements on the overlaid sections. The control sections excluded from this calculation were listed previously.

The mean “preoverlay” IRI of the control sections is lower than the mean preoverlay IRI values for the treatment groups. This is not related to the exclusion of some control sections from the calculation, because the same trend is observed when mean values are calculated using only those 11 sites for which a valid control section value is available. It would be interesting to know whether or not the control sections tended to be in better condition than the treated sections at the start of the experiment.

Table 21. Mean preoverlay IRI and PSI values by SPS-5 treatment type.

Group	IRI (m/km)	PSI (0–5 scale)
Control (501 or linked GPS)	1.40	3.46
2-in overlay, recycled mix, minimal prep (502)	1.83	3.03
5-in overlay, recycled mix, minimal prep (503)	1.76	3.10
5-in overlay, virgin mix, minimal prep (504)	1.76	3.10
2-in overlay, virgin mix, minimal prep (505)	1.58	3.27
2-in overlay, virgin mix, intensive prep (506)	1.51	3.34
5-in overlay, virgin mix, intensive prep (507)	1.68	3.17
5-in overlay, recycled mix, intensive prep (508)	1.59	3.26
2-in overlay, recycled mix, intensive prep (509)	1.79	3.07

This was analyzed using Dunnett's method for multiple comparisons with a control, described in Chapter 2. The results are shown in Table 22. In every case, the confidence interval around the difference between the treatment mean and the control mean contains zero, which indicates that the differences between the control mean and treatment means are not significant.

Table 22. Analysis of mean preoverlay IRI in control sections versus treated sections.

	Mean Preoverlay IRI (m/km)								
	501	502	503	504	505	506	507	508	509
Treatment mean	1.40	1.83	1.76	1.76	1.58	1.51	1.68	1.59	1.79
Treatment standard deviation	0.40	0.69	0.56	0.58	0.46	0.40	0.54	0.46	0.65
Treatment variance	0.16	0.47	0.31	0.34	0.21	0.16	0.29	0.21	0.42
n	11	15	15	15	16	13	14	15	14
n-1	10	14	14	14	15	12	13	14	13
Pooled variance	0.290								
Pooled standard deviation	0.538								
Degrees of freedom	119								
Dunnett's d for 9,df=119,0.05	2.692								
Treatment mean - control mean		0.43	0.35	0.36	0.18	0.11	0.27	0.18	0.39
Confidence interval lower limit		-0.145	-0.222	-0.218	-0.389	-0.483	-0.309	-0.393	-0.196
Confidence interval upper limit		1.005	0.928	0.932	0.745	0.704	0.858	0.757	0.972
Significantly different than control		no	no	no	no	no	no	no	no

In an analysis of variance, summarized in Table 23, no significant differences were detected among the mean preoverlay IRI values of the eight overlay treatment groups. Note that the usual analysis of variance calculations must be adjusted for unequal sample sizes because preoverlay IRI values are not available for the same number of SPS-5 sites for all treatment types.

Table 23. Analysis of variance of preoverlay IRI with respect to SPS-5 treatment type.

Source of variation	Sum of squares (SS)	Degrees of freedom	Mean squares (MS)	Calculated F	Theoretical F ($\alpha = 0.05$)
Between treatments	2.170	8	0.271	0.937	2.017
Within treatments	34.465	119	0.290		
Total	36.635	127			

The null hypothesis (that the population treatment means are equal) is not rejected because the calculated F value, 0.937, does not exceed the upper 5 percent of an F distribution with 8 and 119 degrees of freedom, 2.017. This is as might be expected, and indicates that there is no evidence of bias with respect to preoverlay roughness in the State DOTs' assignments of treatments to different sections.

IRI After Overlay

The mean initial postoverlay IRI values for the eighteen SPS-5 sites are given in Table 24, along with estimated PSI values. The mean initial postoverlay IRI values are shown by treatment type in Table 25, along with estimated corresponding PSI values. In the case of the control sections, the term "postoverlay" refers to profile measurements obtained at the same time as the initial postoverlay measurements on the overlaid sections. Only those control sections used in the preoverlay IRI analysis were used in the postoverlay IRI analysis.

The mean IRI of the 11 control sections used in this analysis rose from 1.40 m/km (see Table 21) to 1.47 m/km (see Table 25) in the interval between the preoverlay and postoverlay profile measurement dates. This corresponds to a decline in average estimated PSI from 3.46 to 3.38. In all of the overlay treatment groups, however, the mean initial postoverlay IRI is considerably less than the preoverlay IRI.

Table 24. Mean initial postoverlay IRI values by SPS-5 site.

Site	IRI (m/km)	PSI (0–5 scale)
Alabama	0.83	4.20
Arizona	1.14	3.76
California	0.90	4.09
Colorado	0.82	4.21
Florida	0.71	4.36
Georgia	0.53	4.61
Maine	0.88	4.13
Maryland	1.01	3.94
Minnesota	1.06	3.88
Mississippi	1.45	3.40
Missouri	1.14	3.77
Montana	0.81	4.22
New Jersey	0.90	4.10
New Mexico	0.47	4.69
Oklahoma	1.06	3.88
Texas	1.37	3.49
Alberta	1.18	3.72
Manitoba	0.97	4.00

Table 25. Initial SPS-5 postoverlay IRI and PSI by treatment type.

Treatment Group	IRI (m/km)	PSI (0–5 scale)
Without overlay:		
Control (501 or linked GPS)	1.47	3.38
With overlay:		
2-in overlay, recycled mix, minimal prep (502)	1.01	3.94
5-in overlay, recycled mix, minimal prep (503)	0.94	4.04
5-in overlay, virgin mix, minimal prep (504)	0.96	4.01
2-in overlay, virgin mix, minimal prep (505)	0.93	4.05
2-in overlay, virgin mix, intensive prep (506)	0.93	4.05
5-in overlay, virgin mix, intensive prep (507)	0.96	4.01
5-in overlay, recycled mix, intensive prep (508)	0.89	4.11
2-in overlay, recycled mix, intensive prep (509)	0.96	4.01
Overall mean with overlay	**0.95**	**4.07**

In an analysis of variance, summarized in Table 26, no significant differences were detected among the mean initial postoverlay IRI values of the different overlay treatment groups. Note that the control section group is excluded from this analysis. Note also that the usual analysis of variance calculations must be adjusted for unequal sample sizes because initial postoverlay IRI values are not available for the same number of SPS-5 sites for all treatment types. The null hypothesis (that all the overlay treatment population means are equal) is not rejected because the calculated F value, 0.269, does not exceed the upper 5 percent of an F distribution with 7 and 125 degrees of freedom, 2.084.

Table 26. Analysis of variance of initial postoverlay IRI with respect to SPS-5 treatment type.

Source of variation	Sum of squares (SS)	Degrees of freedom	Mean squares (MS)	Calculated F	Theoretical F ($\alpha = 0.05$)
Between treatments	0.153	7	0.022	0.269	2.084
Within treatments	10.148	125	0.081		
Total	10.301	132			

The overlay groups' mean initial postoverlay IRI values could also be analyzed using a three-factor analysis of variance – the three factors being overlay thickness, intensity of preoverlay preparation, and asphalt concrete mix type. Such an analysis would be expected to yield the same conclusion concerning lack of significant differences among treatments as the single-factor ANOVA, considering that only about 1 percent of the total sum of squared errors is attributable to between-treatment variation, while about 99 percent is attributable to within-treatment (that is, site to site) variation.

Summary statistics for initial postoverlay IRI and PSI for the SPS-5 and GPS-6B experiments are shown in Table 27. Note that the PSI statistics are calculated from the distribution of estimated PSI values, not from the IRI statistics.

The two distributions are similar. A large-sample (z) test indicates no significant difference in the means of the two data sets, but an F test indicates that they do not have a common variance – the variance of the GPS-6B initial postoverlay IRI values is significantly greater than the variance of the SPS-5 initial postoverlay IRI values.

Table 27. SPS-5 and GPS-6B initial postoverlay IRI and PSI summary statistics.

	SPS-5		GPS-6B	
	IRI (m/km)	**PSI (0-5 scale)**	**IRI (m/km)**	**PSI (0-5 scale)**
Min IRI, Max PSI	0.47	4.69	0.52	4.62
Mean	0.95	4.04	1.06	3.92
Standard deviation	0.28	0.38	0.42	0.48
Median	0.94	4.04	0.97	3.99
Max IRI, Min PSI	1.80	3.06	2.52	2.53
Number of sections	133		55	

Since the two distributions are not significantly different in the mean, it is reasonable to calculate the overall average initial postoverlay IRI as the weighted average of the two means (weighted with respect to the number of sections in each data set). This produces an overall average initial postoverlay IRI value of 0.98 m/km, which corresponds to an overall average PSI of 4.00. It is worth noting that this is lower than the PSI value of 4.20 that is often mentioned as a typical initial PSI for newly constructed asphalt pavements.

Preoverlay versus Postoverlay IRI

A plot of IRI values in the control section group, before and after the date of rehabilitation of the accompanying treated sections, is shown in Figure 39. The best-fit line is very close to the 1:1 line, as one might expect.

The plots of IRI values in the eight overlay treatment groups are shown in Figures 40 through 47. The trends are all very different than the trend for the control section group: the postoverlay IRI is considerably lower than the preoverlay IRI, in nearly every case. However, for every one of the overlay treatments, there is a slight but statistically significant positive correlation between preoverlay IRI and initial postoverlay IRI.

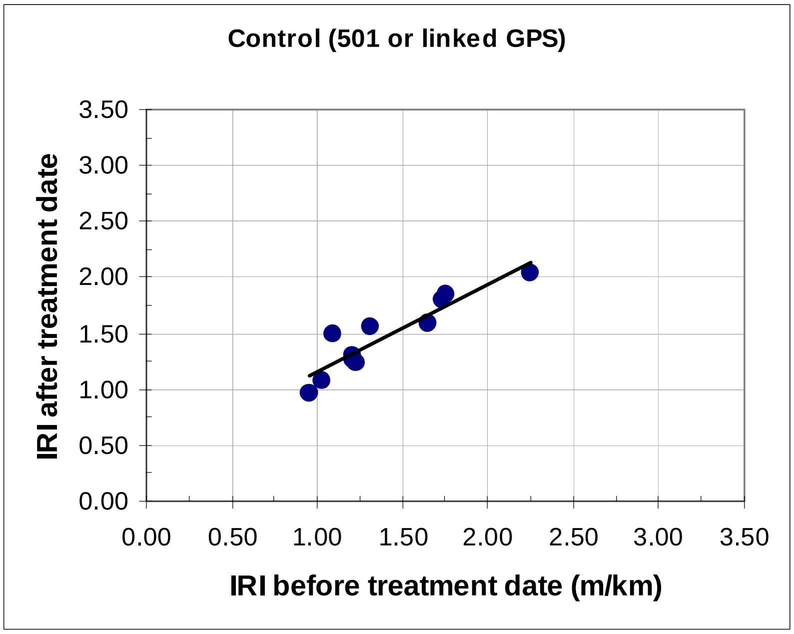

Figure 39. IRI before and after date of treatment, SPS-5 control sections (group 501 or linked GPS).

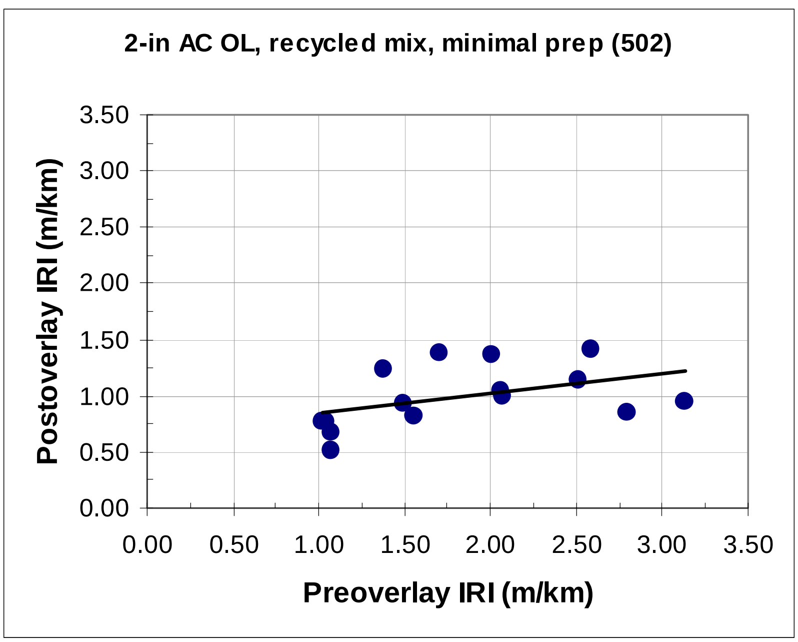

Figure 40. IRI before and after treatment, SPS-5 sections with 2-inch overlay, recycled mix, minimal preparation (treatment group 502).

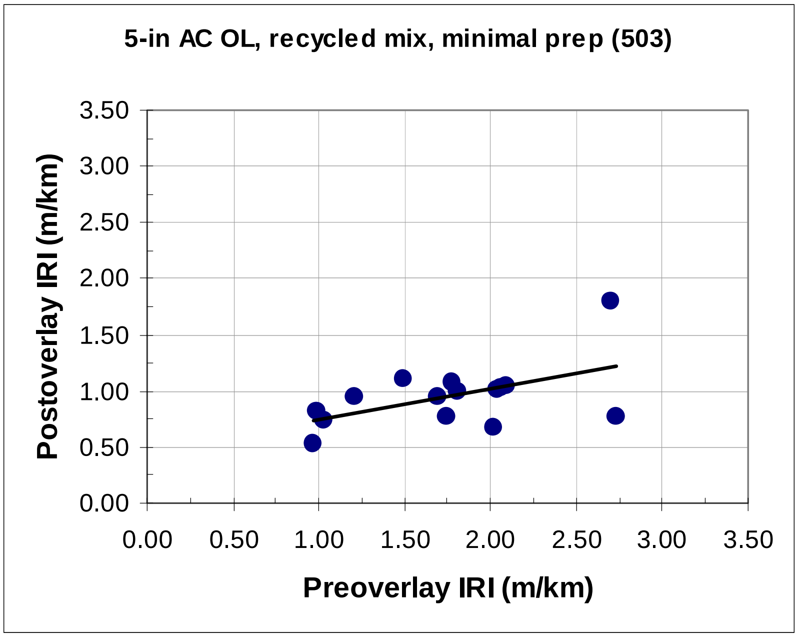

Figure 41. IRI before and after treatment, SPS-5 sections with 5-inch overlay, recycled mix, minimal preparation (treatment group 503).

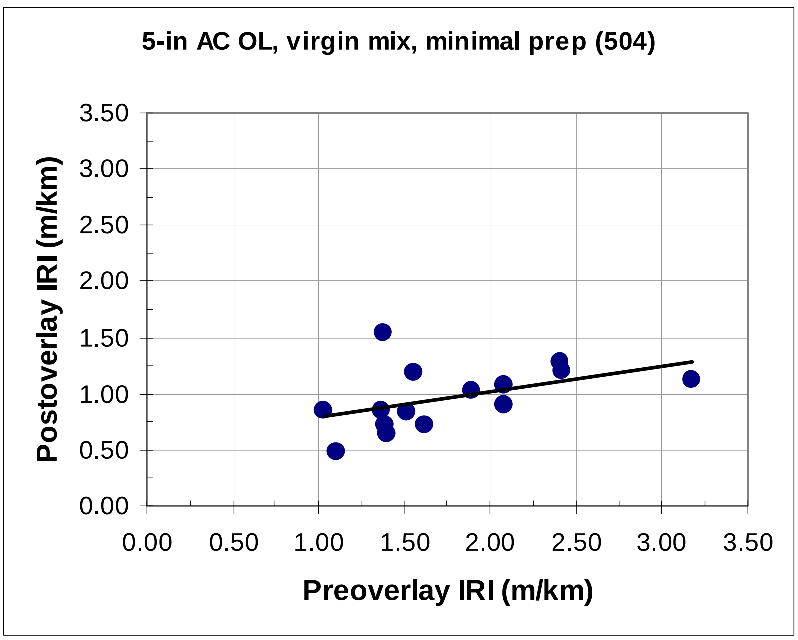

Figure 42. IRI before and after treatment, SPS-5 sections with 5-inch overlay, virgin mix, minimal preparation (treatment group 504).

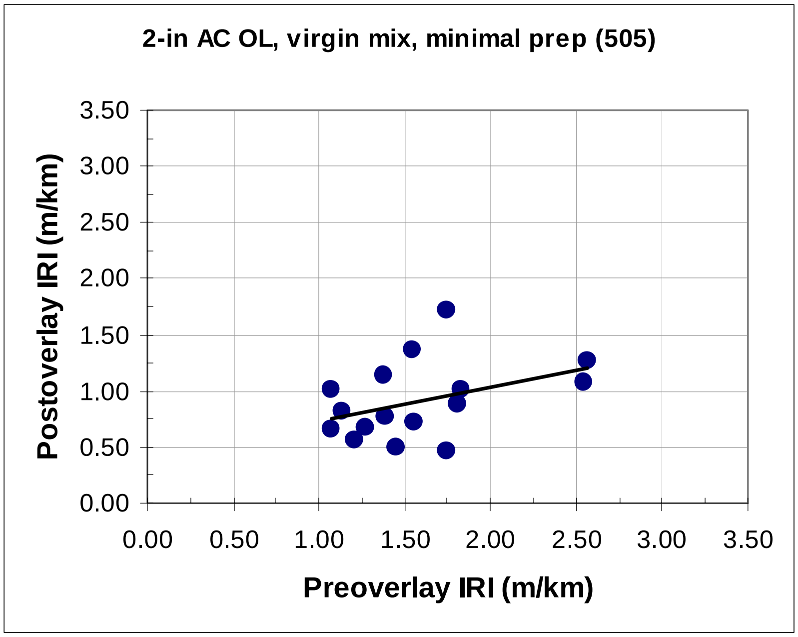

Figure 43. IRI before and after treatment, SPS-5 sections with 2-inch overlay, virgin mix, minimal preparation (treatment group 505).

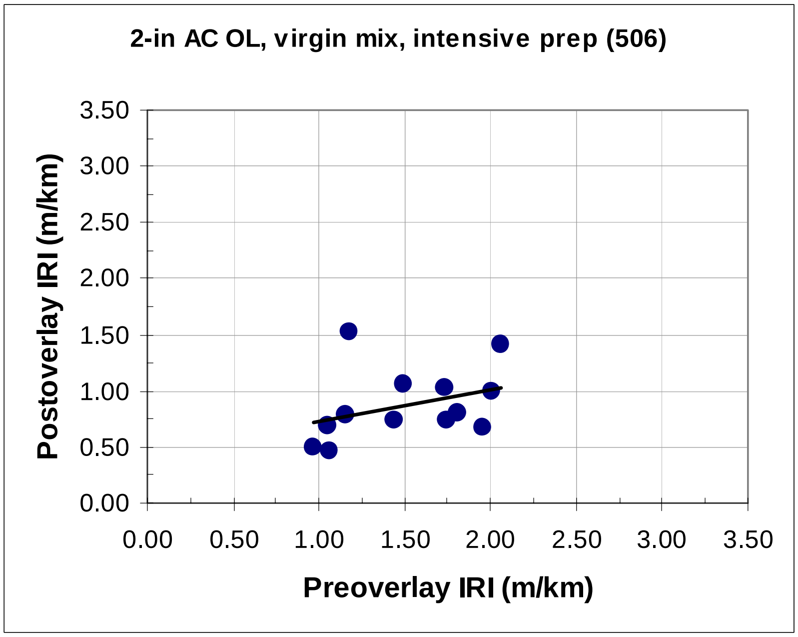

Figure 44. IRI before and after treatment, SPS-5 sections with 2-inch overlay, virgin mix, intensive preparation (treatment group 506).

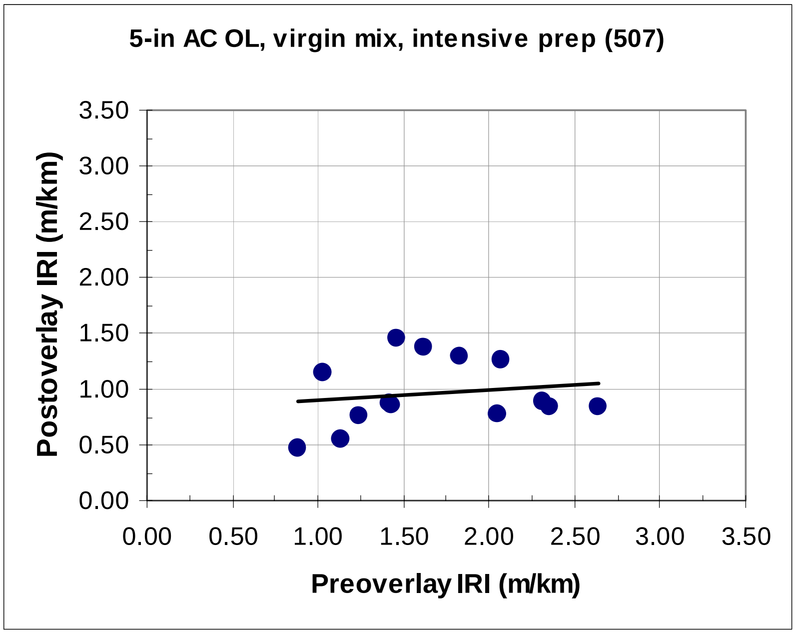

Figure 45. IRI before and after treatment, SPS-5 sections with 5-inch overlay, virgin mix, intensive preparation (treatment group 507).

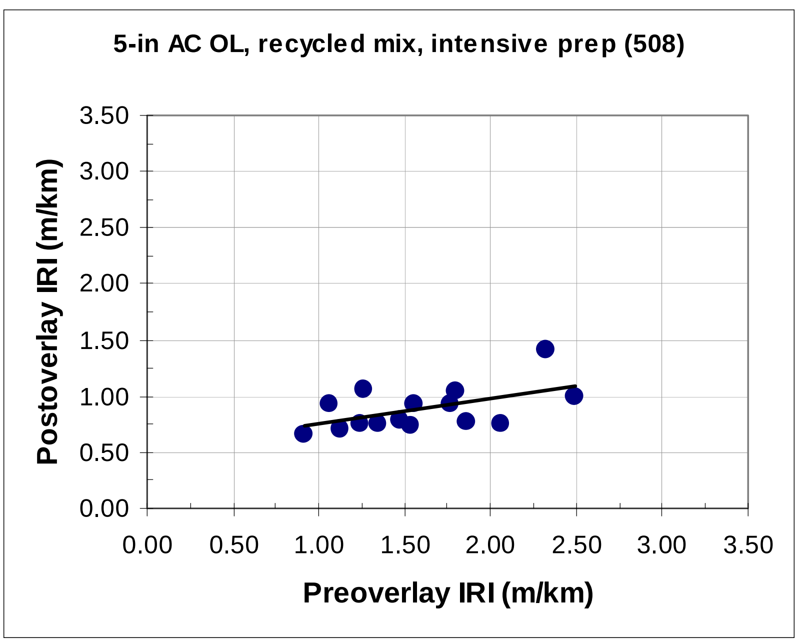

Figure 46. IRI before and after treatment, SPS-5 sections with 5-inch overlay, recycled mix, intensive preparation treatment group 508).

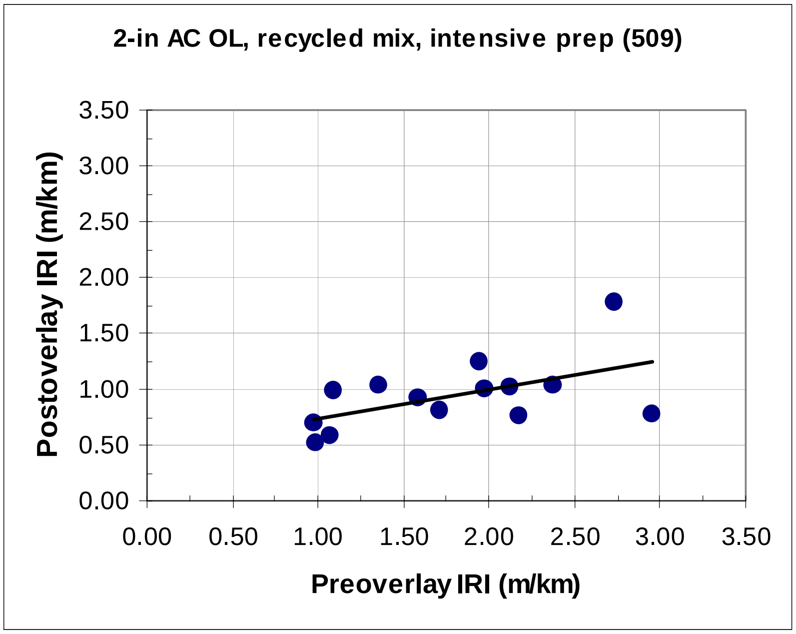

Figure 47. IRI before and after treatment, SPS-5 sections with 2-inch overlay, recycled mix, intensive preparation (treatment group 509) .

The preoverlay versus postoverlay IRI values for all of the SPS-5 overlay sections are shown in Figure 48, together with those in the GPS-6B data set. The two correlations are almost exactly parallel, though not quite coincident. Again, the slight but statistically significant positive correlation between preoverlay IRI and initial postoverlay IRI is evident. In the case of the GPS-6B data set, the slope of the best-fit line is 0.19. The null hypothesis (that the slope is zero) is rejected, with 95 percent confidence (that is, with 5 percent chance of error) because the calculated F value of 8.05 (the ratio of the regression mean square to the error mean square), exceeds 4.02, the upper 5 percent of an F distribution with 1 and 53 degrees of freedom.

Similarly, in the case of the SPS-5 data points, the slope of the best-fit line is 0.20. The null hypothesis (that the slope is zero) is rejected, with 95 percent confidence, because the calculated F value of 17.74 exceeds 3.92, the upper 5 percent of an F distribution with 1 and 124 degrees of freedom. Furthermore, an F test of the relationship of initial postoverlay IRI to preoverlay IRI was conducted for every individual overlay treatment within the SPS-5 experiment, and the relationship was found to be statistically significant in every case.

These results suggest that asphalt pavements overlaid when rougher tend to have somewhat higher initial roughness with the overlay than pavements overlaid when smoother. It should be kept in mind that no significant differences in initial postoverlay IRI were detected among the different overlay treatments.

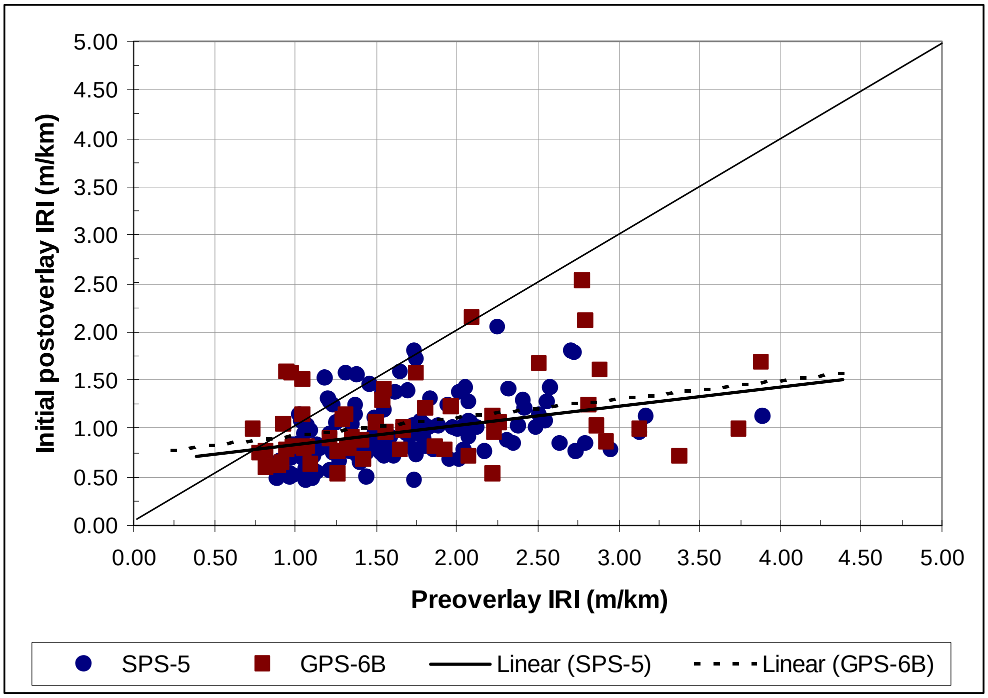

Figure 48. Preoverlay versus initial postoverlay IRI in SPS-5 and GPS-6B pavements.

Long-Term Effects on Roughness

The first step in the analysis of long-term treatment effects involves testing for significant effects by treatment type, holding constant for age, traffic, climate, etc. This is done by selected multiple comparisons. Rather than compare the means of many sections within different treatment groups, one analyzes the mean difference between specific groups of test sections). Paired difference tests are used to determine which if any of those mean differences are significantly different than zero. This prevents the within-treatment (i.e., site-to-site) variation from masking significant between-treatment differences.

The design of the SPS-5 experiment (see Table 14) makes possible the following interesting comparisons of long-term performance:

- **No overlay** (501or linked GPS) **versus overlay** (groups 502 through 509).
- **Recycled** (502, 503, 508, 509) **versus virgin** (504, 505, 506, 507) **overlay mixes**.
- **Minimal** (502, 503, 504, 505) **versus intensive** (506, 507,508, 509) **preparation**.
- **Two-inch** (502, 505, 506, 509) **versus five-inch** (503, 504, 507, 508) **overlay thickness**.

Since there are four comparisons of interest, the significance level, α, used for each individual comparison should be selected so that $(1 - \alpha)^4$ = the desired overall level of confidence. For four comparisons to yield a 95 overall level of confidence, the required significance level α is 0.01274.

The long-term effect of each rehabilitation treatment on roughness is analyzed using IRI values obtained from the most recent profile measurements. The IRI data available for these analyses cover a range of time from 2.6 to 10.8 years, with an average of 7.8 years.

Overlay Rehabilitation versus No Rehabilitation

The long-term effect of overlay versus no overlay on IRI is analyzed by evaluating the mean of eighty pairs of IRI measurements: the control versus each of the eight treatments, at ten sites with control section IRI data available. At each site, the difference in IRI is calculated for each of the following section pairs:

- Control (501 or linked GPS) versus 2-inch overlay, recycled mix, minimal preparation (502);
- Control (501 or linked GPS) versus 5-inch overlay, recycled mix, minimal preparation (503);
- Control (501 or linked GPS) versus 5-inch overlay, virgin mix, minimal preparation (504);
- Control (501 or linked GPS) versus 2-inch overlay, virgin mix, minimal preparation (505);
- Control (501 or linked GPS) versus 2-inch overlay, virgin mix, intensive preparation (506);
- Control (501 or linked GPS) versus 5-inch overlay, virgin mix, intensive preparation (507);
- Control (501 or linked GPS) versus 5-inch overlay, recycled mix, intensive preparation (508); and
- Control (501 or linked GPS) versus 2-inch overlay, recycled mix, intensive preparation (509).

The results are summarized in Table 28, and a plot of the control versus overlay long-term IRI values is shown in Figure 49. In nearly every case, the control IRI is greater than the overlay IRI, and the mean difference is significant. These results indicate that over the time period that the data cover, the overlays are performing better than the nonoverlaid control sections in terms of IRI, as one might expect.

Table 28. Analysis of long-term effect of SPS-5 overlay versus no overlay on IRI.

	IRI (no overlay versus overlay), m/km
Mean difference	0.80
n	80
S_D	0.55
$T_{\alpha/2,\, n-1}$	2.55
Confidence interval lower limit	0.65
Confidence interval upper limit	0.96
Significant difference	yes

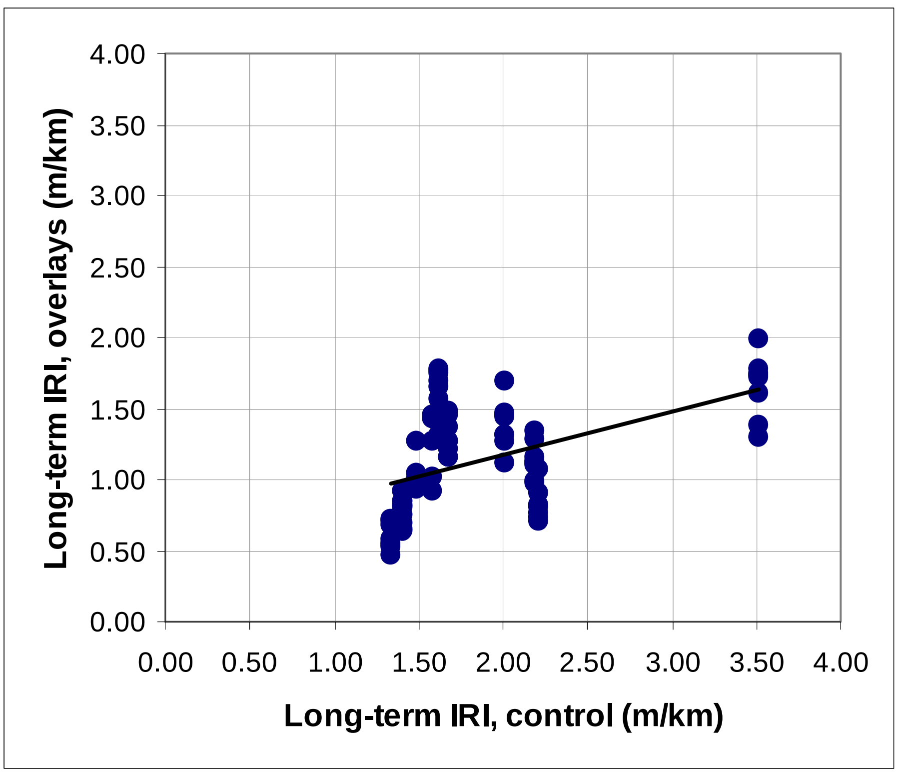

Figure 49. Long-term IRI, SPS-5 control versus overlay treatments.

Recycled versus Virgin Overlay MIx

The long-term effect of recycled versus virgin asphalt overlay mixes on IRI is analyzed by evaluating the mean of 69 available pairs of IRI measurements. At each site, the difference in IRI is calculated for each of the following section pairs:

- 2-inch overlays with minimal preparation, recycled (502) versus virgin (505) mix;
- 5-inch overlays with minimal preparation, recycled (504) versus virgin (503) mix;
- 2-inch overlays with intensive preparation, recycled (509) versus virgin (506) mix; and
- 5-inch overlays with intensive preparation, recycled (508) versus virgin (507) mix.

The results are summarized in Table 29, and a plot of the recycled-mix versus virgin-mix long-term IRI values is shown in Figure 50. The results indicate that over the time period that the data cover, there is no significant difference overall in the performance of recycled mixes versus virgin mixes with respect to IRI. At higher IRI levels, there is a very slight tendency for virgin mixes to perform better than recycled mixes.

Minimal versus Intensive Preoverlay Preparation

The long-term effect of minimal versus intensive preoverlay preparation on IRI is analyzed by evaluating the mean of 70 available pairs of IRI measurements. At each site, the difference in IRI is calculated for each of the following section pairs:

- 2-inch overlays with virgin mixes, minimal (505) versus intensive (506) preparation;
- 2-inch overlays with recycled mixes, minimal (502) versus intensive (509) preparation;
- 5-inch overlays with virgin mixes, minimal (504) versus intensive (507) preparation; and
- 5-inch overlays with recycled mixes, minimal (503) versus intensive (508) preparation.

The results are summarized in Table 30, and a plot of the minimal-preparation versus intensive-preparation long-term IRI values is shown in Figure 51. The results indicate that over the time period that the data cover, there is no significant difference overall in the performance, with respect to IRI, of overlays with minimal preoverlay preparation versus overlays with intensive preoverlay preparation. At higher IRI levels, there is a very slight tendency for overlays with minimal preparation to perform better than overlays with intensive preparation.

Table 29. Analysis of long-term effect of SPS-5 overlay mix type on IRI.

	IRI (recycled versus virgin mix), m/km
Mean difference	0.01
n	69
S_D	0.33
$T_{\alpha/2, n-1}$	2.56
Confidence interval lower limit	-0.08
Confidence interval upper limit	0.11
Significant difference	No

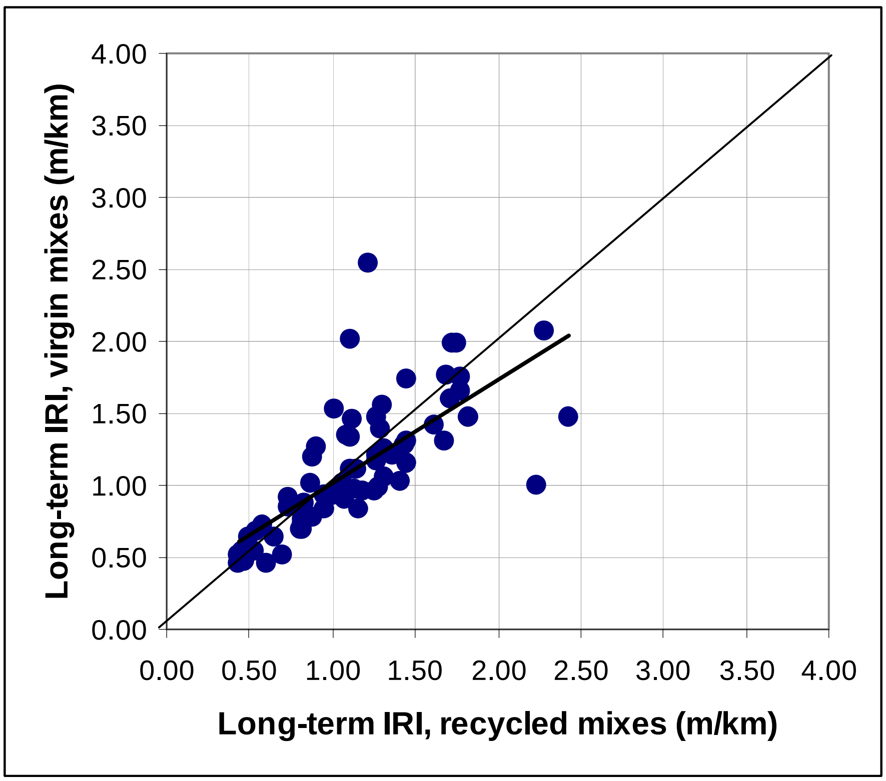

Figure 50. Long-term IRI, SPS-5 recycled versus virgin overlay mixes.

Table 30. Analysis of long-term effect of SPS-5 preoverlay preparation on IRI.

	IRI (minimal versus intensive preparation), m/km
Mean difference	0.08
n	70
S_D	0.25
$T_{\alpha/2, n-1}$	2.56
Confidence interval lower limit	0.00
Confidence interval upper limit	0.15
Significant difference	Yes

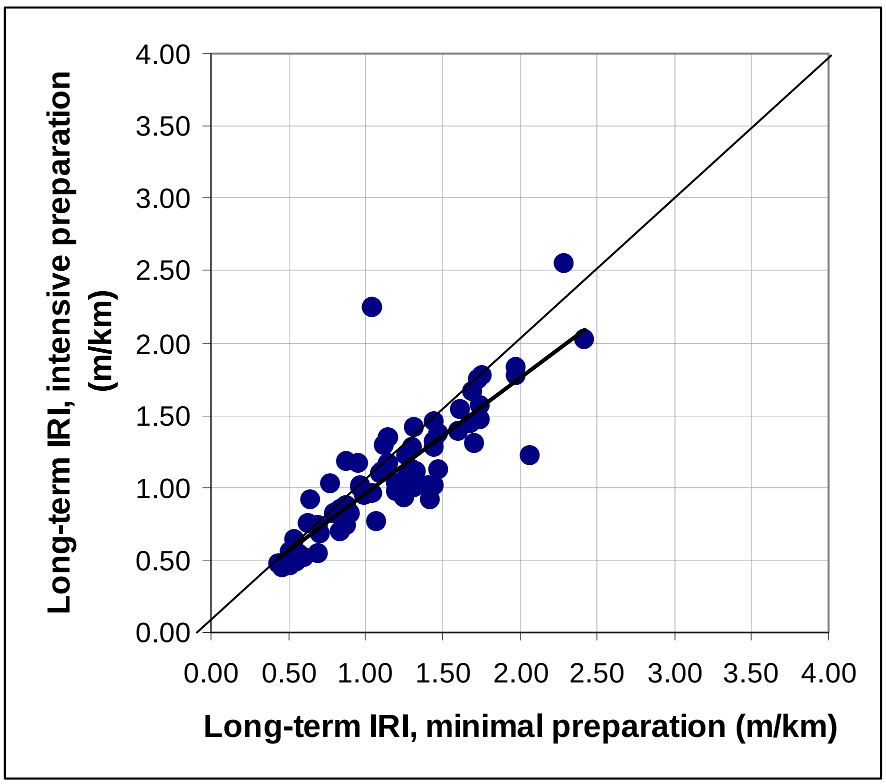

Figure 51. Long-term IRI, SPS-5 overlays with minimal versus intensive preparation.

Two-Inch versus Five-Inch Overlay Thickness

The long-term effect of overlay thickness on IRI is analyzed by evaluating the mean of 70 available pairs of IRI measurements. At each site, the difference in IRI is calculated for each of the following section pairs:

- Virgin mixes with minimal preparation, 2 inches (505) versus 5 inches (504);
- Recycled mixes with minimal preparation, 2 inches (502) versus 5 inches (503);
- Virgin mixes with intensive preparation, 2 inches (506) versus 5 inches (507); and
- Recycled mixes with intensive preparation, 2 inches (509) versus 5 inches (508).

The results are summarized in Table 31, and a plot of the two-inch-overlay versus five-inch-overlay long-term IRI values is shown in Figure 52. The results indicate that over the time period that the data cover, the 5-inch overlays outperform the 2-inch overlays in terms of IRI.

Table 31. Analysis of long-term effect of SPS-5 overlay thickness on IRI.

	IRI (2 inches versus 5 inches), m/km
Mean difference	0.19
n	70
S_D	0.37
$T_{\alpha/2,\ n-1}$	2.56
Confidence interval lower limit	0.08
Confidence interval upper limit	0.30
Significant difference	yes

The second step in the analysis of long-term treatment effects on IRI is to test for significant effects of other factors (age, accumulated traffic, climate, and pretreatment IRI). This is done in nearly the same procedure as described in Chapter 2 for assessment of influence of factors on maintenance treatment effectiveness. The difference is that in the SPS-3 analysis, each treatment was compared to the control, whereas in this SPS-5 analysis, the comparisons of interest are those four mentioned earlier: overlay versus no overlay, recycled versus virgin mixes, minimal versus intensive preoverlay preparation, and 2-inch versus 5-inch overlay thicknesses. The treatment group pairs used in these comparisons were identified earlier.

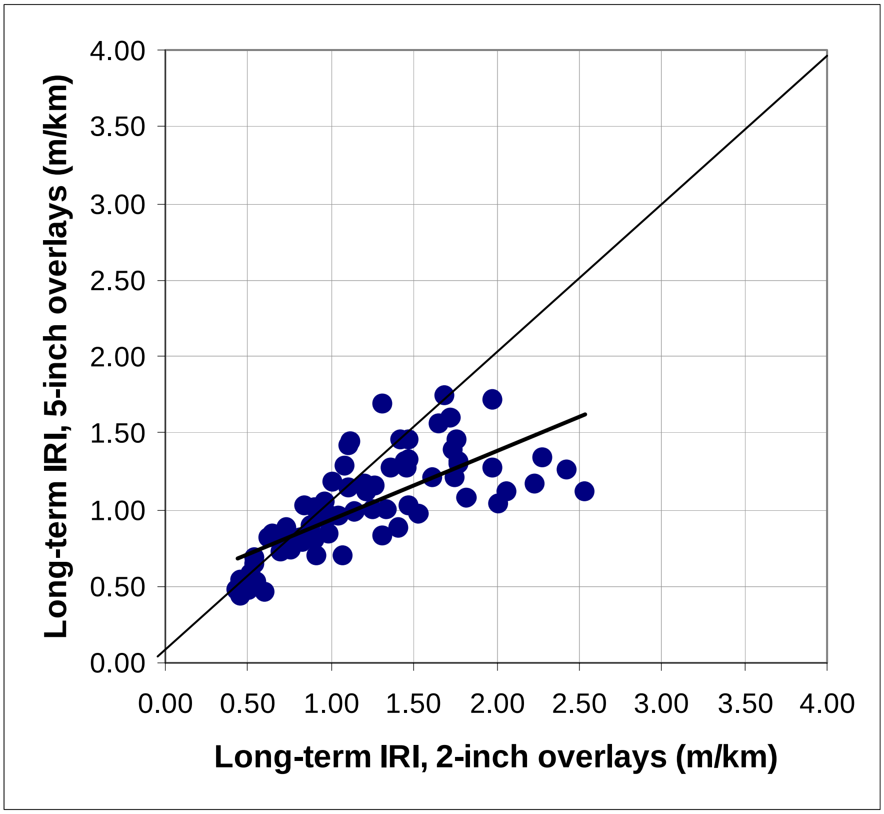

Figure 52. Long-term IRI, SPS-5 two-inch versus five-inch overlays.

The results of the F tests for significance of factor effects on the relative long-term IRI performance of the SPS-5 rehabilitation treatments are summarized in Table 32. A significant factor influence means that there is a significant correlation between the factor and the difference in the rates of increase in IRI in the two groups compared.

It should be noted that judgments should not be made by comparing the slopes reported in Table 32 for different factors, because of the different scales of the factors analyzed. Age ranges from 1.3 to 10.7 years, accumulated ESALs range from about 0.6 to 17.7 million, pretreatment IRI ranges from 1 to 2.7, average annual precipitation ranges from 4 to 57 inches, and average annual temperature in 39 to 75. The degree to which the calculated F value exceeds the theoretical F value is the best indication of the significance of a factor's effect.

Table 32. Tests for significance of factor effects on relative long-term IRI performance of SPS-5 rehabilitation treatments.

Treatment		Factor				
		Age	Accumulated ESALs	Pre treatment IRI	Average annual precipitation	Average annual temperature
No overlay Versus Overlay	slope	0.028	0.000	0.434	-0.001	-0.010
	n	60	60	60	60	60
	Fcalc	7.17	1.90	39.30	0.10	6.19
	F at 0.05	4.01	4.01	4.01	4.01	4.01
	Significant?	**yes**	no	**yes**	no	**yes**
Recycled Versus Virgin Mix	slope	-0.007	0.000	-0.014	0.005	0.000
	n	58	58	58	58	58
	Fcalc	0.25	0.22	0.03	6.39	0.02
	F at 0.05	4.01	4.01	4.01	4.01	4.01
	Significant?	no	no	no	**yes**	no
Minimal Versus Intensive Preparation	slope	0.015	0.000	0.076	-0.003	-0.002
	n	58	58	58	58	58
	Fcalc	2.41	0.11	1.68	3.27	0.44
	F at 0.05	4.01	4.01	4.01	4.01	4.01
	Significant?	no	no	no	no	no
2-inch Versus 5-inch Thickness	slope	0.026	0.000	0.217	-0.013	0.002
	n	59	59	59	59	59
	Fcalc	2.54	2.90	5.03	40.49	0.19
	F at 0.05	4.01	4.01	4.01	4.01	4.01
	Significant?	no	no	**yes**	**yes**	no

The factor effects found to be significant for the comparisons conducted are summarized below.

- ***Overlay versus no overlay:*** Pretreatment IRI had the most significant effect; age and average annual temperature had slightly significant effects. The difference between how fast IRI increased in the nonoverlaid sections and how fast IRI increased in the overlaid sections is positively correlated to pretreatment IRI, slightly positively correlated to age, and slightly negatively correlated to average annual temperature. It is curious that age was significant but accumulated ESALs were not.

- ***Recycled versus virgin mix:*** Average annual precipitation had a slightly significant effect. The difference between how fast IRI increased in the sections with recycled mixes and how fast IRI increased in the sections with virgin mixes is slightly positively correlated to average annual precipitation.

- ***Minimal versus intensive preparation:*** None of the factors tested were found to have a significant effect.

- ***2-inch versus 5-inch overlay thickness:*** Average annual precipitation had a very significant effect; pretreatment IRI had a slightly significant effect. The difference between how fast IRI increased in the 2-inch overlay sections and how fast IRI increased in the 5-inch overlay sections is negatively correlated to average annual precipitation and slightly positively correlated to pretreatment IRI.

Recall that the treatment effects found to be significant to long-term IRI performance were overlay versus no overlay, minimal versus intensive preparation, and 2-inch versus 5-inch overlay thickness. For any of these significant treatment effects, a significant factor effect means that the difference in performance depends to some degree on the factor, whereas an insignificant factor effect means that the difference in performance is consistent across the range of the factor studied.

The treatment effect previously found to be insignificant to long-term IRI performance was recycled versus virgin overlay mix. This means that the difference in rates of long-term IRI increase is negligible and consistently so across the ranges of the factors studied, with the exception of a slight positive correlation with precipitation.

Effects of Flexible Pavement Overlay Rehabilitation on Rutting

Initial Effects on Rutting

Rutting Before Overlay

The mean preoverlay rutting values (average of all nine test sections) for the ten SPS-5 sites for which these data are available are given in Table 33. The overall average preoverlay rutting at these sites was 16.3 mm. Similarly, at the 77 GPS-6B sites for which preoverlay rutting data are available, the average preoverlay rutting was 15.2 mm.

Table 33. Mean preoverlay ruttting values by SPS-5 site.

Site	Rutting (mm)
Alabama	–
Arizona	–
California	15.7
Colorado	21.4
Florida	–
Georgia	–
Maine	18.9
Maryland	11.4
Minnesota	–
Mississippi	23.9
Missouri	10.7
Montana	19.7
New Jersey	10.9
New Mexico	–
Oklahoma	15.8
Texas	14.4
Alberta	–
Manitoba	–

Rutting After Overlay

Rutting measurements in the SPS-5 control sections, before and after the date of treatment of the adjacent sections, are available for seven sites (Florida, Maine, Maryland, Mississippi, Missouri, New Jersey, and Oklahoma). A plot of these rutting measurements is shown in Figure 53. As might be expected, the “before” and “after” rutting measurements are very similar for the control sections.

The mean initial postoverlay rutting values (average of the eight overlay test sections) for the ten SPS-5 sites for which these data are available are given in Table 34.   Also shown is the time from placement of the overlay to the first initial postoverlay rutting measurement. Note that for seven of the ten sites, rutting was measured within a year of placement of the overlays, whereas for three of the sites, the first postoverlay rutting measurements were obtained considerably later.

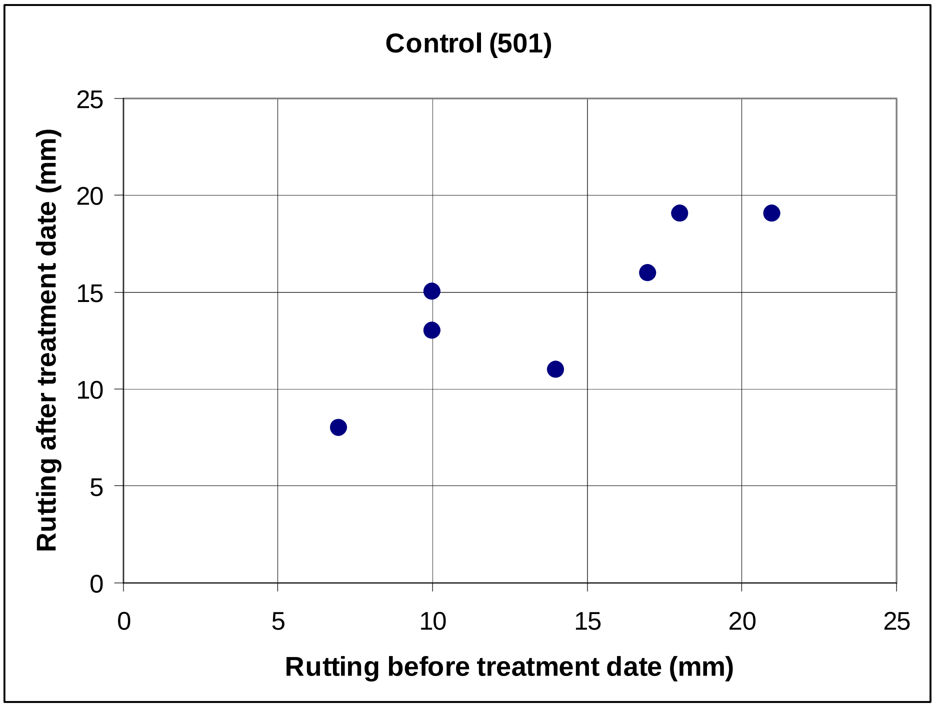

Figure 53. Rutting before and after rehabilitation date, SPS-5 control sections.

Table 34. Mean initial postoverlay ruttting values by SPS-5 site.

Site	Rutting (mm)	Time (yrs)
Alabama	–	–
Arizona	–	–
California	5.4	0.43
Colorado	3.9	0.39
Florida	–	–
Georgia	–	–
Maine	3.6	0.27
Maryland	7.5	0.34
Minnesota	–	–
Mississippi	9.0	1.55
Missouri	4.6	0.3
Montana	10.6	4.74
New Jersey	7.5	0.52

Table 34. Mean initial postoverlay ruttting values by SPS-5 site (continued).

Site	Rutting (mm)	Time (yrs)
New Mexico	–	–
Oklahoma	6.4	2.21
Texas	3.1	0.34
Alberta	–	–
Manitoba	–	–

The overall average initial postoverlay rutting at these sites was 6.2 mm. Similarly, at the 77 GPS-6B sites for which preoverlay rutting data are available, the average initial postoverlay rutting was 6.1 mm.

The average initial postoverlay rutting values are shown by treatment type in Table 35. In an analysis of variance, summarized in Table 36, no significant differences were detected among the mean initial postoverlay rutting values of the different overlay treatment groups. Note that the control section group is excluded from this analysis.

Table 35. Mean initial postoverlay rutting by SPS-5 treatment type.

Treatment Group	Rutting (mm)
2-in overlay, recycled mix, minimal prep (502)	7.2
5-in overlay, recycled mix, minimal prep (503)	5.9
5-in overlay, virgin mix, minimal prep (504)	5.7
2-in overlay, virgin mix, minimal prep (505)	5.8
2-in overlay, virgin mix, intensive prep (506)	6.0
5-in overlay, virgin mix, intensive prep (507)	6.8
5-in overlay, recycled mix, intensive prep (508)	5.9
2-in overlay, recycled mix, intensive prep (509)	6.0
Overall mean	**6.2**

Table 36. Analysis of variance of initial postoverlay rutting with respect to SPS-5 overlay treatment.

Source of variation	Sum of squares (SS)	Degrees of freedom	Mean squares (MS)	Calculated F	Theoretical F (α = 0.05)
Between treatments	20.188	7	2.884	0.299	2.140
Within treatments	694.700	72	9.649		
Total	714.888	79			

A plot of preoverlay versus initial postoverlay rutting measurements for the SPS-5 and GPS-6B overlays is shown in Figure 54. The trendline for the GPS-6B sections is very close to horizontal, at the overall mean value of 6.1 mm. In the case of the SPS-5 sections, it would appear that there is a slight upward trend to the data, i.e., a slight positive correlation between preoverlay and initial postoverlay rutting. However, examination of the data reveals that this slope to the trendline is due to a particular cloud of points representing some of the sections at the Montana and Missouri sites, which were measured 4.74 and 1.55 years after overlay, respectively. On the other hand, the initial postoverlay measurements at the Oklahoma site (measured 2.21 years after overlay) were all very close to the experiment-wide average of 6.2 mm.

It appears that on average, about 6 mm of rutting develops in the first year or so after placement of an asphalt overlay of an asphalt pavement. This may be due to compaction of the mix by traffic, and appears to be independent of the overlay thickness, mix type, preoverlay preparation, or preoverlay rutting level.

Long-Term Effects on Rutting

The long-term effects of each rehabilitation treatment on rutting are assessed by analyzing the most recently obtained rutting measurements for each site. The analysis method is the same as described earlier for analysis of IRI. There are four comparisons of interest in the SPS-5 experiment:

- Overlay versus no overlay.
- Recycled versus virgin asphalt concrete overlay mixes.
- Minimal versus intensive preoverlay preparation.
- Two-inch versus 5-inch overlay thickness.

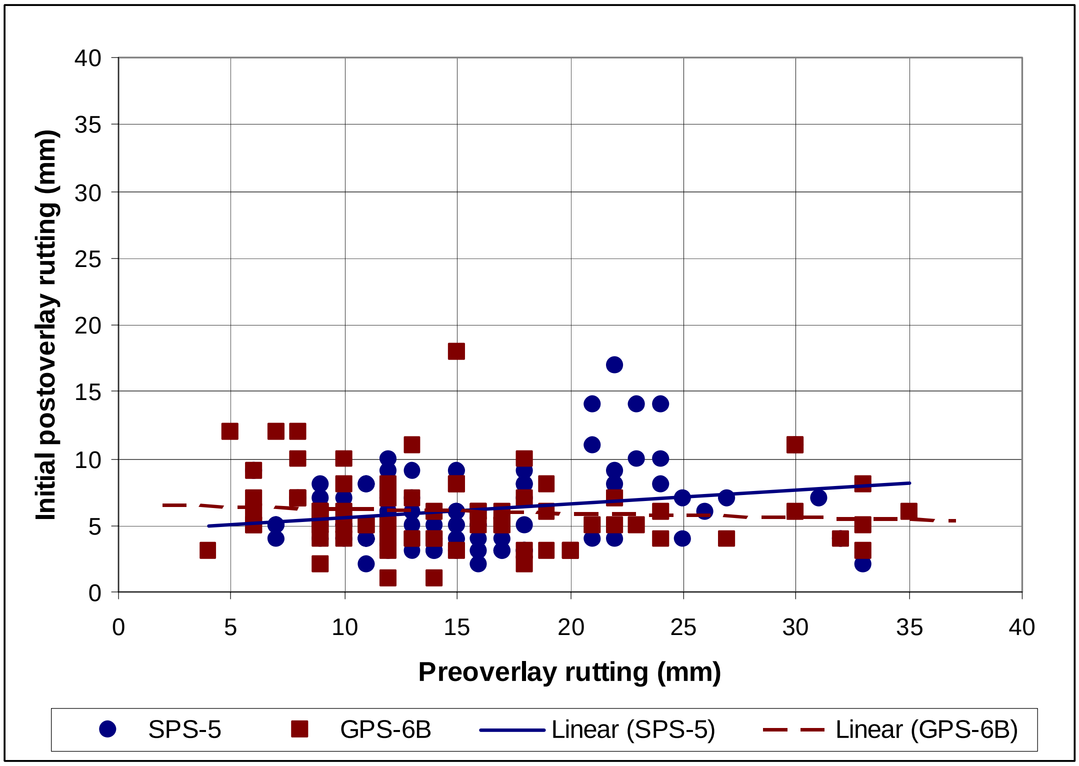

Figure 54. Preoverlay versus initial postoverlay rutting in SPS-5 overlay sections.

The treatment groups used in these four comparisons were listed before, in the description of the IRI analysis. Since there are four comparisons of interest, the significance level, α, used for each individual comparison should be selected so that $(1 - \alpha)^4$ = the desired overall level of confidence. For four comparisons to yield a 95 overall level of confidence, the required significance level α is 0.01274.

Overlay Rehabilitation versus No Rehabilitation

The long-term effect of overlay versus no overlay on rutting is analyzed by evaluating the mean of 64 available pairs of rutting measurements: the control versus each of the eight treatments, at the eight sites that (a) have a valid control section and (b) have rutting data measured in the control section at the same time as in the overlaid sections.

The results are summarized in Table 37, and a plot of the control versus overlay long-term rutting values is shown in Figure 55. In most cases, the control section rutting is greater than

Table 37. Analysis of long-term effect of SPS-5 overlay versus no overlay on rutting.

	Rutting (control versus treatment), mm
Mean difference	5.83
n	64
S_D	5.27
$T_{\alpha/2, n-1}$	2.56
Confidence interval lower limit	4.14
Confidence interval upper limit	7.52
Significant difference	yes

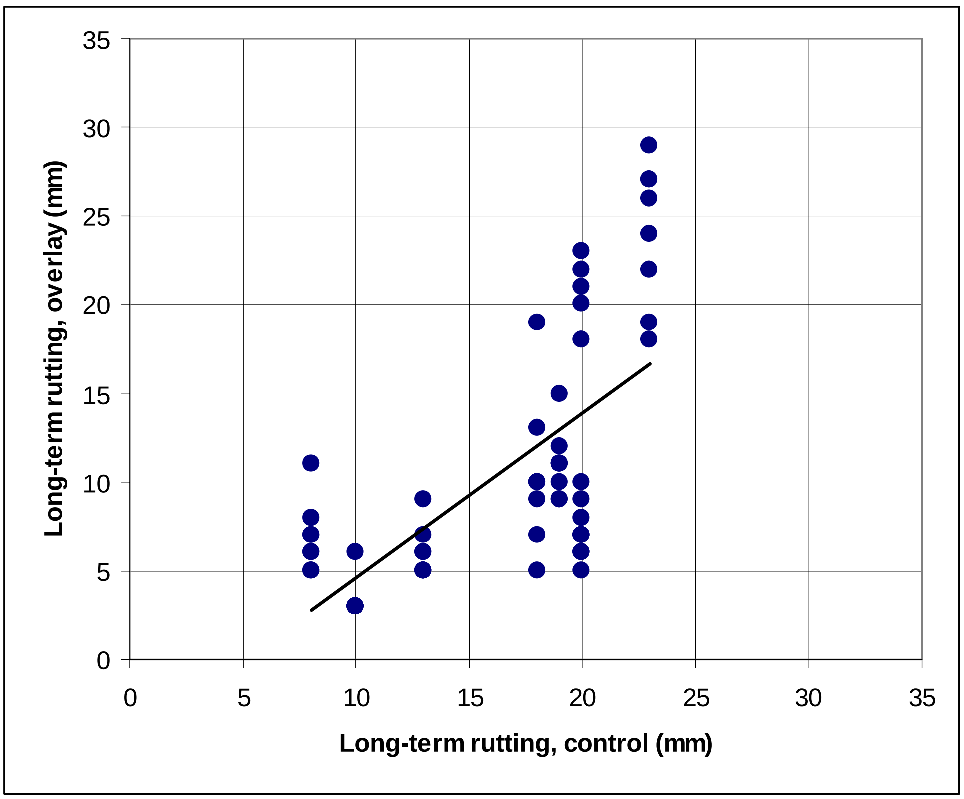

Figure 55. Long-term rutting, SPS-5 control versus overlay treatments.

the rutting in the overlay section, and the mean difference is significant. However, there are a few cases where one or more overlay sections has more rutting. The two sites where about half of the overlays have more rutting than the control are Maryland (control = 20 mm) and Missouri (control = 23 mm).

Recycled versus Virgin Overlay MIx

The long-term effect of recycled versus virgin asphalt overlay mixes on rutting is analyzed by evaluating the mean of 72 available pairs of rutting measurements. The results are summarized in Table 38, and a plot of the recycled-mix versus virgin-mix long-term rutting values is shown in Figure 56. The results indicate that over the time period that the data cover, there is no significant difference overall in the performance of recycled mixes versus virgin mixes with respect to rutting. At higher rutting levels, there is a very slight tendency for virgin mixes to perform better than recycled mixes.

Minimal versus Intensive Preoverlay Preparation

The long-term effect of minimal versus intensive preoverlay preparation on rutting is analyzed by evaluating the mean of 72 available pairs of rutting measurements. The results are summarized in Table 39, and a plot of the minimal-preparation versus intensive-preparation long-term rutting values is shown in Figure 57. The results indicate that over the time period that the data cover, there is no significant difference overall in the performance, with respect to rutting, of overlays with minimal preoverlay preparation versus overlays with intensive preoverlay preparation. At higher rutting levels, there is a very slight tendency for overlays with intensive preparation to perform better than overlays with minimal preparation.

Two-Inch versus Five-Inch Overlay Thickness

The long-term effect of overlay thickness on rutting is analyzed by evaluating the mean of 72 available pairs of rutting measurements. The results are summarized in Table 40, and a plot of the two-inch-overlay versus five-inch-overlay long-term rutting values is shown in Figure 58. The results indicate that over the time period that the data cover, there is no significant difference overall in the performance, with respect to rutting, of 2-inch overlays versus 5-inch overlays. At higher rutting levels, there is a very slight tendency for 5-inch overlays to perform better than 2-inch overlays.

Table 38. Analysis of long-term effect of SPS-5 overlay mix type on rutting.

	Rutting (recycled versus virgin), mm
Mean difference	0.58
n	72
S_D	4.25
$T_{\alpha/2, n-1}$	2.56
Confidence interval lower limit	-0.064
Confidence interval upper limit	1.81
Significant difference	no

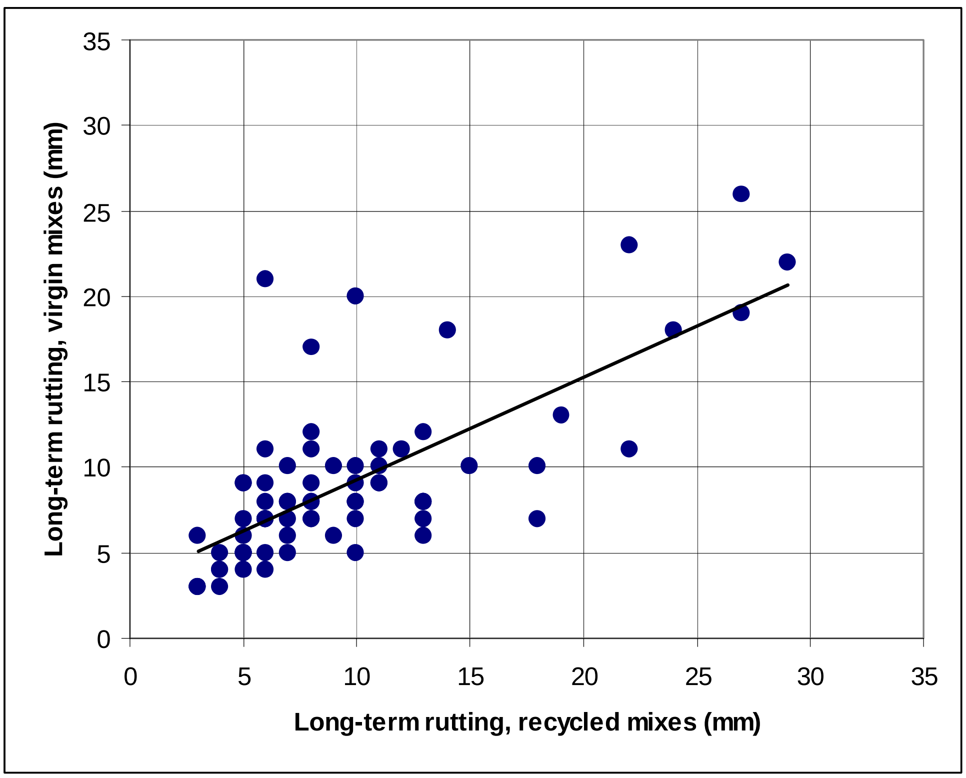

Figure 56. Long-term rutting, SPS-5 recycled versus virgin overlay mixes.

Table 39. Analysis of long-term effect of SPS-5 preoverlay preparation on rutting.

	Rutting (minimal versus intensive), mm
Mean difference	-0.11
n	72
S_D	3.63
$T_{\alpha/2, n-1}$	2.56
Confidence interval lower limit	-1.16
Confidence interval upper limit	0.93
Significant difference	no

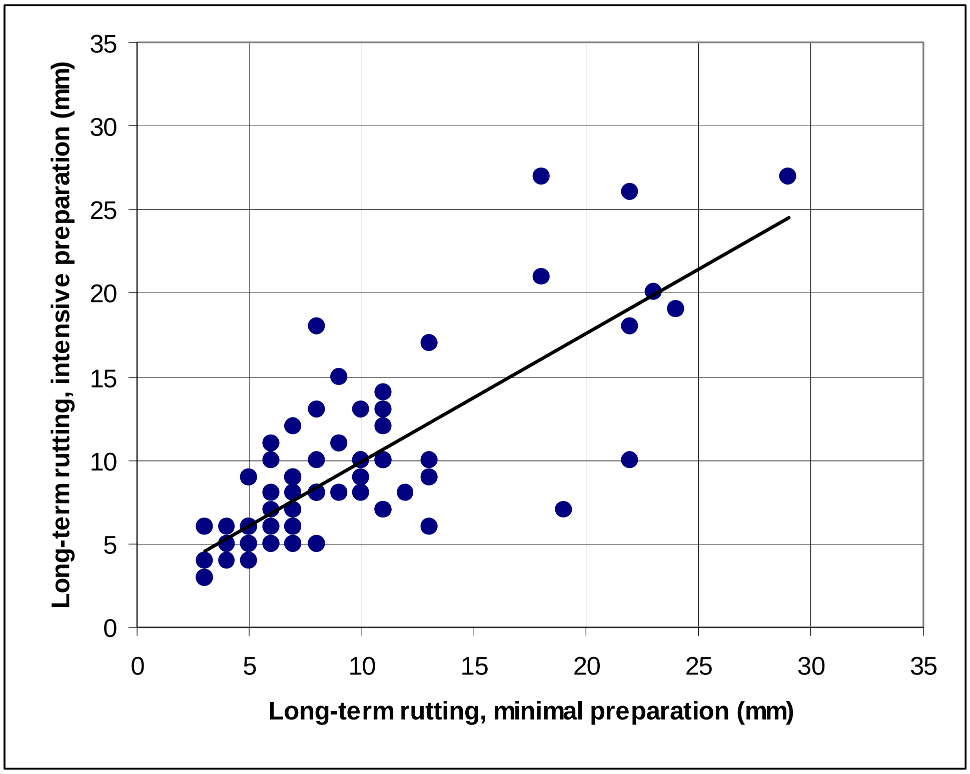

Figure 57. Long-term rutting, SPS-5 overlays with minimal versus intensive preparation.

Table 40. Analysis of long-term effect of SPS-5 overlay thickness on rutting.

	Rutting (2 inches versus 5 inches), mm
Mean difference	-0.50
n	72
S_D	4.51
$T_{\alpha/2, n-1}$	2.56
Confidence interval lower limit	-1.80
Confidence interval upper limit	0.80
Significant difference	no

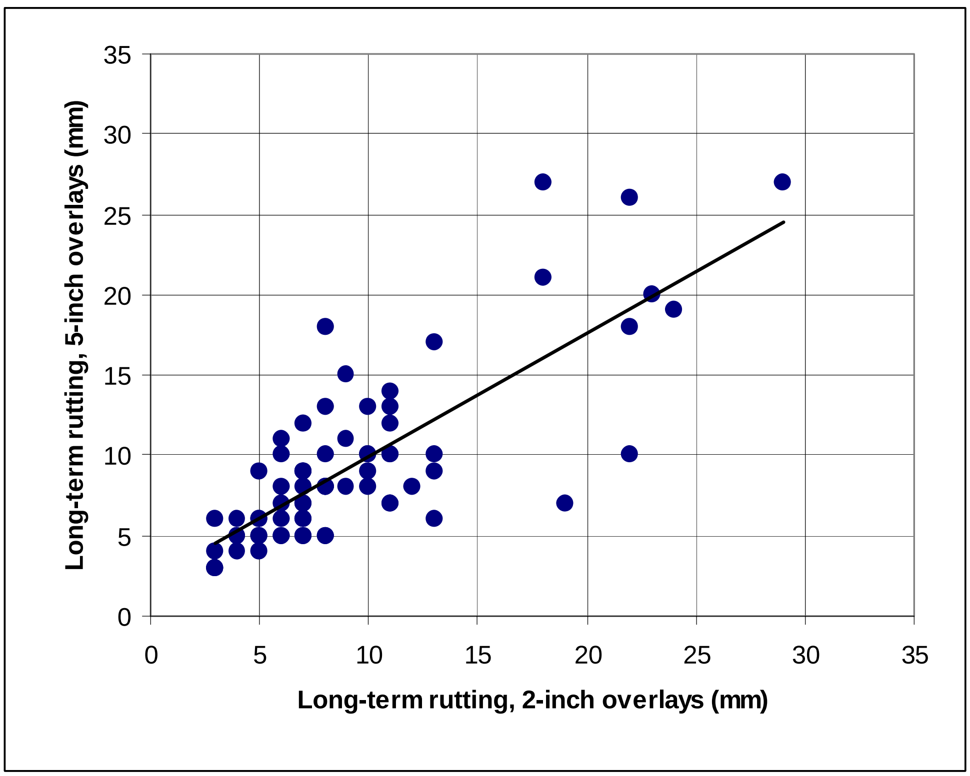

Figure 58. Long-term rutting, SPS-5 two-inch versus five-inch overlays.

The results of the F tests for significance of factor effects on long-term rutting performance of SPS-5 rehabilitation treatments are summarized in Table 41.

Table 41. Tests for significance of factor effects on relative long-term rutting performance of SPS-5 rehabilitation treatments.

Treatment		Factor				
		Age	Accumulated ESALs	Pre treatment rutting	Average annual precipitation	Average annual temperature
No overlay Versus Overlay	slope	-0.929	0.000	-0.432	-0.294	0.143
	n	40	40	40	40	40
	Fcalc	16.90	0.66	1.17	7.29	1.87
	F at 0.05	4.10	4.10	4.10	4.10	4.10
	Significant?	**yes**	no	no	**yes**	no
Recycled Versus Virgin Mix	slope	-0.123	0.000	-0.642	-0.006	0.084
	n	35	35	35	35	35
	Fcalc	0.21	0.01	4.47	0.01	0.99
	F at 0.05	4.14	4.14	4.14	4.14	4.14
	Significant?	no	no	**yes**	no	no
Minimal Versus Intensive Preparation	slope	0.137	0.000	0.380	0.022	-0.021
	n	40	40	40	40	40
	Fcalc	0.49	0.18	3.30	0.44	0.14
	F at 0.05	4.10	4.10	4.10	4.10	4.10
	Significant?	no	no	no	no	no
2-inch Versus 5-inch Thickness	slope	0.232	0.000	-0.052	-0.103	-0.017
	n	40	40	40	40	40
	Fcalc	0.98	1.08	0.04	7.50	0.06
	F at 0.05	4.10	4.10	4.10	4.10	4.10
	Significant?	no	no	no	**yes**	no

The factor effects found to be significant for the comparisons conducted are summarized below.

- ***Overlay versus no overlay:*** Age had the most significant effect; average annual precipitation had a slightly significant effect. The difference between how fast rutting increased in the nonoverlaid sections and how fast rutting increased in the overlaid sections is negatively correlated to age, and slightly negatively correlated to precipitation.

- ***Recycled versus virgin mix:*** Pretreatment rutting had a slightly significant effect. The difference between how fast rutting increased in the sections with recycled mixes and how fast rutting increased in the sections with virgin mixes is slightly negatively correlated to pretreatment rutting.

- ***Minimal versus intensive preparation:*** None of the factors tested were found to have a significant effect.

- ***2-inch versus 5-inch overlay thickness:*** Average annual precipitation had a slightly significant effect. The difference between how fast rutting increased in the 2-inch overlay sections and how fast rutting increased in the 5-inch overlay sections is negatively correlated to average annual precipitation.

Effects of Flexible Pavement Overlay Rehabilitation on Fatigue Cracking

Initial Effects on Cracking

Cracking Before Overlay

The mean preoverlay cracking (average of all nine test sections) for the fourteen SPS-5 sites for which these data are available are given in Table 42. The percent area cracked is calculated as described in Chapter 2, as the sum of all severities of fatigue cracking plus the sum of all severities of sealed and unsealed longitudinal cracking, expressed as a percentage of the traffic lane area.

Cracking After Overlay

Cracking data for the SPS-5 control sections, before and shortly after the date of treatment of the adjacent sections, are available for six sites (Maine, Maryland, Mississippi, Missouri, New Jersey, and Oklahoma). A plot of these cracking data is shown in Figure 59. The data are more scattered than one might expect.

A plot of cracking data for the SPS-5 core experiment overlay sections, before and shortly after the date of treatment, is shown in Figure 60. There is really no need to conduct more statistical analysis of these data; as one might expect, initial postoverlay cracking levels were zero or close to zero for all overlay treatment types. All of the nonzero values are from the Alabama and Colorado sites. However, this does not appear to be related to any delay in surveying these sites; they were both surveyed about six months after overlay.

Table 42. Mean preoverlay cracking by SPS-5 site.

Site	Percent area cracked
Alabama	4.3
Arizona	–
California	6.2
Colorado	–
Florida	44.1
Georgia	0.5
Maine	22.3
Maryland	13.4
Minnesota	–
Mississippi	11.2
Missouri	21.0
Montana	27.2
New Jersey	22.5
New Mexico	10.2
Oklahoma	0.5
Texas	37.3
Alberta	–
Manitoba	1.7

Long-Term Effects on Cracking

The long-term effects of each rehabilitation treatment on cracking are assessed by analyzing the most recently obtained cracking data for each site. The analysis method is the same as described earlier for analyses of IRI and rutting. There are four comparisons of interest (the treatment group pairs were listed earlier):

- Overlay versus no overlay.
- Recycled versus virgin asphalt concrete overlay mixes.
- Minimal versus intensive preoverlay preparation.
- Two-inch versus 5-inch overlay thickness.

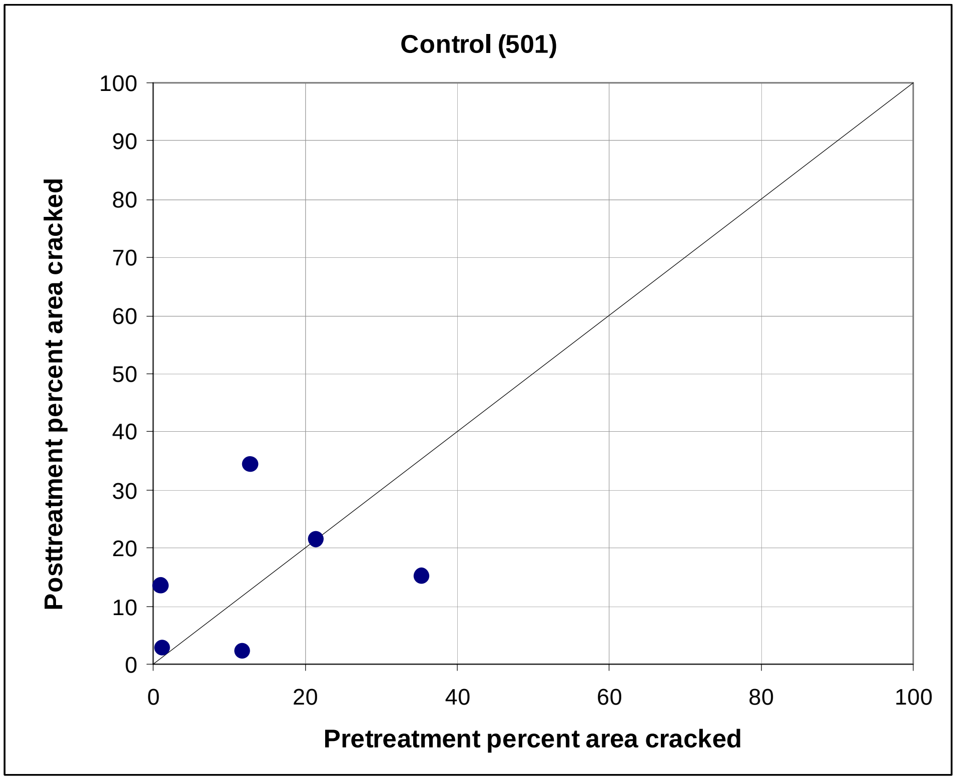

Figure 59. Cracking before and after rehabilitation date, SPS-5 control sections.

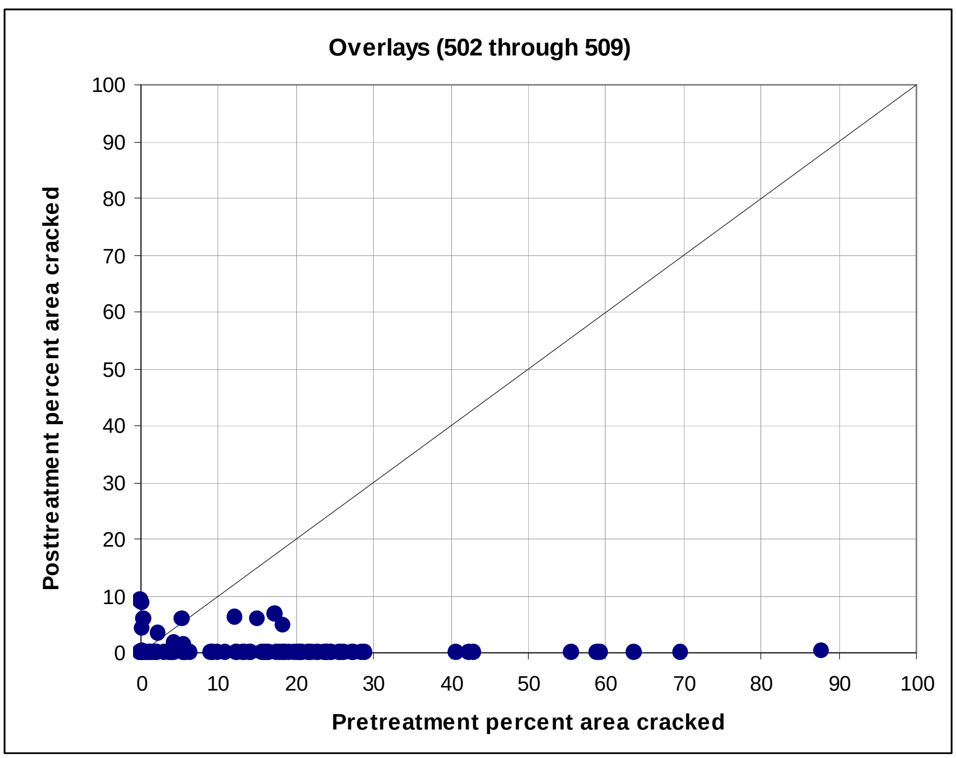

Figure 60. Cracking before and after rehabilitation date, SPS-5 overlay sections.

Overlay Rehabilitation versus No Rehabilitation

The long-term effect of overlay versus no overlay on cracking is analyzed by evaluating the mean of 80 available pairs of cracking measurements: the control versus each of the eight treatments, at the tent sites that (a) have a valid control section and (b) have cracking data measured in the control section at the same time as in the overlaid sections.

The results are summarized in Table 43, and a plot of the control versus overlay long-term cracking values is shown in Figure 61. In most cases, the control section cracking is greater than the cracking in the overlay section, and the mean difference is significant. However, at the Maryland site, the cracking levels are similar in the overlay and control sections, and at the Mississippi site, half of the overlays have more cracking than the control. Three of those four overlays are recycled mixes. Note that these are the same two sites at which long-term rutting in about half of the overlays was greater than in the control.

Recycled versus Virgin Overlay MIx

The long-term effect of recycled versus virgin asphalt overlay mixes on cracking is analyzed by evaluating the mean of 72 available pairs of cracking measurements. The results are summarized in Table 44, and a plot of the recycled-mix versus virgin-mix long-term cracking values is shown in Figure 62. The results indicate that over the time period that the data cover, there is no significant difference overall in the performance of recycled mixes versus virgin mixes with respect to cracking. At higher rutting levels, there appears to be a tendency for recycled mixes to perform better than virgin mixes, but given the scatter in the data, this tendency is not detected as being statistically significant.

Minimal versus Intensive Preoverlay Preparation

The long-term effect of minimal versus intensive preoverlay preparation on cracking is analyzed by evaluating the mean of 72 available pairs of rutting measurements. The results are summarized in Table 45, and a plot of the minimal-preparation versus intensive-preparation long-term cracking values is shown in Figure 63. The results indicate that over the time period that the data cover, there is no significant difference overall in the performance, with respect to cracking, of overlays with minimal preoverlay preparation versus overlays with intensive preoverlay preparation. The best-fit line through the data points is very close to the 1:1 line.

Table 43. Analysis of long-term effect of SPS-5 overlay versus no overlay on cracking.

	Cracking (control versus treatment), percent
Mean difference	14.5
n	80
S_D	28.8
$T_{\alpha/2, n-1}$	2.55
Confidence interval lower limit	6.3
Confidence interval upper limit	22.7
Significant difference	yes

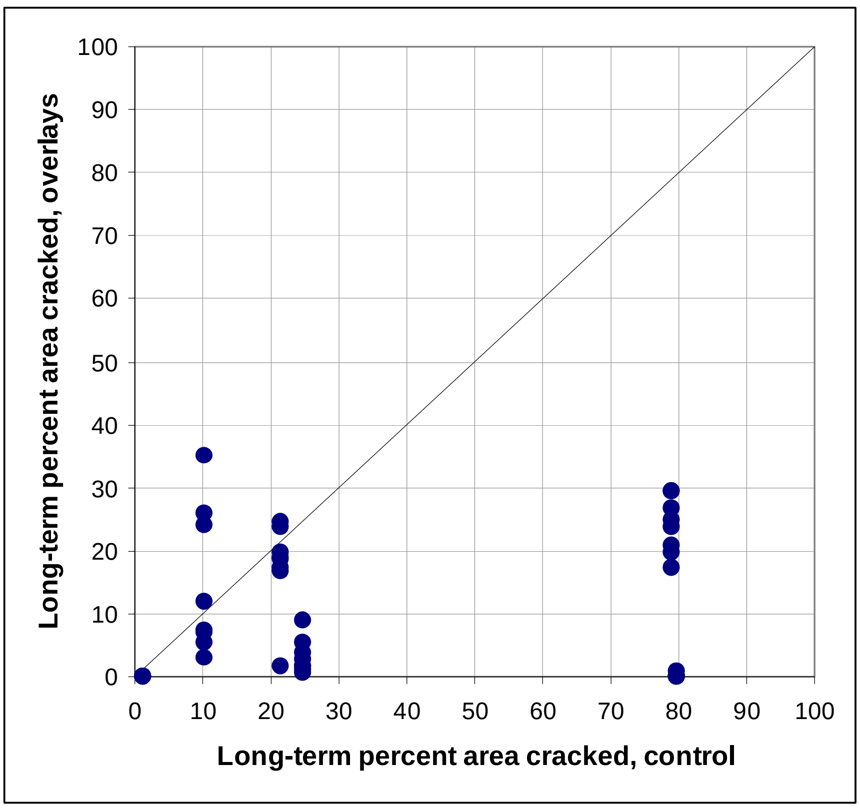

Figure 61. Long-term cracking, SPS-5 control versus overlay treatments.

Table 44. Analysis of long-term effect of SPS-5 overlay mix type on cracking.

	Cracking (recycled versus virgin), percent
Mean difference	-1.4
n	72
S_D	15.5
$T_{\alpha/2, n-1}$	2.56
Confidence interval lower limit	-5.8
Confidence interval upper limit	3.1
Significant difference	no

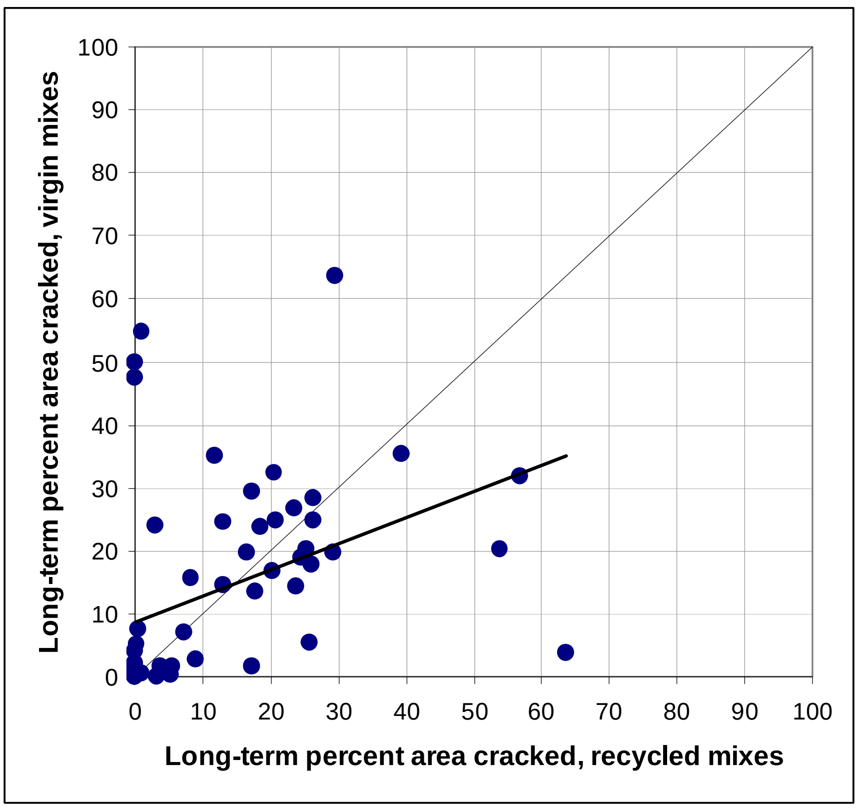

Figure 62. Long-term cracking, SPS-5 recycled versus virgin overlay mixes.

Table 45. Analysis of long-term effect of SPS-5 preoverlay preparation on cracking.

	Cracking (minimal versus intensive), percent
Mean difference	0.7
n	72
S_D	7.6
$T_{\alpha/2, n-1}$	2.56
Confidence interval lower limit	-1.5
Confidence interval upper limit	2.9
Significant difference	no

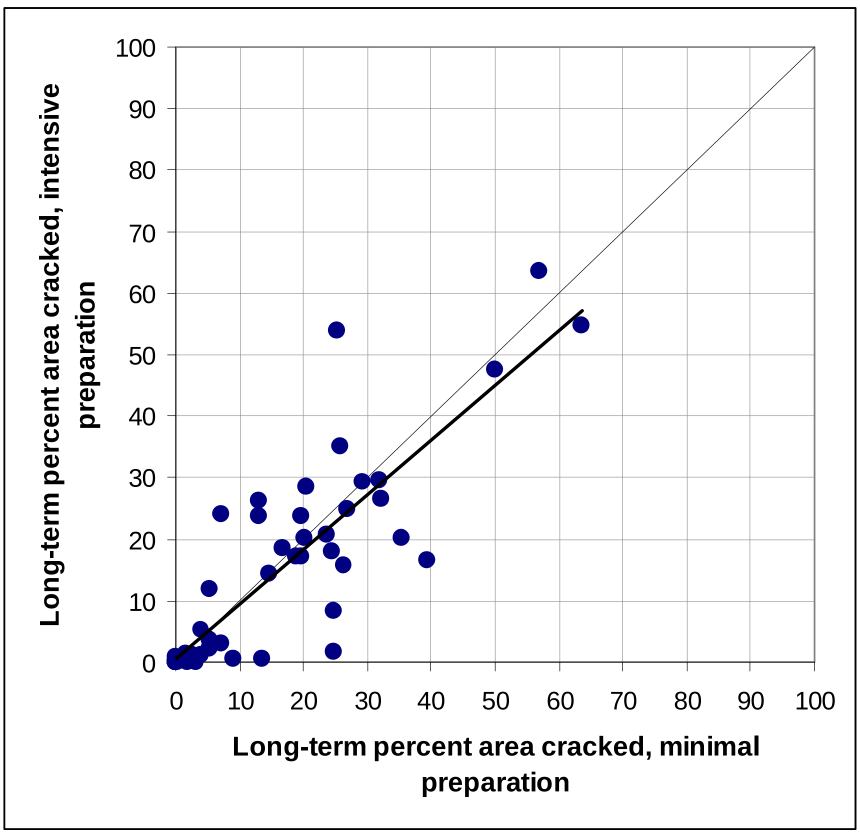

Figure 63. Long-term cracking, SPS-5 overlays with minimal versus intensive preparation.

Two-Inch versus Five-Inch Overlay Thickness

The long-term effect of overlay thickness on cracking is analyzed by evaluating the mean of 72 available pairs of IRI measurements. The results are summarized in Table 46, and a plot of the two-inch-overlay versus five-inch-overlay long-term cracking values is shown in Figure 64. The results indicate that over the time period that the data cover, there is a significant difference overall in the performance, with respect to cracking, of 2-inch overlays versus 5-inch overlays, with 5-inch overlays performing better than 2-inch overlays.

Table 46. Analysis of long-term effect of SPS-5 overlay thickness on cracking.

	Cracking (2 inches versus 5 inches), percent
Mean difference	3.85
n	72
S_D	10.46
$T_{\alpha/2, n-1}$	2.56
Confidence interval lower limit	0.84
Confidence interval upper limit	6.87
Significant difference	yes

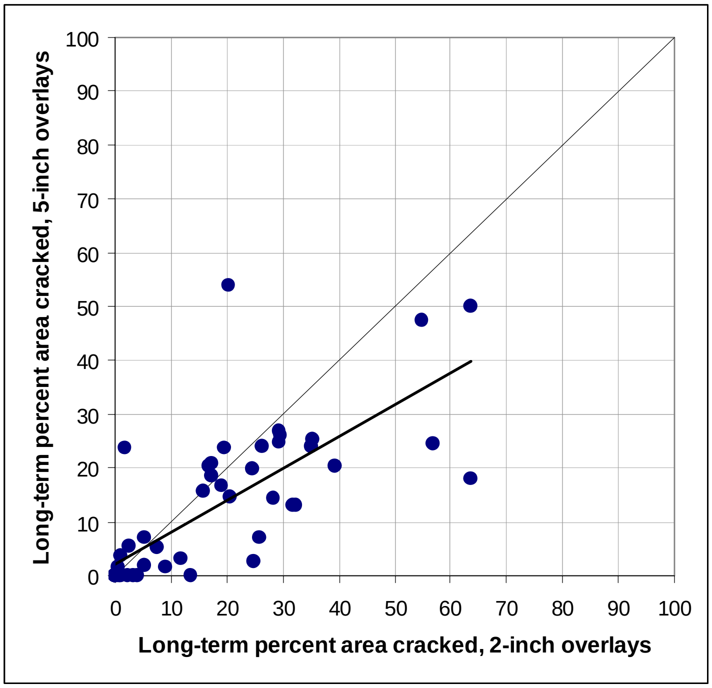

Figure 64. Long-term cracking, SPS-5 two-inch versus five-inch overlays.

The results of the F tests for significance of factor effects on long-term cracking performance of SPS-5 rehabilitation treatments are summarized in Table 47. The factor effects found to be significant for the comparisons conducted are summarized below.

Table 47. Tests for significance of factor effects on relative long-term cracking performance of SPS-5 rehabilitation treatments.

Treatment		Factor				
		Age	Accumulated ESALs	Pre Treatment cracking	Average annual precipitation	Average annual temperature
No overlay Versus Overlay	slope	-3.206	-0.003	1.665	0.861	-0.057
	n	48	48	48	48	48
	Fcalc	7.72	4.10	21.81	2.62	0.01
	F at 0.05	4.05	4.05	4.05	4.05	4.05
	Significant?	**yes**	**yes**	**yes**	no	no
Recycled Versus Virgin Mix	slope	-0.810	0.000	-0.105	0.002	0.008
	n	58	58	58	58	58
	Fcalc	0.93	0.01	0.33	0.00	0.00
	F at 0.05	4.01	4.01	4.01	4.01	4.01
	Significant?	no	no	no	no	no
Minimal Versus Intensive Preparation	slope	-0.098	0.000	0.095	0.039	0.056
	n	58	58	58	58	58
	Fcalc	0.04	0.68	0.98	0.31	0.24
	F at 0.05	4.01	4.01	4.01	4.01	4.01
	Significant?	no	no	no	no	no
2-inch Versus 5-inch Thickness	slope	0.781	0.000	-0.211	-0.124	0.283
	n	58	58	58	58	58
	Fcalc	1.75	1.84	2.92	1.97	3.91
	F at 0.05	4.01	4.01	4.01	4.01	4.01
	Significant?	no	no	no	no	no

- ***Overlay versus no overlay:*** Pretreatment cracking had a very significant effect; age and accumulated ESALs had slightly significant effects. The difference between how fast cracking increased in the nonoverlaid sections and how fast cracking increased in the overlaid sections is positively correlated to pretreatment cracking, and slightly negatively correlated to age and accumulated ESALs.

- ***Recycled versus virgin mix:*** None of the factors tested were found to have a significant effect.

- ***Minimal versus intensive preparation:*** None of the factors tested were found to have a significant effect.

- ***2-inch versus 5-inch overlay thickness:*** None of the factors tested were found to have a significant effect.

References for Chapter 3

[17] Strategic Highway Research Program, "Specific Pavement Studies, Experimental Design and Research Plan for Experiment SPS-5, Rehabilitation of Asphalt Concrete Pavements," National Research Council, April 1989.

[18] Strategic Highway Research Program, "Specific Pavement Studies Construction Guidelines for Experiment SPS-5, Rehabilitation of Asphalt Concrete Pavements," Operational Memorandum SHRP-LTPP-OM-012, 1990.

[19] Von Quintus, H. L., Simpson, A. L., and Eltahan, A. A., "Initial Evaluation of the SPS-5 Experiment," Draft Final Report, LTPP Data Analysis Technical Support Contract No. DTFH61-96-C-00003, 2000.

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[21] Perera, R. W., Byrum, C., and Kohn, S. D., "Investigation of Development of Pavement Roughness, Report No. FHWA-RD-97-147, 1998.

[22] Perera, R. W. and Kohn, S. D., "International Roughness Index of Asphalt Concrete Overlays: Analysis of Data from Long-Term Pavement Performance Program SPS-5 Projects," *Transportation Research Record* 1655, 1999.

[23] Federal Highway Administration, "Reducing Roughness in Rehabilitated Asphalt Concrete (AC) Pavements," Tech Brief, Publication No. FHWA-RD-09-149, 1988.

[24] Hall, K. T. and Correa, C. E., "Estimation of Present Serviceability Index from International Roughness Index," *Transportation Research Record* 1655, 1999.

Chapter 4

Rigid Pavement Rehabilitation Effectiveness

Description of LTPP Experiments SPS-6 and GPS-7B

The SPS-6 experiment was designed to assess the effects of different rehabilitation treatments on the performance of jointed concrete pavements. The Strategic Highway Research Program's experimental design and research plan for SPS-6 are described in Reference 25.

Each SPS-6 project has 8 main experimental sections, listed in Table 48. The numbers shown in the cells are the test section numbers. Section 601 is the unrehabilitated control section. This section can receive routine maintenance over the course of the experiment. Sections 602, 603, and 604 are the "minimum preparation" sections, and the three receive no overlay, a 4-inch asphalt overlay, and a 4-inch asphalt overlay with sawed and sealed joints, respectively. Sections 605 and 606 are the "intensive preparation" sections, and the two receive no overlay and a 4-inch asphalt overlay, respectively. Sections 607 and 608 are cracked or broken and seated, and receive a 4-inch and 8-inch asphalt overlay, respectively. The specific techniques applied to the test sections are summarized in Table 49.

Table 48. SPS-6 experimental treatments.

Overlay thickness	Preoverlay preparation			
	None/control	**Minimal**	**Intensive**	**Crack/break and seat**
0	601	602	605	
4		603	606	607
4 with saw and seal		604		
8				608

Fourteen SPS-6 projects have been constructed in the United States. Their locations are shown in Figure 65. Location data for the SPS-6 projects are given in Table 50. Note that only one of the fourteen SPS-6 sites is linked to a GPS section. At this site, in California, there is no 601 section; the linked GPS section serves as the control.

Table 49. SPS-6 test section treatments.[26]

Rehabilitation Treatments	Test Section 1	2	3	4	5	6	7	8
Asphalt overlay thickness (inches)	0	0	4	4	0	4	4	8
Crack/break and seat							✔	✔
Saw and seal				✔				
Joint sealing	✔[a]	✔[a]			✔[b]			
Crack sealing	✔[a]	✔[a]			✔[b]			
Partial-depth repair		✔[a]	✔[a]	✔[a]	✔[b]	✔[b]		
Full-depth repair		✔[a]	✔[a]	✔[a]	✔[b]	✔[b]		
Load transfer restoration					✔[c]	✔[c]		
Diamond grinding		✔[a]			✔[d]			
Undersealing					✔[a]	✔[a]		
Subdrainage					✔[d]	✔[d]	✔[d]	✔[d]

[a] As needed.
[b] Remove and replace existing, and apply additional as needed.
[c] Full-depth dowelled repair or retrofit dowels in slots.
[d] Apply treatment regardless of condition or need.

Figure 65. SPS-6 locations.

Table 50. SPS-6 location data.

SHRP ID	State	Linked GPS	County	Nearby city or town	Route	Latitude	Longitude
010600	AL		Etowah	Gadsen	I-59	34.18	85.96
040600	AZ		Coconino	Flagstaff	I-40	35.22	111.56
05A600	AR		Jefferson	Redfield	US 65	34.43	92.20
060600	CA	63005	Siskiyou*	Black Butte*	I-5	41.31*	122.40*
170600	IL		Champaign	Pesotum	I-57	39.94	88.31
180600	IN		Marshall	Argos	US 31	41.18	86.25
190600	IA		Polk	Huxley	I-35	41.82	93.57
260600	MI		Bay	Bay City	US 10	43.60	84.04
290600	MO		Harrison	Bethany	I-35**	40.20	94.01
29A600	MO		Washington	Potosi	SR 8	37.92	90.57***
400600	OK		Kay	Ponca City	I-35	36.73	97.35
420600	PA		Centre	Bellefonte	I-80	40.97	77.79
460600	SD		Browne	Groton	US 12	45.46	98.11
470600	TN		Madison	Jackson	I-40	35.70	88.67

*The location data shown for the California SPS-6 site are estimated based on the information that the site is on I-5, 1.4 miles north of Abrams Lake Road Bridge. The location given in LTPP data release 11.5 is believed to be incorrect.

**The location data shown for the Missouri 0600 SPS-6 site are estimated based on the latitude/longitude data and the location information in Reference 27. The route number and location description given in LTPP data release 11.5 are believed to be incorrect.

***The longitude shown for the Missouri A600 SPS-6 site is believed to be correct as shown and incorrect in LTPP data release 11.5.

Climate Characterization

The climatic distribution of the SPS-6 and GPS-7B sites was determined by extracting the latitude and longitude for each site from the LTPP database, searching the National Oceanic and Atmospheric Administration (NOAA) database for the weather station nearest the SPS-6 or GPS-7B site, and extracting the 30-year average annual precipitation and average annual temperature for the weather station. These data are provided in Appendix C. The distributions of SPS-6 sites and GPS-7B sites with respect to average annual precipitation and temperature are illustrated in Figures 66 and 67 respectively.

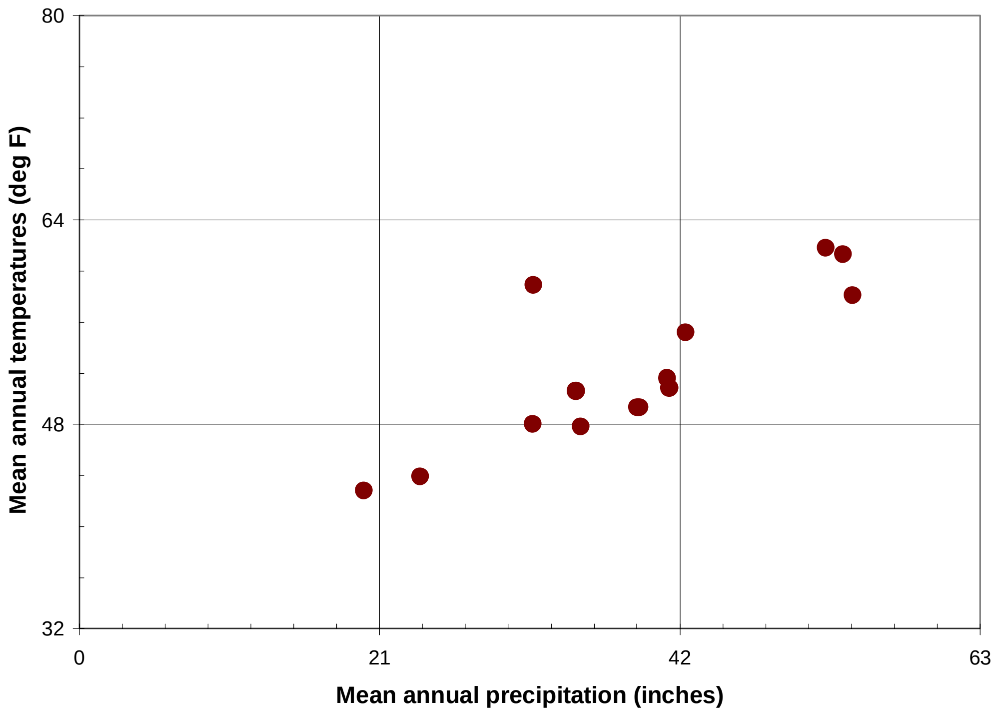

Figure 66. Distribution of SPS-6 sites with respect to precipitation and temperature.

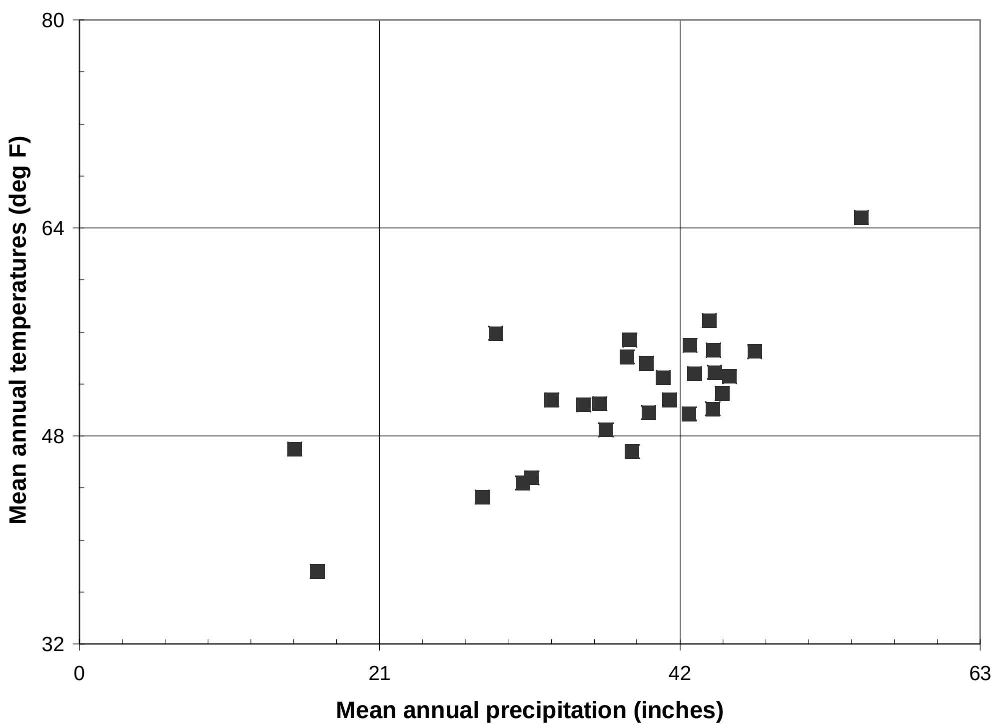

Figure 67. Distribution of GPS-7B sites with respect to precipitation and temperature.

Four of the nine combinations of low, medium, and high precipitation and temperature ranges defined earlier are covered by the SPS-6 experiment. The climatic distribution of the GPS-7B sites echoes the fairly narrow distribution of the SPS-6 sites.

Test Section Layouts and Pavement Structures

The station limits, layer thicknesses, and material types for each of the SPS-6 test sections were extracted from the SPS_PROJECT_STATIONS and TST_L05B data tables in the LTPP database. The thicknesses in the TST_L05B table represent the LTPP regional data collection centers' best estimates of the as-constructed layer thicknesses and materials, from historical records, cores, and rod-and-level surveys. The pavement structure data are given in Appendix C. An example is shown in Figure 68. The as-constructed concrete slab thicknesses were used for the purposes of structural characterization.

Traffic Characterization

The 18-kip-equivalent single-axle (ESAL) levels at the SPS-6 sites were determined in the same way as described previously for the SPS-3 and SPS-5 sites, except that the equations for rigid pavement ESALs were used, and the ESALs were calculated as a function of the as-constructed slab thicknesses.

For the purpose of analyzing the long-term effects of SPS-6 rehabilitation treatments on pavement performance, the accumulated ESALs from the dates of initial posttreatment profile and distress measurement to the dates of the most recent measurements were also calculated for each SPS-6 site. These accumulated ESAL estimates are provided in Appendix C. The accuracy of these accumulated ESAL estimates should, however, be viewed with caution.

Pretreatment Condition

The original design of the SPS-6 experiment identified pretreatment condition as a categorical variable to be used in site selection, with a balance of sites in "fair" and "poor" condition to be identified.[25] However, since definitions of "fair" and "poor" levels of pretreatment condition were not established and furnished to the states for use in site selection, pretreatment condition became a quantitative independent variable in the experiment.

PENNSYLVANIA - SPS-6

Station (m)	Section	Original Construction					Rehabilitation		
		PCC		Base		Subgrade			
		Thickness	Type	Thickness	Type	Type	AC	PC	Base
0 305	420602	10.2	PC (5)	12	GB (303)	SS (141)		10.2	12
605 758	420659	10.3	PC (5)	10	GB (303)	SS (141)		10.3	10
765 918	420601	10.3	PC (5)	10	GB (303)	SS (141)		10.3	10
1,641 1,946	420605	10.1	PC (5)	11	GB (303)	SS (141)		10.1	11
2,030 2,182	420606	10.1	PC (5)	9	GB (303)	SS (141)	1.9 2.6	10.1	9
2,216 2,368	420603	10.1	PC (5)	10	GB (303)	SS (141)	1.8 2.4	10.1	10
2,399 2,552	420604	10.3	PC (5)	10	GB (303)	SS (141)	1.8 2.6	10.3	10
2,583 2,735	420607	10.1	PC (5)	10.4	GB (303)	SS (141)	1.7 2.4	10.1	10.4
3,006 3,159	420608	10.1	PC (5)	9.5	GB (303)	SS (141)	1.7 2.5 3 1.1	10.1	9.5
3,278 3,431	420660	10.6	PC (5)	10	GB (303)	SS (141)	1.4 2.5 4.5 1.1	10.6	10
3,513 3,666	420661	10	PC (5)	11	GB (303)	SS (141)	1.5 2.5 8 1.1	10	11
3,794 3,946	420662	10.2	PC (5)	10	GB (303)	SS (141)	1.2 2.5 3 1	10.2	10

Figure 68. Example SPS-6 pavement structure information.

The pretreatment International Roughness Index (IRI), rutting, and cracking levels in the SPS-6 test sections were determined using the last measurement of each of these parameters prior to treatment. The relationship of pretreatment condition to long-term treatment effectiveness has been examined wherever possible, i.e., for those test sections with pretreatment condition data available.

Construction Problems and Deviations

At some of the SPS-6 sites, some problem or deviation occurred with the application of one or more of the rehabilitation treatments.[28] The sites with noteworthy construction problems and deviations are listed in Table 51. The deviations that are considered of particular significance to this analysis are the rehabilitation activities in what should have been the control section at the Arkansas, Indiana, Oklahoma, and Tennessee sites.

Table 51. SPS-6 construction problems and deviations.[28]

SHRP ID	State	Problem or Deviation
010600	AL	In section 010661, about 0.61 m did not get rubblized.
05A600	AR	***Full- and partial-depth repairs, as well as joint and cracks sealing, were performed in the control section (601).*** In sections 05A607 and 05A608, the slab was not cracked through its full depth in the cracking and seating process, which was done using a Guillotine drop hammer and one pass of a 50-ton roller. In section 05A607, a transverse cold joint was formed when the asphalt paver stopped during paving.
060600	CA	In section 060605, because of the poor condition of the slabs and poor load transfer, all slabs in the outer lane were replaced, and the existing edgedrains were removed and replaced. In section 060607, because of spalling caused by the pavement breaker, several slabs were replaced [and presumably fractured] before the overlay was placed.
170600	IL	[Although not mentioned in Reference 28, it began to rain during rubblizing of the second of two rubblized sections, 170664, and the pace of the pavement breaker was increased to complete the rubblizing process before the rain became heavy].
180600	IN	***The control section, 180601, was overlaid in July 1993 and removed from service.***
400600	OK	***The control section, 400601, received full-depth repairs and joint resealing.*** The crack and seat sections, 400607 and 400608, were fractured with an RMI resonant frequency breaker, resulting in smaller pieces than in typical crack and seat operations.
470600	TN	***The control section, 470601, received two slab replacements and joint resealing.***

The GPS-7B experiment consists of concrete pavements (formerly in the GPS-3, GPS-4, or GPS-5 experiment), that have received a conventional AC overlay at least 1.5 inch thick. The pavements receive either no pretreatment prior to overlay, or concrete pavement restoration (CPR) treatment. The LTPP data set used for this analysis included 39 pavement sections belonging to the GPS-7B experiment. Location data for the GPS-7B sections are given in Table 52. The locations of the GPS-7B sites are shown in Figure 69.

Table 52. GPS-7B location data.

SHRP ID	State	County	Nearby city or town	Route	Latitude	Longitude
094020	CT	Hartford	Glastonbury	SR 2	41.70	72.57
095001	CT	Tolland	Vernon	I-84	41.85	72.44
104002	DE	Kent	Lebanon	SR 10	39.12	75.51
105005	DE	Kent	Milford	SR 1	38.93	75.41
165025	ID	Bannock	Virginia	I-15	42.38	112.21
175151	IL	Rock Island	Barstow	I-80	41.53	90.35
175217	IL	McLean	Bloomington	I-74/US 51	40.44	89.00
175849	IL	Champaign	Ludlow	I-57	40.39	88.13
175854	IL	Peoria	Pioneer	SR 6	40.79	89.66
179267	IL	Henry	Cleveland	I-80	41.51	90.34
179327	IL	McLean	Bloomington	I-74/US 51	40.44	89.00
183003	IN	Marshall	Argos	US 31	41.27	86.27
185022	IN	Johnson	Greenwood	I-65	39.63	86.07
185518	IN	Tippecanoe	Lafayette	I-65	40.48	86.85
185528	IN	La Porte	La Porte	SR 2	41.65	86.66
185538	IN	La Porte	La Porte	SR 2	41.67	86.62
199116	IA	Worth	Silver Lake	I-35	43.48	93.35
199126	IA	Scott	Bettendorf	80	41.60	90.48
204067	KS	Harvey	Newton	US 50	38.03	97.34
275076	MN	Washington	Pine Springs	I-694	45.03	92.97
283099	MS	Scott	Forest	I-20	32.33	89.41
294069	MO	Platte	Kansas City	I-635	39.16	94.64
295393	MO	St. Charles	Saint Paul	SR 79	38.87	90.72
295473	MO	Cooper	Overton	I-70	38.94	92.65
295483	MO	Clay	Birmingham	SR 210	39.16	94.43
316702	NE	Cheyenne	Sidney	I-80	41.11	102.92
375826	NC	Surry	Mount Airy	I-77	36.47	80.76

Table 52. GPS-7B location data (continued).

SHRP ID	State	County	Nearby city or town	Route	Latitude	Longitude
393013	OH	Brown	Georgetown	US 68	38.88	83.89
394031	OH	Franklin	Upper Arlington	I-270	39.99	83.12
395010	OH	Mahoning	Boardman	I-680	40.98	80.64
421613	PA	Delaware	Havertown	I-476	40.00	75.35
421614	PA	Centre	Port Matilda	US 220/US 322	40.82	78.03
421617	PA	Montgomery	Radnor	I-476	40.06	75.33
421691	PA	Beaver	Darlington	SR 51	40.81	80.45
501682	VT	Chittenden	Charlotte	US 7	44.33	73.24
544004	WV	Fayette	Collinsdale	I-64/I-77	38.02	81.35
545007	WV	Harrison	Clarksburg	US 50	39.29	80.42
833802	MB	–	Sainte Agathe	SR 75	49.63	97.14
836452	MB	–	Winnipeg	TCH 100	49.82	97.01

TCH stands for Trans-Canada Highway. SR is used for Canadian projects located on the equivalent of state routes in the United States.

Figure 69. GPS-7B locations.

Performance Findings from Previous Studies

Analysis of Trends in Distress, Roughness, and Deflections

Reference 20 describes analyses conducted to identify any trends in the early performance data (through mid 1995) from the SPS-6 experiment. The SPS-6 test sections were evaluated with respect to transverse cracking and reflection cracking. Roughness, overlay rutting, and deflections were also evaluated.

The age of the experiment and the amount of data available were identified as the main limitations to analysis of the data available in 1995. Most of the sections were only a few years old at that time, and for many of them, there had been little if any change in condition since rehabiliation. Also, since the sections were not very old, much of the sampling, testing, and monitoring data were in various stages of checking and had not yet been classified as Level E in the LTPP database. For example, although SPS projects should have had monitored traffic data since the date of completion of construction, these data were not available at the time that the study described in Reference 20 was conducted. Similarly, climatic data for SPS sites were not yet available, so these data were estimated using climatic data for nearby GPS sites.

The overlay rehabilitation treatments were judged to have improved condition and reduced roughness, compared to the condition and roughness levels prior to construction. Diamond grinding reduced roughness in some sections to which it was applied, but for the majority of these sections, the IRI values after treatment were about the same as before treatment. Two projects had higher IRI values after diamond grinding than before.

In overlaid sections without breaking/cracking and seating, maximum deflections (under the load plate) ranged from 100 μm to 400 μm prior to overlay, and ranged from 50 μm to 120 μm after overlay. Nonetheless, Reference 20 states that the overlays did not increase pavement stiffness. Outermost sensor deflections were unchanged, indicating consistency in measured foundation stiffnesses. The pavement structure and foundation stiffnesses were not, however, quantified by analysis of the deflection measurements.

In the sections with 4-inch overlays, other than the break/crack and seat sections, most of the joints were reported to have reflected through the overlays within one to two years. Some of the break/crack and seat sections with 4-inch overlays also exhibited reflection cracking at transverse joints in the first few years. Nonetheless, the break/crack and seat sections were judged to be performing considerably better than the other treatments.

Reference 20 also describes efforts made to conduct correlation analyses of early (through 1995) SPS-6 performance data. The goal of the correlation analyses was to attempt to identify significant factors in any performance trends observed. However, these correlation analyses yielded few results, because of the low levels of distress present in most sections at the time. Although some of the correlation analysis results appeared reasonable, others did not, and overall the correlation analysis results were not considered reliable enough to report.

Analysis of Roughness Before and After Rehabilitation

Reference 21 reports the results of analyses of roughness data from experiments SPS-6 and GPS-7B. At the time of these analyses (1997), profile data were available for 9 SPS-6 projects and 21 GPS-7B sections.

The main findings noted in Reference 21 from analysis of the pretreatment and posttreatment IRI data from the SPS-6 experiment are the following:

- At the time of the analysis, most of the SPS-6 sections had shown little if any change in IRI since rehabilitation.
- Within a given SPS-6 project, the postoverlay IRI values of the overlaid sections fell within a relatively narrow band, irrespective of the preoverlay IRI values. However, the lower and upper limits of the range of postoverlay IRI values varied from project to project.
- Overlaid sections with sawed and sealed joints tended to exhibit slower rates of increase in postoverlay IRI than overlaid sections without sawed and sealed joints.

Of the 21 GPS-7B sections with postoverlay profile data available in 1997 for analysis, fifteen sections also had preoverlay profile data available for analysis. The IRI values before and after overlay for these sections are shown in Figure 70, in order of increasing overlay thickness. A frequency distribution of the postoverlay IRI values for the 21 GPS-7B projects with profile data available is shown in Figure 71.

The GPS-7B sections were no more than six years old at the time of the analysis. As these sections had thus far exhibited little if any change in IRI, it was considered too soon to conduct any statistical analysis of IRI trends.

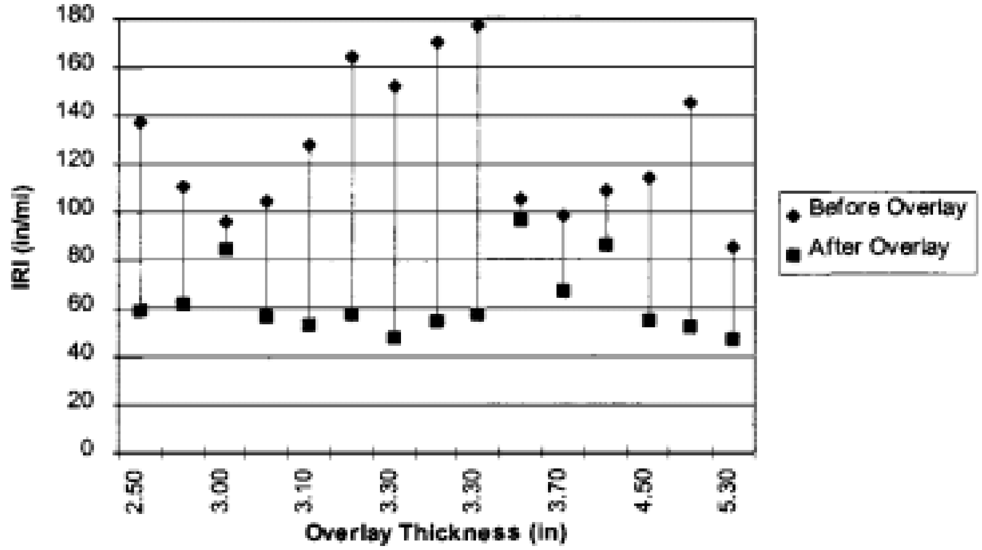

Figure 70. IRI before and after overlay for 15 GPS-7B sections, data as of 1997.[21]

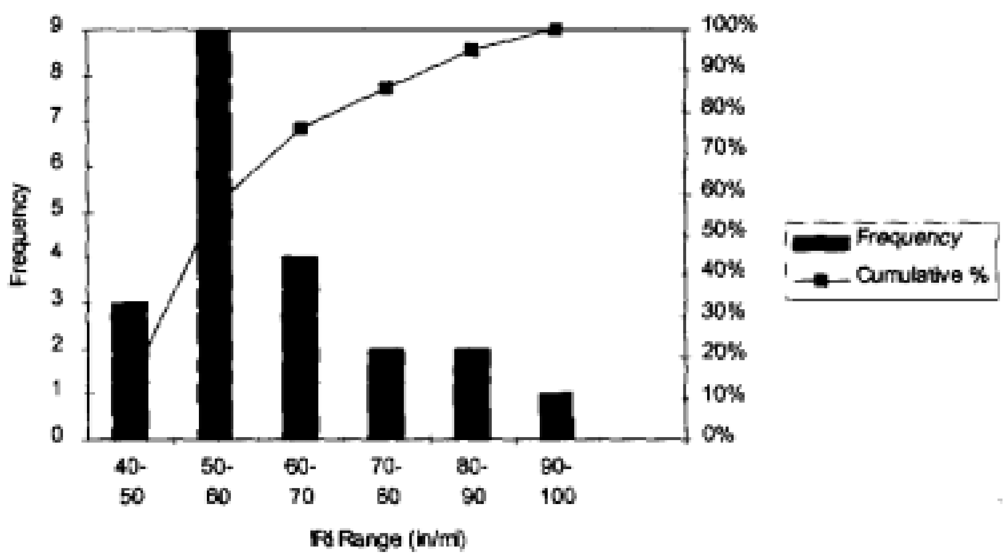

Figure 71. Frequency distribution of postoverlay IRI values for GPS-7B sections 1997 analysis.[21]

Backcalculation Analysis

Reference 29 presents an analysis of deflections measured on the Illinois SPS-6 project, before rehabilitation in 1990, and after rehabilitation, in 1991 through 1994. In addition to the main experimental sections, this project has additional sections designed by the Illinois DOT: one nonoverlaid section with milling instead of grinding, two overlaid sections with Illinois' standard overlay thickness (3.25 inches), and two sections with the concrete slab rubblized, one with a 6-inch overlay and the other with an 8-inch overlay. An elastic layer backcalculation program was used for all sections, to allow comparisons among the different treatments.

Diametral resilient modulus testing was performed on cores from the asphalt overlay material. The mean laboratory modulus values at 70º and 90ºF, were converted to equivalent field values (for the more rapid frequency corresponding the Falling Weight Deflectometer's impulse loading rate), as described in Reference 30, using an Asphalt Institute equation.[31] The range of asphalt modulus values backcalculated for the asphalt-overlaid sections, with respect to the mix temperature at the time of deflection testing, is illustrated in Figure 72. These results define a band of reasonable asphalt modulus values with respect to mix temperature for this site.

The backcalculated concrete modulus values in the control section and the overlaid intact sections were consistent before and after the rehabilitation date, whereas the concrete modulus values in the break-and-seat sections were about fifty percent lower after breaking and seating. In the rubblized sections, the concrete modulus values were greatly reduced by the rubblizing: about 5 to 20 percent of the pretreatment values. The coefficients of variation of backcalculated concrete modulus values in the break-and-seat and rubblized sections were about twice as high as those in the control and overlaid intact sections. The subgrade modulus values, on the other hand, remained fairly consistent in the mean and in variance in all of the test sections.

Similar deflection analyses of SPS-6 sites in the North Central region have been reported in Reference 27 and similar reports.

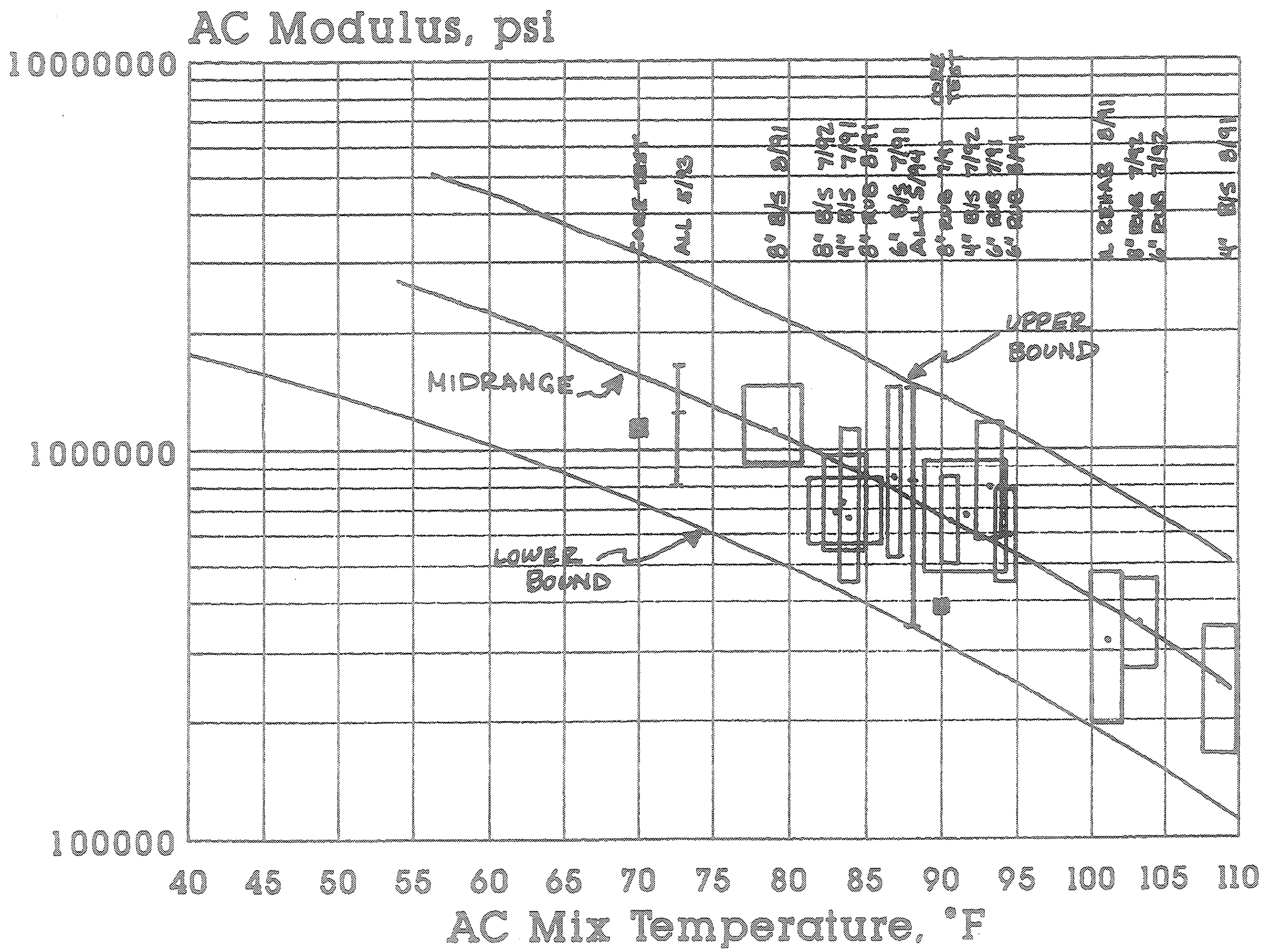

Figure 72. Backcalculated modulus values versus mix temperature at time of testing, Illinois SPS-6 site.[29]

Analysis Objectives

The objectives of the analysis of the SPS-6 and GPS-7B experiments conducted for the present study are to assess the following:

- The initial effects, if any, of rehabilitation on the condition of the pavement,
- The long-term effects, if any, of rehabilitation on the performance of the pavement,
- The influence, if any, of pretreatment condition and other factors on rehabilitation effectiveness, and
- The relative effectiveness of the different treatments considered.

With respect to both initial and long-term effects, the analysis of the SPS-6 experiment aims to assess the changes in condition that occur in treated test sections, compared to the changes that occur in the control sections over the same time intervals. The analysis of the GPS-7B sites supplements the SPS-6 analysis. In addition to the comparisons of the rehabilitated sections with the control sections, the following specific comparisons are of interest in the analyses of long-term effects:

- Minimal versus intensive preparation in nonoverlay sections,
- Minimal versus intensive preparation in overlay sections,
- 4-inch overlay without saw/seal versus with saw/seal,
- 4-inch overlay with saw/seal versus 4-inch overlay with crack/seat, and
- Crack/seat with 4-inch versus 8-inch overlay.

The pavement condition measures considered are the following:

- Roughness, as expressed by the International Roughness Index (IRI);
- Rutting in overlay sections; and
- Reflection cracking in overlay sections.

Effects of Rigid Pavement Rehabilitation on Roughness

Initial Effects on Roughness

IRI Before Treatment

The mean preoverlay IRI values of twelve of the fourteen SPS-6 sites are given in Table 53, along with estimated mean PSI values.

Table 53. Mean pretreatment IRI and PSI values by SPS-6 site.

Site	IRI (m/km)	PSI (0–5 scale)
Alabama	2.39	2.98
Arizona	1.95	3.41
Arkansas	2.00	3.34
California	3.11	2.37
Illinois	2.27	3.06
Indiana	1.83	3.52
Iowa	–	–
Michigan	2.13	3.20
Missouri 0	2.00	3.35
Missouri A	–	–
Oklahoma	1.71	3.65
Pennsylvania	2.71	2.71
South Dakota	2.80	2.61
Tennessee	1.89	3.50

The following details should be noted:

- Prerehabilitation IRI data are not available for any test sections at the Iowa and Missouri A sites.
- Prerehabilitation IRI data are not available for the nonoverlay minimal preparation (602), saw-and-seal overlay (604), nonoverlay intensive preparation (605), and 4-inch overlay with intensive preparation (606) test sections at the Illinois site.
- Prerehabilitation IRI data are not available for the control (601) section at the Indiana site.
- Control sections at the Oklahoma and Tennessee sites were excluded from this calculation.

The PSI values shown throughout this chapter were estimated from the following equation:[24]

PSI	=	$5 + 0.6046\, x^3 - 2.2217\, x^2 - 0.0434\, x$	(Eqn. 7)
x	=	$\log(1 + SV)$	(Eqn. 8)
SV	=	$2.2704\, IRI^2$	(Eqn. 9)

where:

PSI	=	present serviceability index
SV	=	10^6 * population variance of slopes calculated at 1-ft intervals
variance	=	$\Sigma (Y_i - Y_{mean})^2 / n$
Y_i	=	individual measured slope
Y_{mean}	=	mean of measured slopes
n	=	number of slope measurements
IRI	=	International Roughness Index, m/km, for a 1-ft sample interval

Note that the above IRI-PSI correlation applies only to rigid pavements. A different correlation is presented in Reference 24 for flexible pavements.

In addition to the sixteen SPS-6 sites listed above, pretreatment IRI data were available for 31 of the 39 total pavement sections belonging to the GPS-7B experiment at the time of this analysis. Summary statistics for preoverlay IRI and PSI for the SPS-6 and GPS-7B experiments are shown in Table 54. The statistics for the two data sets are similar, except that the GPS-7B data cover a broader range. Note that the PSI statistics are calculated from the distribution of estimated PSI values, not from the IRI statistics.

Table 54. SPS-6 and GPS-7B pretreatment IRI and PSI summary statistics.

	SPS-6		**GPS-7B**	
	IRI (m/km)	**PSI (0-5 scale)**	**IRI (m/km)**	**PSI (0-5 scale)**
Min IRI, Max PSI	1.31	4.11	0.76	4.72
Mean	2.23	3.14	2.14	3.26
Standard deviation	0.57	0.53	0.78	0.72
Median	2.14	3.19	2.11	3.22
Max IRI, Min PSI	3.74	1.94	4.11	1.73
Number of sections	87		31	

The mean pretreatment IRI values of the different SPS-6 treatment groups are given in Table 55, along with the corresponding estimated PSI values. In the case of the control section, the term "pretreatment" refers to profile measurements obtained at the same time as the pretreatment measurements on the treatment sections. The control sections excluded from this calculation were listed previously.

In an analysis of variance, summarized in Table 56, no significant differences were detected among the mean pretreatment IRI values of the different treatment groups. Note that the usual analysis of variance calculations must be adjusted for unequal sample sizes because pretreatment IRI values are not available for the same number of SPS-6 sites for all treatment types.

Table 55. Mean pretreatment IRI and PSI values by SPS-6 treatment type.

Treatment Group	IRI (m/km)	PSI (0–5 scale)
Control (601 or linked GPS)	2.39	2.97
Nonoverlay minimal repair (602)	2.26	3.12
4-inch overlay with minimal preparation (603)	2.15	3.20
4-inch saw-and-seal overlay with minimal preparation (604)	2.20	3.20
Nonoverlay intensive repair (605)	2.40	3.02
4-inch overlay with intensive preparation (606)	2.27	3.09
4-inch overlay with crack/break-and-seat (607)	2.08	3.27
8-inch overlay with crack/break-and-seat (608)	2.23	3.15

Table 56. Analysis of variance of preoverlay IRI with respect to SPS-6 treatment type.

Source of variation	Sum of squares (SS)	Degrees of freedom	Mean squares (MS)	Calculated F	Theoretical F ($\alpha = 0.05$)
Between treatments	0.879	7	0.126	0.370	2.129
Within treatments	26.474	78	0.339		
Total	27.679	85			

The null hypothesis (that all the population treatment means are equal) is not rejected because the calculated F value, 0.370, does not exceed the upper 5 percent of an F distribution with 7 and 78 degrees of freedom, 2.129. This is as might be expected, and indicates that there is no evidence of bias with respect to preoverlay roughness in the State DOTs' assignments of treatments to different sections.

IRI After Treatment

The mean initial posttreatment IRI values for the fourteen SPS-6 sites are given in Table 57, along with estimated PSI values.

Table 57. Mean initial posttreatment IRI values by SPS-6 site.

Site	IRI (m/km)	PSI (0–5 scale)
Alabama	1.39	4.05
Arizona	1.34	4.14
Arkansas	1.25	4.19
California	1.21	4.25
Illinois	1.41	4.03
Indiana	1.67	3.84
Iowa	1.25	4.19
Michigan	1.55	3.87
Missouri 0	1.48	3.93
Missouri A	1.36	4.11
Oklahoma	1.08	4.38
Pennsylvania	1.31	4.12
South Dakota	1.22	4.23
Tennessee	0.81	4.66

The mean initial posttreatment IRI values are shown by treatment type in Table 58, along with estimated mean PSI values. In the case of the control sections, the term "posttreatment" refers to profile measurements obtained at the same time as the initial posttreatment measurements on the overlaid sections.

Table 58. Initial SPS-6 postreatment IRI and PSI by treatment type.

Treatment Group	IRI (m/km)	PSI (0–5 scale)
Without overlay:		
Control (601 or linked GPS)	2.54	2.82
Nonoverlay minimal repair (602)	1.82	3.63
Nonoverlay intensive repair (605)	1.36	4.10
With overlay:		
4-inch overlay with minimal preparation (603)	0.98	4.49
4-inch saw-and-seal overlay with minimal preparation (604)	1.00	4.47
4-inch overlay with intensive preparation (606)	1.00	4.47
4-inch overlay with crack/break-and-seat (607)	1.08	4.38
8-inch overlay with crack/break-and-seat (608)	0.97	4.50

Comparing Table 55 and Table 58, it is seen that for the seven SPS-6 sites with both "pretreatment" and "posttreatment" IRI data for the control section (601 or linked GPS), the mean IRI rose from 2.39 to 2.54 m/km in the interval between the pretreatment and posttreatment profile measurement dates. This corresponds to a decline in average estimated PSI from 2.97 to 2.82. In all of the overlay treatment groups, however, the mean initial posttreatment IRI is considerably less than the pretreatment IRI.

An analysis of variance, summarized in Table 59, indicates that one or more significant differences exist among the mean initial posttreatment IRI values of the different ***treated*** groups. Note that the control section group is excluded from this analysis. Note also that the usual analysis of variance calculations must be adjusted for unequal sample sizes because initial posttreatment IRI values are not available for the same number of SPS-6 sites for all treatment types.

The null hypothesis (that all the population overlay treatment means are equal) is rejected because the calculated F value, 4.832, exceeds the upper 5 percent of an F distribution with 6 and 80 degrees of freedom, 2.214. This is as might be expected, considering that, as shown in Table 58, the mean initial posttreatment IRI values for the two nonoverlay treatments (602 and 605, with minimal and intensive repair respectively) appear to be notably higher than those of all of the overlay treatments.

Table 59. Analysis of variance of initial posttreatment IRI with respect to SPS-6 treatment type (excluding the control).

Source of variation	Sum of squares (SS)	Degrees of freedom	Mean squares (MS)	Calculated F	Theoretical F ($\alpha = 0.05$)
Between treatments	6.913	6	1.152	4.832	2.214
Within treatments	19.075	80	0.238		
Total	25.988	86			

On the other hand, in an analysis of variance in initial postrreatment IRI for the **overlay treatment groups only** (603, 604, 606, 607, and 608), no significant differences are detected among the mean initial posttreatment IRI values. The results are summarized in Table 60. Thus, it appears that the significant difference detected in the analysis of variance summarized in Table 59 is attributable to the difference between rehabilitation without overlay and rehabilitation with overlay.

Table 60. Analysis of variance of initial posttreatment IRI for overlay groups only.

Source of variation	Sum of squares (SS)	Degrees of freedom	Mean squares (MS)	Calculated F	Theoretical F ($\alpha = 0.05$)
Between treatments	0.099	4	0.025	0.780	2.525
Within treatments	1.904	60	0.032		
Total	2.003	64			

Pretreatment versus Posttreatment IRI

A plot of IRI values in the SPS-6 control section group, before and after the date of rehabilitation of the accompanying treated sections, is shown in Figure 73. The best-fit line is very close to the 1:1 line, but all of the "post" values are slightly greater than the "pre" values, which probably reflects the lapse of time between the "pre" and "post" measurements. Note that in this plot as well as in the similar plots that follow for the other treatment groups, points are shown only for those sites that have both pretreatment and posttreatment IRI values available.

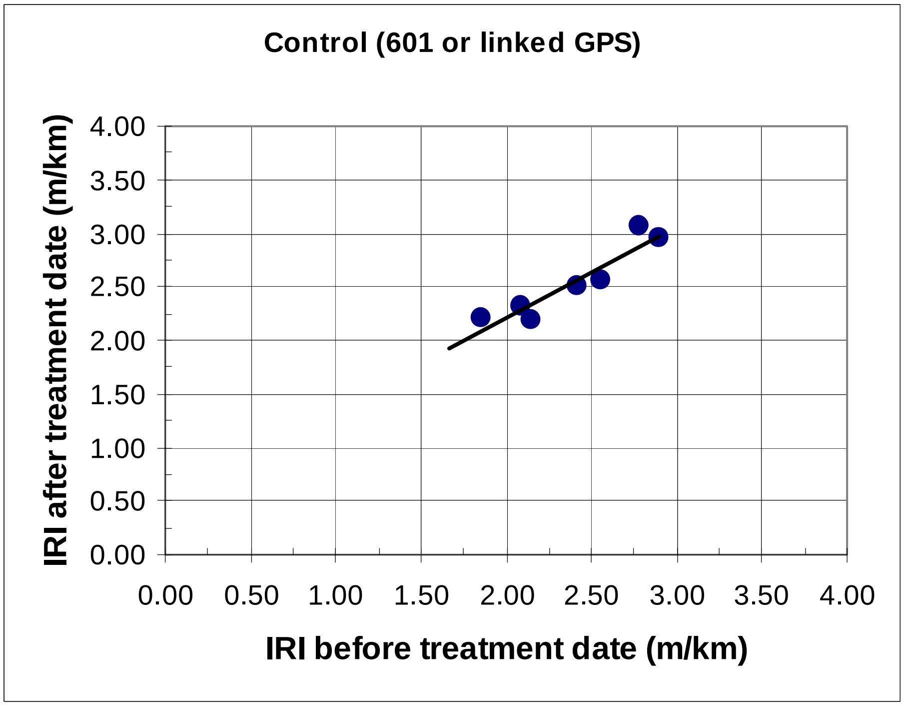

Figure 73. IRI before and after date of treatment, SPS-6 control sections.

The plots of IRI values in the two nonoverlay treatment groups, with minimal and intensive repair, are shown in Figures 74 and 75 respectively. Both plots show a wide scatter in the data.

In comparing the nonoverlay treatment groups with minimal (602) versus intensive (605) repair, it is worth noting that the techniques allowed for sections in the nonoverlay minimal repair (602) group stretch the meaning of the word "minimal." Joint sealing, crack sealing, partial-depth repair, full-depth repair, and diamond grinding were permitted for these sections. Which of these treatments were applied varies by site, depending on pavement condition. Any or all of these techniques, plus load transfer restoration (either by full-depth joint replacement or by dowel retrofitting), undersealing, and subdrainage installation, were permitted for sections in the nonoverlay intensive repair (605) group. Again, which treatments were actually applied varies by site.

If the data plotted in Figure 74 are examined closely, it becomes evident that the points fall in three subgroups:

- ***Sites where posttreatment IRI was considerably higher than pretreatment IRI:*** Arizona and Indiana. At the Arizona site, the nonoverlay minimal repair (602) section received some partial-depth repairs, joint and crack sealing, shoulder replacement, and lane/shoulder joint

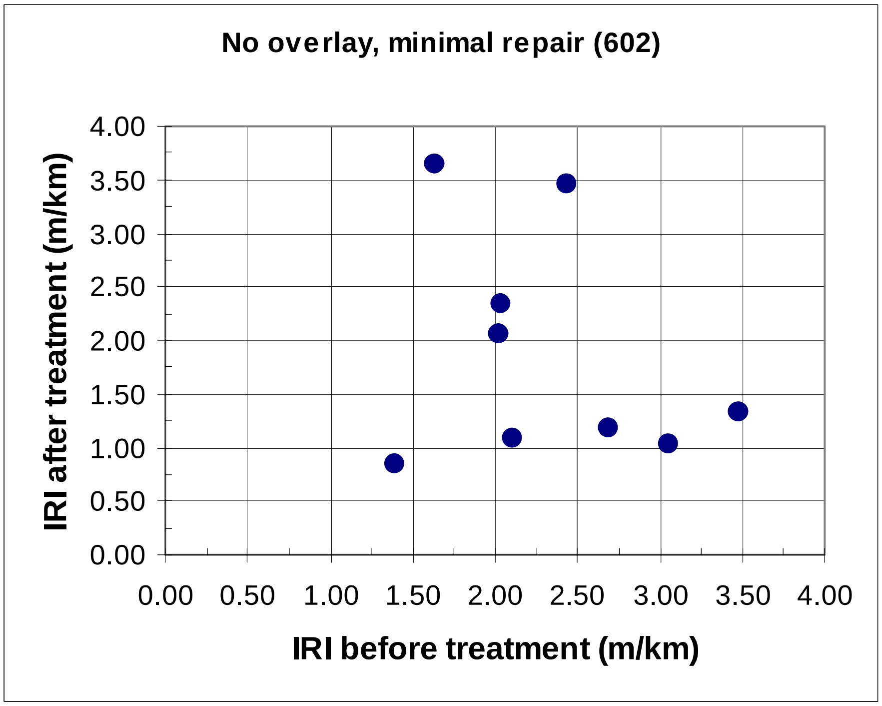

Figure 74. IRI before and after treatment, SPS-6 nonoverlay, minimal repair sections.

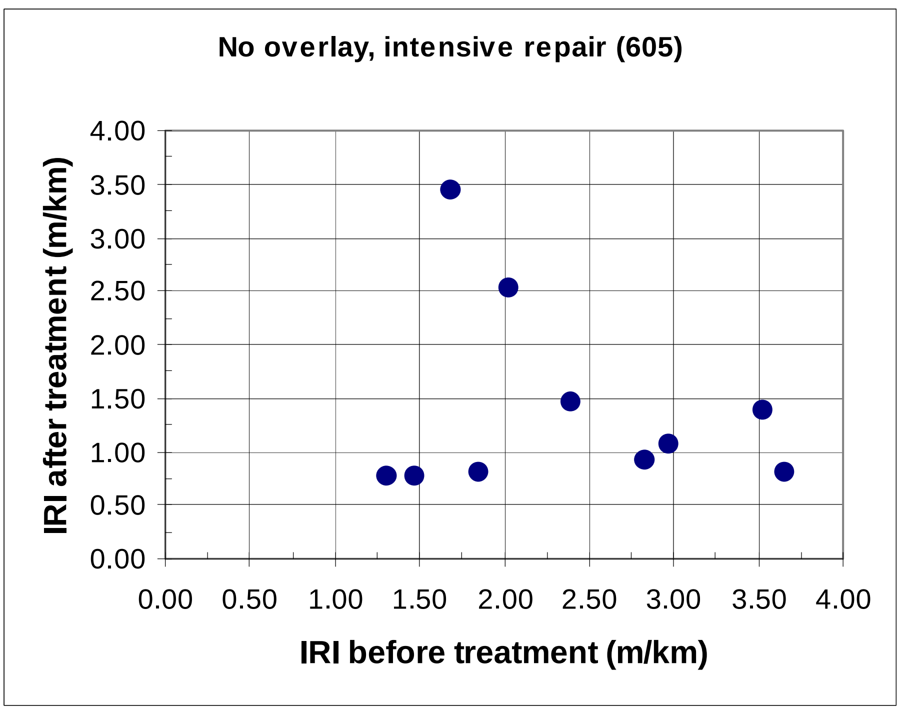

Figure 75. IRI before and after treatment, SPS-6 nonoverlay, intensive repair sections.

sealing. At the Indiana site, virtually every joint in the nonoverlay minimal repair (602) section was replaced with a doweled full-depth repair. Neither diamond grinding nor milling was done at either site.

- ***Sites where posttreatment IRI was similar to pretreatment IRI:*** Arkansas and Michigan. At the Arkansas site, the nonoverlay minimal repair (602) section received full-depth repairs, partial-depth repairs, transverse and longitudinal joint and crack sealing, and diamond grinding. At the Michigan site, the nonoverlay minimal repair (602) section received some full- and partial-depth asphalt concrete repairs, and crack sealing. No diamond grinding or milling was done.

- ***Sites where posttreatment IRI was considerably lower than pretreatment IRI:*** Alabama, California, Oklahoma, South Dakota, and Tennessee. The nonoverlay minimal repair (602) sections at all of these sites received full-depth repairs, joint and crack sealing, and diamond grinding. At the Alabama site, partial-depth repairs were done as well.

Similarly, if the data plotted in Figure 75 are examined closely, it becomes evident that the points fall in three subgroups:

- ***A site where posttreatment IRI was considerably higher than pretreatment IRI:*** Indiana. At the Indiana site, every joint in the nonoverlay intensive repair (605) section was replaced with a doweled full-depth repair. Pipe edgedrains were installed, and the shoulder was overlaid.

- ***A site where posttreatment IRI was similar to pretreatment IRI:*** Michigan. At the Michigan site, the nonoverlay intensive repair (605) section received full-depth concrete repairs, partial-depth asphalt concrete repairs, joint sealing, crack sealing, and installation of edgedrains. No diamond grinding or milling was done.

- ***Sites where posttreatment IRI was considerably lower than pretreatment IRI:*** Alabama, Arizona, Arkansas, California, Oklahoma, Pennsylvania, South Dakota, and Tennessee. At the California site, the outer traffic lane in the nonoverlay intensive repair (605) section was completely removed and replaced. At all of the other sites listed, the nonoverlay intensive repair (605) section received full-depth repairs, diamond grinding, joint resealing, and installation or replacement of subdrainage (pipes or mat). Load transfer restoration was also performed at all but the Oklahoma and Tennessee sites.

From these details, it may be observed that in general, concrete pavement restoration without diamond grinding initially resulted in an IRI equal to or greater than the IRI before treatment, whereas concrete pavement restoration with diamond grinding results in an IRI considerably lower than the IRI before treatment. The one exception to this latter observation is the Arkansas nonoverlay minimal repair (602) section, where IRI increased with treatment despite diamond grinding.

The average posttreatment IRI at the five nonoverlay minimal repair (602) sections where diamond grinding was done (excluding the Arkansas section, where posttreatment IRI was higher than pretreatment IRI) is 1.10 m/km. The average posttreatment IRI for the seven nonoverlay intensive preparation (605) sections where diamond grinding was done (excluding the California section, which is really a lane reconstruction) is 1.02 m/km. A small-sample (t) test indicates that there is no significant difference between these two means. The overall average posttreatment IRI for the twelve total nonoverlay repair sections where diamond grinding successfully reduced roughness 1.05 m/km, which corresponds to an average PSI of about 4.4.

Turning now to the SPS-6 treatments involving asphalt overlays of intact concrete pavements, the plots of preoverlay IRI versus postoverlay IRI for the 4-inch overlay with minimal preparation (603), 4-inch saw-and-seal overlay with minimal preparation (604), and 4-inch overlay with intensive preparation (606) are shown in Figures 76, 77, and 78 respectively.

As the analysis of variance showed (see Table 60), the means of the three groups are not significantly different. Also, although there appears to be in each plot a slightly positive correlation between pretreatment and posttreatment IRI, in none of the three cases is the slope of the best-fit line significantly different than zero.

Summary statistics for initial postoverlay IRI and PSI are shown in Table 61 for the three groups of asphalt overlays of intact concrete slabs in the SPS-6 experiment, and the GPS-7B experiment. Note that the PSI statistics shown are calculated from the distributions of estimated PSI values, not from the IRI statistics.

A large-sample (z) test indicates no significant difference in the means of the two data sets, but an F test indicates that they do not have a common variance – the variance of the GPS-7B initial postoverlay IRI values is significantly greater than the variance of the SPS-6 initial postoverlay IRI values (for the three groups with overlays of intact slabs: 603, 604, and 606).

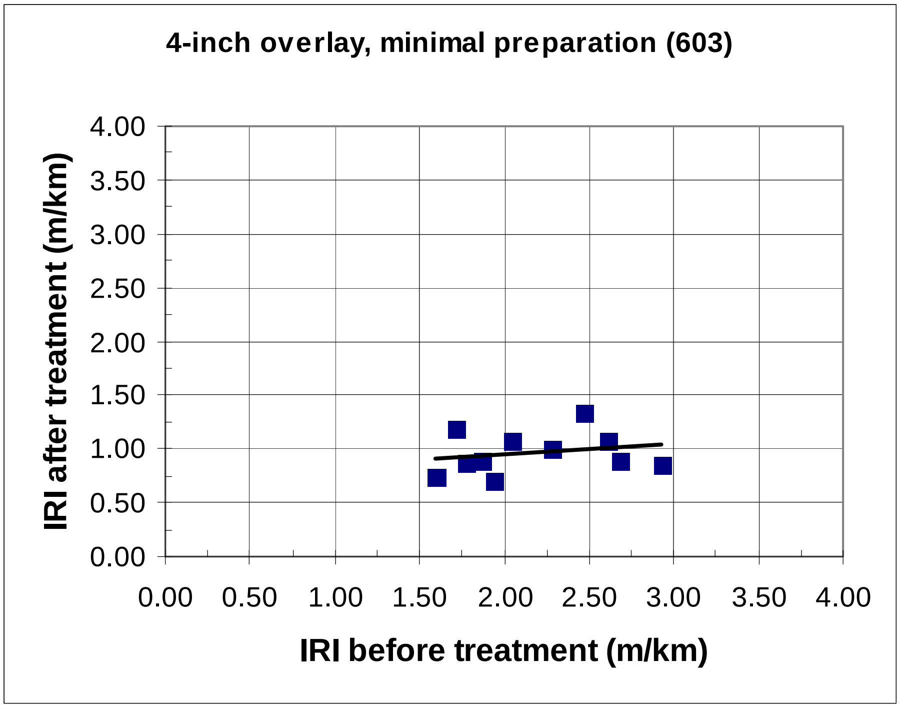

Figure 76. IRI before and after treatment, SPS-6 4-inch overlay, minimal preparation sections.

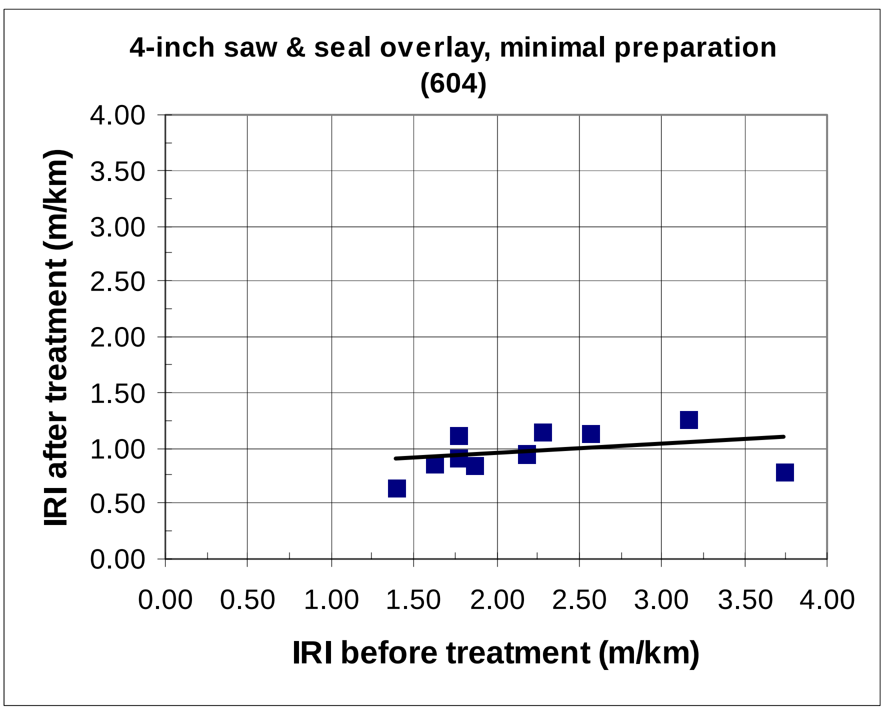

Figure 77. IRI before and after treatment, SPS-6 4-inch saw/seal overlay, minimal preparation sections.

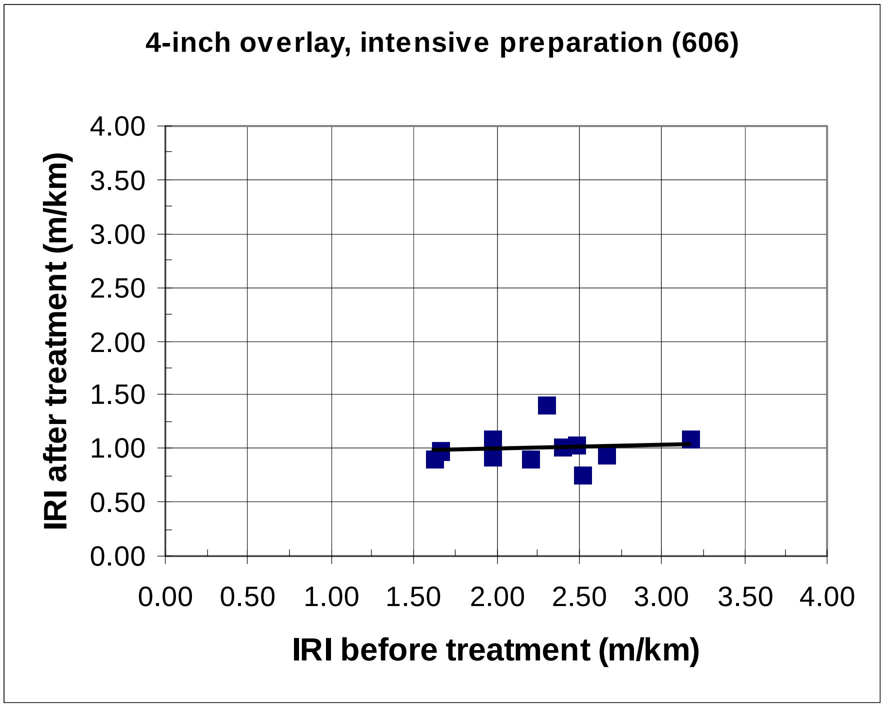

Figure 78. IRI before and after treatment, SPS-6 4-inch overlay, intensive preparation sections.

Table 61. Initial postoverlay IRI and PSI summary statistics for asphalt overlays of intact concrete slabs in SPS-6 and GPS-7B experiments.

	SPS-6 overlays of intact slabs (Groups 603, 604, and 606)		**GPS-7B**	
	IRI (m/km)	**PSI (0-5 scale)**	**IRI (m/km)**	**PSI (0-5 scale)**
Min IRI, Max PSI	0.65	4.81	0.58	4.87
Mean	0.99	4.47	1.00	4.47
Standard deviation	0.17	0.18	0.27	0.30
Median	0.95	4.53	0.93	4.55
Max IRI, Min PSI	1.42	3.99	2.03	3.30
Number of sections	38		31	

Since the two distributions are not significantly different in the mean, and since an analysis of variance (see Table 60) showed that there were also no significant differences among the mean posttreatment IRI values of all of the SPS-6 overlay groups, it is reasonable to calculate the overall average initial postoverlay IRI as the weighted average of the means of the five SPS-6 overlay treatment groups (including the 4-inch and 8-inch overlays with break/crack-and-seat:

groups 607 and 608), as well as that of the GPS-7B group. This produces an overall average initial postoverlay IRI value of 1.00 m/km, which corresponds to an overall average PSI of about 4.47, for asphalt overlays of both intact and cracked/broken and seated slabs.

The mean initial postoverlay PSI of 4.47 for the overlaid SPS-6 sections and the GPS-7B overlays is very close to the PSI value of 4.50 that is often mentioned as a typical initial PSI for newly constructed concrete pavements. Recalling that the mean initial postoverlay PSI for the SPS-5/GPS-6B overlays was 4.07, it is natural to wonder what is responsible for the difference, if the mean initial postoverlay IRIs for the SPS-5/GPS-6B and SPS-6/GPS-7B groups were so similar (0.98 versus 1.00 m/km)?

The difference is due to the PSI values for the asphalt overlays in the two data sets being estimated from two different equations, both derived from AASHO Road Test data,[6] one for asphalt pavements and one for concrete pavements.[24] These two equations use a common correlation between IRI and slope variance. However, the Road Test data clearly demonstrate a divergence in PSI between the two different pavement types as a function of slope variance, for PSI values above about 2.0. That is, the same roughness value obtained from profile measurements on an asphalt pavement and a concrete pavement does not correspond to the same PSI value for the two pavement types.

The concrete pavement IRI-PSI equation is applied in this study to the overlaid SPS-6 and the GPS-7B sections for the purpose of comparing IRI and PSI values in the nonoverlaid SPS-6 treatment groups with those in the overlaid treatment groups. Clearly, the overlay treatments in the SPS-6 experiment yielded lower initial IRI values – thus, higher estimated PSI values – than the nonoverlay treatments. However, when comparing the initial postoverlay IRI and PSI values of the SPS-5 overlays with those of the SPS-6 overlays, it is important to keep in mind that the mean initial postoverlay IRI values are very similar (0.98 versus 1.00 m/km), and would yield essentially the same PSI estimates if the same IRI-PSI correlation equation were applied to both.

Strictly speaking, it is not possible to derive from AASHO Road Test data an IRI-PSI correlation for asphalt overlays of either asphalt or concrete pavements. Which correlation (that developed from concrete pavement data, or that developed from asphalt pavement data) should be used for asphalt overlays of either pavement type depends on the application. For comparing overlay versus nonoverlay concrete pavement rehabilitation treatments, it makes sense to use the concrete pavement equation. For comparing asphalt overlays of both pavement types, either one of the equations should be used. For comparing overlay with reconstruction options in a life-cycle cost analysis, which equation or equations should be used depends on whether one is considering as options reconstruction in asphalt, or in concrete, or both.

The plots of preoverlay IRI versus postoverlay IRI for the 4-inch and 8-inch overlay treatments after cracking/breaking and seating (groups 607 and 608 respectively) are shown in Figures 79 and 80 respectively. Although there is a slight upward trend to the data in Figure 79, and a slight downward trend to the data in Figure 80, in neither case is this trend statistically significant. There is furthermore no obvious practical reason why postoverlay IRI would have any relationship to preoverlay IRI, which was measured prior to fracturing of the slab.

The preoverlay versus initial postoverlay IRI values for all of the SPS-6 overlay treatments (groups 603, 604, 606, 607, and 608) are shown plotted in Figure 81, along with those for the GPS-7B pavements. Best-fit lines for the two distributions and a 1:1 line are also shown. The best-fit lines coincide almost perfectly. In addition, they are almost perfectly horizontal, their intercepts corresponding to the mean of 1.00 m/km. It is interesting to compare Figure 81 with Figure 48 in Chapter 2, and observe that a slight but statistically significant positive correlation between preoverlay IRI and initial postoverlay IRI is detected only for asphalt overlays of asphalt pavements, not asphalt overlays of concrete pavements.

Long-Term Effects on Roughness

The first step in the analysis of long-term treatment effects involves testing for significant effects by treatment type, holding constant for age, traffic, climate, etc. This is done by selected multiple comparisons. Rather than compare the means of many sections within different treatment groups, one analyzes the mean difference between specific groups of test sections). Paired difference tests are used to determine which if any of those mean differences are significantly different than zero. This prevents the within-treatment (i.e., site-to-site) variation from masking significant between-treatment differences.

The design of the SPS-6 experiment (see Table 48) suggests the following interesting comparisons of long-term performance:

- **No rehabilitation** (501 or linked GPS) **versus nonoverlay rehabilitation without grinding** (some 602 and 605 sections).
- **No rehabilitation** (501 or linked GPS) **versus nonoverlay rehabilitation with grinding** (some 602 and 605 sections).

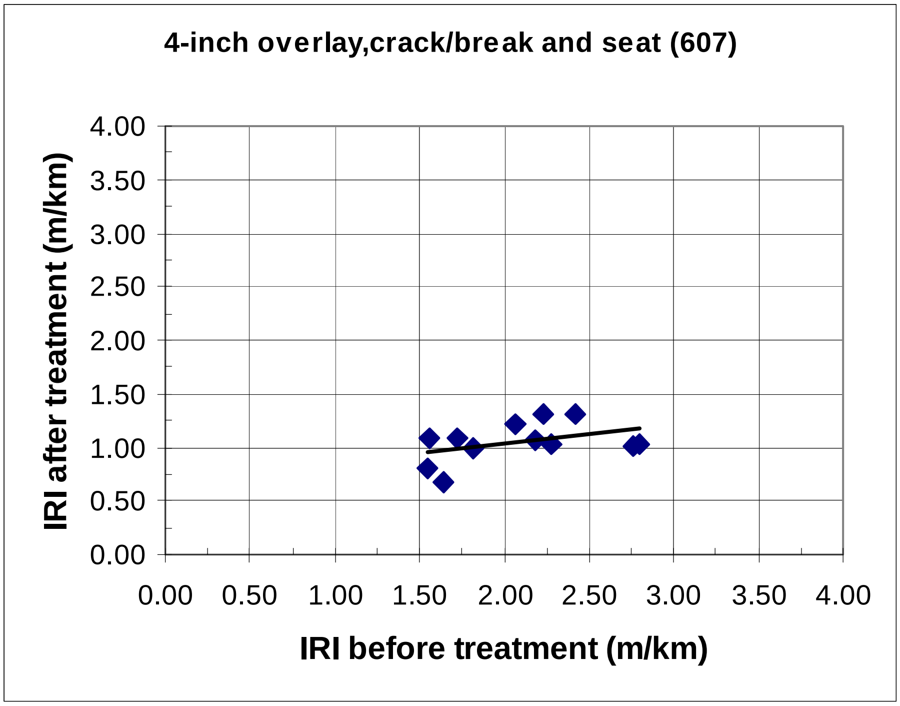

Figure 79. IRI before and after treatment, SPS-6 4-inch overlay with crack/break and seat.

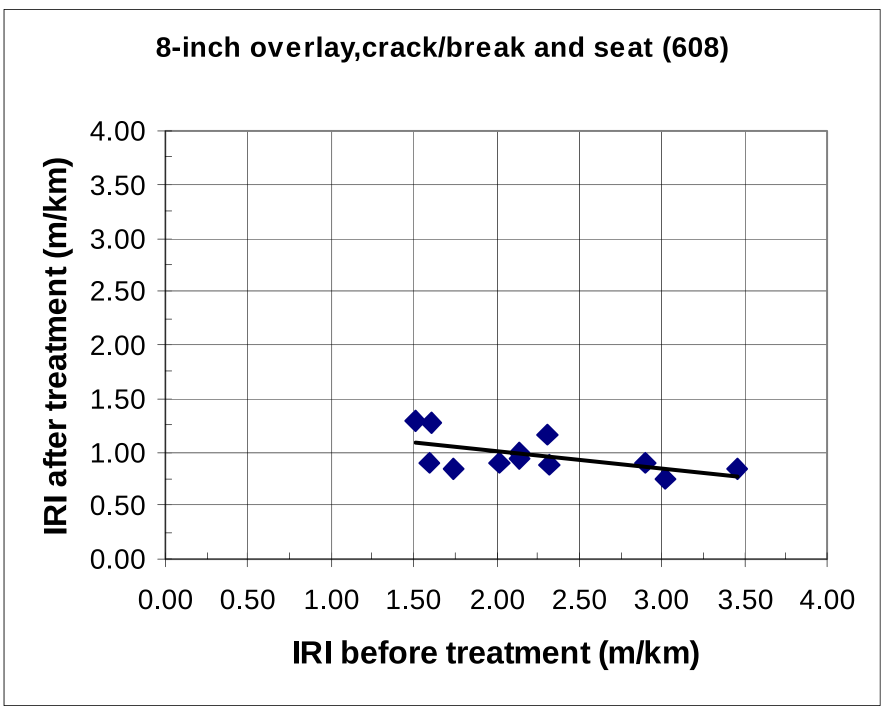

Figure 80. IRI before and after treatment, SPS-6 8-inch overlay with crack/break and seat.

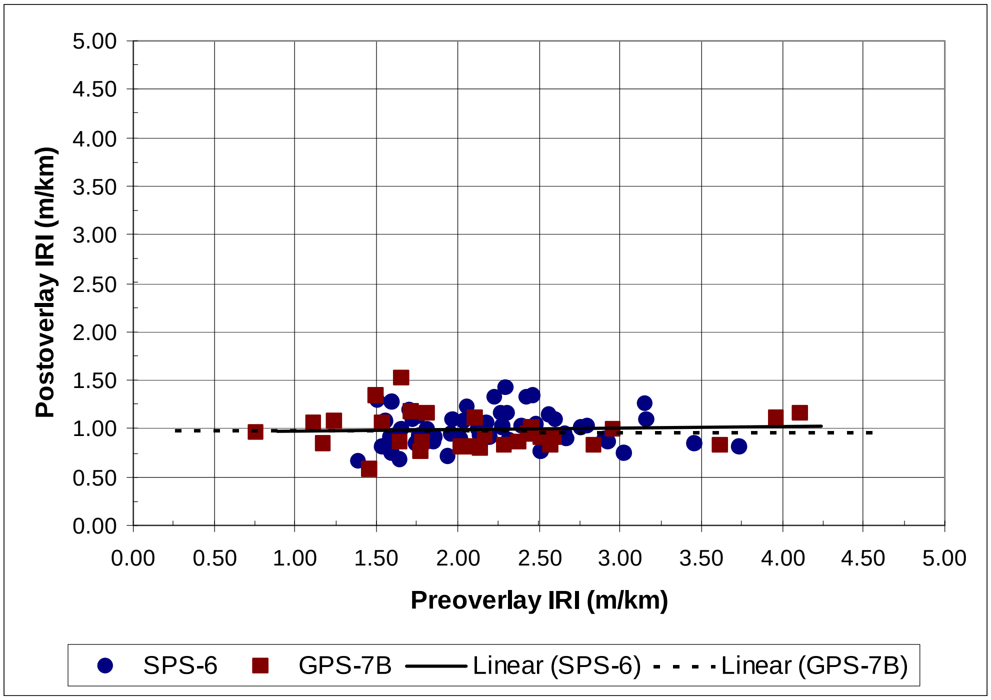

Figure 81. Preoverlay IRI versus initial postoverlay IRI, SPS-6 overlay treatments and GPS-7B pavements.

- **No rehabilitation** (501 or linked GPS) **versus overlay** (603, 604, 606, 607, and 608).
- **Minimal** (some 602 sections) **versus intensive** (some 605 sections) **nonoverlay repair with grinding**.
- **Minimal** (603) **versus intensive** (606) **preoverlay preparation**.
- **4-inch overlay without saw/seal** (603) **versus with saw/seal** (604).
- **4-inch overlay with saw/seal** (604) **versus 4-inch overlay with crack/break and seat** (607).
- **Crack/break and seat with 4-inch** (607) **versus 8-inch** (608) **overlay**.

The first comparison *would* be interesting, but alas, is not possible with the available data. The three sites and test sections at which nonoverlay rehabilitation was done without grinding are Arizona (minimal repair: 602), Indiana (minimal and intensive repair: 602 and 605 respectively), and Michigan (minimal and intensive repair: 602 and 605 respectively).

Long-term IRI data are not available for the 602 and 605 sections at the Arizona site; and long-term IRI data are not available for the unrehabilitated (601) section at the Indiana site.

At the Michigan site, the IRI in the unrehabilitated (601) section increased fairly steadily from 2.14 m/km in 1990 to 2.78 m/km in 1997, but then dropped dramatically to 1.46 m/km in 1998 – presumably due to some repairs, although no record was found in LTPP database release 11.5 of any maintenance or rehabilitation having been applied to the section, either in 1997 or any time since.

In 1997, (i.e., prior to the presumed repairs in the control section), the unrehabilitated (601) section's IRI was 2.78 m/km, the nonoverlay minimal repair (602) section's IRI was 2.85 m/km, and the nonoverlay intensive repair (605) section's IRI was 3.69 m/km. These numbers do not speak well of the nonoverlay rehabilitation's performance at the Michigan site. However, they should not be taken as representative of the performance of restoration without grinding, first because they are data from only one site, and second because Michigan was the site at which full-depth repairs were done with asphalt concrete.

There remain, then, seven feasible comparisons of interest. The significance level, α, used for each individual comparison should be selected so that $(1 - \alpha)^7$ = the desired overall level of confidence. For seven comparisons to yield a 95 overall level of confidence, the required significance level α is 0.0073.

Control versus Nonoverlay Rehabilitation with Grinding

The mean difference is calculated from the IRI values of 12 available section pairs. The results are summarized in Table 62, and a plot of the control versus grinding long-term IRI values is shown in Figure 82. The results indicate that the grinding sections have performed significantly better than the control sections at nearly all sites.

However, considering that the initial preoverlay IRI of grinding sections (excluding Arkansas) averaged 1.05 m/km, it is evident that the IRI levels of the grinding sections are approaching those of the control sections at several sites, and now equal or exceed the control section IRI levels at two sites (Missouri 0 and Pennsylvania).

Table 62. Analysis of long-term effect of SPS-6 control versus grinding on IRI.

	IRI (control versus grinding), m/km
Mean difference	0.79
n	12
S_D	0.81
$T_{\alpha/2,\, n-1}$	3.28
Confidence interval lower limit	0.02
Confidence interval upper limit	1.55
Significant difference	yes

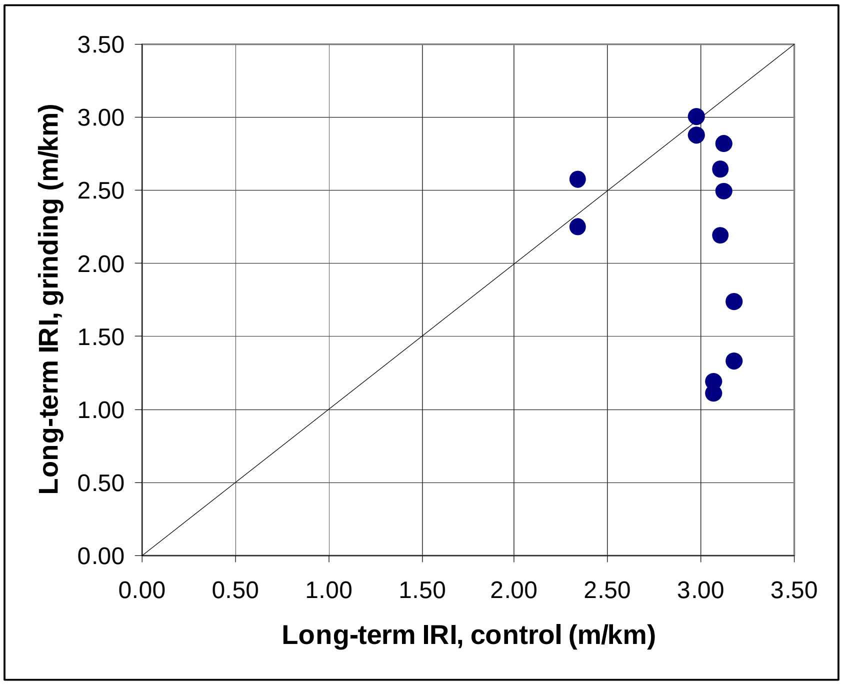

Figure 82. Long-term IRI, SPS-6 control versus grinding.

Control versus Overlay Rehabilitation

The mean difference is calculated from the IRI values of 30 available section pairs. The results are summarized in Table 63, and a plot of the control versus overlay long-term IRI values is shown in Figure 83. The results indicate that the overlay sections have performed significantly better than the control sections at all sites. Comparing Figure 83 with Figure 82, it also appears that the overlay sections have performed more consistently than the grinding sections.

Minimal versus Intensive Nonoverlay Repair with Grinding

The mean difference is calculated from the IRI values of 9 available section pairs. The results are summarized in Table 64, and a plot of the minimal-repair versus intensive-repair long-term IRI values is shown in Figure 84. The intensive-repair sections have performed slightly better to date with respect to IRI than the minimal-repair sections – 0.22 m/km lower in IRI on average – but the mean difference is not statistically significant.

At nearly every site, both the minimal and intensive repair sections have full-depth repair, joint sealing, and crack sealing, while the intensive repair sections also have subdrainage retrofitting, and at some sites load transfer restoration and/or undersealing as well. The available IRI data suggest that these additional treatments in the intensive sections have not produced significant differences in roughness levels. Future analysis of longer-term data may show a more significant effect, but some of these sites are already approaching roughness levels warranting another rehabilitation cycle.

Minimal versus Intensive Preoverlay Preparation

The mean difference is calculated from the IRI values of 12 available section pairs. The results are summarized in Table 65, and a plot of the minimal-preparation versus intensive-preparation long-term IRI values is shown in Figure 85. Aside from one odd point – Arizona's minimal preoverlay preparation (603) section, which has developed much more roughness than any other overlay section – the two preoverlay treatment levels correspond to very similar long-term IRI levels. Indeed, the minimal preoverlay preparation (603) sections tend to have slightly lower IRI values than the intensive preoverlay preparation (605) sections. However, the difference is not statistically significant. The same is true if the Arizona section pair is excluded from the analysis.

Table 63. Analysis of long-term effect of SPS-6 control versus overlay on IRI.

	IRI (control versus overlay), m/km
Mean difference	1.59
n	30
S_D	0.41
$T_{\alpha/2,\ n-1}$	2.89
Confidence interval lower limit	1.37
Confidence interval upper limit	1.81
Significant difference	yes

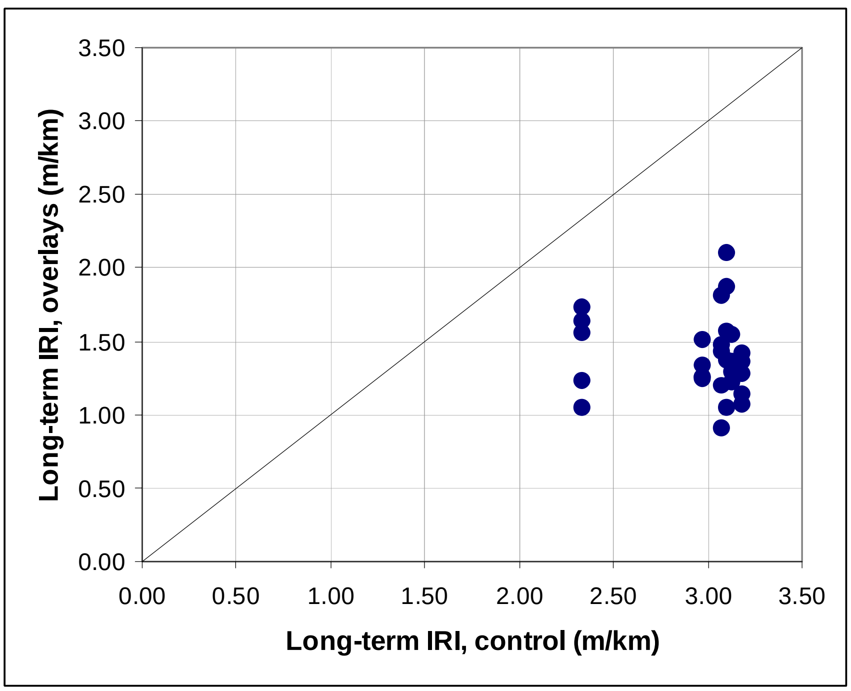

Figure 83. Long-term IRI, SPS-6 control versus overlay.

Table 64. Analysis of long-term effect of SPS-6 minimal versus intensive nonoverlay rehabilitation (with grinding) on IRI.

	IRI (minimal vs. intensive w/grinding), m/km
Mean difference	0.22
n	9
S_D	0.20
$T_{\alpha/2, n-1}$	3.57
Confidence interval lower limit	-0.02
Confidence interval upper limit	0.46
Significant difference	No

.

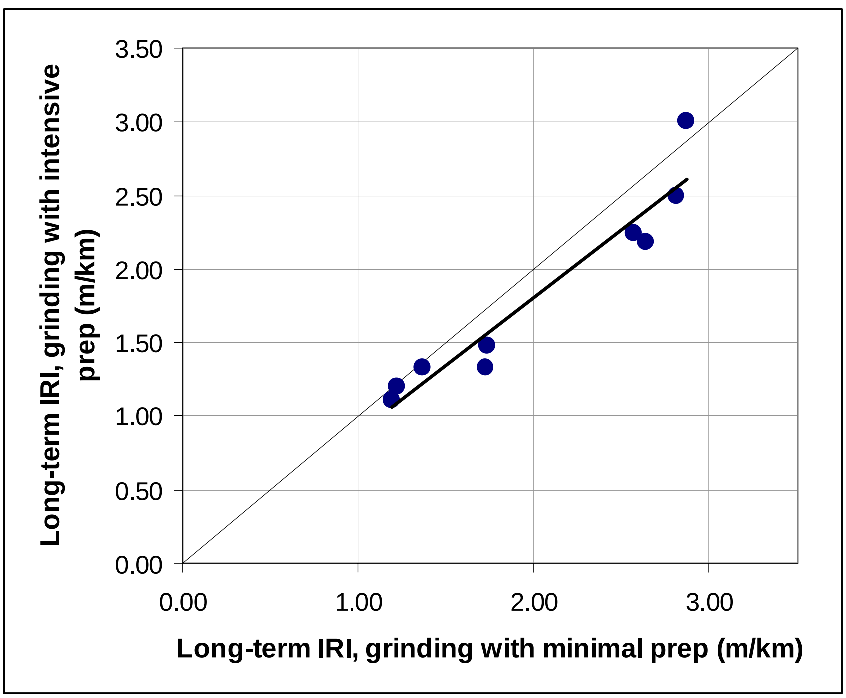

Figure 84. Long-term IRI, SPS-6 minimal versus intensive nonoverlay rehabilitation with grinding.

Table 65. Analysis of long-term effect of SPS-6 minimal versus intensive preoverlay preparation on IRI.

	IRI (minimal vs. intensive preoverlay preparation), m/km
Mean difference	0.03
n	12
S_D	0.53
$T_{\alpha/2, n-1}$	3.28
Confidence interval lower limit	-0.47
Confidence interval upper limit	0.54
Significant difference	no

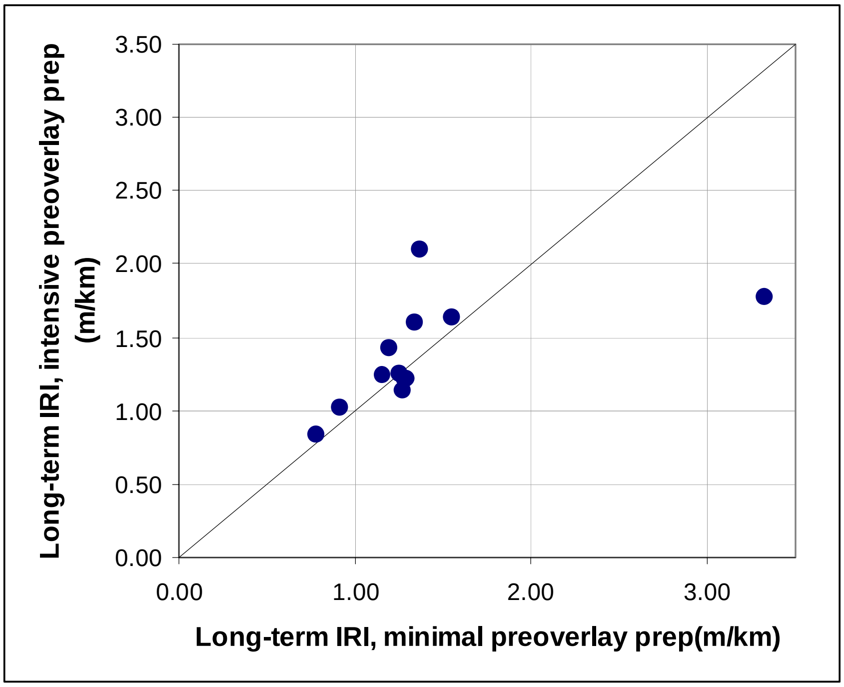

Figure 85. Long-term IRI, SPS-6 minimal versus intensive preoverlay preparation.

4-inch Overlay without versus with Saw and Seal

The mean difference is calculated from the IRI values of 12 available section pairs. The results are summarized in Table 66, and a plot of the long-term IRI values without and with saw and seal is shown in Figure 86. Again, aside from the Arizona minimal preoverlay preparation (603) section, the two preoverlay treatment levels correspond to very similar long-term IRI levels. The sections without sawed and sealed joints tend to have slightly lower IRI values than the sections with sawed and sealed joints. However, the difference is not statistically significant. The same is true if the Arizona section pair is excluded from the analysis.

4-inch Saw-and-Seal Overlay versus 4-inch Crack/Break-and-Seat Overlay

The mean difference is calculated from the IRI values of 12 available section pairs. Instead of just the saw-and-seal (604) sections, the minimal (603) and/or intensive (606) preoverlay preparation sections could have been used as well, but the saw-and-seal (604) versus break/crack-and seat (607) comparison was selected because they are both ostensibly reflection crack control techniques.

The results are summarized in Table 67, and a plot of the saw-and-seal versus crack/break-and-seat long-term IRI values is shown in Figure 87. Except for one section with an unusually high IRI – the Pennsylvania 4-inch overlay with break/crack-and-seat (607) section – the data are balanced fairly closely around the 1:1 line, and the analysis indicates no significant difference, in terms of long-term IRI between the two treatments.

4-inch versus 8-inch Overlay with Crack/Break and Seat

The mean difference is calculated from the IRI values of 13 available section pairs. The results are summarized in Table 68, and a plot of the 4-inch versus 8-inch long-term IRI values is shown in Figure 88. At every site, the section with the 4-inch overlay has a higher IRI than the section with the 8-inch overlay.

Table 66. Analysis of long-term effect of saw/seal on SPS-6 4-inch overlay IRI.

	IRI (without versus with saw/seal), m/km
Mean difference	0.02
n	12
S_D	0.57
$T_{\alpha/2,\, n-1}$	3.28
Confidence interval lower limit	-0.53
Confidence interval upper limit	0.56
Significant difference	no

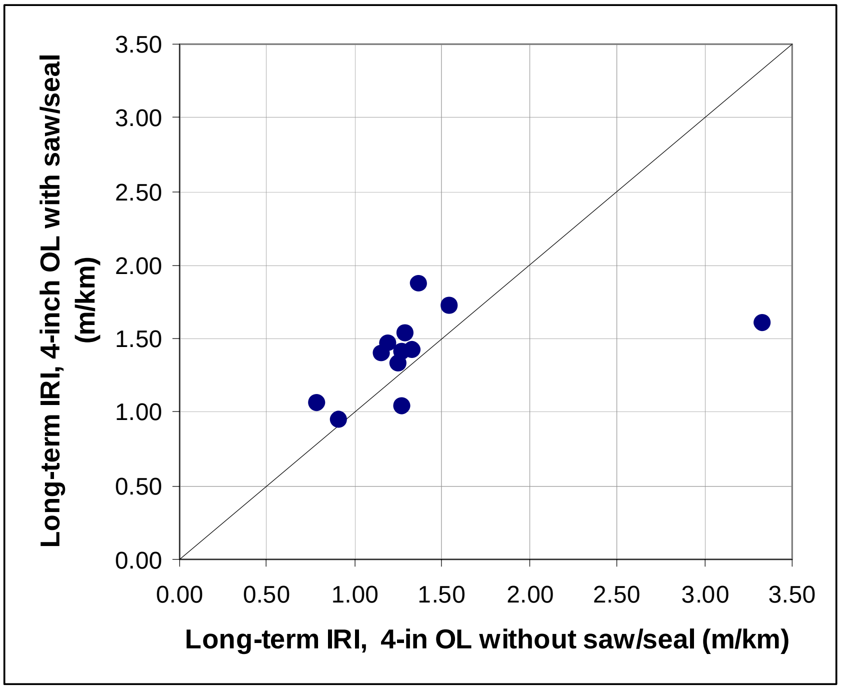

Figure 86. Long-term IRI, SPS-6 4-inch overlay without versus with saw/seal.

Table 67. Analysis of long-term effect of SPS-6 saw/seal versus crack/seat reflection crack control treatments on IRI.

	IRI (saw/seal vs. crack/seat), m/km
Mean difference	-0.18
n	12
S_D	0.63
$T_{\alpha/2, n-1}$	3.28
Confidence interval lower limit	-0.77
Confidence interval upper limit	0.42
Significant difference	no

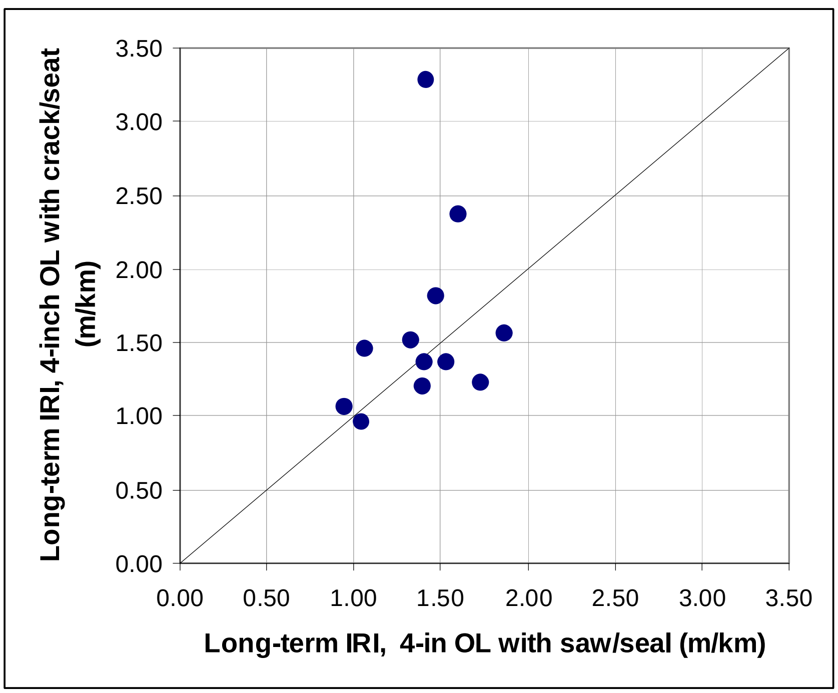

Figure 87. Long-term IRI, SPS-6 4-inch overlay with saw and seal versus crack/break and seat.

Table 68. Analysis of long-term effect on IRI of SPS-6 4-inch versus 8-inch overlay crack/break and seat.

	IRI (4 inches versus 8 inches), m/km
Mean difference	0.49
n	13
S_D	0.52
$T_{\alpha/2, n-1}$	3.22
Confidence interval lower limit	0.03
Confidence interval upper limit	0.96
Significant difference	yes

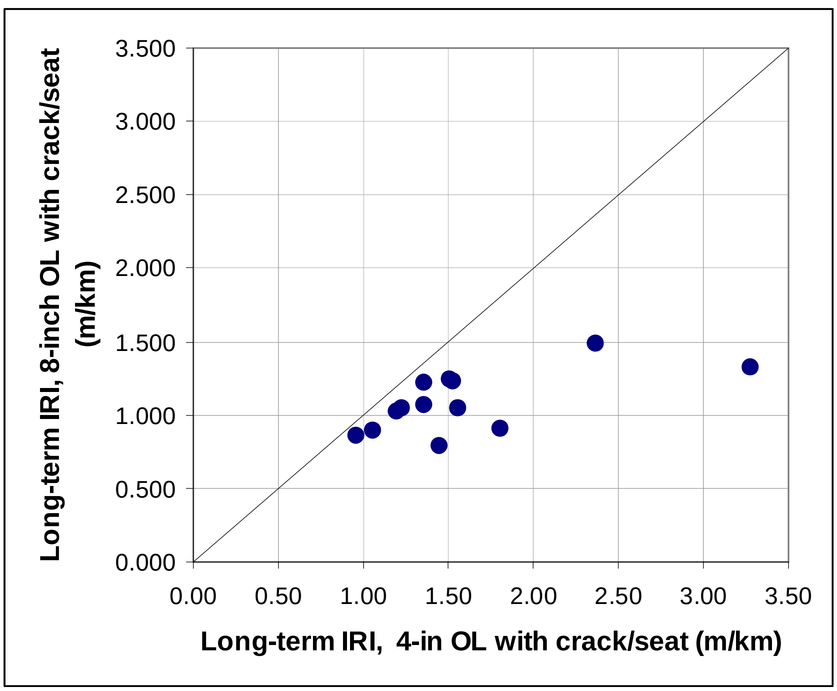

Figure 88. Long-term IRI, SPS-6 4-inch versus 8-inch overlay with crack/break and seat.

The results of the F tests for significance of factor effects on the relative long-term IRI performance of the SPS-6 rehabilitation treatments are summarized in Table 69. A significant factor influence means that there is a significant correlation between the factor and the difference in the rates of increase in IRI in the two groups compared.

The factor effects found to be significant for the comparisons conducted are summarized below.

- ***No rehabilitation versus minimal or intensive repair with grinding:*** Pretreatment IRI had a significant effect; and accumulated ESALs had a slightly significant effect. The difference between how fast IRI increased in the unrehabilitated sections and how fast IRI increased in the minimal and intensive repair sections that received grinding is negatively correlated to pretreatment IRI and slightly positively correlated to accumulated ESALs.

- ***No rehabilitation versus overlay:*** Accumulated ESALs had the most significant effect, and pretreatment IRI also had a significant effect. The difference between how fast IRI increased in the unrehabilitated sections and how fast IRI increased in sections with overlays of intact and fractured slabs is positively correlated to accumulated ESALs and negatively correlated to pretreatment IRI.

No significant factor effects were detected for the five other comparisons conducted.

The positive correlation to accumulated ESALs in the above two comparisons means that the rate at which IRI increases in the unrehabilitated sections exceeded IRI increases in the rehabilitated sections is higher at sites with more accumulated traffic since rehabilitation. That is, with truck traffic accumulation over time, the difference in IRI growth between unrehabilitated and rehabilitated concrete pavements becomes more evident.

The negative correlation to pretreatment IRI in the above two comparisons means that the rate at which IRI increases in the unrehabilitated sections exceeded IRI increases in the rehabilitated sections is higher at sites with lower IRIs before rehabilitation. That is, the biggest disparities in IRI increase occurred at sites with less roughness prior to rehabilitation. This could be interpreted as an argument for application of rehabilitation sooner rather than later, especially if it can be confirmed over longer time periods and larger data sets.

Table 69. Tests for significance of factor effects on relative long-term IRI performance of SPS-6 rehabilitation treatments.

Treatment		Factor				
		Age	Accumulated ESALs	Pre Treatment IRI	Average annual precipitation	Average annual temperature
No Rehabilitation Versus Grinding	slope	-0.103	0.000	-1.896	-0.002	0.015
	n	8	8	8	8	8
	Fcalc	1.49	6.76	12.51	0.01	0.17
	F at 0.05	5.99	5.99	5.99	5.99	5.99
	Significant?	no	**yes**	**yes**	no	no
No Rehabilitation Versus Overlay	slope	0.023	0.000	-0.822	-0.016	-0.018
	n	27	27	27	27	27
	Fcalc	0.41	24.94	14.53	3.35	1.22
	F at 0.05	4.24	4.24	4.24	4.24	4.24
	Significant?	no	**yes**	**yes**	no	no
Minimal Versus Intensive Repair With Grinding	slope	-0.016	0.000	0.071	-0.008	-0.009
	n	7	7	7	7	7
	Fcalc	0.30	2.96	0.24	1.70	0.60
	F at 0.05	6.61	6.61	6.61	6.61	6.61
	Significant?	no	no	no	no	no
Minimal Versus Intensive Preoverlay Repair	slope	0.042	0.000	-0.462	-0.018	-0.026
	n	10	10	10	10	10
	Fcalc	0.35	2.59	1.23	1.15	0.80
	F at 0.05	5.32	5.32	5.32	5.32	5.32
	Significant?	no	no	no	no	no
4-inch Overlay Without Versus With Saw-and-Seal	slope	0.063	0.000	-0.446	-0.028	-0.038
	n	11	11	11	11	11
	Fcalc	1.00	2.58	1.19	3.91	2.03
	F at 0.05	5.12	5.12	5.12	5.12	5.12
	Significant?	no	no	no	no	no
4-inch Overlay Saw-and-Seal Versus 4-inch Overlay Crack-and-Seat	slope	-0.004	0.000	0.812	0.016	-0.019
	n	11	11	11	11	11
	Fcalc	0.00	0.00	4.90	0.90	0.41
	F at 0.05	5.12	5.12	5.12	5.12	5.12
	Significant?	no	no	no	no	no
4-inch Overlay Versus 8-inch Overlay With Crack-and-Seat	slope	0.028	0.000	-0.555	-0.009	0.026
	n	12	12	12	12	12
	Fcalc	0.17	0.77	1.78	0.26	0.79
	F at 0.05	4.96	4.96	4.96	4.96	4.96
	Significant?	no	no	no	no	no

Rutting in Asphalt Overlays of Concrete Pavements

Rutting in Asphalt Overlays of Intact Slabs

Unlike rutting in asphalt overlays of asphalt pavements, rutting in asphalt concrete pavements occurs entirely in the overlay. After some initial rutting due to compaction of the mix, additional long-term rutting in asphalt overlays of concrete tends to develop slowly, as the result of plastic flow of the mix laterally away from the wheelpaths, due to shear stress produced by applied loads.

The rutting measurements obtained for the SPS-6 asphalt overlays of intact slabs (groups 603, 604, and 606) are shown in Table 70. The following observations are drawn from a site-by-site examination of these data:

- The rutting measurements are so erratic that they demonstrate few if any consistently upward trends. The most predominantly (although not consistently) upward trends are exhibited by the Colorado, Iowa, Oklahoma, and Pennsylvania data.
- The first rutting measurement, obtained within a year or so of overlay construction, is often not zero or close to zero, but rather about 4 to 9 mm.
- In many cases, rutting does not seem to increase much after the first year.

The first rutting measurements and the annual rate of change in rutting between the first and last measurements are summarized by test section in Table 71. Illinois section 060603 is omitted, because of a very high initial rutting measurement that is believed to be an error.

In general, it appears that most of the rutting that an asphalt overlay of an intact concrete pavement will manifest in the first twelve years of service develops in the first year or so. This is also illustrated in Figure 89, in which the rutting trends of the eleven longest-lived GPS-7B overlays are plotted. For all of these overlays, the rutting measured within about a year of placement of the overlay was between 4 and 9 mm. For most of these overlays, the rutting measured through the seventh year of service was still within this range. In one overlay, the rutting increased notably after the fifth year of service, and in a few other overlays, the rutting began to increase after the seventh year of service.

Table 70. Rutting in SPS-6 asphalt overlays of intact concrete slabs.

State	603		604		606	
	Time (yrs)	**Rut (mm)**	**Time (yrs)**	**Rut (mm)**	**Time (yrs)**	**Rut (mm)**
AL	0.01	3	0.01	1	0.21	2
AL	1.26	2	1.26	2	1.47	2
AL	1.61	4	1.61	5	1.82	3
AL	2.26	3	2.26	2	2.46	4
AZ	1.11	8	0.96	10	1.16	8
AZ	4.11	13	3.96	8	4.15	10
AZ	4.62	14	4.47	12	4.67	9
AZ	7.21	15	7.06	10	7.26	8
AZ	9.32	20	9.17	10	9.36	10
AZ	10.17	18	9.88	13	10.08	9
AR	2.89	6	0.78	4	1.00	7
AR	3.50	5	2.89	5	3.11	3
AR			3.50	5	3.72	7
CO	0.10	1	0.10	1	0.10	2
CO	2.95	3	2.96	4	2.95	4
CO	3.73	6	3.73	5	3.73	6
CO	3.80	13	3.80	4	3.79	5
CO	5.63	6	5.64	5	5.62	7
CO	6.90	8	6.90	6	6.90	11
CO	7.96	9	7.96	6	7.95	10
IL	0.52	18	1.51	2	1.46	2
IL	2.15	1	3.91	1	3.09	2
IL	3.13	6	4.12	6	4.08	5
IL	4.03	2	5.02	2	4.97	3
IL	4.03	2	5.02	2	5.74	6
IL	4.79	6	5.78	5	8.21	5
IL	7.27	4	8.24	2	9.13	4
IL	8.19	3	9.17	3		
IN	2.03	3	0.82	3	1.04	3
IN	2.78	9	1.07	3	2.25	4
IN	2.95	3	2.03	4	3.00	7
IN	5.85	5	2.78	7	3.16	3
IN	9.62	5	2.82	3	6.06	6
IN			2.95	4	9.83	5
IN			5.85	9		
IN			9.62	6		

Table 70. Rutting in SPS-6 asphalt overlays of intact concrete slabs (continued).

	603		604		606	
State	Time (yrs)	Rut (mm)	Time (yrs)	Rut (mm)	Time (yrs)	Rut (mm)
IA	3.11	6	3.14	7	3.18	5
IA	3.68	7	3.71	7	3.75	5
IA	4.05	5	4.08	7	6.70	8
IA	6.63	12	6.66	9	7.80	7
IA	7.72	7	7.75	9	10.21	7
IA	10.14	10	10.17	8	11.29	8
IA	11.22	11	11.25	12		
MI	2.28	6	2.28	7	3.05	7
MI	3.05	6	3.05	6	3.07	14
MI	3.07	12	3.07	13	5.00	8
MI	5.00	7	4.97	8	5.08	10
MI	5.08	10	5.00	8	5.73	7
MI	5.73	6	5.08	13	8.41	13
MI	8.41	13	5.73	7		
MI			8.41	10		
MO 0	0.84	4	0.84	4	0.87	3
MO 0	1.37	3	1.37	3	1.40	2
MO 0	3.13	3	3.13	3	3.16	3
MO 0	3.68	17	3.68	13	3.71	3
MO 0	3.87	7	3.87	5	3.90	5
MO 0	6.27	3	6.27	4	6.22	2
MO 0	7.75	3	7.75	4	7.82	4
MO A	1.45	4	1.44	4	0.42	6
MO A					1.61	5
OK	0.53	5	0.53	6	0.53	4
OK	3.65	8	3.65	6	3.65	8
OK	4.73	7	6.22	10	6.22	9
OK	6.22	7	7.18	8	7.18	4
OK	7.18	7	8.05	9		
OK	8.05	7				
PA	1.83	11	1.72	10	1.72	10
PA	1.97	13	1.85	14	1.85	14
PA	3.92	13	3.80	12	3.80	11
PA	5.02	12	4.90	12	4.90	14
PA	6.92	14	6.80	13	6.80	14
PA	6.95	15	6.83	14	6.83	19
PA	7.96	14	7.84	13	7.84	17

Table 70. Rutting in SPS-6 asphalt overlays of intact concrete slabs (continued).

State	603		604		606	
	Time (yrs)	Rut (mm)	Time (yrs)	Rut (mm)	Time (yrs)	Rut (mm)
SD	1.37	5	1.37	3	1.38	6
SD	3.27	4	3.28	3	3.27	3
SD	3.80	4	4.14	6	3.80	4
SD	4.14	4	6.27	4	4.14	5
SD	6.27	4	8.32	5	6.27	4
SD	8.32	6			8.32	4
TN	3.15	6	3.12	9	3.09	6
TN	3.57	6	3.54	9	3.51	8
TN	4.14	6	4.11	10	4.08	6

Table 71. First rutting measurement and rate of change, SPS-6 asphalt overlays of intact slabs.

State	603		604		606	
	First rutting measured (mm)	Rate of change (mm/yr)	First rutting measured (mm)	Rate of change (mm/yr)	First rutting measured (mm)	Rate of change (mm/yr)
AL	3	0.00	1	0.44	2	0.81
AZ	8	0.98	10	0.30	8	0.10
AR	6	-0.29	4	0.29	7	0.00
CA	1	0.00	1	-0.13	2	1.01
IL			2	0.11	2	0.22
IN	3	0.21	3	0.31	3	0.20
IA	6	0.45	7	0.44	5	0.27
MI	6	0.83	7	0.36	7	0.00
MO 0	4	-0.13	4	0.00	3	0.13
MO A	4		4		6	-0.62
OK	5	0.25	6	0.37	4	0.00
PA	11	0.38	10	0.38	10	0.89
SD	5	0.00	3	0.24	6	-0.32
TN	6	0.00	9	0.24	4	0.49

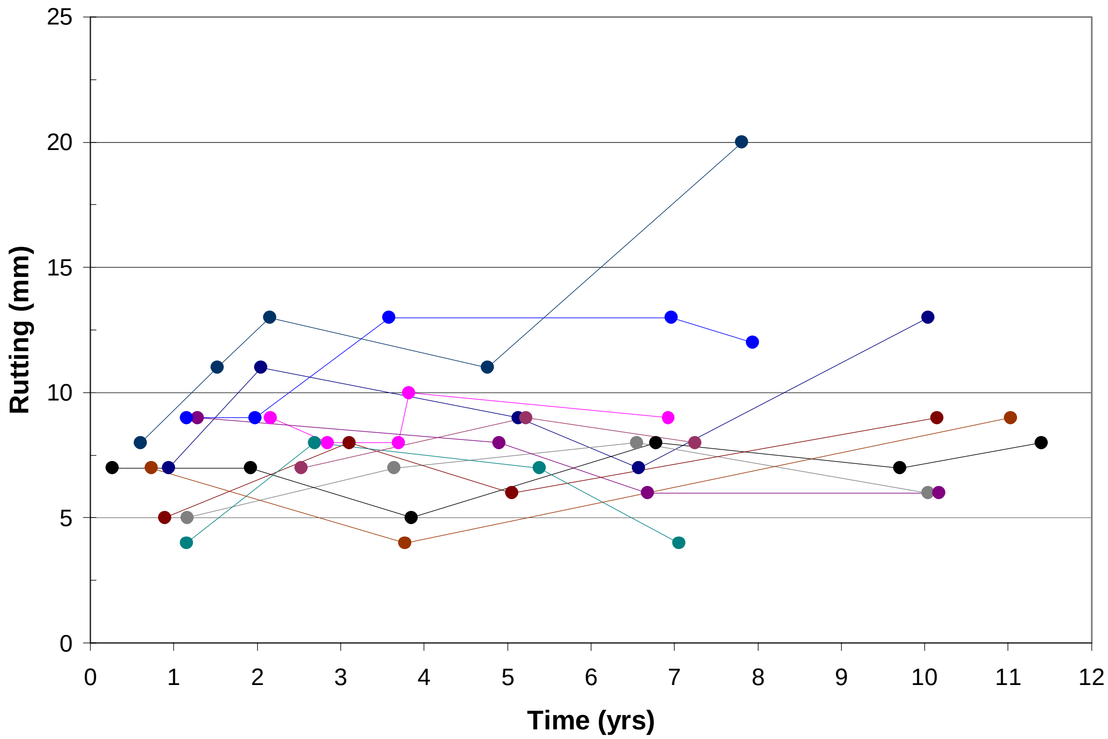

Figure 89. Rutting trends in longest-lived GPS-7B overlays.

The average first rutting measurement, average time from construction to first rutting measurement, and average annual rutting change are summarized in Table 72 for the three SPS-6 treatment groups with 4-inch overlays of intact slabs (minimal preoverlay preparation, 603; saw and seal, 604; and intensive preparation, 606), as well as for GPS-7B (in which 39 sections have rutting data available).

Analyses of variance, summarized in Tables 73 and 74, indicate that there are no significant differences among the four groups in either the average first rutting measurement or the average annual rates of change in rutting.

Table 72. Initial rutting and rate of change in asphalt overlays of intact slabs, SPS-6 and GPS-7B.

	4-inch overlay, minimal prep (603)	4-inch overlay, saw and seal (604)	4-inch overlay, intensive prep (606)	GPS-7B
Average first measured rutting (mm)	5.3	5.1	4.9	6.2
Average time to first measurement (yrs)	1.6	1.3	1.7	1.2
Average rate of change (mm/yr)	0.22	0.26	0.23	0.18

Table 73. Analysis of variance of average first rutting measurement, for asphalt overlays of intact concrete pavements (SPS-6 groups 603, 604, and 606, and GPS-7B)

Source of variation	Sum of squares (SS)	Degrees of freedom	Mean squares (MS)	Calculated F	Theoretical F ($\alpha = 0.05$)
Between groups	21.80	3	7.265	1.071	2.725
Within groups	515.76	76	6.786		
Total	537.55	79			

Table 74. Analysis of variance of annual rate of change in rutting after first measurement, for asphalt overlays of intact concrete pavements (SPS-6 groups 603, 604, and 606, and GPS-7B).

Source of variation	Sum of squares (SS)	Degrees of freedom	Mean squares (MS)	Calculated F	Theoretical F ($\alpha = 0.05$)
Between groups	0.081	3	0.027	0.090	2.729
Within groups	22.291	74	0.301		
Total	22.372	77			

That being true, it is reasonable to consider all of the data representative of a single population. The overall average first rutting measurement (the expected value for measurements obtained within a year or so after construction) is 5.8 mm, and the overall average rate of change in rutting after the initial measurement is 0.21 mm/year. Note that all of the overlays in the three SPS-6 groups considered are nominally 4 inches thick, while the overlays in the GPS-7B may range from about 1.5 to about 6.5 inches. Note also that this average rate of change was determined from rutting measurements obtained within twelve years of overlay.

Rutting in Asphalt Overlays of Cracked/Broken and Seated Slabs

The rutting measurements obtained for the SPS-6 asphalt overlays of cracked or broken and seated slabs (groups 607 and 608) are shown in Table 75. The following observations are drawn from a site-by-site examination of these data:

- The rutting measurements are very erratic at some sites (e.g., Illinois, Michigan, Pennsylvania, South Dakota), but demonstrate fairly consistent trends at other sites (e.g., Colorado, Iowa).
- The first rutting measurement, obtained within a year or so of overlay construction, is often not zero or close to zero, but considerably more.
- In some cases, rutting does not seem to increase much after the first year.
- In most cases, the rutting measured in the 8-inch overlay section is lower than the rutting measured in the 4-inch overlay section at the same site on the same date.

The first rutting measurements and the annual rate of change in rutting between the first and last measurements are summarized by test section in Table 76. On average, the first rutting measurement is higher in the 4-inch overlays than in the 8-inch overlays, as are the annual rates of change in rutting. However, paired difference tests of the currently available data indicate that these differences are not statistically significant, as shown in Tables 77 and 78. Each of these two tests was conducted at a significance level of α = 0.0253, so that the combined level of confidence would be 95 percent.

Table 75. Rutting in SPS-6 asphalt overlays of cracked/broken and seated slabs.

State	607		608	
	Time (yrs)	Rut (mm)	Time (yrs)	Rut (mm)
AL	8.32	3	0.01	3
AL	3.09	3	1.26	2
AL	3.51	5	1.61	3
AL	4.08	8	2.25	3
AZ	1.14	9	0.96	6
AZ	4.13	8	3.95	6
AZ	4.64	8	4.47	7
AZ	7.23	8	7.05	8
AZ	9.33	12	9.16	7
AZ	10.05	13	9.88	6
AR	3.07	5	2.89	3
AR	3.68	6	3.49	3
CO	0.41	1	0.41	1
CO	3.26	4	3.26	4
CO	4.04	5	4.04	5
CO	4.11	5	4.10	4
CO	5.94	8	5.94	3
CO	7.21	8	7.21	5
CO	8.26	12	8.26	5
IL	1.46	2	1.46	1
IL	3.09	2	3.09	2
IL	4.08	5	4.08	5
IL	4.98	2	4.98	2
IL	5.74	6	5.74	7
IL	8.21	3	8.21	2
IL	9.13	3	9.13	2
IN	1.25	4	0.82	3
IN	2.21	4	2.03	5
IN	2.95	6	2.78	7
IN	3.13	4	2.95	5
IN	6.02	6	5.85	6
IN	9.83	7	9.64	5

Table 75. Rutting in SPS-6 asphalt overlays of cracked/broken and seated slabs (continued).

State	607		608	
	Time (yrs)	Rut (mm)	Time (yrs)	Rut (mm)
IA	3.07	5	3.09	4
IA	3.64	7	3.66	5
IA	4.00	5	4.03	5
IA	6.59	8	6.61	6
IA	7.68	8	7.70	6
IA	10.10	8	10.12	6
IA	11.18	8	11.20	10
MI	2.28	7	2.24	8
MI	3.05	7	3.01	9
MI	3.07	12	3.03	13
MI	5.00	8	4.96	12
MI	5.08	9	5.04	15
MI	5.73	7	5.69	8
MI	8.41	9	8.37	13
MO 0	0.82	5	0.82	6
MO 0	1.35	5	1.35	3
MO 0	3.11	3	3.11	4
MO 0	3.66	3	3.66	4
MO 0	3.85	3	3.85	6
MO 0	6.25	2	6.25	4
MO 0			7.73	5
MO A	1.51	4	1.45	3
MO A			1.61	5
OK	0.59	4	0.62	5
OK	3.71	7	3.73	5
OK	6.29	8	6.31	5
OK	7.24	7	7.27	4
OK	8.10	7	8.13	6
PA	1.74	11	1.74	12
PA	1.88	11	1.87	8
PA	3.82	12	3.82	11
PA	4.93	11	4.92	9
PA	6.83	13	6.83	10
PA	6.86	11	6.86	14
PA	7.88	12	7.87	9

Table 75. Rutting in SPS-6 asphalt overlays of cracked/broken and seated slabs (continued).

State	607		608	
	Time (yrs)	Rut (mm)	Time (yrs)	Rut (mm)
SD	0.97	4	0.97	3
SD	2.87	2	2.87	3
SD	3.39	5	3.39	3
SD	3.73	5	3.73	6
SD	5.86	3	5.86	3
SD	7.91	4	7.91	4
TN	3.12	15	3.22	8
TN	3.54	13	3.64	9
TN	4.11	11	4.22	8

Table 76. First rutting measurement and rate of change, SPS-6 asphalt overlays of cracked/broken slabs.

State	607		608	
	First rutting measured (mm)	Rate of change (mm/yr)	First rutting measured (mm)	Rate of change (mm/yr)
AL	3	2.03	3	0.00
AZ	9	0.40	6	0.00
AR	5	0.27	3	0.00
CA	1	1.33	1	0.48
IL	2	0.11	1	0.11
IN	4	0.31	3	0.21
IA	5	0.27	4	0.54
MI	7	0.24	8	0.60
MO 0	5	-0.48	6	-0.13
MO A	4	0.00	3	0.00
OK	4	0.37	5	0.12
PA	11	0.13	12	-0.38
SD	4	0.00	3	0.13
TN	15	-0.97	8	0.00

Table 77. Analysis of first rutting measurement on SPS-6 4-inch versus 8-inch overlays of cracked/broken and seated slabs.

	Rutting (4 inches versus 8 inches), mm
Mean difference	0.93
n	14
S_D	2.13
$T_{\alpha/2, n-1}$	2.53
Confidence interval lower limit	-0.51
Confidence interval upper limit	2.37
Significant difference	no

Table 78. Analysis of annual change in rutting in SPS-6 4-inch versus 8-inch overlays of cracked/broken and seated slabs.

	Rate of change (4 inches versus 8 inches), mm/yr
Mean difference	0.17
n	14
S_D	0.70
$T_{\alpha/2, n-1}$	2.53
Confidence interval lower limit	-0.30
Confidence interval upper limit	0.64
Significant difference	no

Cracking in Asphalt Overlays of Concrete Pavements

For the purpose of this analysis, percent area cracked was calculated in a manner similar to that described earlier (i.e., using the area of alligator cracking of all severities plus 18 inches times the length of all sealed and unsealed longitudinal cracking of all severities, divided by the lane area). To these cracking quantities, however, were added the area of block cracking of all severities, and 6 inches times the length of all sealed and unsealed transverse cracking and reflection cracking of all severities, divided by the lane area. These different cracking quantities are combined in order to attempt to overcome discrepancies related to differences from technician to technician and/or from year to year in how cracking is identified. It is conceivable that in some cases the actual percent area cracked that is calculated is too high, because of multiple types of cracking occurring in the same area but being recorded separately. That is, the *scale* of this cracking parameter may warrant adjustment, but as long as it is calculated the same way for all sections, the comparisons made with it are considered reasonable.

The following comparisons of long-term cracking performance were made:

- Minimal versus intensive preparation in overlay sections,
- 4-inch overlay without saw/seal versus with saw/seal,
- 4-inch overlay with saw/seal versus 4-inch overlay with crack/break and seat, and
- Crack/break and seat with 4-inch versus 8-inch overlay.

The analysis of long-term cracking performance was conducted using data from 11 of the 14 SPS-6 sites. The Arkansas site did not have cracking data available, the Missouri A site was too young, and the South Dakota site was excluded from the analysis because the cracking quantities were very erratic from year to year.

The data used in the analysis of long-term cracking cover a range of time from 2.3 to 11.2 years, with an average of 7.9 years.

Minimal versus Intensive Preoverlay Preparation

The mean difference is calculated from the cracking values of 10 available section pairs. The results are summarized in Table 79, and a plot of the minimal-preparation versus intensive-preparation long-term cracking values is shown in Figure 90. The results indicate no significant difference in long-term cracking performance with minimal versus intensive preoverlay preparation.

4-inch Overlay without versus with Saw and Seal

The mean difference is calculated from the cracking values of 10 available section pairs. The results are summarized in Table 80, and a plot of the long-term cracking values without and with saw and seal is shown in Figure 91. The results indicate no significant difference in long-term cracking performance between 4-inch overlays without sawed and sealed joints, and 4-inch overlays with sawed and sealed joints.

Table 79. Analysis of long-term effect of SPS-6 minimal versus intensive preoverlay preparation on cracking.

	Cracking (minimal vs. intensive preOL), percent
Mean difference	1.3
n	10
S_D	14.6
$T_{\alpha/2, n-1}$	3.45
Confidence interval lower limit	-14.6
Confidence interval upper limit	17.2
Significant difference	no

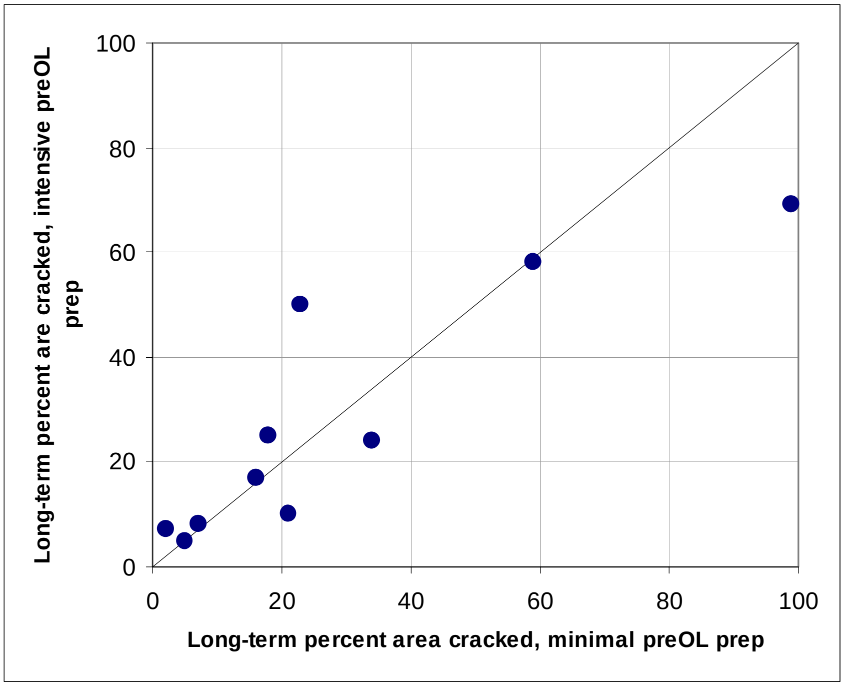

Figure 90. Long-term cracking, SPS-6 minimal versus intensive preoverlay preparation.

Table 80. Analysis of long-term effect of saw/seal on SPS-6 4-inch overlay cracking.

	Cracking (without versus with saw/seal), percent
Mean difference	0.4
n	10
S_D	11.1
$T_{\alpha/2,\ n-1}$	3.45
Confidence interval lower limit	-11.7
Confidence interval upper limit	12.6
Significant difference	no

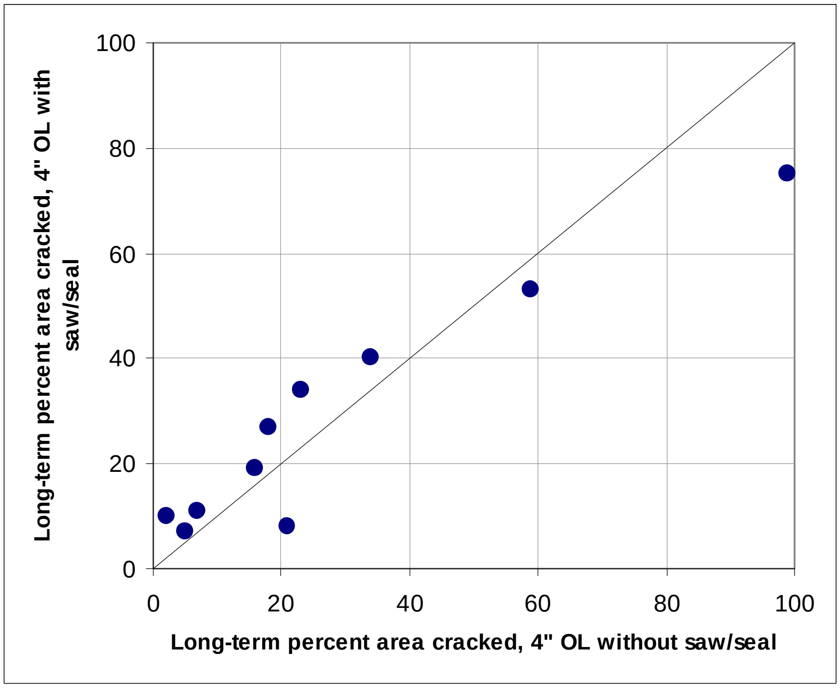

Figure 91. Long-term cracking, SPS-6 4-inch overlay without versus with saw/seal.

4-inch Saw-and-Seal Overlay versus 4-inch Crack/Break-and-Seat Overlay

The mean difference is calculated from the cracking values of 10 available section pairs. The results are summarized in Table 81, and a plot of the saw-and-seal versus crack/break-and-seat long-term cracking values is shown in Figure 92. The results indicate no significant difference in cracking quantities between the two reflection crack control methods. However, at higher cracking levels, the 4-inch crack/break-and-seat sections appear to perform somewhat better, in terms of cracking quantities, than the 4-inch saw-and-seal sections.

4-inch versus 8-inch Overlay with Crack/Break and Seat

The mean difference is calculated from the cracking values of 11 available section pairs. The results are summarized in Table 82, and a plot of the 4-inch versus 8-inch long-term cracking values is shown in Figure 93. The results indicate no significant difference in cracking between the two overlay thicknesses. This is somewhat surprising because the analysis of long-term IRI (see Table 68 and Figure 88) indicated that the 4-inch overlays consistently were rougher (had higher IRI values) than the 8-inch overlays.

The results of the F tests for significance of factor effects on SPS-6 treatment effectiveness are shown in Table 83. The influence of age, accumulated traffic, precipitation and temperature were tested for the following four comparisons:

- Minimal versus intensive preparation in overlay sections,
- 4-inch overlay without saw/seal versus with saw/seal,
- 4-inch overlay with saw/seal versus 4-inch overlay with crack/break and seat, and
- Crack/break and seat with 4-inch versus 8-inch overlay.

Insufficient preoverlay cracking data were available to permit testing for the significance of this factor in the cracking performance of the overlays of intact slabs.

As Table 83 shows, the only significant factor effect detected was a slightly significant correlation between accumulated ESALs and the difference in long-term cracking in 4-inch versus 8-inch overlays of broken-cracked-and-seated pavements.

Table 81. Analysis of long-term effect of SPS-6 reflection crack control treatments on cracking.

	Cracking (saw/seal vs. crack/seat), percent
Mean difference	2.7
n	10
S_D	17.6
$T_{\alpha/2, n-1}$	3.45
Confidence interval lower limit	-16.5
Confidence interval upper limit	21.8
Significant difference	no

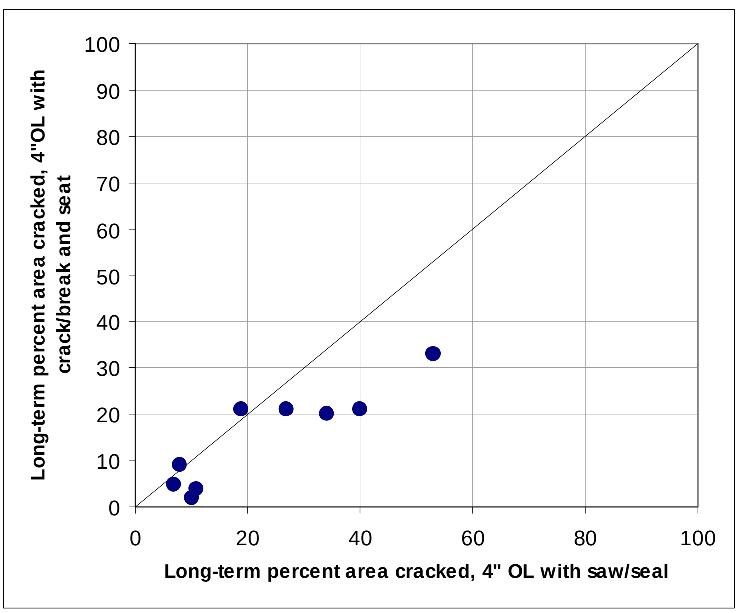

Figure 92. Long-term cracking, SPS-6 4-inch overlay with saw and seal versus crack/break and seat.

Table 82. Analysis of long-term effect on cracking of SPS-6 4-inch versus 8-inch overlay with crack/break and seat.

	Cracking (4 inches versus 8 inches), percent
Mean difference	-0.9
n	11
S_D	15.8
$T_{\alpha/2, n-1}$	3.36
Confidence interval lower limit	-16.9
Confidence interval upper limit	15.1
Significant difference	no

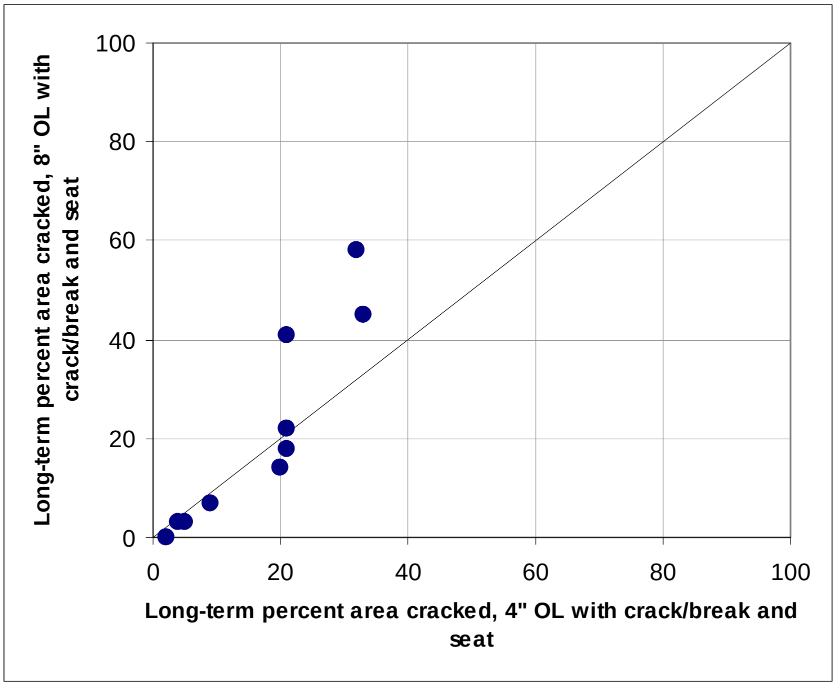

Figure 93. Long-term cracking, SPS-6 4-inch versus 8-inch overlay with crack/break and seat.

Table 83. Tests for significance of factor effects on relative long-term IRI performance of SPS-6 overlay rehabilitation treatments.

Treatment		Factor			
		Age	Accumulated ESALs	Average annual precipitation	Average annual temperature
Minimal	slope	0.794	0.001	0.241	-1.028
Versus	n	11	11	11	11
Intensive	Fcalc	0.14	0.42	0.23	1.69
Preoverlay	F at 0.05	5.12	5.12	5.12	5.12
Repair	Significant?	no	no	no	no
4-inch Overlay	slope	2.450	0.000	0.067	-0.836
Without	n	11	11	11	11
Versus	Fcalc	2.05	0.03	0.02	1.34
With	F at 0.05	5.12	5.12	5.12	5.12
Saw-and-Seal	Significant?	no	no	no	no
4-inch Overlay	slope	-1.690	-0.001	0.104	1.115
Saw-and-Seal	n	11	11	11	11
Versus	Fcalc	0.39	1.56	0.02	1.09
4-inch Overlay	F at 0.05	5.12	5.12	5.12	5.12
Crack-and-Seat	Significant?	no	no	no	no
4-inch Overlay	slope	-0.937	0.002	0.160	0.330
Versus	n	11	11	11	11
8-inch Overlay	Fcalc	0.15	6.65	0.08	0.11
With	F at 0.05	5.12	5.12	5.12	5.12
Crack-and-Seat	Significant?	no	**yes**	no	no

References for Chapter 4

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Chapter 5

Conclusions

Flexible Pavement Maintenance Effectiveness

In terms of roughness, rutting, and fatigue cracking, the most effective of the maintenance treatments in the SPS-3 core experiment has been the thin overlay treatment, followed by the chip seal treatment, and then the slurry seal treatment.

The thin overlay treatment had small but significant effect in initial reduction of roughness, and was the only one of the four to have a significant effect on long-term roughness, relative to the control sections. For rougher pavements, there was some evidence that chip seals also had some effect on long-term roughness, relative to the control sections. Slurry seals and crack seals did not have any significant effect on long-term roughness. A slight but statistically significant correlation between average annual precipitation and rate of IRI increase was detected for thin overlay and slurry seal sections. A slightly significant correlation was detected between pretreatment IRI and the rate of IRI increase for crack seal sections.

The thin overlay treatment was also the only one of the four treatments to have a significant initial effect on rutting. The thin overlays had the greatest effect on long-term rutting development. Age was the only one of the factors studied that was found to be significantly correlated to the rate of rutting in thin overlay sections. Average annual precipitation was the only one of the factors studied that was found to be significantly correlated to the rate of rutting in crack seal and chip seal sections.

Fatigue cracking has so far been remarkably consistent among the thin overlays in the SPS-3 experiment, which range from about two to eleven years in age. Some control sections have more than four times as much cracking as the thin overlay sections at the same sites. The chip seals and slurry seals are also exhibiting considerably less cracking than the control sections, although for these two treatments an increasing trend in cracking over time is evident. The crack seal treatment did not reduce long-term cracking at all. Indeed, the crack seal sections showed more long-term cracking than the controls sections. However, this may not be due to any truly adverse effect of crack sealing, but rather to (1) sealing of new cracks (cracks that appeared after the initial treatment date), and/or (2) the greater visibility of sealed cracks.

Overall, the thin overlays were the most effective of the SPS-3 maintenance treatments, followed by the chip seals and then the slurry seals. The crack seals did not demonstrate any beneficial initial or long-term effect with respect to IRI, rutting, or cracking.

Flexible Pavement Rehabilitation Effectiveness

Based on analysis of the overlay treatments in the SPS-5 experiment, and the overlays in the GPS-6B experiment, the average initial postoverlay IRI of an asphalt overlay of an asphalt pavement was found to be 0.98 m/km. This corresponds to an estimated mean PSI of 4.00. However, both data sets show a slight but statistically significant correlation between preoverlay IRI and initial postoverlay IRI. That is, asphalt pavements overlaid when rougher tend to have somewhat more initial roughness after overlay than asphalt pavements overlaid when smoother.

All of the overlay treatments reduced long-term roughness, relative to the nonoverlaid sections, and the five-inch overlays in the SPS-5 experiment had significantly lower long-term roughness than the two-inch overlays. There was no significant mean difference in long-term roughness between recycled mixes versus virgin mixes, nor between overlays with minimal versus intensive preoverlay preparation (the key difference between the two being whether or not milling is done).

Preoverlay IRI, overlay age, and average annual temperature were found to be significantly correlated to the difference in long-term IRI increase in the nonoverlaid sections and long-term IRI increase in the overlaid sections. A slightly significant correlation was detected between average annual precipitation and long-term IRI increase in recycled versus virgin overlay mixes. Average annual precipitation, and to a much lesser degree, preoverlay IRI, were found to be significantly correlated to long-term IRI increase in two-inch versus five-inch overlays.

The rutting data from the SPS-5 and GPS-6B experiments indicate that on average, about six mm of rutting develops in the first year or so after placement of an asphalt overlay of an asphalt pavement. This may be due to compaction of the mix by traffic, and appears to be independent of the overlay thickness, mix type, preoverlay preparation, and preoverlay rutting level. No significant mean differences were detected in long-term rutting between virgin versus recycled mixes, minimal versus intensive preparation, or thin versus thick overlays.

Overlay age and average annual precipitation were found to be significantly correlated to the difference in long-term rutting in the nonoverlaid sections versus the overlaid sections. A slightly significant correlation was detected between pretreatment rutting and the difference in long-term rutting in sections with recycled versus virgin mixes. A significant correlation was detected between average annual precipitation and the difference in long-term rutting in two-inch versus five-inch overlays.

Over the long term, five-inch overlays significantly outperformed two-inch overlays with respect to cracking. No significant mean differences were detected in long-term cracking between virgin versus recycled mixes, nor between minimal versus intensive preparation. Preoverlay cracking, age, and accumulated ESALs were found to be significantly correlated to the difference in long-term cracking in nonoverlaid versus overlaid sections.

Overall, overlay thickness and preoverlay roughness level were the two factors that most influenced the performance of asphalt overlays of asphalt pavements. Overlay mix type (virgin versus recycled) and preoverlay preparation (with or without milling) had slight and inconsistent effects.

Rigid Pavement Rehabilitation Effectiveness

In nearly every case, SPS-6 test sections that received nonoverlay repair without diamond grinding were rougher after the treatment than before, while sections that received nonoverlay repair with grinding were considerably smoother after treatment. The average initial IRI after grinding was 1.05 m/km, which in a concrete pavement corresponds to an average PSI of about 4.4.

Of the test sections that received grinding, most also received full-depth repair, joint resealing, and crack sealing. In addition to those four techniques, some sections also received subdrainage retrofitting, undersealing, and/or load transfer restoration. These last three techniques do not appear to have produced significantly lower long-term roughness levels, compared to sections where only diamond grinding, full-depth repair, and joint and crack sealing were done.

A slightly better initial posttreatment IRI, 1.00 m/km, which corresponds to an average PSI of about 4.47, was achieved by the SPS-6 overlay treatments. This average applies to asphalt overlays of intact slabs as well as asphalt overlays of cracked/broken and seated slabs.

It should be noted that the correlation of IRI to PSI is different for concrete than for asphalt pavements, but the average initial postoverlay IRIs for asphalt overlays of both pavement types were almost identical. An interesting difference is that, unlike the case of asphalt overlays of asphalt pavements, the initial postoverlay IRI of asphalt overlays of concrete pavements shows no correlation to pretreatment IRI.

Both concrete pavement restoration with grinding and asphalt overlays in the SPS-6 performed better than the control sections in terms of long-term roughness. However, the grinding sections are approaching the control sections in terms of roughness faster than are the overlay sections. For both restoration with grinding and asphalt overlays, the difference in long-term IRI between the unrehabilitated (control) sections and the rehabilitated (grinding or overlay) sections is positively correlated to accumulated ESALs. That is, with truck traffic accumulation over time, the difference in IRI growth between unrehabilitated and rehabilitated concrete pavements becomes more evident.

Also, for both restoration with grinding and asphalt overlays, the difference in long-term IRI between the unrehabilitated (control) sections and the rehabilitated (grinding or overlay) sections is negatively correlated to pretreatment IRI. That is, the biggest disparities in IRI increase occurred at sites with less roughness prior to rehabilitation. This could be interpreted as an argument for application of rehabilitation sooner rather than later, especially if it can be confirmed over longer time periods and larger data sets.

In four-inch asphalt overlays of intact slabs, no significant mean differences in long-term roughness were detected between minimal versus intensive preoverlay preparation, nor between sections without versus with sawing and sealing of transverse joints, nor even between overlays with sawed and sealed joints versus overlays of cracked/broken and seated slabs. Among overlays of cracked/broken and seated slabs, the eight-inch overlays had significantly lower long-term roughness than the four-inch overlays.

The rutting data from the SPS-6 and GPS-7B experiments indicate that on average, about 6 mm of rutting develops in the first year or so after placement of an asphalt overlay of either an intact or a cracked/broken and seated concrete pavement. This may be due to compaction of the mix by traffic, and appears to be independent of the overlay thickness, mix type, preoverlay preparation, and preoverlay rutting level. No significant differences in the average first rutting measurement or the annual rate of change of rutting were detected among the various groups of asphalt overlays of intact slabs, nor between four-inch versus eight-inch overlays of cracked/broken and seated slabs.

No significant difference in long-term cracking performance was detected between minimal versus intensive preoverlay preparation, nor between sections without versus with sawed and sealed joints, nor between four-inch overlays with sawed-and sealed joints versus those over cracked/broken and seated pavements, nor between four-inch versus eight-inch overlays of cracked/broken and seated pavements.

Overall, the rehabilitation treatments in the SPS-6 experiment could be ranked in the following order from most to least effective, with respect to IRI, rutting, and cracking:

- 8-inch asphalt overlay of cracked/broken and seated pavement.
- 4-inch asphalt overlay of either cracked/broken and seated pavement or intact pavement, the latter with either minimal or intensive preoverlay repair, and either with or without sawing and sealing of transverse joints.
- Concrete pavement restoration with diamond grinding, full-depth repair, and joint and crack sealing (no significant additional benefits were achieved with subdrainage improvement, load transfer restoration, or undersealing).
- Concrete pavement restoration with full-depth repair, joint and crack sealing, but without diamond grinding. This last treatment category did not provide any benefit, and in fact tended to make the pavement rougher than it was before restoration.

Final Comments

The analysis of long-term treatment effects described in this report represents the first two steps in building models for the effects of maintenance and rehabilitation treatments on pavement performance:

- Determining which treatment types significantly affect long-term performance, and
- Determining which factors (traffic, climate, pretreatment condition, etc.), if any, significantly influence how much effect the treatment types have on long-term performance.

Once the significant independent variables have been identified, the next step in the model-building process – which is beyond the scope of this study – would be to select the model forms that best reflect the effects of the independent variables, including nonlinear effects and interaction effects, if any.

The most effective treatment is not always the most cost-effective treatment. It was not an objective of this research study to identify which maintenance or rehabilitation treatments are likely to be most cost-effective at different times in a pavement's life (i.e., at different condition levels). Such an assessment cannot be based on condition data alone, but rather should be based on an analysis of condition data together with predicted performance of different maintenance and rehabilitation alternatives, and the life-cycle costs of those alternatives.

The conclusions reached in this study concerning relative long-term performance of different maintenance and rehabilitation treatments are based on data collected through the year 2001. In the longer term, more marked differences in performance may become apparent.

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Appendix A: Flexible Pavement Maintenance Effectiveness

Annual Precipitation and Temperature Levels for SPS-3 Sites

SPS-3 Site					Nearest Weather Station				Average Annual Precipitation (inches)	Average Annual Temperature (degrees F)	Precipitation Range	Temperature Range
SHRP ID	State	State Code	Latitude (degrees)	Longitude (degrees)	ID	Name	Latitude (degrees)	Longitude (degrees)				
A300	AL	1	32.42	86.24	01169466	CLANTON	32.51	86.38	54.96	62.40	H	M
B300	AL	1	31.35	88.03	01156666	CHATOM 4 N	31.32	88.15	62.02	64.60	H	H
C300	AL	1	31.24	85.57	01621866	OZARK 6 NNW	31.32	85.41	51.89	66.10	H	H
A300	AZ	4	35.71	114.47	26107166	BOULDER CITY	35.59	114.51	6.58	67.70	L	H
B300	AZ	4	35.16	113.68	028778 6	TRUXTON CANYON	35.32	113.40	10.20	59.10	L	M
C300	AZ	4	31.77	111.04	02028766	ANVIL RANCH	31.59	111.23	14.82	66.30	L	H
D300	AZ	4	31.64	111.06	02028766	ANVIL RANCH	31.59	111.23	14.82	66.30	L	H
A300	AR	5	36.27	94.15	03058666	BENTONVILLE 4 S	36.19	94.13	46.70	56.00	H	M
A300	CA	6	39.77	121.73	04171566	CHICO UNIVERSITY FARM	39.42	121.49	25.81	60.90	M	M
A300	CO	8	38.70	108.03	052192 6	DELTA	38.45	108.04	9.47	51.40	L	M
B300	CO	8	38.09	103.19	05483466	LAS ANIMAS	38.04	103.13	12.49	53.40	L	M
A300	FL	12	30.62	81.63	08435866	JACKSONVILLE WSO AP	30.30	81.42	47.93	68.50	H	H
B300	FL	12	30.09	81.71	08435866	JACKSONVILLE WSO AP	30.30	81.42	47.93	68.50	H	H
C300	FL	12	28.95	80.94	08215866	DAYTONA BEACH WSO AP	29.11	81.03	46.24	70.50	H	H
A300	ID	16	42.74	114.44	10838046	SHOSHONE 1 WNW	42.58	114.26	10.49	48.50	L	M
B300	ID	16	43.65	111.93	10396446	HAMER 4 NW	43.58	112.16	9.87	41.90	L	L
C300	ID	16	43.68	112.12	10396446	HAMER 4 NW	43.58	112.16	9.87	41.90	L	L
A300	IL	17	38.62	89.63	11051066	BELLEVILLE SIU RES CTR	38.30	89.51	40.10	55.50	M	M
B300	IL	17	42.32	89.61	11590166	MOUNT CARROLL	42.05	89.59	38.95	46.30	M	L
A300	IN	18	38.20	87.02	12835224	SPURGEON 2 N	38.17	87.15	47.25	54.50	H	M
A300	IA	19	42.35	94.96	13731266	SAC CITY	42.26	95.00	34.11	46.70	M	L
A300	KS	20	38.62	95.25	14455966	LAWRENCE	38.58	95.16	39.37	57.00	M	M
B300	KS	20	37.64	99.75	14216466	DODGE CITY WSO AP	37.46	99.58	21.00	55.60	M	M
A300	KY	21	37.48	83.71	15374126	HEIDELBERG LOCK 14	37.33	83.46	46.02	54.50	H	M
B300	KY	21	36.99	85.97	15509766	MAMMOTH CAVE PARK	37.11	86.05	50.71	57.00	H	M
A300	MD	24	38.37	75.26	07357066	GEORGETOWN 5 SW	38.38	75.27	43.83	55.20	H	M
A300	MI	26	43.44	85.49	20044666	BALDWIN	43.54	85.51	37.21	44.60	M	L
B300	MI	26	43.71	85.53	20044666	BALDWIN	43.54	85.51	37.21	44.60	M	L
C300	MI	26	44.03	84.92	20450266	LAKE CITY EXP FARM	44.19	85.12	31.91	42.60	M	L
D300	MI	26	43.18	83.66	20721766	SAGINAW CONSUMERS PWR	43.27	83.58	34.66	49.30	M	M
A300	MN	27	47.52	94.91	21679566	RED LAKE INDIAN AGENCY	47.52	95.02	21.88	39.30	M	L
B300	MN	27	47.46	94.91	21679566	RED LAKE INDIAN AGENCY	47.52	95.02	21.88	39.30	M	L
C300	MN	27	46.68	95.67	21214266	DETROIT LAKES 1 NNE	46.50	95.51	25.83	40.70	M	L
D300	MN	27	45.59	93.60	21539266	MILACA 1 ENE	45.48	93.40	29.12	41.60	M	L
A300	MS	28	31.70	89.42	22238566	D'LO 2 SW	31.57	89.56	58.84	63.30	H	M
A300	MO	29	38.25	92.60	23860346	VERSAILLES	38.26	92.51	42.58	55.00	H	M
B300	MO	29	38.53	92.34	23081766	BOONVILLE	38.58	92.45	48.79	54.10	H	M
A300	MT	30	47.24	110.47	24754066	SHONKIN 7 S	47.32	110.35	26.17	43.90	M	L
A300	NE	31	40.31	99.84	25141566	CAMBRIDGE	40.16	100.10	21.47	50.60	M	M
A300	NV	32	39.56	119.76	04250666	DOYLE 4 SSE	39.58	120.05	18.41	49.60	L	M
B300	NV	32	40.88	114.25	26535226	MONTELLO 1 SE	41.15	114.12	8.20	46.00	L	L
C300	NV	32	40.99	114.43	26898866	WELLS	41.07	114.58	11.20	44.10	L	L

SPS-3 Site					Nearest Weather Station				Average Annual Precipitation (inches)	Average Annual Temperature (degrees F)	Precipitation Range	Temperature Range
SHRP ID	State	State Code	Latitude (degrees)	Longitude (degrees)	ID	Name	Latitude (degrees)	Longitude (degrees)				
A300	NY	36	43.44	73.46	30328466	GLENS FALLS FARM	43.20	73.44	44.88	46.60	H	L
B300	NY	36	44.25	74.77	30894466	WANAKENA RANGER SCHOOL	44.09	74.54	44.15	40.90	H	L
A300	OK	40	34.64	99.29	34550966	MANGUM RESEARCH STN	34.50	99.26	28.67	62.10	M	M
B300	OK	40	35.19	96.67	34811056	SHAWNEE	35.21	96.54	42.61	61.50	H	M
C300	OK	40	36.69	97.27	340818 6	BLACKWELL 2 E	36.49	97.14	31.78	58.90	M	M
A300	PA	42	41.00	76.83	36972866	WILLIAMSPORT WSO AP	41.15	76.55	38.33	50.20	M	M
B300	PA	42	41.97	77.24	300023 6	ADDISON	42.06	77.13	31.00	46.30	M	L
A300	PA	47	35.94	86.12	40510866	LEBANON 3 W	36.13	86.20	51.14	57.50	H	M
B300	PA	47	36.07	85.74	40498766	LAFAYETTE	36.31	86.02	54.85	59.00	H	M
C300	PA	47	36.19	84.10	40661946	NORRIS	36.13	84.03	47.94	56.00	H	M
A300	TX	48	29.60	98.71	41090266	BOERNE	29.48	98.43	33.52	65.50	M	H
B300	TX	48	32.62	96.43	41224466	DALLAS FAA AP	32.51	96.51	36.51	66.60	M	H
D300	TX	48	32.36	100.99	41341156	GAIL	32.46	101.27	19.73	63.70	L	M
E300	TX	48	33.33	101.52	41541166	LUBBOCK WSFO AP	33.39	101.49	18.83	60.40	L	M
F300	TX	48	32.62	95.85	41980066	WILLS POINT	32.42	96.01	40.88	64.60	M	H
G300	TX	48	32.20	94.80	41354666	GILMER 2 W	32.44	94.59	43.19	63.20	H	M
H300	TX	48	30.35	95.92	41949166	WASHINGTON STATE PARK	30.20	96.09	38.99	67.30	M	H
I300	TX	48	30.70	95.64	41547766	MADISONVILLE	30.57	95.55	42.63	68.40	H	H
J300	TX	48	29.24	98.25	41794566	SAN ANTONIO WSFO	29.32	98.28	30.65	69.00	M	H
K300	TX	48	29.52	98.72	41090266	BOERNE	29.48	98.43	33.52	65.50	M	H
L300	TX	48	31.80	106.26	41493166	LA TUNA 1 S	31.58	106.36	8.81	64.00	L	H
M300	TX	48	27.93	98.56	41290666	ENCINAL EADS RANCH	27.57	98.58	21.01	71.20	M	H
N300	TX	48	26.98	97.80	41306366	FALFURRIAS	27.14	98.08	24.55	72.10	M	H
Q300	TX	48	31.57	98.67	41113866	BROWNWOOD	31.43	99.00	27.86	65.90	M	H
A300	UT	49	38.03	112.36	42051946	BEAVER	38.18	112.39	12.92	48.00	L	M
B300	UT	49	38.57	112.26	42282866	FILLMORE	38.57	112.19	17.76	51.40	L	M
C300	UT	49	39.19	111.84	42771446	SCIPIO	39.15	112.06	16.02	48.40	L	M
A300	VA	51	37.02	77.39	44410166	HOPEWELL	37.18	77.18	41.57	59.60	M	M
A300	WA	53	47.56	117.39	45793866	SPOKANE WSO AP	47.38	117.32	16.82	47.30	L	L
B300	WA	53	47.65	120.07	45135066	CHELAN	47.50	120.02	11.05	50.00	L	M
C300	WA	53	45.57	122.31	45048266	BATTLE GROUND	45.46	122.32	53.69	51.00	H	M
A300	WY	56	44.50	108.92	48177566	CLARK 7 NE	44.59	109.05	8.51	44.60	L	L
B300	WY	56	42.00	109.63	483170 6	FARSON	42.07	109.26	8.94	36.80	L	L
A300	MB	83	49.77	100.54	32094166	BOTTINEAU	48.50	100.27	16.74	38.70	L	L
A300	ON	87	44.65	79.65	30484966	LOCKPORT 4 NE	43.12	78.38	36.38	47.80	M	L
B300	ON	87	45.11	79.31	30484966	LOCKPORT 4 NE	43.12	78.38	36.38	47.80	M	L
A300	PQ	89	46.46	72.42	27299966	FIRST CONN LAKE	45.05	71.17	44.37	37.10	H	L
A300	SK	90	50.17	102.30	32096166	BOWBELLS	48.48	102.15	14.88	39.00	L	L
B300	SK	90	51.90	105.31	24623644	OPHEIM 10 N	49.00	106.23	10.84	40.00	L	L

Precipitation ranges: L = less than 21 in, M = 21 to 42 in, H = more than 42 in
Temperature ranges: L = less than 48 deg, M = 48 to 64 deg, H = more than 64 deg

SPS-3 Pavement Structure Data

The as-constructed test section station limits, pavement layer thicknesses, and material and subgrade types for the SPS-3 test sections and linked GPS sections are summarized in this section of the Appendix.

The data in the columns under the heading Construction Number 1 represent the pavement structure prior to treatment. The data in the columns under the heading CN = 2 represent the asphalt concrete layers and thicknesses present after treatment, including overlay if any. Only the asphalt concrete layer data are shown for CN = 2 because the base, subbase, and subgrade thicknesses and material types are the same before and after treatment. One or more asphalt concrete layer thicknesses may be shown, if the material was placed in several lifts. When some asphalt concrete has been removed by milling prior to placement of an overlay, this is reflected by a reduction in one of the asphalt concrete layer thicknesses.

Empty cells indicate that according to the available LTPP data, no layer is present, whereas cells containing question marks (???) indicate that a layer is present but some information about the layer is missing.

For most SPS-3 sites, the linked GPS section is within the SPS-3 station limits or is adjacent. However, for some SPS-3 sites, the linked GPS section is located farther away from the SPS-3 test sections. These pavement structures are shown separately, on the last page.

The following codes are used in this Appendix for test section types:

Th0	=	thin overlay
SlS	=	slurry seal
CrS	=	crack seal
CnL	=	control
ChS	=	chip seal
GPS	=	linked GPS
Sup	=	agency supplemental section (type is indicated if known)

The following codes are used for material types identified in SPS-3 test sections:

1	=	hot-mixed, hot-laid, dense-graded asphalt concrete
2	=	hot-mixed, hot-laid, open-graded asphalt concrete
11	=	single surface treatment

20	=	other
71	=	chip seal
72	=	slurry seal
101	=	fine-grained soil: clay
102	=	fine-grained soil: lean inorganic clay
103	=	fine-grained soil: fat inorganic clay
105	=	fine-grained soil: lean clay with gravel
108	=	fine-grained soil: lean clay with sand
109	=	fine-grained soil: fat clay with sand
111	=	fine-grained soil: gravelly lean clay
113	=	fine-grained soil: sandy clay
114	=	fine-grained soil: sandy lean clay
118	=	fine-grained soil: gravelly fat clay with sand
120	=	fine-grained soil: sandy lean clay with gravel
135	=	fine-grained soil: sandy silty clay
141	=	fine-grained soil: silt
145	=	fine-grained soil: sandy silt
148	=	fine-grained soil: clayey silt
202	=	coarse-grained soil: poorly graded sand
203	=	coarse-grained soil: poorly graded sand with gravel
204	=	coarse-grained soil: poorly graded sand with silt
211	=	coarse-grained soil: well-graded sand with silt and gravel
214	=	coarse-grained soil: silty sand
215	=	coarse-grained soil: silty sand with gravel
216	=	coarse-grained soil: clayey sand
217	=	coarse-grained soil: clayey sand with gravel
254	=	coarse-grained soil: poorly graded gravel with silt
255	=	coarse-grained soil: poorly graded gravel with silt and sand
265	=	coarse-grained soil: silty gravel with sand
267	=	coarse-grained soil: clayey gravel with sand
302	=	uncrushed gravel
303	=	crushed stone
304	=	crushed gravel
306	=	sand
307	=	soil-aggregate mixture (predominantly fine-grained)
308	=	soil-aggregate mixture predominantly coarse-grained)
309	=	fine-grained soils
319	=	HMAC

320	=	sand asphalt
321	=	asphalt-treated mixture
324	=	dense-graded, cold-laid, mixed in-place [asphalt concrete]
337	=	limerock, caliche
338	=	lime-treated soil
350	=	other

Alabama

Station (m)	Section	AC Thicknesses		Base Thickness	Base Type	Subbase Thickness	Subbase Type	Subgrade Type	CN = 2 AC Thicknesses	
		Construction Number = 1								
0 / 152	014125 GPS	0.8 / 2.6		6.2	TB (319)	6.5	GS (309)	SS (217)		
274 / 427	01A310 ThO	0.8 / 2.8	6.2	6.5	GB (309)			SS (217)	1.6 / 0.8	2.8 / 6.2
488 / 640	01A320 SlS	0.8 / 2.8	6.2	6.5	GB (309)			SS (217)	0.2 (72) / 0.8	2.8 / 6.2
686 / 838	01A330 CrS	0.9 / 2.8	6.2	6.5	GB (309)			SS (217)	0.9 / 2.8	6.2
884 / 1,036	01A340 CnL	1 / 2.2	6.1	6.5	GB (309)			SS (217)		
1,210 / 1,363	01A350 ChS	0.8 / 2.8	6.2	6.5	GB (309)			SS (217)	0.3 (71) / 0.8	2.8 / 6.2

0 / 152	011019 GPS	0.9 / 2.6		3	TB (319)	5.5	GS (308)	SS (214)	?? / 0.9	2.6
457 / 610	01B310 ThO	1.1 / 2.8	3.1			5.5	GS (308)	SS (214)	1.2 / 1	2.6 / 3.1
762 / 914	01B320 SlS	1 / 3.1	3			5.5	GS (308)	SS (214)	0.2 (72) / 0.8	2.6 / 3
960 / 1,113	01B330 CrS	0.9 / 2.6	3.3			5.5	GS (308)	SS (214)		
1,250 / 1,402	01B350 ChS	1.3 / 2.7	3.1	5.5	GB (308)			SS (214)	0.3 (71) / 1.1	2.7 / 2.9
3,414 / 3,566	01B340 CnL	1 / 3.1	3.2	5.5	GB (308)			SS (214)		

0 152	014155 GPS	1 2.7		10.4	GB (303)			SS (214)	?? 1	2.7
305 457	01C310 ThO	1 2.8		10.4	GB (303)			SS (214)	1.5 1.1	2.6
549 701	01C320 SIS	1 2.7		10.4	GB (303)			SS (214)	0.2 (72) 1	2.7
762 914	01C330 CrS	0.9 3.1		10.4	GB (303)			SS (214)	0.9 3.1	
1,189 1,341	01C340 CnL	1 3.2		10.4	GB (303)			SS (214)		
1,459 1,612	01C350 ChS	0.9 3		10.4	GB (303)			SS (214)	0.3 (71) 0.9	2.6

Arizona

Station (m)	Section	Construction Number = 1							CN = 2	
		AC Thicknesses		Base		Subbase		Subgrade Type	AC Thicknesses	
				Thickness	Type	Thickness	Type			
0 152	041036 GPS	0.6 (2) 3.8		18.6	GB (308)			SS (217)	?? (71) 0.6 (2)	3.8
305 457	04A390 Sup-???	0.6 (2) 3.8		18.6	GB (308)			SS (217)	1.5 (71) 0.6 (2)	3.8
899 1,052	04A320 SIS	0.4 (2) 3.5		18.6	GB (308)			SS (217)	0.1 (72) 0.4 (2)	3.7
1,478 1,631	04A330 CrS	0.6 (2) 3.5		18.6	GB (308)			SS (217)	0.6 (2) 3.5	
1,692 1,844	04A310 ThO	0.4 (2) 3.4		18.6	GB (308)			SS (217)	1.5 0.4 (2)	4.1
2,027 2,179	04A350 ChS	0.5 (2) 3.5		18.6	GB (308)			SS (217)	0.2 (71) 0.5 (2)	3.9

0 152	04B310 ThO	0.1 (11) 0.5 (2)	5.8	8.4	GB (308)			SS (215)	1.4 0.2 (2)	5.3
213 366	04B330 CrS	0.1 (11) 0.5 (2)	4.7	8.4	GB (308)			SS (215)	0.1 (11) 0.5 (2)	4.7
482 635	041021 GPS	0.1 (82) 0.5 (2)	4.7	8.4	GB (308)			SS (215)	0.1 (82) 0.5 (2)	4.7
711 863	04B320 SIS	0.1 (11) 0.6 (2)	5.5	8.4	GB (308)			SS (215)	0.2 (72) 0.4 (2)	5.5
965 1,117	04B350 ChS	0.1 (11) 0.5 (2)	5.4	8.4	GB (308)			SS (215)	0.3 (71) 0.4 (2)	5.6

0 152	041017 GPS	0.7 (2) 8.2		11.2	GB (308)			SS (267)	0.7 (2) 8.2	
213 366	04C320 SIS	0.6 (2) 7.4		11.2	GB (308)			SS (267)	0.1 (72) 0.6 (2)	7.4
427 579	04C330 CrS	0.5 (2) 8.4		11.2	GB (308)			SS (267)	0.5 (2) 8.4	
988 1,140	04C350 ChS	0.7 (2) 7.3		11.2	GB (308)			SS (267)	0.3 (71) 0.6 (2)	7.9
1,264 1,417	04C310 ThO	0.8 (2) 7		11.2	GB (308)			SS (267)	1.6 0.8 (2)	7.6
1,541 1,694	04C340 CnL	0.6 (2) 6.9		11.2	GB (308)			SS (267)		

Station (m)	Section	AC Thicknesses		Base Thickness	Base Type	Subbase Thickness	Subbase Type	Subgrade Type	CN = 2 AC Thicknesses	
0 152	041016 GPS	0.5 (2) 9.5		6.7	GB (304)			SS (267)	0.5 (2) 9.5	
438 591	04D320 SIS	0.5 (2) 10		6.7	GB (304)			SS (267)	0.1 (72) 0.7 (2)	9.5
652 804	04D330 CrS	0.4 (2) 9.7		6.7	GB (304)			SS (267)	0.4 (2) 9.7	
865 1,017	04D310 ThO	0.4 (2) 9.1		6.7	GB (304)			SS (267)	1.7 0.5 (2)	9.8
1,357 1,510	04D350 ChS	0.4 (2) 9.4		6.7	GB (304)			SS (267)	0.2 (71) 0.4 (2)	9.4

Arkansas

Station (m)	Section	Construction Number = 1							CN = 2	
		AC Thicknesses		Base		Subbase		Subgrade Type	AC Thicknesses	
				Thickness	Type	Thickness	Type			
0 152	053071 GPS	0.5 (71) 1.5	3.9	10.5	TB (319)			SS (102)	?? 0.5 (71)	1.5 3.9
290 442	05A310 ThO	0.5 (71) 1.5	4.1	10.9	TB (319)			SS (102)	0.9 0.5 (71)	1.5 4.1
564 716	05A320 SIS	0.5 (71) 1.4	3.7	10.5	TB (319)			SS (102)	0.2 (72) 0.5 (71)	1.4 3.7
777 930	05A330 CrS	0.4 (71) 1.3	3.9	8	TB (319)			SS (102)		
991 1,143	05A350 ChS	0.4 (71) 1.5	3.7	10.5	TB (319)			SS (102)	0.2 (71) 0.4 (71)	1.5 3.7

California

Station (m)	Section	Construction Number = 1: AC Thicknesses		Base: Thickness	Base: Type	Subbase: Thickness	Subbase: Type	Subgrade Type	CN = 2: AC Thicknesses	
0–152	061253 GPS	0.2 (71) 3.6		15.3	GB (304)			SS (267)		
354–506	06A321 Sup-SIS	0.2 (71) 4.3		15.3	GB (304)			SS (267)	0.2 (72) 0.2 (71)	3.9
596–748	06A320 SIS	0.2 (71) 3.4		15.3	GB (304)			SS (267)	0.3 (72) 0.2 (71)	3.4
839–992	06A351 Sup-ChS	0.2 (71) 3.8		15.3	GB (304)			SS (267)	0.2 (71) 0.2 (71)	3.9
1,083–1,236	06A350 ChS	0.2 (71) 4.3		15.3	GB (304)			SS (267)	0.2 (71) 0.1 (71)	3.7
1,297–1,449	06A330 CrS	0.2 (71) 3.6		15.3	GB (304)			SS (267)	0.2 (71) 3.6	
1,510–1,662	06A311 Sup-ThO	0.2 (71) 2.3		15.3	GB (304)			SS (267)	1.4 0.1 (71)	3.6
1,693–1,845	06A310 ThO	0.2 (71) 3		15.3	GB (304)			SS (267)	1.3 0.2 (71)	3.1
1,906–2,059	06A340 CnL	0.2 (71) 3.7		15.3	GB (304)			SS (267)		
2,181–2,333	06A352 Sup-ChS	0.2 (71) 3.5		15.3	GB (304)			SS (267)	0.4 (71) 0.2 (71)	4
2,631–2,783	06A353 Sup-ChS	0.2 (71) 4		15.3	GB (304)			SS (267)	0.3 (71) 0.1 (71)	4
3,065–3,218	06A363 Sup-???	0.2 (71) 3.5		15.3	GB (304)			SS (267)	0.2 (71) 0.2 (71)	4
3,307–3,459	06A362 Sup-???	0.2 (71) 2.9		15.3	GB (304)			SS (267)	1 0.1 (71)	4
3,790–3,942	06A361 Sup-???	0.2 (71) 3		15.3	GB (304)			SS (267)	2 0.2 (71)	3.2

Colorado

Station (m)	Section	Construction Number = 1: AC Thicknesses		Base: Thickness	Base: Type	Subbase: Thickness	Subbase: Type	Subgrade Type	CN = 2: AC Thicknesses	
0 152	08A340 CnL	4.6		5.4	GB (304)	23.5	GS (308)	SS (102)		
244 396	08A330 CrS	4.6		5.4	GB (304)	23.5	GS (308)	SS (102)	4.6	
549 701	08A310 ThO	4.6		5.4	GB (304)	23.5	GS (308)	SS (102)	1.4 4.6	
735 887	08A350 ChS	4.6		5.4	GB (304)	23.5	GS (308)	SS (102)	0.4 (71) 5.2	
1,009 1,161	08A320 SIS	4.5		5.4	GB (304)	23.5	GS (308)	SS (102)	0.2 (72) 5.3	

0 152	08B310 ThO	0.3 (72) 3.7		6	TB (321)	14	GS (308)	SS (113)	1.1 0.3 (72)	2.8
297 449	082008 GPS	0.4 (72) 3.3		7.4	TB (321)	0	GS (308)	SS (113)		
510 663	08B320 SIS	0.4 (72) 4.5		6	TB (321)	15.2	GS (308)	SS (113)	0.2 (72) 0.1 (72)	3
724 876	08B330 CrS	0.3 (72) 4.9		6.5	TB (321)	14	GS (308)	SS (101)	0.3 (72) 4.9	
1,364 1,516	08B350 ChS	0.4 (72) 4.3		6	TB (321)	14.4	GS (308)	SS (113)	0.5 (71) 0.4 (72)	3.8

Florida

Station (m)	Section	Construction Number = 1							CN = 2	
		AC Thicknesses		Base		Subbase		Subgrade	AC Thicknesses	
				Thickness	Type	Thickness	Type	Type		
0										
762 – 914	12A321 Sup-SIS	2.6		10	GB (337)	12	GS (309)	SS (202)	0.5 2.6	
1,036 – 1,189	12A310 ThO	2.4		10	GB (337)	12	GS (309)	SS (202)	1.1 2.4	
1,433 – 1,585	129054 GPS	2.5		10	GB (337)	12	GS (309)	SS (202)		
1,722 – 1,875	12A320 SIS	2.4		10	GB (337)	12	GS (309)	SS (202)	0.2 (72) 2.4	
1,936 – 2,088	12A330 CrS	2.6		10	GB (337)	12	GS (309)	SS (202)	2.6	
2,164 – 2,317	12A350 ChS	2.5		10	GB (337)	12	GS (309)	SS (202)	0.3 (71) 2.5	
2,469 – 2,621	12A351 Sup-ChS	2.5		10	GB (337)	12	GS (309)	SS (202)	0.4 2.5	
2,804 – 2,957	12A352 Sup-ChS	2.5		10	GB (337)	12	GS (309)	SS (202)	0.2 2.5	

0	152	123997	GPS	3.1		11.6	GB (308)	15	GS (309)	SS (204)	?? / 3.1	
357	509	12B310	ThO	3.1		11.6	GB (308)	15	GS (309)	SS (204)	1.2 / 3.1	
601	753	12B320	SIS	3.3		11.6	GB (308)	15	GS (309)	SS (204)	0.3 (72) / 3.3	
875	1,027	12B330	CrS	3.1		11.6	GB (308)	15	GS (309)	SS (204)	3.1	
1,119	1,271	12B350	ChS	3.2		11.6	GB (308)	15	GS (309)	SS (204)	0.4 (71) / 3	
1,454	1,606	12B351	Sup-ChS	3.4		11.6	GB (308)	15	GS (309)	SS (204)	0.5 / 3.4	
1,713	1,865	12B352	Sup-ChS	3.3		11.6	GB (308)	15	GS (309)	SS (204)	0.1 (71) / 3.3	
2,064	2,216	12B360	Sup-???	3		11.6	GB (308)	15	GS (309)	SS (204)	1.6 / 3	
2,734	2,887	12B321	Sup-SIS	3.3		11.6	GB (308)	15	GS (309)	SS (204)	0.4 / 3.3	

0	152	12C310	ThO	1.2		8.8	GB (309)			SS (204)	1.4 / 1.2	
213	366	124154	GPS	1.3		8.8	GB (309)			SS (204)		
776	928	12C320	SIS	1.3		8.8	GB (309)			SS (204)	0.2 (72) / 1.5	
959	1,111	12C330	CrS	1.3		8.8	GB (309)			SS (204)	1.3	
1,324	1,477	12C321	Sup-SIS	1.2		8.8	GB (309)			SS (204)	0.4 (72) / 1.2	
1,599	1,751	12C350	ChS	1.3		8.8	GB (309)			SS (204)	0.3 (71) / 1.3	

Idaho

Station (m)	Section	Construction Number = 1: AC Thicknesses		Base Thickness	Base Type	Subbase Thickness	Subbase Type	Subgrade Type	CN = 2: AC Thicknesses	
0–152	161020 GPS	0.2 (71) 3.6		12.3	GB (304)	8.2	GS (308)	SS (141)	0.2 (71) 3.6	
244–396	16A320 SIS	0.3 (71) 3.8		12.3	GB (304)	8.2	GS (308)	SS (141)	0.2 (72) 0.2 (71)	3.9
427–579	16A330 CrS	0.2 (71) 4.1		12.3	GB (304)	8.2	GS (308)	SS (141)	0.2 (71) 4.1	
640–793	16A350 ChS	0.3 (71) 3.6		12.3	GB (304)	8.2	GS (308)	SS (141)	0.2 (71) 0.3 (71)	3.9
853–1,006	16A310 ThO	0.3 (71) 4		12.3	GB (304)	8.2	GS (308)	SS (141)	1.3 0.2 (71)	3.7

0–152	16B320 SIS	0.3 (71) 5		5.3	GB (304)			SS (254)	0.1 (72) 0.3 (71)	5
183–335	16B330 CrS	0.5 (71) 4.8		5.3	GB (304)			SS (254)	0.5 (71) 4.8	
366–518	161021 GPS	0.3 (71) 5.6		5.3	GB (304)			SS (254)		
610–762	16B310 ThO	0.5 (71) 4.8		5.3	GB (304)			SS (254)	1.1 0.2 (71)	5
823–975	16B350 ChS	0.3 (71) 5.3		5.3	GB (304)			SS (254)	0.2 (71) 0.2 (71)	5.1

0–152	161010 GPS	0.2 (71) 5	5.7	5.4	GB (304)			SS (214)		
244–396	16C320 SIS	0.3 (71) 5.4	5.5	5.4	GB (304)			SS (214)	0.2 (72) 0.2 (71)	5.2 5.6
427–579	16C330 CrS	0.6 (71) 4.9	4.8	5.4	GB (304)			SS (214)	0.6 (71) 4.9	4.8
610–762	16C310 ThO	0.2 (71) 5.3	5	5.4	GB (304)			SS (214)	1.2 0.3 (71)	4.9 4.9
823–975	16C350 ChS	0.6 (71) 4.7	5.1	5.4	GB (304)			SS (214)	0.3 (71) 0.2 (71)	4.5 5.1

Illinois

Station (m)	Section	Construction Number = 1: AC Thicknesses		Base: Thickness	Base: Type	Subbase: Thickness	Subbase: Type	Subgrade Type	CN = 2: AC Thicknesses	
0 152	171003 GPS	1.2 2.5	3.7 4.7			12	TS (338)	SS (102)		
229 381	17A310 ThO	0.8 2.3	3.5 4.7			12	TS (338)	SS (102)	0.5 0.8 2.3	3.5 4.7
442 594	17A320 SIS	1.2 2.2	3.9 4.9			12	TS (338)	SS (102)	0.2 (72) 1.2 2.2	3.9 4.9
686 838	17A350 ChS	1.3 1.9	3.9 4.8			12	TS (338)	SS (102)	0.2 (71) 1.3 1.9	3.9 4.8
899 1,052	17A330 CrS	1.2 2.5	3.7 4.7			12	TS (338)	SS (102)	1.2 2.5	3.7 4.7
1,113 1,265	17A340 CnL	1.2 2.5	3.5 4.4			12	TS (338)	SS (102)		

0 152	171002 GPS	1.4 11.8						SS (217)		
274 427	17B310 ThO	1.4 12.1						SS (217)	1.2 1.4	12.1
488 640	17B320 SIS	1.3 11.4						SS (217)	0.1 (72) 1.3	11.4
701 853	17B330 CrS	1.4 11.8						SS (217)	1.4 11.8	
914 1,067	17B340 CnL	1.4 11.9						SS (217)		
1,128 1,280	17B350 ChS	1.5 12.2						SS (217)	0.2 (71) 1.5	12.2

Indiana

Station (m)	Section	Construction Number = 1: AC Thicknesses		Base: Thickness	Base: Type	Subbase: Thickness	Subbase: Type	Subgrade Type	CN = 2: AC Thicknesses	
0 152	181028 GPS	1.1 2.1 4.2	4 3.9					SS (102)	1 2 3	1.1-2.1 4.2-4.0 3.9
229 381	18A310 ThO	1.1 2.1 4.2	4 3.9					SS (102)	1 1.1 2.1	4.2 4 3.9
850 1,002	18A320 SIS	1.1 2.1 4.2	4 3.9					SS (102)	0.2 (72) 1.1 2.1	4.2 4 3.9
1,063 1,216	18A330 CrS	1.1 2.1 4.2	4 3.9					SS (102)	1.1 2.1 4.2	4 3.9
1,277 1,429	18A340 CnL	1.1 2.1 4.2	4 3.9					SS (102)		
1,642 1,795	18A350 ChS	1.1 2.1 4.2	4 3.9					SS (102)	0.4 (71) 1.1 2.1	4.2 4 3.9

Iowa

Station (m)	Section	Construction Number = 1: AC Thicknesses		Base: Thickness	Base: Type	Subbase: Thickness	Subbase: Type	Subgrade Type	CN = 2: AC Thicknesses	
0 152	196150 GPS	0.4 3.8	0.6 (71)	4.3 3	TB (324) GB (302)			SS (114)	0.4 3.8	0.6 (71)
335 488	19A310 ThO	0.5 4.4	0.9	4.3	TB (324)	3	GS (302)	SS (114)	1.3 0.5	4.4 0.9
762 914	19A320 SIS	0.5 4.2	1.2	4.3	TB (324)	3	GS (302)	SS (114)	0.2 (72) 0.5	4.2 1.2
1,097 1,250	19A330 CrS	0.4 3.5	0.7	4.3	TB (324)	3	GS (302)	SS (114)	0.4 3.5	0.7
1,524 1,676	19A340 CnL	0.4 3.8	0.6	4.3	TB (324)	3	GS (302)	SS (114)		
1,798 1,951	19A350 ChS	0.5 3.1	0.6	4.3	TB (324)	3	GB (302)	SS (114)	0.2 (71) 0.5	3.1 0.6

Kansas

Station (m)	Section	Construction Number = 1: AC Thicknesses		Base: Thickness	Base: Type	Subbase: Thickness	Subbase: Type	Subgrade Type	CN = 2: AC Thicknesses	
0 152	20A330 CrS	2 2.2	4.6 4.4					SS (102)	2 2.2	4.6 4.4
213 366	201005 GPS	2 2.2	4.6 4.4					SS (102)		
457 610	20A310 ThO	2.2 2.5	4.6 4.4					SS (102)	1.2 2.2 2.5	4.6 4.4
701 853	20A320 SIS	2 2.5	4.6 4.4					SS (102)	0.1 (72) 2 2.5	4.6 4.4
914 1,067	20A350 ChS	2 2.5	4.6 4.4					SS (102)	0.2 (71) 2 2.5	4.6 4.4
1,128 1,280	20A340 CnL	1.7 2.2	4.6 4.4					SS (102)		

0 – 152	20B350 ChS	2.5 / 2.4	4.2					SS (114)	0.3 (71) / 2.5	2.4 / 4.2
244 – 396	20B340 CnL	2.1 / 2.4	4.2					SS (114)		
427 – 579	201010 GPS	2.2 / 2.4	4.2					SS (114)		
640 – 793	20B330 CrS	2.2 / 2.4	4.2					SS (114)	2.2 / 2.4	4.2
853 – 1,006	20B320 SIS	2.2 / 2.4	4.2					SS (114)	0.2 (72) / 2.2	2.4 / 4.2
1,067 – 1,219	20B310 ThO	2.5 / 3.3	4.3					SS (114)	1.5 / 2.5	3.3 / 4.3

Kentucky

Station (m)	Section	Construction Number = 1							CN = 2	
		AC Thicknesses		Base		Subbase		Subgrade	AC Thicknesses	
				Thickness	Type	Thickness	Type	Type		
0 – 152	21A320 SIS	1 / 1.1	4.4	9.2	GB (303)			SS (105)	0.1 (72) / 1	1.1 / 4.4
244 – 396	21A350 ChS	0.9 / 1.1	4.4	9.2	GB (303)			SS (105)	0.2 (71) / 0.9	1.1 / 4.4
488 – 640	21A310 ThO	0.9 / 1.2	4.4	9.2	GB (303)			SS (105)	0.8 / 0.9	1.2 / 4.4
701 – 853	21A330 CrS	0.9 / 1.4	4.4	9.2	GB (303)			SS (105)	0.9 / 1.4	4.4 / 9.2
975 – 1,128	21A340 CnL	1.1 / 1.2	4.4	9.2	GB (303)			SS (105)		
1,192 – 1,345	211010 GPS	0.9 / 1.4	4.4	9.2	GB (303)			SS (105)		

0 152	211034 GPS	0.8 3.5	10.3					SS (108)	1 0	3.3 10.3
260 413	21B310 ThO	0.8 3.5	10.3					SS (108)	1 0.8	3.5 10.3
474 626	21B320 SlS	1.3 3.5	6.8					SS (108)	0.2 (72) 1.3	3.5 6.8
687 839	21B330 CrS	0.8 3.5	10.3					SS (108)	0.8 3.5	10.3
900 1,053	21B340 CnL	1.4 3.2	7.4					SS (108)		
1,114 1,266	21B350 ChS	1.1 3.3	6.8					SS (108)	0.3 (71) 1.1	3.3 6.8

Maryland

Station (m)	Section	Construction Number = 1							CN = 2	
		AC Thicknesses		Base		Subbase		Subgrade Type	AC Thicknesses	
				Thickness	Type	Thickness	Type			
0										
320 472	24A310 ThO	3.6		4.8	TB (320)	13	GS (309)	SS (141)	1.5 3.6	
533 686	24A330 CrS	3.6		4.8	TB (320)	13	GS (309)	SS (141)	3.6	
747 899	24A320 SlS	3.2		4.8	TB (320)	13	GS (309)	SS (141)	0.5 (72) 3.2	
960 1,113	24A340 CnL	3.6		4.8	TB (320)	13	GS (309)	SS (141)		
1,173 1,325	24A350 ChS	3.7		4.9	TB (320)	13	GS (309)	SS (141)	0.5 (71) 3.7	
1,386 1,539	24A311 Sup-ThO	3.6		4.8	TB (320)	13	GS (309)	SS (141)	1.5 3.6	
1,584 1,736	24A331 Sup-CrS	3.6		4.8	TB (320)	13	GS (309)	SS (141)	3.6	

Michigan

Station (m)	Section	Construction Number = 1: AC Thicknesses		Base Thickness	Base Type	Subbase Thickness	Subbase Type	Subgrade Type	CN = 2: AC Thicknesses	
0 / 152	261013 GPS	0.8 / 2	3.9	4.8	GB (302)	18.6	GS (306)	SS (202)		
259 / 412	26A310 ThO	0.6 / 2	4.2	4.8	GB (302)	18.6	GS (306)	SS (202)	1.3 / 0.6	2 / 4.2
472 / 625	26A320 SIS	0.6 / 2	4	4.8	GB (302)	18.6	GS (306)	SS (202)	0.1 (72) / 0.6	2 / 4
686 / 838	26A330 CrS	0.8 / 2	3.9	4.8	GB (302)	18.6	GS (306)	SS (202)	0.8 / 2	3.9
899 / 1,052	26A340 CnL	0.6 / 1.7	4.5	4.8	GB (302)	18.6	GS (306)	SS (202)		
1,113 / 1,265	26A350 ChS	0.6 / 1.7	4	4.8	GB (302)	18.6	GS (306)	SS (202)	0.3 (71) / 0.6	1.7 / 4
1,326 / 1,478	26A321 Sup-SIS	0.8 / 2	4.4	4.8	GB (302)	18.6	GS (306)	SS (202)	0.3 (72) / 0.8	2 / 4.4

0 / 152	26B321 Sup-SIS	1.3 / 1.7	2.6	4.8	GB (302)	21.6	GS (306)	SS (114)	0.3 (72) / 1.3	1.7 / 2.6
351 / 503	261012 GPS	1.4 / 1.8	2.9	4.8	GB (302)	21.6	GS (306)	SS (114)		
579 / 732	26B310 ThO	1.3 / 1.9	3.5	4.8	GB (302)	21.6	GS (306)	SS (114)	1.3 / 1.3	1.9 / 3.5
793 / 945	26B320 SIS	0.9 / 2.3	2.7	4.8	GB (302)	21.6	GS (306)	SS (114)	0.2 (72) / 0.9	2.3 / 2.7
1,006 / 1,158	26B330 CrS	1.4 / 1.8	2.9	4.8	GB (302)	21.6	GS (306)	SS (114)	1.4 / 1.8	2.9
1,237 / 1,390	26B340 CnL	0.9 / 2.1	3	4.8	GB (302)	21.6	GS (306)	SS (114)		
1,458 / 1,611	26B350 ChS	0.7 / 1.8	3.3	4.8	GB (302)	21.6	GS (306)	SS (114)	0.3 (71) / 0.7	1.8 / 3.3

0 152	261001 GPS	2.2		10.9	GB (302)			SS (202)		
234 387	26C310 ThO	2		10.9	GB (302)			SS (202)	1.1 2	
727 880	26C320 SIS	1.9		10.9	GB (302)			SS (202)	0.1 (72) 1.9	
941 1,093	26C330 CrS	2.2		10.9	GB (302)			SS (202)	2.2	
1,154 1,306	26C340 CnL	1.9		10.9	GB (302)			SS (202)		
1,367 1,520	26C350 ChS	1.8		10.9	GB (302)			SS (202)	0.3 (71) 1.8	
1,581 1,733	26C351 Sup-ChS	1.9		10.9	GB (302)			SS (202)	0.2 (71) 1.9	

0 152	261010 GPS	0.8 1.4		11.4	GB (302)	19	GS (306)	SS (135)		
427 579	26D320 SIS	0.8 1.5		11.4	GB (302)	19	GS (306)	SS (135)	0.2 (72) 0.8	1.5
640 793	26D330 CrS	0.8 1.4		11.4	GB (302)	19	GS (306)	SS (135)	0.8 1.4	
853 1,006	26D310 ThO	0.9 1.4		11.4	GB (302)	19	GS (306)	SS (135)	1.4 0.9	1.4
1,346 1,498	26D350 ChS	0.9 1.8		11.4	GB (302)	19	GS (306)	SS (135)	0.3 (71) 0.9	1.8
1,559 1,712	26D351 Sup-ChS	0.8 1.9		11.4	GB (302)	19	GS (306)	SS (135)	0.2 (71) 0.8	1.9
1,772 1,925	26D340 CnL	0.9 1.2		11.4	GB (302)	19	GS (306)	SS (135)		

Minnesota

Station (m)	Section	Construction Number = 1							CN = 2	
		AC Thicknesses		Base		Subbase		Subgrade	AC Thicknesses	
				Thickness	Type	Thickness	Type	Type		
0 152	271016 GPS	1.6 1.4		6.5	GB (302)			SS (204)		
383 535	27A310 ThO	1.4 1.8		6.5	GB (303)			SS (204)	1.1 1.4	1.8
596 748	27A320 SIS	1.6 1.7		6.5	GB (303)			SS (204)	0.2 (72) 1.6	1.7
840 992	27A330 CrS	1.6 1.4		6.5	GB (303)			SS (204)	1.6 1.4	
1,206 1,358	27A340 CnL	1.5 1.3		6.5	GB (303)			SS (204)		
1,419 1,571	27A350 ChS	1.5 1.3		6.5	GB (303)			SS (204)	0.2 (71) 1.5	1.3

0 152	276251 GPS	7.4		10.2	GB (302)			SS (204)		
610 762	27B310 ThO	6		10.2	GB (302)			SS (204)	1.3 6	
884 1,036	27B320 SIS	5.4		10.2	GB (302)			SS (204)	0.1 (72) 5.4	
1,555 1,707	27B330 CrS	7.4		10.2	GB (302)			SS (204)	7.4	
1,798 1,951	27B340 CnL	6.3		10.2	GB (302)			SS (204)		
2,499 2,652	27B350 ChS	5.4		10.2	GB (302)			SS (204)	0.1 (71) 5.4	

0 152	271028 GPS	1.6 2	6					SS (204)		
263 415	27C310 ThO	1.5 2	6					SS (204)	1 1.5	2 6
781 934	27C320 SIS	1.4 2	5.6					SS (204)	0.1 (72) 1.4	2 5.6
1,056 1,208	27C330 CrS	1.6 2	6					SS (204)	1.6 2	6
1,482 1,635	27C340 CnL	1.4 2	5.7					SS (204)		
1,696 1,848	27C350 ChS	1.5 2	5.6					SS (204)	0.2 (71) 1.5	2 5.6

0 152	27D310 ThO	0.5 2	2.3	6.4	GB (302)			SS (204)	1.4 0.5	2 2.3
213 366	271019 GPS	0.8 1.7	2.5	6.4	GB (302)			SS (204)		
427 579	27D330 CrS	0.8 1.7	2.4	6.4	GB (302)			SS (204)	0.8 1.7	2.4
762 914	27D320 SIS	0.8 1.7	2.4	6.4	GB (302)			SS (204)	0.3 (72) 0.8	1.7 2.4
975 1,128	27D340 CnL	1.1 1.7	2.4	6.4	GB (302)			SS (204)		
1,311 1,463	27D350 ChS	0.7 1.2	2.3	6.4	GB (302)			SS (204)	0.3 (71) 0.7	1.2 2.3

Mississippi

Station (m)	Section	Construction Number = 1							CN = 2	
		AC Thicknesses		Base Thickness	Base Type	Subbase Thickness	Subbase Type	Subgrade Type	AC Thicknesses	
0–152	281802 GPS	1.3 1.9		4.7	TB (319)	2	GS (309)	SS (202)		
152–244										
244–396	28A310 ThO	1.3 1.9		4.7	TB (1)	2	GS (309)	SS (202)	1.2 1.3	1.9
396–488										
488–640	28A330 CrS	1.2 1.9		4.7	TB (1)	2	GS (309)	SS (202)	1.2 1.9	
640–762										
762–914	28A320 SIS	1 2		5.5	TB (1)	2	GS (309)	SS (202)	0.3 (72) 1	2
914–945										
945–1,097	28A350 ChS	1.3 1.9		4.7	TB (1)	2	GS (309)	SS (202)	0.3 (71) 1.3	1.9

Missouri

Station (m)	Section	Construction Number = 1							CN = 2	
		AC Thicknesses		Base Thickness	Base Type	Subbase Thickness	Subbase Type	Subgrade Type	AC Thicknesses	
0–152	29A340 CnL	0.9 1.7	6.3	38	GB (303)			SS (113)		
152–335										
335–488	291005 GPS	1 1.9	6	39	GB (303)			SS (113)		
488–579										
579–732	29A310 ThO	0.9 1.9	5.9	38	GB (303)			SS (113)	1.8 0.9	1.9 5.9
732–884										
884–1,036	29A320 SIS	1 2.1	5.1	38	GB (303)			SS (113)	0.1 (72) 1	2.1 5.1
1,036–1,097										
1,097–1,250	29A330 CrS	1 1.9	6	38	GB (303)			SS (113)	1 1.9	6
1,250–1,311										
1,311–1,463	29A350 ChS	1.1 2.2	5.6	38	GB (303)			SS (113)	0.3 (71) 1.1	2.2 5.6
1,463–1,555										
1,555–1,707	29A351 Sup-ChS	1 1.9	6	38	GB (303)			SS (113)	0.4 (71) 1	1.9 6

Station (m)	Section	AC Thicknesses		Base Thickness	Base Type	Subbase Thickness	Subbase Type	Subgrade Type	CN = 2 AC Thicknesses	
0–152	29B351 Sup-ChS	2.2 / 8.1	3.6	4.2	GB (303)			SS (217)	0.4 (71) / 2.2	8.1 / 3.6
427–579	29B310 ThO	1.5 / 1.7	4.1	4.2	GB (303)			SS (217)	1.8 / 1.5	1.7 / 4.1
640–793	29B320 SIS	1.6 / 1.6	4	4.2	GB (303)			SS (217)	0.1 (72) / 1.6	1.6 / 4
853–1,006	29B330 CrS	2.2 / 8.1	3.6	4.2	GB (303)			SS (217)	2.2 / 8.1	3.6
1,158–1,311	29B340 CnL	1.4 / 1.1	3.9	4.2	GB (303)			SS (217)		
1,372–1,524	29B350 ChS	1.5 / 1.3	4	4.2	GB (303)			SS (217)	0.3 (71) / 1.5	1.3 / 4
1,707–1,859	291002 GPS	1.2 / 1.6	4	6	GB (303)			SS (267)		

Montana

Station (m)	Section	Construction Number = 1: AC Thicknesses		Base: Thickness	Base: Type	Subbase: Thickness	Subbase: Type	Subgrade Type	CN = 2: AC Thicknesses	
0										
1,067–1,219	30A310 ThO	0.1 (71) / 3		17	GB (302)	12	GS (308)	SS (148)	1.9 / 0.1 (71)	2.9
1,433–1,586	301001 GPS	0.1 (71) / 2.7		13.9	GB (304)	9.2	GS (308)	SS (267)		
1,662–1,814	30A320 SIS	0.1 (71) / 3.2		22	GB (302)	9.2	GS (308)	SS (148)	0.2 (72) / 0.2 (71)	3.2
1,875–2,028	30A330 CrS	0.1 (71) / 3.3		13.3	GB (302)	13	GS (308)	SS (148)	0.1 (71) / 3.3	
2,119–2,271	30A350 ChS	0.1 (71) / 3		17.3	GB (302)	9.2	GS (308)	SS (148)	0.2 (71) / 0.1 (71)	3

Nebraska

Station (m)	Section	Construction Number = 1: AC Thicknesses		Base: Thickness	Base: Type	Subbase: Thickness	Subbase: Type	Subgrade Type	CN = 2: AC Thicknesses	
0 152	311030 GPS	2 5.2						SS (141)	?? (73) 2	5.2
716 869	31A310 ThO	1.8 5.2						SS (141)	1 1.8	5.2
1,113 1,265	31A320 SlS	2 5.3						SS (141)	0.1 (72) 2	5.3
1,448 1,600	31A330 CrS	2 5.2						SS (141)	2 5.2	
1,905 2,057	31A340 CnL	1.9 5.1						SS (141)		
2,698 2,850	31A350 ChS	2 6.5						SS (141)	0.2 (71) 2	6.5
3,002 3,155	31A351 Sup-ChS	2.3 7						SS (141)	0.1 (71) 2.3	7
3,429 3,581	31A352 Sup-ChS	2 5.2						SS (141)	0.4 (71) 2	5.2
3,642 3,795	31A353 Sup-ChS	2.3 8.3						SS (141)	0.1 (71) 2.3	8.3

Nevada

Station (m)	Section	Construction Number = 1: AC Thicknesses		Base Thickness	Base Type	Subbase Thickness	Subbase Type	Subgrade Type	CN = 2: AC Thicknesses	
0 152	32A330 CrS	0.9 (2) 7.5		2.8	GB (308)	8.4	GS (338)	SS (216)	0.9 (2) 7.5	
213 366	321021 GPS	0.8 (2) 7		2.8	GB (308)	3.2	GS (308)	SS (216)		
643 796	32A310 ThO	0.9 (2) 7.5		2.8	GB (308)	3.2	GS (308)	SS (216)	1.1 0.7 (2)	7.5
826 978	32A320 SlS	0.9 (2) 7.6		2.8	GB (308)	3.2	GS (308)	SS (216)	0.3 (72) 0.6 (2)	7.5
1,236 1,388	32A350 ChS	0.9 (2) 8		9.2	GB (308)	3.2	GS (308)	SS (216)	0.3 (71) 0.6 (2)	8.6
1,565 1,717	32A351 Sup-ChS	1 (2) 9.5		2.8	GB (308)	3.2	GS (308)	SS (216)	0.5 (71) 0.9 (2)	9.5 7.2 (GB308) 0 (GS308)
1,778 1,930	32A352 Sup-ChS	1.1 (2) 10.6		2.8	GB (302)	3.2	GS (308)	SS (113)	0.5 (71) 1.1 (2)	10.6

0 152	32B320 SlS	0.8 (2) 5		5	TB (321)	8	GS (308)	SS (255)	0.1 (72) 0.9 (2)	3.9
183 335	32B310 ThO	0.7 (2) 3.8		5.3	TB (321)	4.5	GS (308)	SS (255)	1.5 1 (2)	3.4
571 723	32B350 ChS	0.8 (2) 5.1		4	TB (321)	9	GS (308)	SS (255)	0.2 (71) 0.8 (2)	5.2
784 936	32B330 CrS	0.8 (2) 3.7		5	TB (321)	4	GS (308)	SS (255)	0.8 (2) 3.7	
967 1,119	32B340 CnL	0.8 (2) 5.1		5	TB (321)	10	GS (308)	SS (255)		

Station (m)	Section	AC Thicknesses		Base Thickness	Base Type	Subbase Thickness	Subbase Type	Subgrade Type	CN = 2 AC Thicknesses	
0–152	32C320 SIS	0.2 (71) 0.7 (2)	4.8	4.2	TB (321)	6.4	GS (302)	SS (265)	0.4 (72) 0.2 (71)	0.8 (2) 4.4
213–366	32C330 CrS	0.2 (71) 0.7 (2)	4.8	4.2	TB (321)	6.4	GS (302)	SS (265)	0.2 (71) 0.7 (2)	4.8
431–583	322027 GPS	0.2 (71) 0.7 (2)	4.8	4.2	TB (321)	6.4	GS (302)	SS (265)		
777–930	32C310 ThO	0.2 (71) 0.7 (2)	4.8	4.2	TB (321)	6.4	GS (302)	SS (265)	1.9 0.2 (71)	0.9 (2) 4.4
991–1,143	32C350 ChS	0.2 (71) 0.7 (2)	4.8	4.2	TB (321)	6.4	GS (302)	SS (265)	0.4 (71) 0.2 (71)	0.5 (2) 4.8 (1)

New York

Station (m)	Section	Construction Number = 1: AC Thicknesses		Base: Thickness	Base: Type	Subbase: Thickness	Subbase: Type	Subgrade Type	CN = 2: AC Thicknesses	
0–230										
230–382	36A340 CnL	2.2		8.2	TB (319)	7.2	GS (304)	SS (211)	2.2	
443–596	36A310 ThO	2.2		8.2	TB (319)	7.2	GS (304)	SS (211)	1 2.2	
657–809	36A320 SIS	2.7		7.6	TB (319)	7.2	GS (304)	SS (211)	0.5 (72) 2.7	
870–1,023	36A330 CrS	2.2		8.2	TB (319)	7.2	GS (304)	SS (211)	2.2	
1,084–1,236	36A350 ChS	2.6		8	TB (319)	7.2	GS (304)	SS (211)	0.8 (71) 2.6	
1,298–1,450	36A321 Sup-SIS	2.2		8.2	TB (319)	7.2	GS (304)	SS (211)	2.2	
1,510–1,663	36A331 Sup-CrS	2.2		8.2	TB (319)	7.2	GS (304)	SS (211)	2.2	

0 152	36B331 Sup-CrS	1 1.3		6.3	TB (321)	14.5	GS (308)	SS (203)	1 1.3	
214 366	36B350 ChS	0.9 1.1		6.2	TB (321)	14.5	GS (308)	SS (203)	0.4 (71) 0.9	1.1
428 580	36B340 CnL	1 1.3		6.3	TB (321)	14.5	GS (308)	SS (203)		
642 794	36B330 CrS	1 1.3		6.3	TB (321)	14.5	GS (308)	SS (203)	1 1.3	
855 1,007	36B351 Sup-ChS	1 1.3		6.3	TB (321)	14.5	GS (308)	SS (203)	1 1.3	
1,069 1,221	36B320 SlS	1 2.2		6.9	TB (321)	14.5	GS (308)	SS (203)	0.5 (72) 1	2.2
1,283 1,435	36B310 ThO	1 1.3		6.3	TB (321)	14.5	GS (308)	SS (203)	1 1	1.3
1,878 2,031	36B352 Sup-ChS	1 1.3		6.3	TB (321)	14.5	GS (308)	SS (203)	1 1.3	
2,264 2,417	36B353 Sup-ChS	1 1.3		6.3	TB (321)	14.5	GS (308)	SS (203)	1 1.3	
2,417 2,569	36B354 Sup-ChS	1 1.3		6.3	TB (321)	14.5	GS (308)	SS (203)	1 1.3	

Oklahoma

Station (m)	Section	Construction Number = 1							CN = 2	
		AC Thicknesses		Base		Subbase		Subgrade	AC Thicknesses	
				Thickness	Type	Thickness	Type	Type		
0 152	404087 GPS	2.2		7.9	TB (319)	6	TS (338)	SS (108)	??? ???	2.2
259 412	40A310 ThO	??? ???				???	???	???	??? ???	???
472 625	40A320 SlS	2.3 7.4 (319)				6	TS (338)	SS (108)	0.2 (72) 2	8.3 (319)
700 852	40A330 CrS	1.5 8 (319)				6	TS (338)	SS (108)		
882 1,035	40A340 CnL	1.7 7.9 (319)				6	TS (338)	SS (108)		
1,157 1,309	40A350 ChS	1.9 7.7 (319)				6	TS (338)	SS (108)	0.3 (71) 1.7	7.7 (319)

0 152	401015 GPS	1.4		8.1	TB (319)			SS (214)		
259 412	40B310 ThO	1.4 9 (319)						SS (214)	1.2 1.4	9 (319)
472 625	40B320 SIS	1.4 6.6 (319)						SS (214)	0.2 (72) 1.4	7.7 (319)
671 823	40B330 CrS	1.4 8.3 (319)						SS (214)	1.4 8.3 (319)	
1,535 1,687	40B350 ChS	1.8 8.5 (319)						SS (214)	0.3 (71) 1.3	8.6 (319)
1,768 1,920	40B360 Sup-???	??? ???						???	??? ???	???

0										
213 366	40C310 ThO	1.5 3		7.7	TB (320)	6.1	TS (338)	SS (114)	1.9 1.5	3
627 779	404088 GPS	1.5 3		7.7	TB (320)	6.1	TS (338)	SS (114)		
960 1,113	40C320 SIS	1.6 2.9		8.3	TB (320)	6.1	TS (338)	SS (114)	0.2 (72) 1.4	3
1,204 1,356	40C330 CrS	1.4 2.9		8	TB (320)	6.1	TS (338)	SS (114)	1.4 2.9	
1,448 1,600	40C350 ChS	1.7 2.8		7.6	TB (320)	6.1	TS (338)	SS (114)	0.3 (71) 1.5	2.8

Pennsylvania

Station (m)	Section	Construction Number = 1 AC Thicknesses		Base Thickness	Base Type	Subbase Thickness	Subbase Type	Subgrade Type	CN = 2 AC Thicknesses	
0 152	42A340 CnL	1.5 6.6		16.2	GB (304)			SS (267)		
184 336	42A320 SlS	1.6 6.4		16.2	GB (304)			SS (267)	0.5 (72) 1.6	6.4
368 520	42A310 ThO	1.5 6.6		16.2	GB (304)			SS (267)	1.7 1.5	6.6
552 704	42A350 ChS	1.9 6.4		16.2	GB (304)			SS (267)	0.5 (71) 1.9	6.4
737 889	42A351 Sup-ChS	1.5 6.6		16.2	GB (304)			SS (267)	1.5 6.6	
961 1,113	42A330 CrS	1.5 6.6		16.2	GB (304)			SS (267)	1.5 6.6	

0 152	42B351 Sup-ChS	1.5 4.9		16.4	GB (302)			SS (111)		
176 328	42B340 CnL	1.5 4.9		16.4	GB (302)			SS (111)		
2,325 2,477	42B330 CrS	1.5 4.9		16.4	GB (302)			SS (111)		
2,500 2,653	42B350 ChS	1.7 5.1		16.4	GB (302)			SS (111)		
2,995 3,148	42B310 ThO	1.5 4.9		16.4	GB (302)			SS (111)	1.6 1.5	4.9

Tennessee

Station (m)	Section	Construction Number = 1: AC Thicknesses		Base: Thickness	Base: Type	Subbase: Thickness	Subbase: Type	Subgrade Type	CN = 2: AC Thicknesses	
0 152	47A310 ThO	1 (71) 1.6	3 2.2	5.5	GB (303)			SS (109)	1.2 0.9 (71) 1.6	3.4 2.9
152 259										
259 412	47A320 SlS	1.1 (71) 2.2	2.4 3.3	5.5	GB(303)			SS (109)	0.3 (72) 1.1 (71) 1.5	3.8 3.3
442 594	47A330 CrS	0.9 (71) 1.4	2.6 4.8	5.5	GB (303)			SS (109)	0.9 (71) 1.4	2.6 4.8
594 762										
762 914	473101 GPS	0.6 (71) 3.5	2.1	3.3	TB (319)	5.5	GS (303)	SS (109)	??? 0.6 (71)	3.5 2.1
914 1,052										
1,052 1,204	47A350 ChS	0.6 (71) 3.5	2.1 3.3	5.5	GB (303)			SS (109)	0.4 (71) 0.6 (71) 3.5	2.1 3.3

0 152	47B310 ThO	0.8 0.8		3.6	TB (319)	9.2	GS (303)	SS (265)	0.9 0.8	1 4.1 (TB319)
152 267										
267 419	47B320 SlS	0.7 0.6		3.3	TB (319)	9.2	GS (303)	SS (265)	0.2 (72) 0.7	1
770 922	473075 GPS	0.7 1.2	3.1	9.2	GB (303)			SS (265)		
1,410 1,562	47B330 CrS	0.8 1		4.3	TB (319)	9.2	GS (303)	SS (265)	0.8 1	
1,562 1,654										
1,654 1,806	47B350 ChS	0.6 1.5		3	TB (319)	9.2	GS (303)	SS (265)	0.3 (71) 0.8	1.6 3.4 (TB319)

0 152	471023 GPS	0.5 1.5	3.4	6.1	TB (321)	6	GS (303)	SS (120)	0.5 1.5	3.4
259 412	47C330 CrS	0.5 1.6	3.2	5.7	TB (321)	6	GS (303)	SS (120)	0.5 1.6	3.2
488 640	47C350 ChS	0.6 1.8	3	5.9	TB (321)	6	GS (303)	SS (120)	0.3 (71) 0.6	1.8 3
777 930	47C320 SlS	0.4 2	3	7.1	TB (321)	6	GS (303)	SS (120)	0.1 (72) 0.4	2 3
960 1,113	47C310 ThO	0.6 2.5	2.8	6.3	TB (321)	6	GS (303)	SS (120)	0.9 0.6	2.5 2.8
1,161 1,313	47C311 Sup-ThO	0.5 1.5	3.4	6.1	TB (321)	6	GS (303)	SS (120)	1 0.5	1.5 3.4

Texas

Station (m)	Section	Construction Number = 1							CN = 2	
		AC Thicknesses		Base		Subbase		Subgrade Type	AC Thicknesses	
				Thickness	Type	Thickness	Type			
0 152	48A310 ThO	0.8 1.2		8.4	GB (303)			SS (217)	1.1 0.8	1.2
305 457	481094 GPS	0.7 1.2		8.4	GB (303)			SS (217)	??? 0.7	1.2
640 793	48A320 SlS	0.7 1.2		8.4	GB (303)			SS (217)	0.2 (72) 0.7	1.2
914 1,067	48A330 CrS	0.7 1.1		8.4	GB (303)			SS (217)		
1,128 1,280	48A340 CnL	0.9 1.1		8.4	GB (303)			SS (217)		

0 152	48B310 ThO	1.5 6.6		15.2	TB (350)	6.5	TS (338)	SS (103)	0.7 1.2	7.4
274 427	48B320 SlS	2.1 7.8		15.2	TB (350)	6.5	TS (338)	SS (103)	0.2 (72) 1.7	7.8
793 945	481069 GPS	1.7 7.8		15.2	TB (350)	6.5	TS (338)	SS (103)	1.7 7.8	
1,036 1,189	48B330 CrS	1.9 8.2		15.2	TB (350)	6.5	TS (338)	SS (103)	1.9 8.2	
1,250 1,402	48B340 CnL	1.7 7.9		15.2	TB (350)	6.5	TS (103)	SS (103)		
1,555 1,707	48B350 ChS	1.6 8.2		15.2	TB (350)	6.5	TS (338)	SS (103)	0.3 (71) 1.5	8

0 152	48D310 ThO	1 (2) 1.8	7.3	6.8	TB (327)	8.8	GS (309)	SS (216)	1 (2) 1.8	7.3
274 427	48D320 SlS	1.2 (2) 2.4	7	6.8	TB (327)	8.8	GS (309)	SS (216)	1.2 (2) 2.4	7
975 1,128	482172 GPS	0.9 (2) 2.1	7.9	6.8	TB (327)	8.8	GS (309)	SS (216)	0.9 (2) 2.1	7.9
1,356 1,509	48D330 CrS	1 (2) 2.2	8.1	6.8	TB (327)	8.8	GS (309)	SS (216)	1 (2) 2.2	8.1
1,600 1,753	48D350 ChS	0.8 (2) 2.6	6.7	6.8	TB (327)	8.8	GS (309)	SS (216)	0.8 (2) 2.6	6.7

0 152	481183 GPS	0.4 (71) 0.9	4.4	8.4	GB (309)			SS (114)	0.4 (71) 0.9	4.4
533 686	48E310 ThO	0.6 (71) 1.2	4.4	8.4	GB (309)			SS (114)	0.6 (71) 1.2	4.4
869 1,021	48E320 SlS	0.6 (71) 1.4	4.1	8.4	GB (309)			SS (114)	0.6 (71) 1.4	4.1
1,082 1,234	48E330 CrS	0.6 (71) 1.8	3.9	8.4	GB (309)			SS (114)	0.6 (71) 1.8	3.9
1,295 1,448	48E340 CnL	0.6 (71) 1.6	3.8	8.4	GB (309)			SS (114)	0.6 (71) 1.6	3.8
1,600 1,753	48E350 ChS	0.3 (71) 1.6	4.2	8.4	GB (309)			SS (114)	0.3 (71) 1.6	4.2
1,936 2,088	48E351 Sup-ChS	??? ???	???	???	???			???	??? ???	???
2,240 2,393	48E352 Sup-ChS	0.5 (71) 1.8	4.3	8.4	GB (309)			SS (114)	0.5 (71) 1.8	4.3

0 152	483579 GPS	1.1 0.6 (71)		10.8	GB (308)	9.2	TS (338)	SS (114)	??? 1.1	0.6 (71)
579 732	48F310 ThO	1.3 0.6 (71)		10.8	GB (308)	9.2	TS (338)	SS (114)	1 1.6	0.6 (71)
1,128 1,280	48F320 SlS	1.2 0.6 (71)		10.8	GB (308)	9.2	TS (338)	SS (114)	0.1 (72) 1	0.7 (71)
1,433 1,585	48F330 CrS	0.8 0.8 (71)		10.8	GB (308)	9.2	TS (338)	SS (114)	0.8 0.8 (71)	
1,676 1,829	48F340 CnL	1.3 0.8 (71)		10.8	GB (308)	9.2	TS (338)	SS (114)	1.3 0.8 (71)	
1,905 2,057	48F350 ChS	1.2 0.6 (71)		10.8	GB (308)	9.2	TS (338)	SS (114)	0.3 (71) 0.9	0.6 (71)

0 152	48G310 ThO	0.5 (71) 1.6	0.4 (71)	11.3	GB (309)			SS (202)	1.2 0.5 (71)	1.2 0.4 (71)
366 518	481169 GPS	0.4 (71) 1.1	0.4 (71)	11.3	GB (309)			SS (202)		
762 914	48G320 SlS	0.4 (71) 1.6	0.4 (71)	11.3	GB (309)			SS (202)	0.1 (72) 0.4 (71)	0.8 0.4 (71)
1,036 1,189	48G330 CrS	0.5 (71) 1.6	0.4 (71)	11.3	GB (309)			SS (202)		
1,280 1,433	48G350 ChS	0.6 (71) 1.5	0.4 (71)	11.3	GB (309)			SS (202)	0.2 (71) 0.4 (71)	1.5 0.4 (71)

0 152	48H351 Sup-ChS	1.1 0.3 (71)		8.6	GB (303)	6.5	TS (338)	SS (108)	0.3 (71) 1.1	0.3 (71) 9.6(GB303)
366 518	48H310 ThO	1.4 0.8 (71)		9.6	GB (303)	6.5	TS (338)	SS (108)	1.2 1	0.8 (71)
671 823	48H320 SlS	1.8 0.8 (71)		9.6	GB (303)	6.5	TS (338)	SS (108)	0.2 (72) 1	0.8 (71)
1,006 1,158	481050 GPS	1 0.8 (71)		9.6	GB (303)	6.5	TS (338)	SS (108)		
1,250 1,402	48H350 ChS	1.7 0.8 (71)		9.6	GB (303)	6.5	TS (338)	SS (108)	0.2 (71) 1	0.8 (71)
1,463 1,615	48H340 CnL	1.9 0.5 (71)		9.6	GB (303)	6.5	TS (338)	SS (108)		
1,707 1,859	48H330 CrS	1.2 0.6 (71)		9.6	GB (303)	6.5	TS (338)	SS (108)	1.2 0.6 (71)	

0 152	483559 GPS	0.3 (71) 0.6		6.1	TB (319)	6.3	GS (308)	SS (214)		
305 457	48I310 ThO	0.2 (71) 1	6.6	6.3	GB (308)			SS (214)	0.6 0.3 (71)	0.9 8.6
549 701	48I320 SlS	0.2 (71) 1	7	6.3	GB (308)			SS (214)	0.2 (72) 0.3 (71)	0.6 7
762 914	48I330 CrS	0.2 (71) 1.1	6.2	6.3	GB (308)			SS (214)		
1,067 1,219	48I340 CnL	0.3 (71) 0.8	6.4	6.3	GB (308)			SS (214)		
1,737 1,890	48I350 ChS	0.2 (71) 0.7	8.4	6.3	GB (308)			SS (214)	0.2 (71) 0.4 (71)	0.6 8

0										
914 1,067	48J310 ThO	1 (71) 1.8	1.6	15.6	GB (308)	8.4	GS (309)	SS (216)	0.9 1 (71)	1.8 1.6
1,219 1,372	48J320 SlS	1 (71) 1.5	1.6	15.6	GB (308)	8.4	GS (309)	SS (216)	0.1 (72) 1 (71)	1.5 1.6
1,433 1,585	48J330 CrS	0.8 (71) 1.5	1.6	15.6	GB (308)	8.4	GS (309)	SS (216)		
1,829 1,981	481122 GPS	0.4 (71) 1.4	1.6	15.6	GB (308)	8.4	GS (309)	SS (216)		
2,073 2,225	48J340 CnL	0.7 (71) 1.7	1.6	15.6	GB (308)	8.4	GS (309)	SS (216)		
2,591 2,743	48J350 ChS	0.8 (71) 1.8	1.6	15.6	GB (308)	8.4	GS (309)	SS (216)	0.2 (71) 0.7 (71)	1.8 1.6
3,688 3,841	48J351 Sup-ChS	0.5 (71) 2.1	1.6	15.6	GB (308)	8.4	GS (309)	SS (216)	0.1 (71) 0.5 (71)	2.1 1.6

0										
518 671	48K351 Sup-ChS	1.2 0.5 (71)		9.4	GB (307)			SS (118)	1.2 0.5 (71)	
1,920 2,073	48K310 ThO	1.9 0.4 (71)		9.4	GB (307)			SS (118)	1.9 0.4 (71)	
2,256 2,408	48K320 SlS	1.8 0.4 (71)		9.4	GB (307)			SS (118)	1.8 0.4 (71)	
2,469 2,621	48K330 CrS	1.1 0.5 (71)		9.4	GB (307)			SS (118)		
2,804 2,957	489005 GPS	1.1 0.4 (71)		9.4	GB (307)			SS (118)		
3,048 3,200	48K340 CnL	1.1 0.4 (71)		9.4	GB (307)			SS (118)		
3,353 3,505	48K350 ChS	1.1 0.4 (71)		9.4	GB (307)			SS (118)	1.1 0.4 (71)	

0 152	483769 GPS	0.4 (71) 2		8.4	GB (303)			SS (215)		
351 503	48L310 ThO	0.3 (71) 1.8		8.4	GB (303)			SS (215)	0.3 (71) 1.8	
625 777	48L320 SlS	0.3 (71) 1.8		8.4	GB (303)			SS (215)	0.3 (71) 1.8	
960 1,113	48L330 CrS	0.3 (71) 1.6		8.4	GB (303)			SS (215)	0.3 (71) 1.6	
1,158 1,311	48L340 CnL	0.3 (71) 1.6		8.4	GB (303)			SS (215)		
1,402 1,555	48L350 ChS	0.4 (71) 1.6		8.4	GB (303)			SS (215)	0.4 (71) 1.6	

0 152	483749 GPS	0.3 (71) 1.5		8.1	GB (308)	8.8	TS (338)	SS (216)	0.3 (71) 1.5	
305 457	48M310 ThO	0.2 (71) 1.6		8.1	GB (308)	8.8	TS (338)	SS (216)	0.6 0.4 (71)	1.6
610 762	48M320 SlS	0.2 (71) 1.5		8.1	GB (308)	8.8	TS (338)	SS (216)	0.1 (72) 0.2 (71)	1.8
823 975	48M330 CrS	0.3 (71) 2.1		8.1	GB (308)	8.8	TS (338)	SS (216)	0.3 (71) 2.1	
1,036 1,189	48M340 CnL	0.4 (71) 2		8.1	GB (308)	8.8	TS (338)	SS (216)	0.4 (71) 2	
1,341 1,494	48M350 ChS	0.2 (71) 1.8		8.1	GB (308)	8.8	TS (338)	SS (216)	0.2 (71) 0.4 (71)	1.5

0 152	483739 GPS	0.3 (71) 1.5		11.4	GB (308)	7.4	TS (338)	SS (202)	0.3 (71) 0.3 (71)	1.5
366 518	48N310 ThO	0.2 (71) 1.4		11.4	GB (308)	7.4	TS (338)	SS (202)	1 0.2 (71)	1.4
671 823	48N320 SlS	0.3 (71) 1.8		11.4	GB (308)	7.4	TS (338)	SS (202)	0.4 (72) 0.3 (71)	1.8
914 1,067	48N330 CrS	0.3 (71) 1.5		11.4	GB (308)	7.4	TS (338)	SS (202)	0.3 (71) 1.5	
1,128 1,280	48N340 CnL	0.3 (71) 1.5		11.4	GB (308)	7.4	TS (338)	SS (202)		
2,012 2,164	48N350 ChS	0.3 (71) 1.6		11.4	GB (308)	7.4	TS (338)	SS (202)	0.4 (71) 0.3 (71)	1.6

0 152	48Q310 ThO	0.3 (71) 1.8		7.5	GB (308)	10	GS (308)	SS (114)	0.8 0.4 (71)	2
244 396	48Q320 SlS	0.3 (71) 1.8		7.5	GB (308)	10	GS (308)	SS (114)	0.1 (72) 0.4 (71)	1.9
579 732	483865 GPS	0.4 (71) 1.9		7.5	GB (308)	10	GS (308)	SS (114)		
884 1,036	48Q330 CrS	0.5 (71) 1.8		7.5	GB (308)	10	GS (308)	SS (114)		
2,256 2,408	48Q340 CnL	0.5 (71) 1.5		7.5	GB (308)	10	GS (308)	SS (114)		
2,499 2,652	48Q350 ChS	0.4 (71) 1.8		7.5	GB (308)	10	GS (308)	SS (114)	0.3 (71) 0.6 (71)	1.5
2,713 2,865	48Q353 Sup-ChS	0.5 (71) 1.6		7.5	GB (308)	10	GS (308)	SS (114)	0.3 (71) 0.5 (71)	1.6

Utah

Station (m)	Section	Construction Number = 1 AC Thicknesses		Base Thickness	Base Type	Subbase Thickness	Subbase Type	Subgrade Type	CN = 2 AC Thicknesses	
0 152	49A330 CrS	0.5 (71) 4.4	3.6	7	GB (304)			SS (215)	0.5 (71) 4.4	3.6
213 366	49A320 SlS	0.3 (71) 4.1	2.4	8.7	GB (304)			SS (215)	0.2 (72) 0.3 (71)	4.4 2.8
427 579	49A350 ChS	0.3 (71) 4.5	3	7.2	GB (304)			SS (215)	0.2 (71) 0.4 (71)	4.4 2.9
671 823	49A390 Sup-???	0.4 (71) 4.2	2.9	9.2	GB (304)			SS (215)	0.3 (71) 0.2 (71)	4.2 2.5
914 1,067	49A310 ThO	0.4 (71) 4.8	2.9	8.2	GB (304)			SS (215)	0.9 0.4 (71)	4.7 2.9
1,250 1,402	491004 GPS	0.4 (71) 4.2	0.3 (71) 2.9	9.2	GB (304)			SS (215)		
1,509 1,661	49A332 Sup-CrS	0.2 (71) 4.2	2	6.4	GB (304)			SS (215)		
1,753 1,905	49A351 Sup-ChS	0.5 (71) 4.4	2.5	8.5	GB (304)			SS (215)	0.3 (71) 0.4 (71)	4.4 2.7
2,027 2,179	49A352 Sup-ChS	0.3 (71) 5.1	3.4	8.2	GB (304)			SS (215)	0.4 (71) 0.3 (71)	4.8 3.2
2,277 2,429	49A361 Sup-???	0.4 (71) 4.2	2.1	8.9	GB (304)			SS (215)	0.6 0.4 (71)	4.3 2.4

0 152	491017 GPS	0.2 (71) 0.9 (2)	3.9	5.6	GB (308)	6.8	GS (308)	SS (267)	???(71) 0.2 (71)	0.9 (2) 3.9
288 440	49B390 Sup-???	0.2 (71) 0.9 (2)	3.9	5.6	GB (308)			SS (267)	0.8 (71) 0.1 (71)	0.9 (2) 3.6
562 715	49B351 Sup-ChS	1.2 (2) 3.6		5.5	GB (308)			SS (267)	0.4 (71) 1.1 (2)	3.8
928 1,080	49B330 CrS	1.6 (2) 4.3		5.5	GB (308)			SS (267)	1.6 (2) 4.3	
1,141 1,294	49B350 ChS	1.3 (2) 3.4		6.1	GB (308)			SS (267)	0.3 (71) 1.3	3.8
1,457 1,609	49B352 Sup-ChS	1.2 (2) 3.4		6.6	GB (308)	8.8	GS (306)	SS (267)	0.4 (71) 1.1 (2)	3.4 8.8(GB308) 6.6(GS306)
1,701 1,853	49B361 Sup-???	1.2 (2) 3.3		5.2	GB (308)	15	GS (306)	SS (267)	0.9 1.2 (2)	3.7
1,914 2,066	49B310 ThO	1.2 (2) 3.2		4	GB (308)	8.5	GS (304)	SS (267)	1.7 1.2 (2)	3.4
2,127 2,280	49B320 SIS	1.2 (2) 4.3		7	GB (308)	14.5	GS (306)	SS (267)	0.1 (72) 0.8 (2)	4.1
2,556 2,709	49B331 Sup-CrS	1.1 (2) 3.4		6.2	GB (308)			SS (267)		

Station (m)	Section	AC Thicknesses		Base Thickness	Base Type	Subbase Thickness	Subbase Type	Subgrade Type	CN = 2 AC Thicknesses	
0–152	491006 GPS	1.2 (2) 1.3	9.2	7.9	GB (308)			SS (267)		
259–412	49C320 SlS	2.1 10.1		6.8	GB (304)			SS (267)	0.3 (72) 2.2	10
472–625	49C330 CrS	2.2 11.1		6.8	GB (304)	4	GS (308)	SS (267)	2.2 11.1	
686–838	49C310 ThO	3 9.6		5.3	GB (304)	25	GS (308)	SS (267)	1.3 2.6	9.9
930–1,082	49C350 ChS	2.3 9.6		7.5	GB (304)			SS (267)	0.3 (71) 2.4	9.6
1,295–1,448	49C351 Sup-ChS	2.1 9.6		8.5	GB (304)	21.8	GS (308)	SS (267)	0.3 (71) 2.1	9.7
1,570–1,722	49C352 Sup-ChS	2.6 8.9		6.5	GB (304)	12.5	GS (308)	SS (267)	0.2 (71) 2.5	9.3
1,814–1,966	49C331 Sup-CrS	2.4 9.2		8.5	GB (304)	17.5	GS (308)	SS (267)		
2,027–2,179	49C361 Sup-???	2.1 9		5.2	GB (304)	28.5	GS (308)	SS (267)	0.5 2.5	9.3

Virginia

Station (m)	Section	Construction Number = 1							CN = 2	
		AC Thicknesses		Base		Subbase		Subgrade Type	AC Thicknesses	
				Thickness	Type	Thickness	Type			
0–249										
249–401	51A340 CnL	2.5 7.6		5.6	GB (307)	8.4	TS (338)	SS (141)		
464–616	51A310 ThO	2.5 7.6		5.6	GB (307)	8.4	TS (338)	SS (141)		
677–829	51A350 ChS	1.8 8.9		5.6	GB (307)	8.4	TS (338)	SS (141)	0.7 (71) 1.8	8.9
892–1,044	51A330 CrS	2.5 7.6		5.6	GB (307)	8.4	TS (338)	SS (141)	2.5 7.6	
1,106–1,258	51A320 SlS	2.5 8.3		5.6	GB (307)	8.4	TS (338)	SS (141)	0.5 (72) 2.5	8.3
1,318–1,470	51A321 Sup-SlS	2.5 7.6		5.6	GB (307)	8.4	TS (338)	SS (141)		

Washington

Station (m)	Section	Construction Number = 1: AC Thicknesses		Base Thickness	Base Type	Subbase Thickness	Subbase Type	Subgrade Type	CN = 2: AC Thicknesses	
0 152	531008 GPS	3.4		3.1	GB (304)	9.8	GS (304)	SS (257)	1.7 3.9	
320 472	53A320 SIS	3		3.1	GB (304)	9.8	GS (304)	SS (257)	0.2 (72) 2.5	
503 655	53A330 CrS	3.4		3.1	GB (304)	9.8	GS (304)	SS (257)	3.4	
747 899	53A350 ChS	2.8		3.1	GB (304)	9.8	GS (304)	SS (257)	0.2 (71) 2.8	
960 1,113	53A310 ThO	2.5		3.1	GB (304)	9.8	GS (304)	SS (257)	1.8 2.9	

Station (m)	Section	AC Thicknesses		Base Thickness	Base Type	Subbase Thickness	Subbase Type	Subgrade Type	CN = 2: AC Thicknesses	
0 152	53B350 ChS	2		6.4 2.4	GB (304) AC (20)	5.7	GS (304)	SS (265)	2.5 0 (71)	
213 366	53B330 CrS	2		6.4 2.4	GB (304) AC (20)	5.7	GS (304)	SS (265)	2	
396 549	53B320 SIS	2		6.4 2.4	GB (304) AC (20)	5.7	GS (304)	SS (265)	0.2 (72) 2.2	
579 732	53B310 ThO	1.9		6.4 2.4	GB (304) AC (20)	5.7	GS (304)	SS (265)	1.3 2.2	
884 1,036	531501 GPS	1.9		6.4 2.4	GB (304) AC (20)	5.7	GS (304)	SS (265)		

Station (m)	Section	AC Thicknesses		Base Thickness	Base Type	Subbase Thickness	Subbase Type	Subgrade Type	CN = 2 AC Thicknesses	
0 152	53C310 ThO	3.5 4.5		3.7	GB (304)			SS (267)	1.1 3.8	4.1
183 335	53C320 SlS	3.5 5		3.7	GB (304)			SS (267)	0.2 (72) 4.2	4.5
366 518	53C330 CrS	4.1 4.3		3.7	GB (304)			SS (267)	4.1 4.3	
579 732	53C350 ChS	4 4		3.7	GB (304)			SS (267)	0.3 (71) 3.7	4.4
999 1,151	531801 GPS	4.5 4.7		3.7	GB (304)			SS (267)	4.5 4.7	

Wyoming

Station (m)	Section	Construction Number = 1							CN = 2	
		AC Thicknesses		Base		Subbase		Subgrade Type	AC Thicknesses	
				Thickness	Type	Thickness	Type			
0										
829 981	56A363 Sup-???	0.1 (71) 2.3		7.7	GB (304)			SS (214)	0.2 (71) 0.1 (71)	2.7
1,073 1,225	561007 GPS	2.8		6.2	GB (304)			SS (215)	??? 2.8	
1,301 1,454	56A320 SlS	0.1 (71) 2.4		6.5	GB (304)			SS (214)	0.2 (72) 0.1 (71)	2.6
1,637 1,789	56A330 CrS	0.1 (71) 2.8		7.1	GB (304)			SS (214)		
1,972 2,124	56A350 ChS	0.1 (71) 2.8		5.6	GB (304)			SS (214)	0.3 (71) 0.1 (71)	2.6
2,216 2,368	56A310 ThO	0.1 (71) 2.9		7	GB (304)			SS (215)	0.8 0.1 (71)	3

0 152	56B310 ThO	0.1 (71) 2.7	1 (77)	6.8	GB (304)			SS (215)	0.9 0.2 (71)	3.2 1 (77)
213 366	56B320 SlS	0.1 (71) 3.3	1.3 (77)	6.8	GB (304)			SS (215)	0.2 (72) 0.2 (71)	3.5 1.1 (77)
457 610	56B350 ChS	0.1 (71) 3.3	0.9 (77)	6.8	GB (304)			SS (215)	0.3 (71) 0.1 (71)	3.6 1 (77)
701 853	56B330 CrS	0.1 (71) 3.2	1.3 (77)	6.8	GB (304)			SS (215)	0.1 (71) 3.2	1.3 (77)
945 1,097	567775 GPS	0.2 (71) 3.2	1.3 (77)	6.8	GB (304)			SS (215)		
1,174 1,326	56B360 Sup-???	0.1 (71) 2.9	1.2 (77)	6.8	GB (304)			SS (215)	0.4 (71) 0.2 (71)	3.2 1.1 (77)

Manitoba

Station (m)	Section	Construction Number = 1							CN = 2	
		AC Thicknesses		Base		Subbase		Subgrade Type	AC Thicknesses	
				Thickness	Type	Thickness	Type			
0 152	831801 GPS	2.2 2.2		5.6	GB (304)	13.2	GS (302)	SS (214)		
259 412	83A310 ThO	2.7 3.2		5.6	GB (304)	13.2	GS (302)	SS (214)	1 2.7	3.2
472 625	83A320 SlS	2.9 3.2		5.6	GB (304)	13.2	GS (302)	SS (214)	0.4 (72) 2.9	3.2
686 838	83A330 CrS	2.2 2.2		5.6	GB (304)	13.2	GS (302)	SS (214)	2.2 2.2	
1,113 1,265	83A340 CnL	2.4 2		5.6	GB (304)	13.2	GS (302)	SS (214)		
1,326 1,478	83A350 ChS	2.5 2.3		5.6	GB (304)	13.2	GS (302)	SS (214)	0.4 (71) 2.5	2.3
1,539 1,692	83A331 Sup-CrS	2.2 2.2		5.6	GB (304)	13.2	GS (302)	SS (214)		
1,753 1,905	83A351 Sup-ChS	1.9 2		5.6	GB (304)	13.2	GS (302)	SS (214)	0.4 (71) 1.9	2

Ontario

Station (m)	Section	Construction Number = 1: AC Thicknesses		Base Thickness	Base Type	Subbase Thickness	Subbase Type	Subgrade Type	CN = 2: AC Thicknesses	
0 – 256										
256 – 409	87A310 ThO	1.2 2.3	1.5	5.7	GB (306)	23.9	GS (306)	SS (102)	1.3 1.2	2.3 1.5
409 – 474										
474 – 626	87A320 SIS	0.9 2.4	1.3	5.7	GB (306)	23.9	GS (306)	SS (102)	0.5 (72) 0.9	2.4 1.3
626 – 657										
657 – 809	87A330 CrS	1.2 2.3	1.5	5.7	GB (306)	23.9	GS (306)	SS (102)	1.2 2.3	1.5
809 – 839										
839 – 992	87A340 CnL	1.2 2.3	1.5	5.7	GB (306)	23.9	GS (306)	SS (102)		
992 – 1,053										
1,053 – 1,206	87A350 ChS	1.3 1.7	1.3	5.7	GB (306)	23.9	GS (306)	SS (102)	0.5 (71) 1.3	1.7 1.3
1,206 – 1,480										
1,480 – 1,633	87A311 Sup-ThO	1.2 2.3	1.5	5.7	GB (306)	23.9	GS (306)	SS (102)	1.3 1.2	2.3 1.5

Station (m)	Section	Construction Number = 1: AC Thicknesses		Base Thickness	Base Type	Subbase Thickness	Subbase Type	Subgrade Type	CN = 2: AC Thicknesses	
0 – 260										
260 – 413	87B310 ThO	1.1 3.1	1.4	6.6	GB (304)	26.3	GS (306)	SS (145)	1.4 1.1	3.1 1.4
413 – 474										
474 – 626	87B320 SIS	1 3.7	1.4	6.6	GB (304)	26.3	GS (306)	SS (145)	0.4 (72) 1	3.7 1.4
626 – 657										
657 – 810	87B330 CrS	1.1 3.1	1.4	6.6	GB (304)	26.3	GS (306)	SS (145)	1.1 3.1	1.4
810 – 841										
841 – 993	87B340 CnL	1.1 3.1	1.4	6.6	GB (304)	26.3	GS (306)	SS (145)		
993 – 1,055										
1,055 – 1,208	87B361 Sup-???	1.1 3.1	1.4	6.6	GB (304)	26.3	GS (306)	SS (145)		
1,208 – 1,239										
1,239 – 1,391	87B362 Sup-???	1.1 3.1	1.4	6.6	GB (304)	26.3	GS (306)	SS (145)		
1,391 – 1,435										
1,435 – 1,587	87B311 Sup-ThO	1.1 3.1	1.4	6.6	GB (304)	26.3	GS (306)	SS (145)	2.6 1.1	3.1 1.4
1,587 – 1,755										
1,755 – 1,907	87B360 Sup-???	1.1 3.1	1.4	6.6	GB (304)	26.3	GS (306)	SS (145)		

Quebec

Station (m)	Section	Construction Number = 1: AC Thicknesses		Base Thickness	Base Type	Subbase Thickness	Subbase Type	Subgrade Type	CN = 2: AC Thicknesses	
0–244										
244–396	89A310 ThO	2.1 3.1		15	GB (304)			SS (204)	1.4 0.5 (20)	2.1 3.1
445–597	89A320 SIS	2.2 2.8		15	GB (304)			SS (204)	1 (72) 2.2	2.8
646–798	89A330 CrS	2.1 3.1		15	GB (304)			SS (204)	2.1 3.1	
846–998	89A340 CnL	2.1 3.1		15	GB (304)			SS (204)		
1,046–1,199	89A350 ChS	2 2.8		15	GB (304)			SS (204)	0.5 (71) 2	2.8

Saskatchewan

Station (m)	Section	Construction Number = 1: AC Thicknesses		Base Thickness	Base Type	Subbase Thickness	Subbase Type	Subgrade Type	CN = 2: AC Thicknesses	
0–152	90A310 ThO	8						SS (114)	1.1 8	
236–389	906420 GPS	7.3						SS (114)	7.3	
427–579	90A320 SIS	6.7						SS (114)	0.1 (72) 6.7	
640–793	90A330 CrS	7.3						SS (114)	7.3	
884–1,036	90A340 CnL	8.2						SS (114)		
1,128–1,280	90A350 ChS	7.1						SS (114)	0.4 (71) 7.1	
1,372–1,524	90A351 Sup-ChS	7.2						SS (114)	0.4 (71) 7.2	
1,615–1,768	90A352 Sup-ChS	7.3						SS (114)	0.2 (71) 7.3	

0 152	906405 GPS	2.8		9	GB (304)	1.2	TS (320)	SS (214)		
244 396	90B340 CnL	3.4		9	GB (304)	1.2	TB (320)	SS (214)		
488 640	90B310 ThO	2.8		9	GB (304)	1.2	TB (320)	SS (214)	1.1 2.8	
701 853	90B320 SIS	3.1		9	GB (304)	1.2	TB (320)	SS (214)	0.1 (72) 3.1	
914 1,067	90B330 CrS	2.8		9	GB (304)	1.2	TB (320)	SS (214)	2.8	
1,128 1,280	90B350 ChS	2.1		9	GB (304)	1.2	TB (320)	SS (214)	0.3 (71) 2.1	
1,341 1,494	90B331 Sup-CrS	2.8		9	GB (304)	1.2	TB (320)	SS (214)		
1,555 1,707	90B351 Sup-ChS	3.1		9	GB (304)	1.2	TB (320)	SS (214)	0.2 (71) 3.1	

Structural Parameters Calculated for SPS-3 Sites

STATE CODE	SHRP ID	MEAN D0 68 (mils)	MEAN AREA 68 (inches)	MEAN AUPP 68 (inches)	SN (from layer data) (inches)	Hac (inches)
1	A340	5.96	23.29	6.31	5.00	8.4
1	B340	5.88	19.80	7.94	3.98	6.4
1	C340	9.04	16.86	14.46	3.30	3.3
4	A330	15.74	20.13	20.89	4.41	4.1
4	C340	19.12	16.65	30.70	4.87	7.5
4	D330	10.88	20.87	13.83	5.38	10.3
5	A330	3.64	26.75	2.80	4.22	5.6
6	A340	8.47	18.14	12.66	3.86	3.9
8	A340	19.52	17.05	30.91	5.37	4.6
8	B320	30.13	16.79	49.11	5.15	4.9
12	A330	13.14	13.68	24.48	3.86	2.6
12	B330	15.31	14.93	26.87	4.64	3.1
12	C330	16.81	11.43	34.46	1.80	1.3
16	A330	16.10	16.15	26.64	4.52	4.3
16	B330	7.17	16.41	11.69	3.07	5.3
17	A340	8.38	24.69	7.97	7.02	11.6
17	B340	4.39	27.12	3.24	5.85	13.3
18	A340	4.18	25.43	3.67	6.73	15.3
19	A340	23.82	20.11	32.21	3.39	4.8
20	A340	8.22	24.77	7.87	5.68	12.9
20	B340	6.94	22.81	7.68	3.83	8.7
21	A340	9.15	21.24	11.15	4.24	6.7
21	B340	3.91	24.32	3.80	5.28	12.0
24	A340	17.07	20.68	21.79	4.07	3.6
26	A340	11.45	19.97	15.40	5.71	6.8
26	B340	8.98	21.25	11.07	5.69	6.0
26	C340	15.63	16.18	25.85	2.36	1.9
26	D340	16.16	15.54	27.58	4.61	2.1
27	A340	17.30	16.17	28.60	2.14	2.8
27	B340	7.87	21.45	9.55	4.20	6.3
27	C340	7.89	21.87	9.45	4.00	9.3
27	D340	12.57	17.39	19.52	3.18	5.2
28	A330	8.25	25.59	7.15	2.62	3.1
29	A340	8.34	20.60	10.74	9.24	8.9
29	B340	7.17	21.86	8.44	3.40	6.4
30	A330	17.54	13.82	32.42	4.79	3.4
31	A340	12.76	22.73	14.09	3.08	7.0
32	A330	11.07	24.69	10.82	5.01	8.4
32	B340	10.24	20.79	13.10	4.80	5.9
36	A340	15.06	21.02	18.78	3.56	2.2
36	B340	6.97	21.43	8.45	3.99	2.3
40	A340	10.07	15.13	17.52	5.18	9.6
40	B330	9.32	25.80	7.99	4.27	9.7

Structural Parameters Calculated for SPS-3 Sites

STATE CODE	SHRP ID	MEAN D0 68 (mils)	MEAN AREA 68 (inches)	MEAN AUPP 68 (inches)	SN (from layer data) (inches)	Hac (inches)
40	C330	10.46	24.67	9.91	4.63	4.3
42	A340	9.33	18.40	13.72	5.83	8.1
42	B340	15.43	19.67	21.00	5.11	6.4
47	A330	10.60	19.41	14.60	5.04	9.7
47	B330	10.87	15.95	18.27	2.75	1.8
47	C330	3.56	21.88	4.24	4.25	5.3
48	A340	12.33	13.42	23.16	2.06	2.0
48	B340	4.00	24.76	3.83	8.61	9.6
48	D330	4.44	25.91	3.74	7.44	11.3
48	E340	24.40	18.21	38.01	3.82	6.0
48	F340	15.57	15.05	27.14	3.91	2.1
48	G330	28.82	13.10	54.98	2.51	2.5
48	H340	18.34	16.56	29.78	3.44	2.4
48	I340	5.87	25.29	5.25	4.18	7.5
48	J340	5.69	15.83	9.30	4.87	4.0
48	K340	23.89	13.98	43.50	1.98	1.5
48	L340	27.66	15.63	47.18	2.01	1.9
48	M340	22.96	16.42	37.61	3.60	2.4
48	N340	22.49	14.69	39.95	3.57	1.8
48	Q340	15.41	13.41	28.94	3.03	2.0
49	A330	12.60	21.77	15.24	4.72	8.5
49	B330	21.95	17.83	33.63	3.37	5.9
49	C330	5.71	32.41	1.57	7.24	13.3
51	A340	6.36	24.00	6.36	6.57	10.1
53	B330	22.08	17.28	34.37	2.74	2.0
53	C330	7.96	22.63	8.84	4.21	8.4
56	A330	21.34	19.81	28.81	2.27	2.9
56	B330	26.87	19.30	37.35	2.98	4.6
83	A340	14.36	18.10	21.61	4.17	4.4
87	A340	17.08	20.04	22.80	5.63	5.0
87	B340	10.91	20.69	13.90	6.28	5.6
90	A340	19.24	21.46	23.64	3.61	8.2
90	B340	13.66	16.13	22.73	2.95	3.4

Annual ESALs in 1990 for SPS-3 sites

SHRP ID	State	Route	Annual ESALs in 1990 (thousands)
01A300	AL	SR 152	304
01B300	AL	US 43	139
01C300	AL	US 84	135
04A300	AZ	US 93	780
04B300	AZ	I-40	1,443
04C300	AZ	I-19	1,273
04D300	AZ	I-19	1,174
05A300	AR	US 71	692
06A300	CA	SR 32	18
08A300	CO	US 50	37
08B300	CO	US 50	52
12A300	FL	SR 200	169
12B300	FL	US 17	393
12C300	FL	SR 442	131
16A300	ID	US 93	45
16B300	ID	US 20	197
16C300	ID	I-15	164
17A300	IL	US 50	49
17B300	IL	US 20	67
18A300	IN	I-64	2,067
19A300	IA	SR 196	8
20A300	KS	SR 68	45
20B300	KS	US 400	77
21A300	KY	SR 11	18
21B300	KY	Cumb Pkwy	99
24A300	MD	SR 90	61
26A300	MI	US 131	254
26B300	MI	US 131	221
26C300	MI	SR 61	11
26D300	MI	SR 57	66
27A300	MN	US 71	23
27B300	MN	US 2	89
27C300	MN	US 10	73
27D300	MN	US 169	36
28A300	MS	US 84	55
29A300	MO	US 54	154

SHRP ID	State	Route	Annual ESALs in 1990 (thousands)
29B300	MO	SR 3	11
30A300	MT	US 87	40
31A300	NE	US 6	29
32A300	NV	SR 650	12
32B300	NV	I-80	288
32C300	NV	I-80	288
36A300	NY	US 4	1,510
36B300	NY	SR 3	65
40A300	OK	US 62	153
40B300	OK	SR 3E/US377	215
40C300	OK	US 60	185
42A300	PA	SR 147	290
42B300	PA	SR 49	21
47A300	TN	SR 96	43
47B300	TN	SR 56	54
47C300	TN	I-75	1,055
48A300	TX	SR 16	21
48B300	TX	US 175	71
48D300	TX	I-20	321
48E300	TX	US 84	81
48F300	TX	SR 19	64
48G300	TX	SR 322	30
48H300	TX	SR 105	44
48I300	TX	SR 30	44
48J300	TX	US 181	25
48K300	TX	SR 1560	20
48L300	TX	US 62	25
48M300	TX	US 59	42
48N300	TX	US 77	108
48Q300	TX	US 84	20
49A300	UT	US 89	36
49B300	UT	US 89	36
49C300	UT	SR 28	181
51A300	VA	I-95	714
53A300	WA	US 195	68
53B300	WA	US 2	18
53C300	WA	SR 14	79
56A300	WY	US 14	28

SHRP ID	State	Route	Annual ESALs in 1990 (thousands)
56B300	WY	SR 28	52
83A300	MB	TCH 1	140
87A300	ON	400	141
87B300	ON	11	156
89A300	PQ	40	325
90A300	SK	9	76
90B300	SK	TCH 16	121

Alabama (01)

STATE	YEAR	A310 to A350			Average
		IRI	Rutting	Cracking	KESAL'S
1	1989				285
	1990	11-Dec-90			304
	1991		12-Feb-91		322
	1992				341
	1993				360
	1994				313
	1995				329
	1996		9-Jan-96		345
	1997				362
	1998				381
	1999	20-Apr-99			400
ESAL (thousands)		2,891	1,636		

STATE	YEAR	B310,B320,B340.B350			Average
		IRI	Rutting	Cracking	KESAL'S
1	1989				131
	1990				139
	1991	11-Jul-91	15-Jan-91		148
	1992				156
	1993				165
	1994				154
	1995				584
	1996		8-Jan-96		83
	1997				87
	1998	22-Apr-98			91
	1999				96
ESAL (thousands)		1,328	1,203		

STATE	YEAR	C310 to C350			Average
		IRI	Rutting	Cracking	KESAL'S
1	1989				157
	1990				135
	1991		16-Jan-91		112
	1992	25-Aug-92			90
	1993				67
	1994				45
	1995				47
	1996	10-Apr-96	16-Jan-96		49
	1997				52
	1998				54
	1999				57
ESAL (thousands)		204	358		

Arizona (04)

STATE	YEAR	A310,A320,A330,GPS 041036			Average
		IRI	Rutting	Cracking	KESAL'S
4	1989				571
	1990				780
	1991		9-Jan-91		165
	1992	19-Feb-92			175
	1993				175
	1994				200
	1995				200
	1996				220
	1997				226
	1998	7-Apr-98	14-Jan-98		237
	1999				249
ESAL (thousands)		1,236	1,365		

STATE	YEAR	B310 to B350			Average
		IRI	Rutting	Cracking	KESAL'S
4	1989				1,415
	1990				1,443
	1991				900
	1992				950
	1993				730
	1994				900
	1995				1,000
	1996				1,000
	1997				1,100
	1998				1,200
	1999				1,260
ESAL (thousands)					

STATE	YEAR	C310,C330,C340,C350			Average
		IRI	Rutting	Cracking	KESAL'S
4	1989				1,556
	1990				1,273
	1991		17-Jan-91		230
	1992	14-Jan-92			240
	1993				102
	1994				150
	1995				150
	1996		26-Sep-96		150
	1997	5-Feb-97			131
	1998				190
	1999				200
ESAL (thousands)		796	972		

STATE	YEAR	D310,D330			Average
		IRI	Rutting	Cracking	KESAL'S
4	1989				1,245
	1990				1,174
	1991				140
	1992	13-Jan-92			150
	1993				85
	1994				151
	1995				180
	1996				180
	1997	4-Feb-97			200
	1998				220
	1999				231
ESAL (thousands)		759			

Arkansas (05)

STATE	YEAR	A310 to A350,GPS 053071			Average
		IRI	Rutting	Cracking	KESAL'S
5	1989				430
	1990				692
	1991	23-Jan-91	18-Mar-91		729
	1992				340
	1993				292
	1994				168
	1995				1,019
	1996		19-Apr-96		347
	1997				1,723
	1998				3,102
	1999	28-Jul-99			3,257
ESAL (thousands)		9,551	2,496		

California (06)

STATE	YEAR	A310 to A350			Average
		IRI	Rutting	Cracking	KESAL'S
6	1989				18
	1990				18
	1991	9-May-91	11-Jun-91		10
	1992				5
	1993				6
	1994				35
	1995				116
	1996				116
	1997				40
	1998		8-Apr-98		132
	1999	30-Oct-99			139
ESAL (thousands)		572	359		

Colorado (08)

STATE	YEAR	A310 to A350			Average
		IRI	Rutting	Cracking	KESAL'S
8	1989				61
	1990				37
	1991	27-Oct-91	23-Aug-91		83
	1992				51
	1993				60
	1994				6
	1995				90
	1996				115
	1997				77
	1998		14-Oct-98		81
	1999	18-Jul-99			85
ESAL (thousands)		541	492		

STATE	YEAR	B310 to B350,GPS 082008			Average
		IRI	Rutting	Cracking	KESAL'S
8	1989				75
	1990				52
	1991	14-Nov-91			126
	1992				148
	1993	2-Nov-93			144
	1994				146
	1995				82
	1996				71
	1997				75
	1998				78
	1999				82
ESAL (thousands)		285			

Florida (12)

STATE	YEAR	A310 to A350,GPS 129054			Average
		IRI	Rutting	Cracking	KESAL'S
12	1989				161
	1990			20-Nov-90	169
	1991	2-Jul-91	9-Feb-91		178
	1992				159
	1993				161
	1994				65
	1995				39
	1996	30-Jun-96	25-Jan-96	18-Sep-96	160
	1997				149
	1998				156
	1999				164
ESAL (thousands)		590	592	734	

STATE	YEAR	B310 to B350,GPS 123997			Average
		IRI	Rutting	Cracking	KESAL'S
12	1989				374
	1990				393
	1991	3-Jul-91		4-Oct-91	152
	1992				149
	1993				914
	1994	4-Apr-94		16-Mar-94	97
	1995				157
	1996				146
	1997				145
	1998				171
	1999				179
ESAL (thousands)		1,164		1,121	

STATE	YEAR	C310 to C350,GPS 124154			Average
		IRI	Rutting	Cracking	KESAL'S
12	1989				144
	1990			19-Nov-90	131
	1991				42
	1992				68
	1993				54
	1994				58
	1995				46
	1996			19-Sep-96	62
	1997				35
	1998				21
	1999				22
ESAL (thousands)				328	

Idaho (16)

STATE	YEAR	A310 to A350,GPS 161020			Average
		IRI	Rutting	Cracking	KESAL'S
16	1989				41
	1990	1-Oct-90			45
	1991		26-Jul-91		48
	1992				90
	1993				127
	1994				195
	1995				56
	1996				51
	1997				31
	1998				33
	1999	21-Jun-99	23-Jun-99		35
ESAL (thousands)		660	622		

STATE	YEAR	B310,B320,B330,GPS 161021			Average
		IRI	Rutting	Cracking	KESAL'S
16	1989				231
	1990	5-Oct-90			197
	1991				507
	1992				229
	1993				616
	1994				323
	1995				608
	1996				281
	1997				141
	1998				160
	1999	20-Jun-99			168
ESAL (thousands)		2,991			

STATE	YEAR	C310 to C350, GPS 161010			Average
		IRI	Rutting	Cracking	KESAL'S
16	1989				147
	1990	5-Oct-90			164
	1991				225
	1992				185
	1993				460
	1994				397
	1995				247
	1996				184
	1997	23-Jul-97			276
	1998				290
	1999				304
ESAL (thousands)		1,893			

Illinois (17)

STATE	YEAR	A310 to A350			Average
		IRI	Rutting	Cracking	KESAL'S
17	1989				40
	1990				49
	1991	18-Dec-91			38
	1992				41
	1993		15-Nov-93		47
	1994				60
	1995				77
	1996				76
	1997				74
	1998		10-Nov-98		73
	1999				77
	2000	28-Nov-00			81
ESAL (thousands)		599	356		

STATE	YEAR	B320,B330,B340,B350			Average
		IRI	Rutting	Cracking	KESAL'S
17	1989				66
	1990	10-Dec-90			67
	1991		29-Aug-91		56
	1992				21
	1993				273
	1994				236
	1995				68
	1996		3-Jul-96		46
	1997				48
	1998				51
	1999				53
	2000	8-Nov-00			56
ESAL (thousands)		904	607		

Indiana (18)

STATE	YEAR	A310,A330,A340,A350			Average
		IRI	Rutting	Cracking	KESAL'S
18	1989				2,946
	1990				2,067
	1991		20-Dec-91		2,091
	1992	5-Oct-92			1,277
	1993				463
	1994		27-May-94		395
	1995				615
	1996				535
	1997	19-May-97			456
	1998				259
	1999				272
ESAL (thousands)		2,489	1,965		

Iowa (19)

STATE	YEAR	A310,A320,A330			Average
		IRI	Rutting	Cracking	KESAL'S
19	1989				8
	1990				8
	1991	20-Jun-91	2-May-91		8
	1992				19
	1993				16
	1994				14
	1995				11
	1996		31-Mar-96		9
	1997	7-Aug-97			34
	1998				36
	1999				37
ESAL (thousands)		93	67		

Kansas (20)

STATE	YEAR	A310 to A350			Average
		IRI	Rutting	Cracking	KESAL'S
20	1989				37
	1990			30-Nov-90	45
	1991	31-Mar-91			30
	1992				16
	1993		5-Apr-93		17
	1994				14
	1995				15
	1996				16
	1997				17
	1998				18
	1999	24-Mar-99		8-Feb-99	18
	2000		12-Jul-00		19
ESAL (thousands)		140	121	149	

STATE	YEAR	B310 to B350			Average
		IRI	Rutting	Cracking	KESAL'S
20	1989				69
	1990			28-Nov-90	77
	1991	4-Apr-91	29-Apr-91		39
	1992				2
	1993				2
	1994				2
	1995				2
	1996		24-Apr-96		2
	1997	14-Feb-97		24-Mar-97	2
	1998				2
	1999				2
ESAL (thousands)		39	35	56	

Kentucky (21)

STATE	YEAR	A310 to A350			Average
		IRI	Rutting	Cracking	KESAL'S
21	1989				19
	1990	16-Dec-90			18
	1991		9-Jul-91		14
	1992				10
	1993				7
	1994				7
	1995	1-Jun-95			6
	1996		22-Mar-96		6
	1997				5
	1998				5
	1999				6
ESAL (thousands)		41	38		

STATE	YEAR	B310 to B350			Average
		IRI	Rutting	Cracking	KESAL'S
21	1989				48
	1990	16-Dec-90			99
	1991		10-Jul-91		105
	1992				111
	1993				77
	1994				69
	1995				61
	1996		22-Mar-96		93
	1997				125
	1998				131
	1999				137
	2000				144
	2001	9-Apr-01			151
ESAL (thousands)		1,098	388		

Maryland (24)

STATE	YEAR	A310 to A350			Average
		IRI	Rutting	Cracking	KESAL'S
24	1989				64
	1990	5-Dec-90			61
	1991			16-Apr-91	59
	1992		7-Oct-92		56
	1993				60
	1994				63
	1995				64
	1996				29
	1997				70
	1998	25-Feb-98	7-Apr-98	7-Apr-98	70
	1999				74
ESAL (thousands)		416	318	402	

Michigan (26)

STATE	YEAR	A310 to A350			Average
		IRI	Rutting	Cracking	KESAL'S
26	1989				142
	1990				254
	1991	7-Jan-91	17-Jul-91		332
	1992				82
	1993				217
	1994				160
	1995				133
	1996		5-Jul-96		137
	1997	14-Jun-97			151
	1998				171
	1999				180
ESAL (thousands)		1,124	813		

STATE	YEAR	B310 to B350			Average
		IRI	Rutting	Cracking	KESAL'S
26	1989				142
	1990				221
	1991	7-Jan-91	18-Jul-91		221
	1992				196
	1993				171
	1994				142
	1995				151
	1996		5-Jul-96		153
	1997	14-Jun-97			156
	1998				158
	1999				166
ESAL (thousands)		1,101	838		

STATE	YEAR	C310 to C350			Average
		IRI	Rutting	Cracking	KESAL'S
26	1989				12
	1990				11
	1991	10-Jul-91	16-Jul-91		9
	1992				17
	1993				21
	1994				11
	1995				15
	1996		5-Jul-96		28
	1997				11
	1998	4-Nov-98			19
	1999				20
ESAL (thousands)		124	83		

STATE	YEAR	D310 to D350			Average
		IRI	Rutting	Cracking	KESAL'S
26	1989				66
	1990				66
	1991	4-Jan-91	13-Dec-91		26
	1992				11
	1993				67
	1994				52
	1995		16-Jun-95		45
	1996				40
	1997	28-Jun-97			40
	1998				36
	1999				38
ESAL (thousands)		259	151		

Minnesota (27)

STATE	YEAR	A310 to A350			Average
		IRI	Rutting	Cracking	KESAL'S
27	1989				25
	1990				23
	1991	13-Jul-91			32
	1992				35
	1993		2-Jun-93		34
	1994				45
	1995		13-Jun-95		40
	1996				35
	1997				50
	1998	30-Sep-98			52
	1999				55
ESAL (thousands)		292	83		

STATE	YEAR	B310 to B350			Average
		IRI	Rutting	Cracking	KESAL'S
27	1989				105
	1990				89
	1991	13-Jul-91			79
	1992				55
	1993		2-Jun-93	2-Jun-93	67
	1994				69
	1995		13-Jun-95	13-Jun-95	66
	1996				70
	1997	21-Apr-97			73
	1998				77
	1999				81
ESAL (thousands)		387	137	137	

STATE	YEAR	C310 to C350			Average
		IRI	Rutting	Cracking	KESAL'S
27	1989				69
	1990				73
	1991	8-Aug-91			76
	1992				74
	1993		1-Jun-93		77
	1994				76
	1995				75
	1996		19-Jun-96		62
	1997				111
	1998	1-Oct-98			117
	1999				123
ESAL (thousands)		593	225		

STATE	YEAR	D310 to D350			Average
		IRI	Rutting	Cracking	KESAL'S
27	1989				38
	1990				36
	1991				33
	1992	5-Aug-92			49
	1993				52
	1994	27-Jul-94			44
	1995				54
	1996				39
	1997				63
	1998				66
	1999				69
ESAL (thousands)		97			

Mississippi (28)

STATE	YEAR	A310 to A350,GPS 281802			Average
		IRI	Rutting	Cracking	KESAL'S
28	1989				74
	1990				55
	1991	12-Jul-91	14-Jan-91		57
	1992				94
	1993				151
	1994				67
	1995				42
	1996		7-Jan-96		90
	1997				98
	1998				81
	1999	16-Jun-99			85
ESAL (thousands)		689	411		

Missouri (29)

STATE	YEAR	A310 to A350			Average
		IRI	Rutting	Cracking	KESAL'S
29	1989				150
	1990	12-Dec-90			154
	1991				159
	1992				117
	1993		1-Apr-93		76
	1994				120
	1995				47
	1996		17-Apr-96		250
	1997				135
	1998				174
	1999				182
	2000				191
	2001	26-Apr-01			201
ESAL (thousands)		1,524	298		

STATE	YEAR	B310 to B350			Average
		IRI	Rutting	Cracking	KESAL'S
29	1989				11
	1990	12-Dec-90			11
	1991				6
	1992				24
	1993		1-Apr-93		10
	1994				11
	1995				8
	1996		17-Apr-96		33
	1997				22
	1998				17
	1999				18
	2000				19
	2001	26-Apr-01			20
ESAL (thousands)		175	37		

Montana (30)

STATE	YEAR	A310,A320,A330,GPS 301001			Average
		IRI	Rutting	Cracking	KESAL'S
30	1989				65
	1990	19-Oct-90			40
	1991		23-May-91		39
	1992				46
	1993				46
	1994				44
	1995				44
	1996				49
	1997				94
	1998				95
	1999	22-May-99	22-Jun-99		96
ESAL (thousands)		503	487		

Nebraska (31)

STATE	YEAR	A310 to A350			Average
		IRI	Rutting	Cracking	KESAL'S
31	1989				34
	1990			29-Nov-90	29
	1991	5-Apr-91	12-Jun-91		22
	1992				48
	1993				21
	1994				33
	1995	29-Oct-95		7-Nov-95	42
	1996		8-Apr-96		51
	1997				23
	1998				24
	1999				25
ESAL (thousands)		152	168	161	

Nevada (32)

STATE	YEAR	A310 to A350,GPS 321021			Average
		IRI	Rutting	Cracking	KESAL'S
32	1989				19
	1990	17-Sep-90			12
	1991		1-Jul-91		18
	1992				20
	1993				20
	1994				22
	1995				33
	1996				34
	1997	24-Apr-97	28-Apr-97		39
	1998				41
	1999				43
ESAL (thousands)		163	151		

STATE	YEAR	B310 to B350			Average
		IRI	Rutting	Cracking	KESAL'S
32	1989				409
	1990				288
	1991		25-Jul-91		312
	1992	16-Nov-92			358
	1993				394
	1994				404
	1995				432
	1996				477
	1997	6-May-97	2-May-97		433
	1998				454
	1999				477
ESAL (thousands)		1,902	2,346		

STATE	YEAR	C310 to C350			Average
		IRI	Rutting	Cracking	KESAL'S
32	1989				409
	1990				288
	1991				312
	1992				358
	1993				392
	1994				402
	1995				557
	1996				495
	1997				433
	1998				455
	1999				477
ESAL (thousands)					

New York (36)

STATE	YEAR	A310 to A350			Average
		IRI	Rutting	Cracking	KESAL'S
36	1989				1,442
	1990	21-Nov-90		9-Oct-90	1,510
	1991		21-Aug-91		324
	1992				358
	1993				318
	1994				317
	1995	5-Jul-95			399
	1996		29-May-96	29-May-96	372
	1997				327
	1998				343
	1999				361
ESAL (thousands)		1,689	1,662	2,213	

STATE	YEAR	B310 to B350			Average
		IRI	Rutting	Cracking	KESAL'S
36	1989				65
	1990			11-Oct-90	65
	1991		20-Sep-91		26
	1992	7-Jul-92			6
	1993				9
	1994				13
	1995				14
	1996	9-May-96	15-May-96	15-May-96	15
	1997				16
	1998				17
	1999				18
ESAL (thousands)		45	55	89	

Oklahoma (40)

STATE	YEAR	A320,A330,A340,A350			Average
		IRI	Rutting	Cracking	KESAL'S
40	1989				129
	1990				153
	1991		13-Oct-91		153
	1992				122
	1993	19-Mar-93			183
	1994				198
	1995		9-Feb-95		225
	1996				263
	1997	4-Jun-97			295
	1998				352
	1999				370
ESAL (thousands)		955	560		

STATE	YEAR	B310 to B350,GPS 401015			Average
		IRI	Rutting	Cracking	KESAL'S
40	1989				218
	1990				215
	1991	11-Jan-91			215
	1992				160
	1993				105
	1994				104
	1995	31-Mar-95			98
	1996				111
	1997				105
	1998				106
	1999				111
ESAL (thousands)		603			

STATE	YEAR	C310 to C350,GPS 404088			Average
		IRI	Rutting	Cracking	KESAL'S
40	1989				190
	1990				185
	1991				191
	1992				197
	1993	16-Mar-93			23
	1994				23
	1995	13-Apr-95			23
	1996				26
	1997				26
	1998				27
	1999				29
ESAL (thousands)		48			

Pennsylvania (42)

STATE	YEAR	A310 to A350			Average
		IRI	Rutting	Cracking	KESAL'S
42	1989				219
	1990	19-Nov-90		19-Oct-90	290
	1991		8-Aug-91		488
	1992				190
	1993				221
	1994				478
	1995	9-May-95	19-Apr-95	19-Apr-95	601
	1996				310
	1997				326
	1998				326
	1999				326
ESAL (thousands)		1,624	1,263	1,615	

STATE	YEAR	B310,B330,B340,B350			Average
		IRI	Rutting	Cracking	KESAL'S
42	1989				19
	1990	20-Nov-90			21
	1991				13
	1992			18-May-92	21
	1993				18
	1994				19
	1995				19
	1996				23
	1997			3-Sep-97	19
	1998				24
	1999				21
	2000	19-Apr-00			22
ESAL (thousands)		186		105	

Tennessee (47)

STATE	YEAR	A310 to A350			Average
		IRI	Rutting	Cracking	KESAL'S
47	1989				34
	1990				43
	1991				39
	1992				38
	1993				42
	1994				82
	1995				71
	1996				19
	1997				15
	1998				10
	1999				11
ESAL (thousands)					

STATE	YEAR	B310 to B350,GPS 473075			Average
		IRI	Rutting	Cracking	KESAL'S
47	1989				50
	1990				54
	1991	17-Jun-91			59
	1992				37
	1993				43
	1994				100
	1995				79
	1996				97
	1997				102
	1998				107
	1999	13-Jul-99			112
ESAL (thousands)		658			

STATE	YEAR	C320,C350			Average
		IRI	Rutting	Cracking	KESAL'S
47	1989				1,021
	1990				1,055
	1991	14-Jun-91			919
	1992				974
	1993				610
	1994	8-Jun-94			246
	1995				155
	1996				350
	1997				545
	1998				572
	1999				601
ESAL (thousands)		2,194			

Texas (48)

STATE	YEAR	A310,A320,A330,A340			Average
		IRI	Rutting	Cracking	KESAL'S
48	1989				11
	1990	20-Mar-90	14-Oct-90		21
	1991			27-Mar-91	17
	1992				25
	1993				21
	1994				32
	1995		20-Feb-95		24
	1996				60
	1997				57
	1998	6-Jul-98			86
	1999			12-May-99	90
ESAL (thousands)		296	103	350	

STATE	YEAR	B310 to B350			Average
		IRI	Rutting	Cracking	KESAL'S
48	1989				120
	1990		18-Sep-90		71
	1991				71
	1992				74
	1993				78
	1994	28-Jun-94			179
	1995		9-Mar-95		179
	1996				111
	1997	3-Jun-97			207
	1998				133
	1999				140
ESAL (thousands)		469	456		

STATE	YEAR	D310 to D350			Average
		IRI	Rutting	Cracking	KESAL'S
48	1989				328
	1990				321
	1991				414
	1992				290
	1993				281
	1994				351
	1995				488
	1996				512
	1997				538
	1998				565
	1999				593
ESAL (thousands)					

STATE	YEAR	E310 to E350			Average
		IRI	Rutting	Cracking	KESAL'S
48	1989				77
	1990				81
	1991				72
	1992				91
	1993				79
	1994				83
	1995				83
	1996				83
	1997				83
	1998				83
	1999				83
ESAL (thousands)					

STATE	YEAR	F310 to F350			Average
		IRI	Rutting	Cracking	KESAL'S
48	1989				102
	1990				64
	1991		10-Mar-91		64
	1992				66
	1993		3-Mar-93		136
	1994				132
	1995				81
	1996				109
	1997				117
	1998				123
	1999				129
ESAL (thousands)			141		

STATE	YEAR	G310,G320,G330,GPS 481169			Average
		IRI	Rutting	Cracking	KESAL'S
48	1989				73
	1990				30
	1991	25-Mar-91			48
	1992				38
	1993				48
	1994				125
	1995				119
	1996				106
	1997				92
	1998				97
	1999				101
	2000	14-May-00			107
ESAL (thousands)		802			

STATE	YEAR	H310,H320,H340,H350			Average
		IRI	Rutting	Cracking	KESAL'S
48	1989				75
	1990				44
	1991		22-Feb-91		40
	1992	3-Nov-92			46
	1993				38
	1994				75
	1995		16-Feb-95		71
	1996	18-Nov-96			102
	1997				107
	1998				112
	1999				118
ESAL (thousands)		281	202		

STATE	YEAR	I310 to I350			Average
		IRI	Rutting	Cracking	KESAL'S
48	1989				74
	1990				44
	1991		22-Feb-91		38
	1992	4-Nov-92			50
	1993				48
	1994				110
	1995		16-Feb-95		109
	1996				51
	1997				108
	1998				62
	1999	15-Feb-99			66
ESAL (thousands)		504	254		

STATE	YEAR	J310,J320,J340,J350			Average
		IRI	Rutting	Cracking	KESAL'S
48	1989				38
	1990				25
	1991		14-Feb-91		24
	1992	21-Dec-92			28
	1993				38
	1994				32
	1995		20-Feb-95		26
	1996				44
	1997	18-Aug-97			50
	1998				53
	1999				56
ESAL (thousands)		172	123		

STATE	YEAR	K310 to K350			Average
		IRI	Rutting	Cracking	KESAL'S
48	1989				22
	1990			11-Dec-90	20
	1991				28
	1992				26
	1993				22
	1994				15
	1995				19
	1996				23
	1997				21
	1998				22
	1999			12-May-99	23
ESAL (thousands)				185	

STATE	YEAR	L310 to L350			Average
		IRI	Rutting	Cracking	KESAL'S
48	1989				91
	1990				25
	1991			13-Jun-91	21
	1992				24
	1993				35
	1994				322
	1995				76
	1996				310
	1997				202
	1998				212
	1999			8-Jul-99	223
ESAL (thousands)				1,308	

STATE	YEAR	M310 to M350			Average
		IRI	Rutting	Cracking	KESAL'S
48	1989				117
	1990			6-Dec-90	42
	1991	17-Apr-91			46
	1992				60
	1993				66
	1994	1-Dec-94			98
	1995				130
	1996				156
	1997			28-Mar-97	164
	1998				172
	1999				181
ESAL (thousands)		248		599	

STATE	YEAR	N310 to N350			Average
		IRI	Rutting	Cracking	KESAL'S
48	1989				165
	1990				108
	1991		14-Feb-91	9-Apr-91	80
	1992				122
	1993		22-Feb-93	30-Mar-93	53
	1994				40
	1995				261
	1996				387
	1997				306
	1998				321
	1999				337
ESAL (thousands)			200	193	

STATE	YEAR	Q310 to Q350			Average
		IRI	Rutting	Cracking	KESAL'S
48	1989				76
	1990		27-Oct-90		20
	1991	12-Mar-91		30-May-91	27
	1992				46
	1993				56
	1994				67
	1995		17-Feb-95		87
	1996				82
	1997				86
	1998				90
	1999			12-Jul-99	95
	2000				100
	2001	18-Apr-01			105
ESAL (thousands)		761	210	580	

Utah (49)

STATE	YEAR	A310,A320,A330,GPS 491004			Average
		IRI	Rutting	Cracking	KESAL'S
49	1989				49
	1990	29-Jun-90			36
	1991		8-Jan-91		37
	1992				38
	1993				39
	1994				40
	1995				49
	1996				67
	1997				78
	1998	10-Jul-98	9-Jul-98		82
	1999				86
ESAL (thousands)		409	390		

STATE	YEAR	B310 to B350			Average
		IRI	Rutting	Cracking	KESAL'S
49	1989				49
	1990				36
	1991				37
	1992				38
	1993				39
	1994				40
	1995				57
	1996				67
	1997				78
	1998				82
	1999				86
ESAL (thousands)					

STATE	YEAR	C310,C320,C330,GPS 491006			Average
		IRI	Rutting	Cracking	KESAL'S
49	1989				175
	1990	31-Aug-90			181
	1991				185
	1992				190
	1993				195
	1994				200
	1995				181
	1996				190
	1997				239
	1998				251
	1999	14-Jul-99			263
ESAL (thousands)		1,833			

Virginia (51)

STATE	YEAR	A310 to A350			Average
		IRI	Rutting	Cracking	KESAL'S
51	1989				661
	1990	7-Dec-90		27-Nov-90	714
	1991				790
	1992		10-Oct-92		955
	1993				1,043
	1994				1,032
	1995				946
	1996				1,093
	1997	3-Oct-97	25-Mar-97	25-Mar-97	1,188
	1998				1,247
	1999				1,309
ESAL (thousands)		6,804	4,606	6,204	

Washington (53)

STATE	YEAR	A310,A320,A330,GPS 531008			Average
		IRI	Rutting	Cracking	KESAL'S
53	1989				122
	1990	28-Nov-90			68
	1991		28-May-91		70
	1992				92
	1993	7-May-93			83
	1994		16-Jun-94		124
	1995				85
	1996				54
	1997				96
	1998				63
	1999				67
ESAL (thousands)		197	273		

STATE	YEAR	B310,B320,GPS 531501			Average
		IRI	Rutting	Cracking	KESAL'S
53	1989				17
	1990	2-Dec-90			18
	1991				33
	1992				24
	1993				25
	1994				25
	1995				9
	1996				8
	1997				11
	1998				11
	1999				12
	2000	6-Apr-00			12
ESAL (thousands)		162			

STATE	YEAR	C310,C320,C350,GPS 531801			Average KESAL'S
		IRI	Rutting	Cracking	
53	1989				74
	1990				79
	1991	25-Jan-91			42
	1992				31
	1993				28
	1994				47
	1995				54
	1996				67
	1997				37
	1998	14-May-98			19
	1999				20
ESAL (thousands)		311			

Wyoming (56)

STATE	YEAR	A310,A320,A330,GPS 561007			Average KESAL'S
		IRI	Rutting	Cracking	
56	1989				27
	1990	22-Oct-90			28
	1991		13-May-91		28
	1992				27
	1993				3
	1994				24
	1995				16
	1996				7
	1997	12-Oct-97			6
	1998		12-May-98		4
	1999				4
ESAL (thousands)		114	101		

STATE	YEAR	B310,B320,B330,GPS 567775			Average KESAL'S
		IRI	Rutting	Cracking	
56	1989				87
	1990				52
	1991	25-Sep-91			52
	1992				49
	1993				49
	1994				53
	1995				70
	1996				52
	1997				30
	1998				38
	1999	13-Oct-99			40
ESAL (thousands)		387			

Manitoba (83)

STATE	YEAR	A310 to a350			Average KESAL'S
		IRI	Rutting	Cracking	
83	1989				126
	1990				140
	1991	16-Jul-91	9-May-91		137
	1992				348
	1993		10-Jun-93		365
	1994				384
	1995				403
	1996				423
	1997	24-Apr-97			444
	1998				466
	1999				490
ESAL (thousands)		2,125	598		

Ontario (87)

STATE	YEAR	A310 to A350			Average
		IRI	Rutting	Cracking	KESAL'S
87	1989				140
	1990			3-Oct-90	141
	1991		12-Sep-91		376
	1992			22-Apr-92	258
	1993		1-Jun-93		285
	1994				311
	1995				321
	1996				331
	1997				343
	1998				360
	1999				378
ESAL (thousands)			490	490	

STATE	YEAR	B310,B320,B330,B340			Average
		IRI	Rutting	Cracking	KESAL'S
87	1989				152
	1990			2-Oct-90	156
	1991	26-Apr-91	11-Sep-91		170
	1992				180
	1993				256
	1994				411
	1995				415
	1996				298
	1997		23-Sep-97	23-Sep-97	313
	1998	7-May-98			328
	1999				345
ESAL (thousands)		2,103	1,839	1,996	

Quebec (89)

STATE	YEAR	A310 to A350			Average
		IRI	Rutting	Cracking	KESAL'S
89	1989				332
	1990			15-Oct-90	325
	1991		19-Sep-91		335
	1992	25-Aug-92			276
	1993				282
	1994				342
	1995	19-Jul-95	14-Jun-95	14-Jun-95	340
	1996				342
	1997				386
	1998				347
	1999				365
ESAL (thousands)		908	1,149	1,458	

Saskatchewan (90)

STATE	YEAR	A310,A320,A330			Average
		IRI	Rutting	Cracking	KESAL'S
90	1989				129
	1990				76
	1991		7-May-91		86
	1992				97
	1993		10-Jun-93		103
	1994				37
	1995				46
	1996				55
	1997				64
	1998				20
	1999				21
ESAL (thousands)			198		

STATE	YEAR	B310 to B350			Average
		IRI	Rutting	Cracking	KESAL'S
90	1989				46
	1990				121
	1991	18-Jul-91	8-May-91		118
	1992				120
	1993		11-Jun-93		107
	1994				94
	1995	24-Jun-95			81
	1996				112
	1997				143
	1998				107
	1999				113
ESAL (thousands)		413	244		

Appendix B: Flexible Pavement Rehabilitation Effectiveness

Annual Precipitation and Temperature Levels for SPS-5 Sites

SPS-5 Site					Nearest Weather Station				Average Annual Precipitation (inches)	Average Annual Temperature (degrees F)	Precipitation Range	Temperature Range
SHRP ID	State	State Code	Latitude (degrees)	Longitude (degrees)	ID	Name	Latitude (degrees)	Longitude (degrees)				
0500	AL	1	31.24	85.60	01621866	OZARK 6 NNW	31.32	85.41	51.89	66.10	H	H
0500	AZ	4	32.83	112.01	02527066	MARICOPA 4 N	33.07	112.02	8.76	70.10	L	H
0500	CA	6	34.81	116.60	04225766	DAGGETT FAA AIRPORT	34.52	116.47	4.49	68.00	L	H
0500	CO	8	39.29	103.21	05293266	FLAGLER 2 NW	39.19	103.05	16.44	49.50	L	M
0500	FL	12	26.99	80.10	08862066	STUART 1 N	27.13	80.15	57.26	74.50	H	H
0500	GA	13	36.11	84.73	40008166	ALLARDT	36.23	84.52	51.28	55.40	H	M
0500	ME	23	45.05	68.69	179360 6	WEST ENDFIELD	45.15	68.39	41.27	41.40	M	L
0500	MD	24	39.29	77.53	46476366	KEARNEYSVILLE WSO	39.23	77.53	37.42	52.50	M	M
0500	MN	27	47.52	95.13	21679566	RED LAKE INDIAN AGENCY	47.52	95.02	21.88	39.30	M	L
0500	MS	28	32.84	90.04	22506266	LEXINGTON 2 NNW	33.08	90.04	54.57	62.70	H	M
0500	MO	29	36.50	93.22	23309426	GALENA	36.48	93.28	45.18	55.40	H	M
0500	MT	30	45.81	110.00	24560344	MELVILLE 4 W	46.06	110.03	16.65	41.20	L	L
0500	NJ	34	40.18	74.52	28463566	LAMBERTVILLE	40.22	74.57	46.91	53.80	H	M
0500	NM	35	32.20	108.28	29507966	LORDSBURG 4 SE	32.18	108.39	13.65	60.00	L	M
0500	OK	40	34.64	98.67	34962966	WICHITA MT WL REF	34.44	98.43	36.03	59.90	M	M
A500	TX	48	32.61	96.42	41224466	DALLAS FAA AP	32.51	96.51	36.51	66.60	M	H
0500	AB	81	53.59	116.02	10726446	PORTHILL	49.00	116.30	20.94	45.60	L	L
0500	MB	83	49.66	96.28	21345544	HALLOCK	48.46	96.57	18.35	39.00	L	L

Precipitation ranges: L = less than 21 in, M = 21 to 42 in, H = more than 42 in
Temperature ranges: L = less than 48 deg, M = 48 to 64 deg, H = more than 64 deg

Annual Precipitation and Temperature Levels for GPS-6B Sites

GPS-6B Site					Nearest Weather Station				Average Annual Precipitation (inches)	Average Annual Temperature (degrees F)	Precipitation Range	Temperature Range
SHRP ID	State	State Code	Latitude (degrees)	Longitude (degrees)	ID	Name	Latitude (degrees)	Longitude (degrees)				
1001	AL	1	32.53	85.09	09929166	WEST POINT	32.52	85.11	48.11	62.40	H	M
4127	AL	1	34.84	87.36	40508966	LAWRENCEBURG FILT PLT	35.15	87.21	57.69	57.90	H	M
4129	AL	1	33.05	86.14	017999 6	SYLACAUGA 4 NE	33.12	86.12	54.08	61.20	H	M
4155	AL	1	31.24	85.57	01621866	OZARK 6 NNW	31.32	85.41	51.89	66.10	H	H
1002	AK	2	60.76	149.24	456858 6	QUILLAYUTE WSCMO AP	47.57	124.33	99.34	49.20	H	M
1004	AK	2	61.18	149.75	456858 6	QUILLAYUTE WSCMO AP	47.57	124.33	99.34	49.20	H	M
9035	AK	2	62.41	150.26	45731946	SAPPHO 8 E	48.04	124.07	95.54	49.20	H	M
2041	CA	6	40.45	124.05	04291066	EUREKA WSO CI	40.48	124.10	37.36	53.80	M	M
2051	CA	6	38.27	122.30	04764366	SAINT HELENA	38.30	122.28	35.77	59.80	M	M
8153	CA	6	35.21	120.62	04586666	MORRO BAY FIRE DEPT	35.22	120.51	15.29	56.00	L	M
8534	CA	6	32.77	115.77	04104866	BRAWLEY 2 SW	32.57	115.33	3.29	72.50	L	H
8535	CA	6	32.77	115.52	04104866	BRAWLEY 2 SW	32.57	115.33	3.29	72.50	L	H
1029	CO	8	40.53	107.92	055446 6	MAYBELL	40.31	108.05	14.03	41.70	L	L
1047	CO	8	40.10	108.83	052286 6	DINOSAUR NATL MONUMENT	40.14	108.58	12.14	47.50	L	L
7780	CO	8	38.92	104.99	05152846	CHEESMAN	39.13	105.17	17.86	43.80	L	L
7781	CO	8	38.09	103.18	05483466	LAS ANIMAS	38.04	103.13	12.49	53.40	L	M
1400	DC	11	38.87	76.99	18770546	ROCKVILLE 1 NE	39.06	77.06	39.68	53.90	M	M
3997	FL	12	30.09	81.71	08435866	JACKSONVILLE WSO AP	30.30	81.42	47.93	68.50	H	H
4101	FL	12	28.45	81.29	08798266	SANFORD EXP STATION	28.48	81.14	48.68	71.10	H	H
4135-2	FL	12	27.86	81.59	08479766	LAKELAND 3 SE	28.01	81.55	49.87	73.50	H	H
4135-3	FL	12	27.86	81.59	08479766	LAKELAND 3 SE	28.01	81.55	49.87	73.50	H	H
4136-2	FL	12	27.87	81.59	08479766	LAKELAND 3 SE	28.01	81.55	49.87	73.50	H	H
4136-3	FL	12	27.87	81.59	08479766	LAKELAND 3 SE	28.01	81.55	49.87	73.50	H	H
4137-2	FL	12	27.88	81.60	08479766	LAKELAND 3 SE	28.01	81.55	49.87	73.50	H	H
4137-3	FL	12	27.88	81.60	08479766	LAKELAND 3 SE	28.01	81.55	49.87	73.50	H	H
4420	GA	13	31.90	81.36	09784766	SAVANNAH WSO AP	32.08	81.12	46.73	67.00	H	H
1007	ID	16	42.59	114.70	10100246	BLISS 4 NW	42.57	115.00	11.17	50.00	L	M
1037	IN	18	37.80	87.22	12273166	EVANSVILLE	37.58	87.33	46.85	57.80	H	M
1009	ME	23	44.07	69.49	17304666	GARDINER	44.13	69.47	41.33	43.80	M	L
1026	ME	23	44.57	70.29	17732566	RUMFORD 1 SSE	44.32	70.32	43.82	44.10	H	L
1028	ME	23	44.53	70.80	17526144	MIDDLE DAM	44.47	70.55	36.48	39.50	M	L
3087	MS	28	34.44	89.50	22437766	INDEPENDENCE 3 N	34.44	89.48	50.49	59.80	H	M
3093	MS	28	30.43	88.67	22079266	BILOXI CITY	30.24	88.52	62.36	68.50	H	H
3094	MS	28	30.44	88.63	22079266	BILOXI CITY	30.24	88.52	62.36	68.50	H	H
5403	MO	29	36.12	90.17	23441766	KENNETT RADIO KBOA	36.13	90.04	48.93	59.20	H	M
5413	MO	29	36.20	90.09	23441766	KENNETT RADIO KBOA	36.13	90.04	48.93	59.20	H	M
7066	MT	30	45.81	110.00	24560344	MELVILLE 4 W	46.06	110.03	16.65	41.20	L	L
7076	MT	30	45.12	107.35	24917566	WYOLA 2 SW	45.06	107.26	16.23	44.90	L	L
7088	MT	30	45.81	110.00	24560344	MELVILLE 4 W	46.06	110.03	16.65	41.20	L	L
6700	NE	31	40.40	99.44	25145066	CANADAY STEAM PLANT	40.41	99.42	22.65	50.00	M	M
1030	NV	32	36.23	115.22	26224366	DESERT NATL W L RANGE	36.26	115.22	4.74	62.40	L	M

GPS-6B Site					Nearest Weather Station				Average Annual Precipitation (inches)	Average Annual Temperature (degrees F)	Precipitation Range	Temperature Range
SHRP ID	State	State Code	Latitude (degrees)	Longitude (degrees)	ID	Name	Latitude (degrees)	Longitude (degrees)				
1008	NY	36	43.20	75.41	301110 6	CAMDEN 2 NW	43.22	75.47	50.21	44.70	H	L
1011	NY	36	43.12	76.05	30838366	SYRACUSE WSO AP	43.07	76.07	36.98	47.80	M	L
1643	NY	36	43.44	73.46	30328466	GLENS FALLS FARM	43.20	73.44	44.88	46.60	H	L
1040	NC	37	35.91	82.06	40293446	ERWIN 2 SW	36.08	82.26	43.07	55.40	H	M
1802	NC	37	36.32	78.52	31650766	OXFORD 2 SW	36.17	78.37	44.61	58.80	H	M
1803	NC	37	35.39	83.30	40342046	GATLINBURG 2 SW	35.41	83.32	51.61	55.30	H	M
4086	NC	40	35.08	97.96	34022466	ANADARKO 2 NNE	35.06	98.14	31.81	60.40	M	M
4164	OK	40	36.33	98.48	34940466	WAYNOKA	36.35	98.52	26.66	59.10	M	M
1618	PA	42	39.77	78.91	36170566	CONFLUENCE 1 SW DAM	39.48	79.22	44.98	49.20	H	M
1025	SC	45	34.25	82.14	38501766	LAURENS	34.30	82.02	45.22	60.10	H	M
9106-2	SD	46	45.85	102.18	39486446	LEMMON	45.56	102.10	17.23	45.40	L	L
9106-3	SD	46	45.85	102.18	39486446	LEMMON	45.56	102.10	17.23	45.40	L	L
9197	SD	46	44.07	98.51	39907066	WESSINGTON SPRINGS	44.05	98.34	23.03	48.10	M	M
1023	TN	47	36.19	84.10	40661946	NORRIS	36.13	84.03	47.94	56.00	H	M
2001	TN	47	36.18	89.22	40806566	SAMBURG W L REFUGE	36.27	89.19	50.75	58.20	H	M
2008	TN	47	35.86	88.75	40601266	MILAN 6 NW	35.59	88.50	54.10	58.10	H	M
3101	TN	47	35.94	86.12	40510866	LEBANON 3 W	36.13	86.20	51.14	57.50	H	M
3108	TN	47	36.18	84.09	40661946	NORRIS	36.13	84.03	47.94	56.00	H	M
3109	TN	47	35.53	86.93	40195766	COLUMBIA 3 WNW	35.38	87.05	53.27	56.50	H	M
3110	TN	47	35.61	84.57	40783446	ROCKWOOD 2	35.51	84.42	55.83	56.40	H	M
9024	TN	47	35.93	86.24	40510866	LEBANON 3 W	36.13	86.20	51.14	57.50	H	M
9025	TN	47	35.95	86.10	40510866	LEBANON 3 W	36.13	86.20	51.14	57.50	H	M
1039-3	TX	48	32.49	96.82	41224266	DAL-FTW REG WSCMO AP	32.54	97.02	33.90	65.50	M	H
1093	TX	48	28.78	98.31	41721566	POTEET	29.02	98.35	26.51	69.60	M	H
1094	TX	48	29.60	98.71	41090266	BOERNE	29.48	98.43	33.52	65.50	M	H
1113	TX	48	31.96	94.70	41408166	HENDERSON	32.10	94.48	47.14	64.20	H	H
1116	TX	48	31.89	94.68	41408166	HENDERSON	32.10	94.48	47.14	64.20	H	H
1119	TX	48	32.00	95.00	41452566	JACKSONVILLE	31.58	95.16	45.19	66.30	H	H
1130	TX	48	29.56	97.94	41627666	NEW BRAUNFELS	29.44	98.07	32.56	67.60	M	H
3579	TX	48	32.62	95.85	41980066	WILLS POINT	32.42	96.01	40.88	64.60	M	H
3855	TX	48	29.80	96.81	41841566	SMITHVILLE	30.01	97.09	36.41	66.80	M	H
3875	TX	48	36.17	102.03	41869266	STRATFORD	36.21	102.05	16.99	54.60	L	M
1681	VT	50	44.31	73.25	30665966	PLATTSBURGH AFB	44.39	73.28	31.00	44.40	M	L
1683	VT	50	44.33	73.24	30665966	PLATTSBURGH AFB	44.39	73.28	31.00	44.40	M	L
1002	VA	51	36.96	80.37	44695546	PULASKI 2 E	37.03	80.45	37.33	52.10	M	M
1417	VA	51	38.61	77.79	448902 4	WASHINGTON 3 SSW	38.40	78.11	43.61	53.00	H	M
1419	VA	51	36.97	81.92	443640 6	GRUNDY	37.16	82.05	43.17	55.20	H	M
1423	VA	51	36.85	82.76	44662666	PENNINGTON GAP	36.45	83.03	46.47	54.00	H	M
1005	WA	53	47.10	118.63	45603946	ODESSA	47.20	118.41	10.94	47.30	L	L
1007	WA	53	46.05	119.60	45676846	PROSSER 4 NE	46.15	119.45	8.48	51.10	L	M
1008	WA	53	47.56	117.39	45793866	SPOKANE WSO AP	47.38	117.32	16.82	47.30	L	L
1640	WV	54	38.28	81.76	46968366	WINFIELD LOCKS	38.32	81.55	40.54	54.60	M	M
1804	AB	81	53.34	113.59	24230146	DEL BONITA	49.00	112.47	13.19	41.00	L	L

GPS-6B Site					Nearest Weather Station				Average Annual Precipitation (inches)	Average Annual Temperature (degrees F)	Precipitation Range	Temperature Range
SHRP ID	State	State Code	Latitude (degrees)	Longitude (degrees)	ID	Name	Latitude (degrees)	Longitude (degrees)				
1805	AB	81	50.91	113.59	24230146	DEL BONITA	49.00	112.47	13.19	41.00	L	L
6450	MB	83	49.66	96.31	21345544	HALLOCK	48.46	96.57	18.35	39.00	L	L
6451	MB	83	49.66	96.31	21345544	HALLOCK	48.46	96.57	18.35	39.00	L	L
1125	PQ	89	46.70	71.67	27299966	FIRST CONN LAKE	45.05	71.17	44.37	37.10	H	L
1127	PQ	89	46.48	71.04	17408646	JACKMAN	45.38	70.16	37.74	38.00	M	L
6410	SK	90	52.06	106.60	24623644	OPHEIM 10 N	49.00	106.23	10.84	40.00	L	L
6412	SK	90	52.06	106.62	24623644	OPHEIM 10 N	49.00	106.23	10.84	40.00	L	L

Precipitation ranges: L = less than 21 in, M = 21 to 42 in, H = more than 42 in
Temperature ranges: L = less than 48 deg, M = 48 to 64 deg, H = more than 64 deg

SPS-5 Pavement Structure Data

The as-constructed test section station limits, pavement layer thicknesses, and material and subgrade types for the SPS-5 test sections (and in a few cases, linked GPS sections) are summarized in the tables on the following pages of this Appendix.

The data in the columns under the heading Original Construction represent the pavement structure prior to treatment. The data in the columns under the heading Rehabilitation represent the asphalt concrete layers and thicknesses present after treatment, including overlay if any. Only the asphalt concrete layer data are shown under Rehabilitation because the base, subbase, and subgrade thicknesses and material types are the same before and after treatment. One or more asphalt concrete layer thicknesses may be shown, if the material was placed in several lifts. When some asphalt concrete has been removed by milling prior to placement of an overlay, this is reflected by a reduction in one of the asphalt concrete layer thicknesses.

In the case of the SPS-5 experiment, a change from CN = 2 to CN = 3 does not necessarily mean the end of the first rehabilitation's performance period. A recent change in construction numbering policy has resulted, for some sites, in CN changes for multiple activities related to the initial rehabilitation (e.g., patching and then overlay placement), or maintenance work (e.g., crack sealing) done during the performance period of the overlay. The dates and reasons for changes in construction number must be checked carefully to discern which changes really reflect the end of a rehabilitation performance period, and which do not.

Note that empty cells indicate that according to the available LTPP data, no layer is present, whereas cells containing question marks (???) indicate that a layer is present but some information about the layer is missing.

The layer thickness and material type data shown on the following pages were retrieved from LTPP data table TST_L05B, *except for* the data for the Alabama and New Mexico SPS-5 sites. These sites did not have data in the TST_L05B table, in the LTPP database release (11.5) used for this study. Therefore, layer thickness and material type data for these two sites were retrieved from LTPP data table SPS5_LAYER.

The following codes (from LTPP data table CODES) are used for material types identified in SPS-5 test sections:

1	=	hot-mixed, hot-laid, dense-graded asphalt concrete
2	=	hot-mixed, hot-laid, open-graded asphalt concrete
13	=	recycled AC, hot laid, central plant mix
20	=	other
23	=	crushed stone, gravel or slag
26	=	soil-aggregate mixture (predominantly coarse-grained soil)
28	=	dense-graded, hot-laid, central-plant mix
59	=	silty sand
60	=	clayey sand
71	=	chip seal
73	=	fog seal coat
74	=	woven geotextile
76	=	stress-absorbing membrane interlayer [correct code is 77]
102	=	fine-grained soil: lean inorganic clay
103	=	fine-grained soil: fat inorganic clay
107	=	fine-grained soil: clay with sand
108	=	fine-grained soil: lean clay with sand
111	=	fine-grained soil: gravelly lean clay
113	=	fine-grained soil: sandy clay
114	=	fine-grained soil: sandy lean clay
131	=	fine-grained soil: silty clay
141	=	fine-grained soil: silt
202	=	coarse-grained soil: poorly graded sand
204	=	coarse-grained soil: poorly graded sand with silt
214	=	coarse-grained soil: silty sand
215	=	coarse-grained soil: silty sand with gravel
216	=	coarse-grained soil: clayey sand
217	=	coarse-grained soil: clayey sand with gravel
266	=	coarse-grained soil: clayey gravel
265	=	coarse-grained soil: silty gravel with sand
267	=	coarse-grained soil: clayey gravel with sand
302	=	uncrushed gravel
303	=	crushed stone
304	=	crushed gravel
308	=	soil-aggregate mixture (predominantly coarse-grained)

319	=	HMAC
320	=	sand asphalt
321	=	asphalt-treated mixture
322	=	dense-graded, hot-laid, central-plant mix
331	=	cement-aggregate mixture
350	=	other
338	=	lime-treated soil

ALABAMA - SPS-5 (Data from SPS5_LAYER)

Station (m)	Section	Original Construction: AC Thickness	Base Thickness	Base Type	Subbase Thickness	Subbase Type	Subgrade Type	Rehabilitation AC Thicknesses	
0 – 152	010563	1 2.5	10	GB (23)	5	GS (26)	SS (60)	1.4 0	1.8 (28)
320 – 472	010506	1 2.5	10	GB (23)	5	GS (26)	SS (60)	2 1	0 1.9
625 – 777	010507	1 2.5	10	GB (23)	5	GS (26)	SS (60)	2.1 3.5	0 1.9
869 – 1,021	010504	1 2.5	10	GB (23)	5	GS (26)	SS (60)	2 2.4	1 2.5
1,234 – 1,387	010505	1 2.6	10	GB (23)	5	GS (26)	SS (60)	1.4 1	2.6
1,555 – 1,707	010502	1 2.3	10	GB (23)	5	GS (26)	SS (60)	1.3 (13) 1	2.3
1,829 – 1,981	010503	1 2.3	10	GB (23)	5	GS (26)	SS (60)	1.9 (13) 2.1 (13)	1 2.3
2,042 – 2,195	010508	1 2.5	10	GB (23)	5	GS (26)	SS (60)	2 (13) 3.7 (13)	0 1.6
2,377 – 2,530	010509	1 2.5	10	GB (23)	5	GS (26)	SS (60)	1.8 (13) 1.4 (13)	0 2.3
2,728 – 2,880	010564	1 2.5	10	GB (23)	5	GS (26)	SS (60)	1.1 (13) 0	2.3 (28)
	014155 GPS	1 2.7	10.4	GB (303)	5	GS (26)	SS (60)		

ARIZONA - SPS-5

Station (m)	Section	Original Construction						Rehabilitation	
		AC	Base		Subbase		Subgrade	AC	
		Thickness	Thickness	Type	Thickness	Type	Type	Thicknesses	
0 152	040507	0.7 (2) 4.3	20.7	GB (308)			SS (265)	4.1 2.7	2.4
233 385	040504	0.7 (2) 4.2	17.6	GB (308)			SS (265)	4.8 4.2	
469 622	040503	0.8 (2) 4.2	16.6	GB (308)			SS (265)	4.7 (13) 4.2	
884 1,036	040508	0.7 (2) 4.7	15	GB (308)			SS (265)	4.1 (13) 2.4 (13)	2.7
1,165 1,317	040509	0.7 (2) 4.7	14.8	GB (308)			SS (265)	1.3 (13) 2.6 (13)	2.6
1,597 1,750	040502	0.9 (2) 4.2	14.7	GB (308)			SS (265)	2.7 (13) 4.2	
1,844 1,996	040506	0.9 (2) 4	12.8	GB (308)			SS (265)	2.4 2.8	3.0
2,028 2,180	040505	0.9 (2) 4.1	12.8	GB (308)			SS (265)	2.8 4.1	
2,267 2,419	040559	1.0 (2) 4.1	13.2	GB (308)			SS (265)	3.0 (13) 3.0	1.7
2,553 2,736	040560	0.9 (2) 4.1	14	GB (308)			SS (265)	2.2 (20) 4.1	
2,790 2,943	040501	0.9 (2) 4.1	14.2	GB (308)			SS (265)		

CALIFORNIA - SPS-5

Station (m)	Section	Original Construction: AC Thickness	Base Thickness	Base Type	Subbase Thickness	Subbase Type	Subgrade Type	Rehabilitation AC Thicknesses	
0 – 152	060501	0.5 (2) / 4.3	5	TB (331)	16.6	GS (308)	SS (204)	1.8 (13) / 0.5 (2)	4.3
252 – 404	060502	0.5 (2) / 4.4	5.5	TB (331)	17.2	GS (308)	SS (204)	3.0 (13) / 3.7	
442 – 595	060503	0.5 (2) / 4.4	5.5	TB (331)	20.7	GS (308)	SS (204)	6.5 (13) / 3.5	
625 – 777	060504	0.5 (2) / 4.5	4.9	TB (331)	21.2	GS (308)	SS (204)	5.7 / 3.6	
838 – 991	060505	0.5 (2) / 4.7	5.2	TB (331)	20	GS (308)	SS (204)	3.6 / 4	
1,052 – 1,204	060506	0.5 (2) / 4.8	5.3	TB (331)	19.9	GS (308)	SS (204)	2.2 / 2.1	3.6
1,281 – 1,434	060507	0.8 (2) / 5.1	5.4	TB (331)	19.4	GS (308)	SS (204)	4.7 / 2	3.7
1,494 – 1,647	060508	1.0 (2) / 5.4	5.6	TB (331)	19.1	GS (308)	SS (204)	4.5 (13) / 2.1 (13)	4.1
1,727 – 1,879	060509	0.5 (2) / 5.4	5.3	TB (331)	19.5	GS (308)	SS (204)	2.0 (13) / 2.4 (13)	3.9
1,920 – 2,172	060569	0.5 (2) / 5.4	5.3	TB (331)	19.1	GS (308)	SS (204)	1.8 (20) / 1.8 (13)	3.6 / 2.3
2,286 – 2,591	060570	0.5 (2) / 4.8	5.5	TB (331)	19.7	GS (308)	SS (204)	1.8 (20) / 1.8 (13)	3.6 / 1.7
2,652 – 2,957	060571	0.5 (2) / 4.3	5.7	TB (331)	20.2	GS (308)	SS (204)	1.8 (13) / 4.2	3.6 / 1.2
3,881 – 4,186	060560	0.5 (2) / 4.5	5.8	TB (331)	19.4	GS (308)	SS (204)	0.3 (71) / 2	2 / 2.7

4,277 4,582	060561	0.5 (2) 4.8	5.6	TB (331)	20	GS (308)	SS (204)	2 0.2 (EF74) 2	3
4,765 5,070	060562	0.5 (2) 5	4.1	TB (331)	22.3	GS (308)	SS (131)	2.0 (20) 0.2 (EF74) 2	3.2
5,192 5,497	060563	0.5 (2) 5.1	3.8	TB (331)	22.9	GS (308)	SS (131)	2.0 (20) 2	3.3
5,527 5,832	060564	0.5 (2) 5.1	4.4	TB (331)	22.9	GS (308)	SS (131)	2.0 (20) 0.3 (76)	2 3
5,954 6,259	060565	0.5 (2) 5	4.7	TB (331)	21.4	GS (308)	SS (131)	2 0.3 (76)	2 3.2
6,397 6,672	060566	0.5 (2) 4.6	5.6	TB (331)	20	GS (308)	SS (204)	0.7 (2) 0.3 (76) 2	2 2.8
6,701 7,006	060567	0.5 (2) 4.7	5.5	TB (331)	19.8	GS (308)	SS (204)	0.7 (2) 2	2 3
7,059 7,364	060568	0.5 (2) 4.7	5	TB (331)	19.6	GS (308)	SS (216)	4 2	2.9
7,403 7,708	060559	0.5 (2) 4.5	5.8	TB (331)	19.7	GS (308)	SS (216)	2 4	2 2

COLORADO - SPS-5

Station (m)	Section	Original Construction: AC Thickness	Base Thickness	Base Type	Subbase Thickness	Subbase Type	Subgrade Type	Rehabilitation AC Thicknesses	
0–152	080560	5.7	2.5	TB (322)			SS (216)	1.9 (20) 4.2	5.7
213–366	080502	5.4	2.7	TB (322)			SS (216)	2.5 (13) 1.3	5.4
427–579	080509	5.1	2.7	TB (322)			SS (216)	2.2 (13) 2 (13)	3.1
640–793	080503	5	2.1	TB (322)			SS (216)	4.5 (13) 0.9	5
853–1,006	080508	5	2	TB (322)			SS (2160	5.1 (13) 2.8 (13)	2.2
1,280–1,433	080504	4.5	3.5	TB (322)			SS (108)	5.1 0.7	4.6
1,494–1,646	080507	5.8	1	TB (322)			SS (108)	4.8 2	3.8
1,707–1,859	080505	6.4	3	TB (322)			SS (108)	2.5 0.7	6.4
1,920–2,073	080506	6.5	3.4	TB (322)			SS (111)	1.7 2	4.5
2,134–2,286	080501	6.7	3.6	TB (322)			SS (111)	1.3 6.7	
2,347–2,499	080559	6.4	3.9	TB (322)			SS (111)	2.5 4.1	6.4

Station (m) Start	Station (m) End	Section	Original Construction: AC Thickness	Base Thickness	Base Type	Subbase Thickness	Subbase Type	Subgrade Type	Rehabilitation: AC Thicknesses	
0	152	120502	3.1	8.8	GB (303)	15	GS (308)	SS (202)	0.8 (13) 1.8 (13)	1.7
669	821	120561	2	8.8	GB (303)	15	GS (308)	SS (202)	1 (13) 2.8 (13)	2.1
945	1,098	120503	2.7	9.5	GB (303)	15	GS (308)	SS (202)	3.1 (13) 2.2 (13)	2.3
1,190	1,343	120508	2.8	8.8	GB (303)	15	GS (308)	SS (202)	4.4 (13) 2.7 (13)	0.5
1,799	1,951	120565	3.1	8.8	GB (303)	15	GS (308)	SS (202)	1.1 (13) 2.2 (13)	2.6 (13) 0.5
2,072	2,225	120509	3.2	8.8	GB (303)	15	GS (308)	SS (202)	1 (13) 3.1 (13)	0.7
2,380	2,532	120506	2.9	8.8	GB (303)	15	GS (308)	SS (202)	1.1 1.9	1.7
2,620	2,773	120566	2.8	8.8	GB (303)	15	GS (308)	SS (202)	1 2.2	2.3 0.3
2,894	3,047	120507	2.8	8.8	GB (303)	15	GS (308)	SS (202)	4.5 2.1	0.6
3,169	3,321	120504	2.9	8.8	GB (303)	15	GS (308)	SS (202)	1.5 3.6	2.2
3,443	3,595	120562	2.7	8.8	GB (303)	15	GS (308)	SS (202)	1 2.6	1.9
3,717	3,869	120505	2.9	8.8	GB (303)	15	GS (308)	SS (202)	0.8 1.3	2.2
4,357	4,510	120563	3.1	8.8	GB (303)	15	GS (308)	SS (202)	0.9 1.3	0.5
4,631	4,784	120564	3.1	8.8	GB (303)	15	GS (308)	SS (202)	0.6 (13) 1.4 (13)	0.6

Station (m)	Section	Original Construction: AC Thickness	Base Thickness	Base Type	Subbase Thickness	Subbase Type	Subgrade Type	Rehabilitation AC Thicknesses	
0 154	130505	1.0 (2) 2.4	11.3	TB (319)	13	GS (308)	SS (215)	1.0 (2) 2	1.6
201 355	130506	0.8 (2) 2.2	11.4	TB (319)	13	GS (308)	SS (215)	0.9 (2) 1.8	2.4 0.1
416 571	130507	0.7 (2) 2.4	11.6	TB (319)	13	GS (308)	SS (215)	0.8 (2) 1.3	5 1
633 787	130504	0.7 (2) 2.2	11.3	TB (319)	13	GS (308)	SS (215)	1.0 (2) 1.4	3.9 1.3
848 1,003	130503	0.7 (2) 2	11.4	TB (319)	13	GS (308)	SS (215)	1.1 (2) 1.4 (13)	3.7 (13) 1.2
1,064 1,219	130508	0.6 (2) 1.6	11.4	TB (319)	13	GS (308)	SS (215)	1.0 (2) 1.4 (13)	5.3 (13)
1,264 1,417	130509	0.7 (2) 1.8	11.2	TB (319)	13	GS (308)	SS (215)	1.0 (2) 2.0 (13)	1.8 (13) 0.2
1,462 1,615	130502	0.8 (2) 1.8	11	TB (319)	13	GS (308)	SS (215)	1 (2) 1.6 (13)	1.4
1,676 1,828	130501	0.8 (2) 1.8	11	TB (319)	13	GS (308)	SS (215)		
4,789 4,943	130567	0.6 (2) 2	14.7	TB (319)	15.5	GS (308)	SS (215)		
5,004 5,158	130563	0.8 (2) 2.2	15.1	TB (319)	15.5	GS (308)	SS (215)	1.0 (2) 2.2	
5,220 5,375	130566	0.6 (2) 1.6	14.4	TB (319)	15.5	GS (308)	SS (215)	0.9 (2) 1.3	4.1
5,436 5,590	130562	0.6 (2) 1.8	15.2	TB (319)	15.5	GS (308)	SS (215)	1.0 (2) 1.3	2.2 1.4
5,652 5,805	130561	0.7 (2) 1.8	15.6	TB (319)	38.7	GS (308)	SS (215)	1.2 (2) 2.9 (13)	1.7
5,851 6,003	130565	1.0 (2) 2	15.6	TB (319)	38.7	GS (308)	SS (215)	1.0 (2) 1.1 (13)	3.9 (13) 2
6,064 6,217	130564	0.7 (2) 1.6	15.2	TB (319)	38.7	GS (308)	SS (215)	0.9 (2) 2.3 (13)	
6,278 6,430	130560	0.7 (2) 1.6	15.2	TB (319)	38.7	GS (308)	SS (215)	0.9 (2) 1.2	1 1.1

MAINE - SPS-5

Station (m)	Section	Original Construction: AC Thickness	Base: Thickness	Base: Type	Subbase: Thickness	Subbase: Type	Subgrade Type	Rehabilitation: AC Thicknesses	
0–152	230501	0.4 (2) 2.0+2.9+3.1	4.4	GB (304)	9	GS (302)	SS (216)		
235–387	230502	0.5 (2) 2.2+2.8+3.4	4.4	GB (304)	9	GS (302)	SS (216)	3.0 (13) 0.7 (2) 2.1	2.9 3.5 4 (GB304)
485–637	230503	0.5 (2) 2.1+3.0+3.1	4.4	GB (304)	9	GS (302)	SS (216)	2.1(13) 3 (13) 0.5 (2)	2.1 3 3.6
689–841	230504	0.5 (2) 2.2+2.9+3.2	4.4	GB (304)	9	GS (302)	SS (216)	2.2 3.5 0.6 (2)	1.9 3 3
939–1,091	230505	0.5 (2) 2.2+2.7+3.0	4.4	GB (304)	9	GS (302)	SS (216)	2.7 0.5 (2) 2.2	2.7 3
1,146–1,298	230506	0.5 (2) 2.1+2.8+3.0	4.4	GB (304)	9	GS (302)	SS (216)	2.1 2 1.1	2.8 3
1,396–1,548	230507	0.4 (2) 2.1+2.8+2.8	4.4	GB (304)	9	GS (302)	SS (216)	2.1 3.2 2.1	1 3 2.9
1,603–1,756	230508	0.5 (2) 2.1+3.0+3.1	4.5	GB (304)	9	GS (302)	SS (216)	1.9 (13) 3.1 (13) 1.9 (13)	1.3 2.9 3
1,853–2,006	230509	0.5 (2) 2.1+2.7+3.2	4.4	GB (304)	9	GS (302)	SS (214)	2.1 (13) 1.7 (13) 1.1	2.7 3.2
2,067–2,219	230559	0.5 (2) 2.1+2.9+3.3	4.4	GB (304)	9	GS (302)	SS (214)	1.8 1.3 0.5 (2)	2.1 2.9 3.3

MARYLAND - SPS-5

Station (m)	Section	Original Construction: AC Thickness	Base Thickness	Base Type	Subbase Thickness	Subbase Type	Subgrade Type	Rehabilitation: AC Thicknesses	
0 152	240502	1.0 (2) 1.3+1.8	3.9	TB (331)	5.9 8.9	GS (303) TS (338)	SS (141)	2.2 (13) 1.1 (2)	1.3 1.9
274 427	240505	1.1 (2) 1.5+2.0	3.7	TB (331)	5.9 8.9	GS (303) TS (338)	SS (141)	2.2 1.2 (2)	1.4 1.9
640 793	240503	0.9 (2) 1.7+1.9	3.9	TB (331)	5.9 8.9	GS (303) TS (338)	SS (141)	2.3 (13) 3.0 (13) 0.9 (2)	1.7 1.9
853 1,006	240504	0.9 (2) 1.9+2.1	4.1	TB (331)	5.1 7	GS (303) TS (338)	SS (141)	2.3 3 0.9 (2)	1.9 2.1
1,067 1,219	240507	0.8 (2) 1.5+2.2	4.1	TB (331)	5.1 7	GS (303) TS (338)	SS (141)	2 3.4	1.2 2
1,280 1,433	240508	0.9 (2) 1.6+2.0	4.2	TB (331)	5.1 8	GS (303) TS (338)	SS (141)	1.8 (13) 4.8 (13)	1.4 2
1,524 1,676	240506	0.9 (2) 1.9+1.8	4.3	TB (331)	5.1 7	GS (303) TS (338)	SS (141)	2.8 1.5	2.5
2,743 2,896	240509	1.0 (2) 1.6+2.1	3.5	TB (331)	6.5 7.4	GS (303) TS (338)	SS (141)	4.0 (13) 1.3	2.2
3,382 3,535	240559	1.1 (2) 1.7+2.3	3.6	TB (331)	6 7.7	GS (303) TS (338)	SS (141)	3.7 1.1 (2)	1.7 2.3
4,523 4,675	240561	1.1 (2) 1.5+2.1	4.3	TB (331)	5.4 6.8	GS (303) TS (338)	SS (141)	2.9 1.1 (2)	1.5 2.1

4,858 5,011	240562	1.1 (2) 1.5+2.0	4.3	TB (331)	5.4 6.8	GS (303) TS (338)	SS (141)	2.9 1.1 (2)	1.5 2.1
5,742 5,895	240560	1.0 (2) 1.2+1.8	4.1	TB (331)	5.8 5.9	GS (303) TS (338)	SS (141)	2 0.7 1.0 (2)	1.2 1.8
6,230 6,382	240563	0.9 (2) 1.4+1.9	3.7	TB (331)	5.8 5.9	GS (303) TS (338)	SS (141)	2.9 0.9 (2)	1.4 1.9
8,394 8,546	240501	1 (2) 1.6+2.0	4.2	TB (331)	5.8 6	GS (303) TS (338)	SS (141)	1.0 (2) 1.6	2

MINNESOTA - SPS-5

Station (m)	Section	Original Construction: AC Thickness	Base Thickness	Base Type	Subbase Thickness	Subbase Type	Subgrade Type	Rehabilitation AC Thicknesses	
0–152	270503	1.1 5.4	5	GB (304)	12.8	GS (302)	SS (113)	1.5 (13) 3.1 (13)	1.1 5.4
168–320	270508	1.5 4.6	5.1	GB (304)	12.4	GS (302)	SS (113)	1.5 (13) 2.7 (13)	4.1
419–572	270502	1.5 5.4	5	GB (304)	12.8	GS (302)	SS (113)	2.4 (13) 1.5	5.4
648–800	270509	1.5 6	5	GB (304)	12.6	GS (302)	SS (113)	1.5 (13) 5.5	
846–998	270505	1.1 5.6	4.7	GB (304)	12.6	GS (302)	SS (113)	1.9 1.1	5.6
1,212–1,364	270506	1.5 5.9	5	GB (304)	12.5	GS (302)	SS (113)	1.8 5.4	
1,501–1,654	270504	1.5 5.2	5.2	GB (304)	12	GS (302)	SS (131)	1.5 3.1	1.5 5.2
1,760–1,913	270507	1.1 5.8	5.2	GB (304)	12.6	GS (302)	SS (131)	1.5 4.1	5.1
4,473–4,625	270560	1.5 5.9	5.4	GB (304)	12.6	GS (302)	SS (131)	1.5 3.4	
4,808–4,961	270501	1.5 4.7	5.4	GB (304)	12.6	GS (302)	SS (131)		
5,052–5,205	270559	1.1 5.8	5.4	GB (304)	12.6	GS (302)	SS (131)	1.5 1.1	5.8
6,848–7,001	270561	1.5 6.9	5.4	GB (304)	12.6	GS (302)	SS (131)	1.8 1.5	6.9

MISSISSIPPI - SPS-5

Station (m)	Section	Original Construction: AC Thickness	Base Thickness	Base Type	Subbase Thickness	Subbase Type	Subgrade Type	Rehabilitation AC Thicknesses	
0–152	280501	0.2 (2) 4.1	7.6	TB (319)	6	TS (338)	SS (108)		
762–914	280507	0.2 (2) 1.1+2.3	7.3	TB (319)	9.2	TS (338)	SS (114)	1.9 3	1
922–1,074	280504	0.2 (2) 1.6+2.6	8.6	TB (319)	6	TS (338)	SS (107)	2.1 2.8 0.2 (2)	0.7 2.6
1,135–1,288	280505	0.2 (2) 1.6+2.6	7.8	TB (319)	4.5	TS (338)	SS (108)	2 0.2 (2)	1.6 2.6
1,295–1,448	280506	0.2 (2) 1.6+2.6	7.8	TB (319)	4.5	TS (338)	SS (108)	1.8 1.3	
1,707–1,859	280509	0.2 (2) 0.8+3.5	7.6	TB (319)	4	TS (338)	SS (131)	2.3 (13) ??? (13)	0.4
1,867–2,019	280502	0.2 (2) 0.8+3.5	7.1	TB (319)	3.3	TS (338)	SS (108)	2 (13) 0.4	3.5
2,096–2,248	280503	0.2 (2) 0.8+3.5	7.1	TB (319)	3.3	TS (338)	SS (108)	2.4 (13) 2.2 (13) 0.2 (2)	0.9 3.5
2,347–2,499	280508	0.2 (2) 0.7+2.9	7.7	TB (319)			SS (102)	4.8 (13) 1.8	
2,591–2,743	280560	0.2 (2) 0.7 +2.9	8	TB (319)	6	TS (338)	SS (114)	1.5 1.5 0.2 (2)	0.7 2.9

MISSOURI - SPS-5

Station (m)	Section	Original Construction: AC Thickness	Base Thickness	Base Type	Subbase Thickness	Subbase Type	Subgrade Type	Rehabilitation: AC Thicknesses	
0 152	290505	1.1 7.3	4	GB (303)			SS (266)		
808 960	290504	1.1 7.2	4	GB (303)			SS (266)	1.8 3.2	1.1 7.2
1,265 1,417	290506	1.2 7.5	6	GB (303)			SS (266)	2.1 2	0 6.1
2,088 2,240	290507	1.3 7.2	4	GB (303)			SS (266)	1.8 4.6	0.2 7.2
2,728 2,880	290509	1 7.2	4	GB (303)			SS (266)	2.1 (13) 2 (13)	0 6.3
3,917 4,069	290508	1.2 7	4	GB (303)			SS (266)	2.1 (13) 5.5 (13)	0 6.2
4,648 4,801	290503	1.1 7.4	4	GB (303)			SS (266)	1.9 (13) 2.9 (13)	1.1 7.4
5,166 5,319	290502	1.4 7	4.6	GB (303)			SS (266)	2.1 (13) 1.4	7
5,669 5,822	290501	1.1 7.3	4	GB (303)			SS (266)		

MONTANA - SPS-5

Station (m)	Section	Original Construction: AC Thickness	Base Thickness	Base Type	Subbase Thickness	Subbase Type	Subgrade Type	Rehabilitation: AC Thicknesses	
0 – 152	300505	0.6 (2) 4.8	2.8	GB (308)	15.3	GS (308)	SS (267)	2 4.8	
183 – 335	300506	0.6 (2) 4.7	2.8	GB (308)	15.3	GS (308)	SS (267)	2.1 2.1	2.6
366 – 518	300507	0.7 (2) 4.4	3.5	GB (308)	15.6	GS (308)	SS (267)	4.9 2.3	2.3
549 – 701	300504	0.7 (2) 5.1	3.5	GB (308)	15.6	GS (308)	SS (267)	5.6 4.4	
761 – 914	300503	0.6 (2) 4.7	4.3	GB (308)	14.5	GS (308)	SS (267)	4.6 (13) 4.2	4.2 (GB308)
944 – 1,097	300508	0.6 (2) 4.4	4.3	GB (308)	14.8	GS (308)	SS (267)	5 (13) 2.1 (13)	2.2 4.2 (GB308)
1,127 – 1,280	300509	0.6 (2) 4.7	3.8	GB (308)	15	GS (308)	SS (267)	2.4 (13) 2.1 (13)	2.7
1,310 – 1,462	300502	0.7 (2) 4.4	2.8	GB (308)	14.4	GS (308)	SS (267)	2.6 (13) 4.3	
1,493 – 1,645	300561	0.6 (2) 4.6	3.6	GB (308)	14.4	GS (308)	SS (267)	4.6 (20) 4.4	2.8 (GB308)
1,676 – 1,829	300560	0.6 (2) 4.6	3.6	GB (308)	14.4	GS (308)	SS (267)	4.6 (20) 4.4	2.8 (GB308)

NEW JERSEY - SPS-5

Station (m)	Section	Original Construction: AC Thickness	Base Thickness	Base Type	Subbase Thickness	Subbase Type	Subgrade Type	Rehabilitation: AC Thicknesses	
0 152	340507	3 5.4	10	GB (302)	54	GS (308)	SS (216)	1.9 2.9 3	1 5.4
823 975	340503	3 6	11.3	GB (302)	4 15	GS (308) GS (308)	SS (216)	1.7 (13) 3 (13)	3 6
1,052 1,204	340508	3 6.1	11.3	GB (302)	4 18	GS (308) GS (308)	SS (216)	1.8 (13) 3.3 (13) 2.7 (13)	1 6.1
1,433 1,585	340509	3.2 6.3	11.3	GB (302)	4 18	GS (308) GS (308)	SS (216)	1.8 (13) 2.5 (13)	1.2 6.3
1,612 1,765	340506	3 6.5	10	GB (302)			SS (214)	2 2.2	1 6.5
1,981 2,134	340502	2.7 6.2	10.4	GB (302)	41	GS (308)	SS (216)	1.9 (13) 2.7	6.2
2,515 2,667	340560	3 5.5	10.5	GB (302)	4	GS (308)	SS (216)	1 (20) 2.3	1 5.5
2,713 2,865	340559	3 5.6	10.5	GB (302)	30	GS (308)	SS (216)	1.9 (13) 2.5	1 5.6
2,957 3,109	340504	3 5.5	10.7	GB (302)	4 17	GS (308) GS (308)	SS (216)	1.8 2.9	3 5.5
3,216 3,368	340505	3 6	10	GB (302)	4 16	GS (308) GS (308)	SS (216)	1.8 3	6
3,511 3,664	340501	3.5 6	10	GB (302)	66	GS (308)	SS (216)	3.5 6	

NEW MEXICO - SPS-5 (Data from SPS5_LAYER)

Station (m)	Section	Original Construction: AC Thickness	Base Thickness	Base Type	Subbase Thickness	Subbase Type	Subgrade Type	Rehabilitation AC Thicknesses	
0–152	350501	7.5	12	GB(23)			SS (59)	1 (2) 0.1 (73)	1.9 0.1 (73) 7.5
305–457	350505	9.5	12	GB (23)			SS (59)	0.8 (2) 0.1 (73)	2.5 0.1 (73) 9.5
640–793	350506	9.5	12	GB (23)			SS (59)	0.7 (2) 0.1 (73) 2.2	0.1 (73) 2.1 0.1 (73) 7.5
945–1,097	350507	9.5	12	GB (23)			SS (59)	1.2 (2) 0.1 (73) 5.3	0.1 (73) 2.1 0.1 (73) 7.5
1,174–1,326	350504	9.5	12	GB (23)			SS (59)	0.6 (2) 0.1 (73) 4.6	0.1 (73) 9.5
1,539–1,692	350503	9.5	12	GB (23)			SS (59)	1.1 (2) 0.1 (73) 4.2 (13)	0.1 (73) 9.5
2,057–2,210	350508	9.5	12	GB (23)			SS (59)	0.8 (2) 0.1 (73) 5.2 (13)	0.1 (73) 2.2 (13) 0.1 (73) 7.5
2,758–2,911	350509	9.5	12	GB (23)			SS (59)	1.1 (2) 0.1 (73) 2.1 (13)	0.1 (73) 2.1 (13) 0.1 (73) 7.5
2,987–3,139	350502	9.5	12	GB (23)			SS (59)	0.9 (2) 0.1 (73)	2.2 (13) 0.1 (73) 9.5

OKLAHOMA - SPS-5

Station (m)	Section	Original Construction: AC Thickness	Base: Thickness	Base: Type	Subbase: Thickness	Subbase: Type	Subgrade Type	Rehabilitation: AC Thicknesses	
0 152	400501	1.2 2.6	10	TB (320)			SS (216)	1.2 2.6	
274 427	400502	1.3 2.7	10	TB (320)			SS (216)	1.8 (13) 1.3	2.7
579 732	400503	1.3 2.8	10	TB (320)			SS (216)	2 (13) 2.5 (13)	1.3 2.8
975 1,128	400508	1.2 2.5	10	TB (320)			SS (216)	3.1 (13) 3 (13)	2
1,311 1,463	400509	1.5 2.7	6.7	TB (320)			SS (217)	2.8 (13) 2.2	
1,981 2,134	400506	1.4 2.6	6.7	TB (320)			SS (217)	3.9 2.4	
2,560 2,713	400507	1.5 2.9	6.7	TB (320)			SS (217)	3.5 2.9	0.4 2.9
2,835 2,987	400504	1.5 2.8	6.7	TB (320)			SS (217)	1.8 2.5	1.5 2.8
3,322 3,475	400505	1.6 2.8	6	TB (320)			SS (217)	1.8 1.6	2.8
4,145 4,298	400560	1.2 2.8	6.7	TB (320)			SS (217)	3.2 0.3	2.7

TEXAS - SPS-5

Station (m)	Section	Original Construction: AC Thickness	Base Thickness	Base Type	Subbase Thickness	Subbase Type	Subgrade Type	Rehabilitation AC Thicknesses	
0–152	481069								
1,206–1,358	48A502	1.2 7.9	14.8	TB (350)	8	TS (338)	SS (103)	2.2 (13) 1.3	7.9
1,373–1,525	48A509	1.1 7.8	14.8	TB (350)	8	TS (338)	SS (103)	2.2 (13) 2.1 (13)	7.8
1,612–1,764	48A508	1.3 8.3	14	TB (350)	8	TS (338)	SS (103)	2.1 (13) 5.2 (13)	8.3
1,824–1,976	48A503	1.4 8	10	TB (350)	8	TS (338)	SS (103)	2.1 (13) 3.2 (13)	1.4 8 10.6 (TB350)
2,036–2,188	48A504	1.2 7.5	10.6	TB (350)	8	TS (338)	SS (103)	2.2 3.1	1.2 7.5
2,309–2,462	48A507	1.2 7.8	8.8	TB (350)	5.8	TS (338)	SS (103)	2 5	7.8
2,521–2,673	48A506	1.3 7.7	8.8	TB (350)	5.8	TS (338)	SS (103)	2.3 1.6	7.7
2,734–2,886	48A505	1.6 8	8.8	TB (350)	5.8	TS (338)	SS (103)	2 1.4	8

ALBERTA - SPS-5

Station (m)	Section	Original Construction: AC Thickness	Base Thickness	Base Type	Subbase Thickness	Subbase Type	Subgrade Type	Rehabilitation: AC Thicknesses	
0 152	810501	0.2 (71) 6.3	2.9	TB (321)	11.6	GS (308)	SS (267)		
183 335	810505	0.2 (71) 6	2.5	TB (321)	11.6	GS (308)	SS (267)	2.1 0.2 (71)	6
366 518	810506	0.2 (71) 6	1.8	TB (321)	13	GS (308)	SS (267)	2.1 1.6	4.6
549 701	810507	0.2 (71) 6.2	1.6	TB (321)	13	GS (308)	SS (267)	4.9 1.7	4.2
945 1,097	810504	0.2 (71) 6.3	1.2	TB (321)	11	GS (308)	SS (267)	4.8 0.2 (71)	6.3
1,128 1,280	810503	0.2 (71) 6.2	3	TB (321)	12.9	GS (308)	SS (267)	5 (13) 0.2 (71)	6.2
1,311 1,463	810508	0.2 (71) 6.4			14.9	GS (308)	SS (267)	5 (13) 2 (13)	3.6
1,707 1,859	810509	0.2 (71) 6.9			13.5	GS (308)	SS (267)	1.8 (13) 1.5 (13)	4.6
1,920 2,073	810502	0.2 (71) 5.2			15	GS (308)	SS (267)	2.1 (13) 0.2 (71)	5.2

MANITOBA - SPS-5

Station (m)	Section	Original Construction: AC Thickness	Base Thickness	Base Type	Subbase Thickness	Subbase Type	Subgrade Type	Rehabilitation AC Thicknesses	
0 – 152	830502	0.2 (71) 2.0+2.2	5	GB (302)	4	GS (302)	SS (204)	2.7 (13) 0.2 (71)	2 2.2
198 – 351	830503	0.2 (71) 2.0+2.2	7	GB (302)	5	GS (302)	SS (214)	4.9 (13) 0.2 (71)	2 2.2
396 – 549	830508	0.2 (71) 2.3+1.7	6.9	GB (302)	5	GS (302)	SS (145)	6.5 (13) 1	1.7
579 – 732	830509	0.2 (71) 2.6+2.6	6.9	GB (302)	5	GS (302)	SS (145)	3.7 (13) 1.3	2.6
823 – 975	830506	0.1 (71) 2.9+2.5	3.5	GB (302)	10	GS (302)	SS (214)	3.2 1.5	2.5
1,006 – 1,158	830507	0.1 (71) 2.4+2.3	3.5	GB (302)	10	GS (302)	SS (214)	6.5 1	2.3
1,204 – 1,356	830504	0.2 (71) 1.7+2.1	5.1	GB (302)	5	GS (302)	SS (132)	5.6 0.2 (71)	1.7 2.1
1,387 – 1,539	830505	0.2 (71) 2.1+2.7	5.1	GB (302)	5	GS (302)	SS (132)	3.1 0.2 (71)	2.1 2.7
1,585 – 1,737	830501	0.3 (71) 2.1+2.6	5.1	GB (302)	5	GS (302)	SS (132)	0.3 (71) 2.1	2.6

Alabama (01)

STATE	YEAR	0501 to 0509 and GPS 014155			Average
		IRI	Rutting	Cracking	KESAL'S
1	1990				165
	1991				173
	1992	1-Apr-92	1-Apr-92	1-Apr-92	182
	1993				191
	1994				200
	1995				210
	1996				221
	1997				232
	1998				244
	1999				256
	2000				269
	2001	13-Mar-01	17-Jan-01	13-Mar-01	282
ESAL (thousands)		2,015	1,971	2,015	

Arizona (04)

STATE	YEAR	0501 to 0509			Average
		IRI	Rutting	Cracking	KESAL'S
4	1990	21-Sep-90			250
	1991		15-Jan-91	22-Sep-91	180
	1992				220
	1993				202
	1994				200
	1995				200
	1996				200
	1997				226
	1998				323
	1999				339
	2000	6-Dec-00	17-Oct-00	6-Dec-00	356
ESAL (thousands)		2,491	2,366	2,291	

California (06)

STATE	YEAR	0501 to 0509			Average
		IRI	Rutting	Cracking	KESAL'S
6	1990				2,123
	1991				2,229
	1992		24-Sep-92	24-Sep-92	2,341
	1993	2-Feb-93			2,458
	1994				2,184
	1995				1,964
	1996				1,964
	1997				1,341
	1998				1,408
	1999				1,478
	2000	10-Mar-00	8-Mar-00	10-Mar-00	1,552
ESAL (thousands)		12,883	13,717	13,726	

Colorado (08)

STATE	YEAR	0501 to 0509			Average
		IRI	Rutting	Cracking	KESAL'S
8	1990				227
	1991	13-Nov-91			600
	1992		27-Feb-92	27-Feb-92	452
	1993				941
	1994				461
	1995				428
	1996				459
	1997				490
	1998				527
	1999		30-Aug-99		512
	2000	24-Apr-00		24-Apr-00	538
ESAL (thousands)		4,518	4,027	4,368	

Florida (12)

STATE	YEAR	0501 to 0509 and GPS 121030			Average
		IRI	Rutting	Cracking	KESAL'S
12	1990				438
	1991				460
	1992				483
	1993				507
	1994				532
	1995	1-Nov-95			559
	1996		21-Jan-96	21-Jan-96	587
	1997				616
	1998				647
	1999				679
	2000	11-Sep-00	2-Nov-00	11-Sep-00	713
ESAL (thousands)		3,119	3,094	2,993	

Georgia (13)

STATE	YEAR	0501 to 0509			Average
		IRI	Rutting	Cracking	KESAL'S
13	1990				2,046
	1991				2,148
	1992				2,256
	1993				2,369
	1994		7-Apr-94	7-Apr-94	2,487
	1995				2,708
	1996	7-May-96			2,906
	1997				3,832
	1998				4,024
	1999				4,225
	2000	13-Aug-00	7-Jun-00	13-Aug-00	4,436
ESAL (thousands)		16,705	21,440	22,254	

Maine (23)

STATE	YEAR	0501 to 0509			Average
		IRI	Rutting	Cracking	KESAL'S
23	1990				184
	1991				193
	1992				202
	1993				213
	1994				223
	1995	15-Aug-95	3-Oct-95	3-Oct-95	234
	1996				246
	1997				251
	1998				256
	1999				230
	2000	29-Sep-00	27-Sep-00	29-Sep-00	242
ESAL (thousands)		1,251	1,219	1,220	

Maryland (24)

STATE	YEAR	0501 to 0509			Average
		IRI	Rutting	Cracking	KESAL'S
24	1990				356
	1991				374
	1992	11-Jun-92	5-Oct-92	5-Oct-92	392
	1993				412
	1994				445
	1995				478
	1996				531
	1997				544
	1998				553
	1999				261
	2000	5-Dec-00	16-Aug-00	5-Dec-00	274
ESAL (thousands)		3,697	3,490	3,573	

Minnesota (27)

STATE	YEAR	0501 to 0509			Average
		IRI	Rutting	Cracking	KESAL'S
27	1990			5-Nov-90	65
	1991	13-Jul-91			59
	1992				53
	1993		3-Jun-93		64
	1994				65
	1995				64
	1996				67
	1997				70
	1998				74
	1999				77
	2000	20-Sep-00	24-Jul-00	20-Sep-00	81
ESAL (thousands)		619	499	660	

Mississippi (28)

STATE	YEAR	0501 to 0509			Average
		IRI	Rutting	Cracking	KESAL'S
28	1990	14-Nov-90			536
	1991				476
	1992		13-Apr-92	13-Apr-92	599
	1993				723
	1994				846
	1995				969
	1996				1,044
	1997				1,193
	1998				1,267
	1999	13-Apr-99	12-Nov-99	13-Apr-99	1,330
ESAL (thousands)		7,563	7,620	6,848	

Missouri (29)

STATE	YEAR	0501 to 0509			Average
		IRI	Rutting	Cracking	KESAL'S
29	1990				
	1991				
	1992				
	1993				
	1994				
	1995				
	1996				
	1997				
	1998		6-Dec-98	17-Dec-98	
	1999				
	2000	17-Jan-00	1-Feb-00		
	2001	20-Apr-01		20-Apr-01	
ESAL (thousands)					

Montana (30)

STATE	YEAR	0501 to 0509 and GPS 307066			Average
		IRI	Rutting	Cracking	KESAL'S
30	1990				295
	1991	9-Nov-91			369
	1992				443
	1993			18-Aug-93	454
	1994				466
	1995				478
	1996		8-Jun-96		491
	1997				503
	1998				517
	1999				530
	2000	13-Jul-00	24-Jul-00	13-Jul-00	557
ESAL (thousands)		4,232	2,141	3,450	

New Jersey (34)

STATE	YEAR	0501 to 0509			Average
		IRI	Rutting	Cracking	KESAL'S
34	1990				229
	1991				282
	1992	30-Oct-92			335
	1993		24-Feb-93	24-Feb-93	388
	1994				324
	1995				316
	1996				295
	1997				406
	1998				546
	1999				583
	2000	4-Oct-00	18-Oct-00	4-Oct-00	613
ESAL (thousands)		3,379	2,958	2,934	

New Mexico (35)

STATE	YEAR	0501 to 0509			Average
		IRI	Rutting	Cracking	KESAL'S
35	1990				557
	1991				410
	1992				429
	1993				336
	1994				293
	1995				450
	1996				475
	1997	9-Mar-97			490
	1998				1,142
	1999		6-Jun-99	6-Jun-99	1,199
	2000		25-May-00		1,259
	2001	2-May-01		2-May-01	1,322
ESAL (thousands)		4,441	1,186	2,385	

Oklahoma (40)

STATE	YEAR	0501 to 0509			Average
		IRI	Rutting	Cracking	KESAL'S
40	1990				
	1991				
	1992				
	1993				
	1994				
	1995				
	1996				
	1997			22-Jul-97	
	1998	14-Jan-98			
	1999		22-Sep-99		
	2000		7-Sep-00		
	2001	4-Jan-01		4-Jan-01	
ESAL (thousands)					

Texas (48A)

STATE	YEAR	A501 to A509 and GPS 481069			Average
		IRI	Rutting	Cracking	KESAL'S
48	1990				71
	1991				71
	1992	20-Jan-92	28-Jun-92	28-Jan-92	74
	1993				78
	1994				179
	1995				179
	1996				105
	1997				207
	1998				134
	1999				140
	2000	14-Nov-00	26-Apr-00	14-Nov-00	147
ESAL (thousands)		1,219	1,106	1,218	

Alberta (81)

STATE	YEAR	0501 to 0509			Average
		IRI	Rutting	Cracking	KESAL'S
81	1990	15-Oct-90			137
	1991		26-Jun-91	7-May-91	119
	1992				130
	1993				142
	1994				600
	1995				530
	1996				510
	1997				550
	1998				570
	1999				570
	2000		14-Sep-00		599
	2001	21-May-01		21-May-01	628
ESAL (thousands)		4,593	4,084	4,522	

Manitoba (83)

STATE	YEAR	0501 to 0509			Average
		IRI	Rutting	Cracking	KESAL'S
89	1989	18-Oct-89			160
	1990				205
	1991			20-Jun-91	193
	1992		21-Jul-92		191
	1993				190
	1994				188
	1995				198
	1996				207
	1997				218
	1998				229
	1999				240
	2000	23-Jun-00	10-Sep-00	23-Jun-00	252
ESAL (thousands)		2,212	1,729	1,884	

Appendix C: Rigid Pavement Rehabilitation Effectiveness

Annual Precipitation and Temperature Levels for SPS-6 Sites

SPS-6 Site					Nearest Weather Station					Average Annual Precipitation (inches)	Average Annual Temperature (degrees F)	Precipitation Range	Temperature Range
SHRP ID	State	State Code	Latitude (degrees)	Longitude (degrees)	ID	Name	Latitude (degrees)	Longitude (degrees)					
0600	AL	1	34.20	85.90	01315466	GADSDEN STEAM PLANT	34.02	86.00		53.40	61.30	H	M
0600	AZ	4	35.22	111.56	02316066	FORT VALLEY	35.16	111.44		23.85	43.90	M	L
A600	AR	5	34.43	92.20		SHERIDAN	34.30	92.40		52.22	61.81	M	H
0600	CA	6	41.19	122.26	04598366	MOUNT SHASTA WSO CI	41.19	122.19		39.18	49.30	M	M
0600	IL	17	39.94	88.31	11874066	URBANA	40.06	88.14		41.12	51.60	M	M
0600	IN	18	41.18	86.25	12702866	PLYMOUTH POWER SUBSTN	41.20	86.19		41.27	50.80	M	M
0600	IA	19	41.82	93.57	13080766	BOONE	42.03	93.53		35.08	47.80	M	L
0600	MI	26	43.60	84.04	20543446	MIDLAND	43.37	84.13		31.73	48.00	M	M
0600	MO	29	40.20	94.01	23060866	BETHANY	40.15	94.03		34.75	50.60	M	M
A600	MO	29	37.92	90.57						42.42	55.19	H	M
0600	OK	40	36.73	97.35	340818 6	BLACKWELL 2 E	36.49	97.14		31.78	58.90	M	M
0600	PA	42	40.97	77.79	367409 6	RENOVO	41.20	77.44		39.03	49.30	M	M
0600	SD	46	45.46	98.11	39187366	COLUMBIA 8 N	45.44	98.18		19.90	42.80	L	L
0600	TN	47	35.70	88.67	40601266	MILAN 6 NW	35.59	88.50		54.10	58.10	H	M

Precipitation ranges: L = less than 21 in, M = 21 to 42 in, H = more than 42 in
Temperature ranges: L = less than 48 deg, M = 48 to 64 deg, H = more than 64 deg

Annual Precipitation and Temperature Levels for GPS-7B Sites

GPS-7B Site					Nearest Weather Station				Average Annual Precipitation (inches)	Average Annual Temperature (degrees F)	Precipitation Range	Temperature Range
SHRP ID	State	State Code	Latitude (degrees)	Longitude (degrees)	ID	Name	Latitude (degrees)	Longitude (degrees)				
4020	CT	9	41.70	72.57	06345666	HARTFORD WSO AP	41.56	72.41	44.29	50.10	H	M
5001	CT	9	41.85	72.44	198046 6	SPRINGFIELD	42.06	72.35	44.96	51.30	H	M
4002	DE	10	39.12	75.51	18598566	MILLINGTON 1 SE	39.16	75.52	42.69	55.00	H	M
5005	DE	10	38.93	75.41	07273066	DOVER	39.09	75.31	44.05	56.90	H	M
5151	IL	17	41.53	90.35	13163566	CLINTON 1	41.48	90.16	33.04	50.80	M	M
5217	IL	17	40.44	89.00	11571266	MINONK	40.54	89.03	39.81	49.80	M	M
9327	IL	17	40.44	89.00	11571266	MINONK	40.54	89.03	39.81	49.80	M	M
3003	IN	18	41.27	86.27	12702866	PLYMOUTH POWER SUBSTN	41.20	86.19	41.27	50.80	M	M
5022	IN	18	39.63	86.07	12427244	INDIANAPOLIS SE SIDE	39.45	86.07	40.83	52.50	M	M
5518	IN	18	40.48	86.85	12943066	WEST LAFAYETTE 6 NW	40.28	87.00	36.40	50.50	M	M
5528	IN	18	41.65	86.66	12483766	LA PORTE	41.36	86.43	42.64	49.70	H	M
5538	IN	18	41.67	86.62	12483766	LA PORTE	41.36	86.43	42.64	49.70	H	M
9116	IA	19	43.48	93.35	21007566	ALBERT LEA 3 SE	43.37	93.25	31.65	44.80	M	L
9126	IA	19	41.60	90.48	13470566	LE CLAIRE L AND D 14	41.35	90.25	35.28	50.40	M	M
4067	KS	20	38.03	97.34	14574466	NEWTON 2 SW	38.02	97.23	29.12	55.90	M	M
5076	MN	27	45.03	92.97	21122766	CAMBRIDGE ST HOSPITAL	45.34	93.14	28.18	43.30	M	L
3099	MS	28	32.33	89.41	22681166	PELAHATCHIE	32.19	89.48	54.69	64.80	H	H
4069	MO	29	39.16	94.64	14458846	LEAVENWORTH 4 SSE	39.16	94.53	44.33	54.60	H	M
5393	MO	29	38.87	90.72	23259166	ELSBERRY 1 S	39.09	90.47	38.50	55.40	M	M
5483	MO	29	39.16	94.43	234358 6	KANSAS CITY WSO AP	39.19	94.43	38.30	54.10	M	M
6702	NE	31	41.11	102.92	25783066	SIDNEY 6 NNW	41.14	103.00	15.05	47.00	L	L
5826	NC	37	36.47	80.76	44326766	GALAX RADIO WBOB	36.40	80.55	43.02	52.80	H	M
3013	OH	39	38.88	83.89	335268 6	MILFORD WATER WORKS	39.11	84.18	45.46	52.60	H	M
5010	OH	39	40.98	80.64	33124546	CANFIELD 1 S	41.01	80.46	36.82	48.50	M	M
1613	PA	42	40.00	75.35	36211666	DEVAULT 1 W	40.05	75.33	39.65	53.60	M	M
1614	PA	42	40.82	78.03	36691666	PHILIPSBURG 8 E	40.54	78.05	38.67	46.80	M	L
1617	PA	42	40.06	75.33	36211666	DEVAULT 1 W	40.05	75.33	39.65	53.60	M	M
1691	PA	42	40.81	80.45	33124546	CANFIELD 1 S	41.01	80.46	36.82	48.50	M	M
1682	VT	50	44.33	73.24	30665966	PLATTSBURGH AFB	44.39	73.28	31.00	44.40	M	L
4004	WV	54	38.02	81.35	46556366	MADISON	38.03	81.49	47.23	54.50	H	M
5007	WV	54	39.29	80.42	46596366	MIDDLEBOURNE 2 ESE	39.29	80.52	44.40	52.90	H	M
6452	MB	83	49.82	97.01	32694746	PEMBINA	48.58	97.14	16.64	37.60	L	L

Precipitation ranges: L = less than 21 in, M = 21 to 42 in, H = more than 42 in
Temperature ranges: L = less than 48 deg, M = 48 to 64 deg, H = more than 64 deg

SPS-6 Pavement Structure Data

The as-constructed test section station limits, pavement layer thicknesses, and material and subgrade types for the SPS-6 test sections are summarized in the tables on the following pages of this Appendix.

The data in the columns under the heading Original Construction represent the pavement structure prior to treatment. The data in the columns under the heading Rehabilitation represent the asphalt concrete layers and thicknesses present after treatment, including overlay if any. For asphalt concrete layers, one ore more thicknesses may be shown, if the material was placed in several lifts. When some asphalt concrete has been removed by milling prior to placement of an overlay, this is reflected by a reduction in one of the asphalt concrete layer thicknesses.

In the case of the SPS-6 experiment, a change from CN = 2 to CN = 3 does not necessarily mean the end of the first rehabilitation's performance period. A recent change in construction numbering policy has resulted, for some sites, in CN changes for multiple activities related to the initial rehabilitation (e.g., patching and then overlay placement), or maintenance work (e.g., crack sealing) done during the performance period of the overlay. The dates and reasons for changes in construction number must be checked carefully to discern which changes really reflect the end of a rehabilitation performance period, and which do not.

Note that empty cells indicate that according to the available LTPP data, no layer is present, whereas cells containing question marks (???) indicate that a layer is present but some information about the layer is missing.

The layer thickness and material type data shown on the following pages were retrieved from LTPP data table TST_L05B, *except for* the data for the Alabama, Arkansas, and Indiana SPS-6 sites. These sites did not have data in the TST_L05B table, in the LTPP database release (11.5) used for this study. Therefore, layer thickness and material type data for these three sites were retrieved from LTPP data table SPS6_LAYER.

The type of concrete pavement, JPCP or JRCP, is indicated by the relevant code *as it appears in TST_L05B,* in the LTPP database release 11.5. However, the concrete pavement type indicated in this release of the database is believed to be incorrect for four of the fourteen SPS-6 sites, as shown in the following table.

SPS-6 Site	Concrete Pavement Type	
	Database	Believed correct*
AL	JPCP	
AZ	JPCP	
AR	JPCP	
CA	JPCP	
IL	JPCP	JRCP
IN	JPCP	
IA	JPCP	JRCP
MI	JPCP	JRCP
MO 0	JPCP	JRCP
MO A	JPCP	
OK	JRCP	
PA	JRCP	
SD	JPCP	
TN	JPCP	

*If different than that indicated in LTPP database, release 11.5.

The following codes (from LTPP data table CODES) are used for material types identified in SPS-6 test sections:

2	=	hot-mixed, hot-laid, open-graded asphalt concrete
4	=	portland cement concrete (JPCP)
5	=	portland cement concrete (JRCP)
20	=	other
23	=	crushed stone, gravel or slag
27	=	soil cement
52	=	sandy clay
53	=	silty clay
74	=	woven geotextile
85	=	other
102	=	fine-grained soil: lean inorganic clay
104	=	fine-grained soil: sandy lean clay
113	=	fine-grained soil: sandy clay
114	=	fine-grained soil: sandy lean clay
131	=	fine-grained soil: silty clay

141	=	fine-grained soil: silt
148	=	fine-grained soil: clayey silt
203	=	coarse-grained soil: poorly graded sand with gravel
204	=	coarse-grained soil: poorly graded sand with silt
215	=	coarse-grained soil: silty sand with gravel
253	=	coarse-grained soil: poorly graded gravel with sand
287	=	sandstone
302	=	uncrushed gravel
307	=	soil-aggregate mixture (predominantly fine-grained)
331	=	cement-aggregate mixture

ALABAMA - SPS-6 (Data from SPS6_LAYER)

Station (m)	Section	Original Construction: PCC Thickness	PCC Type	Base Thickness	Base Type	Subgrade Type	Rehabilitation: AC	PC	Base
0–152	010601								
183–488	010602								
518–823	010605								
1,158–1,311	010607	10	PC (4)	6	GB (23)	SS (52)	1.3 3	10	6
1,517–1,669	010608	10	PC (4)	6	GB (23)	SS (52)	1.3 2.6 4.5	10	6
1,761–1,913	010663	10	PC (4)	6	GB (23)	SS (52)	1.6 2.6 5.5	10	6
2,051–2,203	010662	10	PC (4)	6	GB (23)	SS (52)	1.2 2.3 4.2	10	6
2,462–2,614	010661	10	PC (4)	6	GB (23)	SS (52)	2.1 1.9	10	6
2,644–2,797	010606	10	PC (4)	6	GB (23)	SS (52)	1.3 2.2	10	6
2,827–2,980	010604	10	PC (4)	6	GB (23)	SS (52)	1.4 3.1	10	6
3,010–3,163	010603	10	PC (4)	6	GB (23)	SS (52)	1.1 2.5	10	6

ARIZONA - SPS-6

Station (m)	Section	Original Construction					Rehabilitation		
		PCC		Base		Subgrade			
		Thickness	Type	Thickness	Type	Type	AC	PC	Base
0 152	040660	8.3	PC (4)	3.5 7.7	TB (331) GS (302)	SS (215)	0.5 (2) 8	8.3	3.5 7.7
204 356	040663	8.3	PC (4)	3.4 7.4	TB (331) GS (302)	SS (215)	10 (PC(4)) 2	8.3	3.4 7.4
439 591	040608	8.2	PC (4)	3.9 8.1 6.2	TB (331) GS (302) GS (307)	SS (215)	0.4 (2) 8.4	8.2	3.9 8.1 6.2
675 828	040607	8.5	PC (4)	4.1 7.5 6.2	TB (331) GS (302) GS (307)	SS (287)	0.3 (2) 4.3	8.4	4.1 7.5 6.2
905 1,058	040606	8.5	PC (4)	3.9 7.6	TB (331) GS (302)	SS (215)	0.4 (2) 4.3	8.5	3.9 7.6
1,149 1,332	040659	8.4	PC (4)	2.7	TB (331)	SS (215)	0.5 (2) 4	8.4	2.7
1,384 1,518	040661	8.4	PC (4)	4.2 6.8	TB (331) GS (302)	SS (287)	0.5 (2) 2 (20) 2	8.4	4.2 6.8
1,562 1,715	040604	8.2	PC (4)	4.9 6.8	TB (331) GS (302)	SS (287)	0.4 (2) 3.6	8.2	4.9 6.8
1,872 2,032	040662	8.1	PC (4)	3.9 9 17.1	TB (331) GS (302) GS (307)	SS (215)	0.5 (2) 2 2 (20)	8	3.9 9 17.1
2,225 2,377	040603	8.3	PC (4)	4.2 7.9	TB (331) GS (302)	SS (287)	0.5 (2) 3.5	8.3	4.2 7.9
2,442 2,744	040605	8.3	PC (4)	3.9 8 21.6	TB (331) GS (302) GS (307)	SS (215)		8.3	3.9 8 21.6
2,922 3,096	040602	8	PC (4)	3.6 8.4 21.6	TB (331) GS (302) GS (307)	SS (287)		8	3.6 8.4 21.6
3,152 3,304	040601	7.9	PC (4)	3.1 9.7	TB (331) GS (302)	SS (287)			

3,413	040664	7.9	PC (4)	2.7 9.7	TB (331) GS (302)	SS (287)	0.5 (2) 2.5 (20) 3	7.9	2.7 9.7
3,565	040665	7.9	PC (4)	2.7 9.7	TB (331) GS (302)	SS (287)	0.5 (2) 2.5 (20) 3	7.9	2.7 9.7
3,755	040666	7.9	PC (4)	2.7 9.7	TB (331) GS (302)	SS (287)	0.5 (2) 2.5 (20) 3	7.9	2.7 9.7
3,907	040667	7.9	PC (4)	2.7 9.7	TB (331) GS (302)	SS (287)	0.5 (2) 2.5 (20) 3	7.9	2.7 9.7
4,059	040668	7.9	PC (4)	2.7 9.7	TB (331) GS (302)	SS (287)	0.5 (2) 2.5 (20) 3	7.9	2.7 9.7
4,212	040669	7.9	PC (4)	2.7 9.7	TB (331) GS (302)	SS (287)	0.5 (2) 2.5 (20) 3	7.9	2.7 9.7
4,364									

ARKANSAS - SPS-6 (Data from SPS6_LAYER)

Station (m)	Section	Original Construction					Rehabilitation		
		PCC		Base		Subgrade			
		Thickness	Type	Thickness	Type	Type	AC	PC	Base
0 – 152	05A608	10	PC (4)	6	TB (27)	SS (53)	4.4 5	10	6
152 – 274									
274 – 427	05A607	10	PC (4)	6	TB (27)	SS (53)	1.5 3.2	10	6
427 – 457									
457 – 610	05A606	10	PC (4)	6	TB (27)	SS (53)	1.5 3.2	10	6
610 – 640									
640 – 793	05A604	10	PC (4)	6	TB (27)	SS (53)	1.5 3.2	10	6
793 – 914									
914 – 1,067	05A603	10	PC (4)	6	TB (27)	SS (53)	1.5 3.2	10	6
1,067 – 1,341									
1,341 – 1,646	05A605								
1,646 – 1,676									
1,676 – 1,981	05A602								
1,981 – 2,042									
2,042 – 2,195	05A601								

CALIFORNIA - SPS-6

Station (m)	Section	Original Construction PCC Thickness	PCC Type	Base Thickness	Base Type	Subgrade Type	Rehabilitation AC	Rehabilitation PC	Rehabilitation Base
0 – 152	060660	4.5	PC (4)	8.1	TB (331)	SS (253)	3 0.2 (EF74) 1.2	4.5	8.1
281 – 586	060659	8.5	PC (4)	4.9	TB (331)	SS (253)	4.2	8.5	4.9
892 – 1,167	060661	8.5	PC (4)	4.9	TB (331)	SS (253)	3 0.2 (EF74) 1.2	8.5	4.9
1,365 – 1,487	060662	8.2	PC (4)	5.1	TB (331)	SS (203)		1 (20) 8.2	5.1
1,517 – 1,585	060663	7.9	PC (4)	5.4	TB (331)	SS (203)		1 (20) 7.9	5.4
2,156 – 2,308	060605	8.9	PC (4)	4.5	TB (331)	SS (253)		8.9	4.5
2,322 – 2,474	060602	8.6	PC (4)	4.1	TB (331)	SS (253)		8.6	4.1
2,520 – 2,672	063005								
2,733 – 2,886	060606	8.2	PC (4)	4.5	TB (331)	SS (253)	3.1	8.2	4.5
2,912 – 3,064	060607	8.2	PC (4)	4.6	TB (331)	SS (253)	3.7	8.2	4.6
3,078 – 3,231	060603	8	PC (4)	4	TB (331)	SS (253)	3.8	8	4
3,467 – 3,620	060608	8.5	PC (4)	4.4	TB (331)	SS (203)	8.1	8.5	4.4
3,784 – 3,967	060604	8.3	PC (4)	5.1	TB (331)	SS (253)	4.5	8.3	5.1
3,984 – 4,289	060664	8.3	PC (4)	5.1	TB (331)	SS (253)	3 0.2 (EF85) 1.2	8.3	5.1

Station (m)	Section	Original Construction					Rehabilitation		
		PCC		Base		Subgrade			
		Thickness	Type	Thickness	Type	Type	AC	PC	Base
0 305	170602	10.1	PC (4)	7	GB (302)	SS (131)		10.1	7
335 640	170605	10.2	PC (4)	7	GB (302)	SS (131)		10.2	7
671 823	170661	10.5	PC (4)	7	GB (302)	SS (131)		10.5	7
1,067 1,219	170660	10.2	PC (4)	7	GB (302)	SS (131)		10.2	7
1,280 1,433	170601	10.2	PC (4)	7	GB (302)	SS (131)		10.2	7
1,494 1,646	170662	10.2	PC (4)	7	GB (302)	SS (131)	1.5 2	10.2	7
1,694 1,847	170606	10.1	PC (4)	7	GB (302)	SS (131)	1.5 1.6	10.1	7
1,890 2,042	170603	10	PC (4)	7	GB (302)	SS (131)	1.5 1.5 0.7	10	7
2,150 2,303	170604	10.2	PC (4)	7	GB (302)	SS (131)	1.4 2.3	10.2	7
2,322 2,475	170659	10.2	PC (4)	7	GB (302)	SS (131)	1.5 1.8	10.2	7
2,652 2,804	170607	10.1	PC (4)	7	GB (302)	SS (131)	1.4 2.3	10.1	7
2,926 3,079	170608	10.1	PC (4)	7.2	GB (302)	SS (131)	1.6 5.2	10.1	7.2
3,231 3,383	170663	10	PC (4)	7	GB (302)	SS (131)	1.5 6.5	10	7
3,444 3,597	170664	10	PC (4)	7	GB (302)	SS (131)	1.5 4.5	10	7

INDIANA - SPS-6 (Data from SPS6_LAYER)

Station (m)	Section	Original Construction					Rehabilitation		
		PCC		Base		Subgrade			
		Thickness	Type	Thickness	Type	Type	AC	PC	Base
0 152	180602	10	PC (4)	4	TB (28)	SS (52)			
213 366	180605	10	PC (4)	4	TB (28)	SS (52)			
518 671	180661	10	PC (4)	4	TB (28)	SS (52)	1 3	10	4
762 914	180606	10	PC (4)	4	TB (28)	SS (52)	1 3	10	4
975 1,128	180604	10	PC (4)	4	TB (28)	SS (52)	1 3	10	4
1,189 1,341	180603	10	PC (4)	4	TB (28)	SS (52)	1 3	10	4
1,402 1,555	180660	10	PC (4)	4	TB (28)	SS (52)	1 2 2.5	10	4
1,615 1,768	180672	10	PC (4)	4	TB (28)	SS (52)	1 2 2.5	10	4
1,829 1,981	180659	10	PC (4)	4	TB (28)	SS (52)	1 2 2.5	10	4
2,103 2,256	180608	10	PC (4)	4	TB (28)	SS (52)	1 2 5	10	4
2,347 2,499	180662	10	PC (4)	4	TB (28)	SS (52)	1 2 7	10	4
2,682 2,835	180663	10	PC (4)	4	TB (28)	SS (52)	1 2 2.5	10	4
2,926 3,079	180664	10	PC (4)	4	TB (28)	SS (52)	1 2 2.5	10	4
3,261 3,414	180665	10	PC (4)	4	TB (28)	SS (52)	1 2 2.5	10	4
3,566 3,719	180666	10	PC (4)	4	TB (28)	SS (52)	1 2 2.5	10	4

3,871 4,023	180667	10	PC (4)	4	TB (28)	SS (52)	1 2 2.5	10	4
4,176 4,328	180668	10	PC (4)	4	TB (28)	SS (52)	1 2 2.5	10	4
4,450 4,603	180669	10	PC (4)	4	TB (28)	SS (52)	1 3	10	4
4,663 4,816	180670	10	PC (4)	4	TB (28)	SS (52)	1 3	10	4
4,877 5,029	180671	10	PC (4)	4	TB (28)	SS (52)	1 3	10	4
5,122 5,275	180607	10	PC (4)	4	TB (28)	SS (52)	1 3	10	4
7,437 7,590	180601	10	PC (4)	4	TB (28)	SS (52)			

IOWA - SPS-6

Station (m)	Section	Original Construction PCC Thickness	PCC Type	Base Thickness	Base Type	Subgrade Type	Rehabilitation AC	PC	Base
0 – 305	190602	10.1	PC (4)	4	GB (303)	SS (113)		10.1	4
395 – 547	190601	10	PC (4)	4	GB (303)	SS (113)		10	4
848 – 1,152	190605	10	PC (4)	4	GB (303)	SS (113)		10	4
4,246 – 4,398	190607	10	PC (4)	4	GB (303)	SS (113)	1.8 2.3	10	4
4,478 – 4,631	190608	10	PC (4)	4	GB (303)	SS (113)	4 4	10	4
4,852 – 5,004	190659	9.6	PC (4)	4	GB (303)	SS (113)	2 2	9.6	4
5,268 – 5,421	190603	10	PC (4)	4	GB (303)	SS (113)	2 2	10	4
5,757 – 5,910	190604	9.7	PC (4)	4	GB (303)	SS (113)	2.3 2.3	9.7	4
6,387 – 6,540	190606	10	PC (4)	4	GB (303)	SS (113)	1.8 2.3	10	4

MICHIGAN - SPS-6

Station (m)	Section	Original Construction: PCC Thickness	PCC Type	Base Thickness	Base Type	Subgrade Type	Rehabilitation: AC	PC	Base
0–152	260659	9.5	PC (4)	4 30	GB (302) GS (202)	SS (104)	4	9.5	4 30
632–784	260608	9.3	PC (4)	4 48	GB (302) GS (202)	SS (104)	1.1 1.6 4.1	9.3	4 48
945–1,097	260607	9	PC (4)	4 66	GB (302) GS (202)	SS (104)	1.2 1.6 1.8	9	4 66
1,338–1,491	260606	9.5	PC (4)	4 36	GB (302) GS (201)	SS (131)	1.2 1.8 2	9.5	4 36
1,551–1,704	260603	9	PC (4)	4 36	GB (302) GS (201)	SS (131)	1.3 1.7 2.1	9	4 36
1,817–1,970	260604	9.2	PC (4)	4 36	GB (302) GS (201)	SS (131)	1.5 1.8 2.1	9.2	4 36
2,093–2,245	260601	9	PC (4)	4 48	GB (302) GS (201)	SS (131)			
2,398–2,702	260602	9	PC (4)	4 48	GB (302) GS (201)	SS (131)		9	4 48
2,742–3,047	260605	9	PC (4)	4 48	GB (302) GS (201)	SS (131)		9	4 48

Station (m)	Section	Original Construction: PCC Thickness	PCC Type	Base Thickness	Base Type	Subgrade Type	Rehabilitation: AC	PC	Base
0 152	290607	9.3	PC (4)	4.2	GB (303)	SS (113)	1.8 2.5	9.3	4.2
716 869	290659	9.3	PC (4)	6	GB (303)	SS (113)	1.7 2.6	9.3	6
1,036 1,189	290660	9.7	PC (4)	4.2	GB (303)	SS (113)	2.4 5.4	9.7	4.2
1,234 1,387	290608	9.4	PC (4)	5.3	GB (303)	SS (113)	2.3 5.6	9.4	5.3
1,844 1,996	290662	9.4	PC (4)	5.5	GB (303)	SS (113)	1.9 5.4	9.4	5.5
2,042 2,195	290664	9.7	PC (4)	5.1	GB (303)	SS (113)	1.5 5.4	9.7	5.1
2,377 2,530	290663	9.5	PC (4)	4.5	GB (303)	SS (113)	1.8 8.9	9.5	4.5
2,621 2,774	290661	9.4	PC (4)	4.2	GB (303)	SS (113)	1.9 9.5	9.4	4.2
3,261 3,566	290605	9.1	PC (4)	3.8	GB (303)	SS (113)		9.1	3.8
3,612 3,764	290601	9.1	PC (4)	4.2	GB (303)	SS (113)			
3,825 4,130	290602	9.2	PC (4)	3.4	GB (303)	SS (113)		9.2	3.4
4,481 4,633	290604	9.1	PC (4)	4.5	GB (303)	SS (113)	1.5 2.3	9.1	4.5

4,892 / 5,044	290603	9.1	PC (4)	4.8	GB (303)	SS (113)	1.7 2.1	9.1	4.8
5,075 / 5,227	290606	8.9	PC (4)	3.5	GB (303)	SS (113)	1.5 2.1	8.9	3.5
5,700 / 5,852	290666	9.1	PC (4)	4.6	GB (303)	SS (113)		9.1	4.6
6,462 / 6,614	290665	9	PC (4)	4.6	GB (303)	SS (113)	1.7 2.9	9	4.6

MISSOURI A - SPS-6

Station (m)	Section	Original Construction: PCC Thickness	PCC Type	Base Thickness	Base Type	Subgrade Type	Rehabilitation: AC	PC	Base
0 – 305	29A602	7	PC (4)	4	GB (303)	SS (115)		7	4
549 – 701	29A601	7.2	PC (4)	4	GB (303)	SS (115)		7.2	4
975 – 1,128	29A606	7	PC (4)	4	GB (303)	SS (115)	2.2 2.6 0 (20)	7	4
1,189 – 1,341	29A604	7.5	PC (4)	4	GB (303)	SS (115)	2.3 2.2 0 (20)	7.5	4
2,042 – 2,347	29A605	7.5	PC (4)	4	GB (303)	SS (112)		7.5	4
7,056 – 7,209	29A608	7	PC (4)	4	GB (303)	SS (112)	2 6.1 0 (20)	7	4
7,391 – 7,544	29A607	7	PC (4)	4	GB (303)	SS (112)	2.2 3.2 0 (20)	7	4
7,757 – 7,910	29A603	7.3	PC (4)	3.8	GB (303)	SS (112)	2.2 2.1 0 (20)	7.3	3.8

OKLAHOMA - SPS-6

Station (m)	Section	Original Construction: PCC Thickness	PCC Type	Base Thickness	Base Type	Subgrade Type	Rehabilitation: AC	PC	Base
0 – 305	400602	8.8	PC (5)	16.5	GB (309)	SS (141)		8.8	16.5
518 – 671	400601	8.8	PC (5)	16.5	GB (309)	SS (141)		8.8	16.5
1,951 – 2,103	400603	9	PC (5)	15.2	GB (309)	SS (141)	4	9	15.2
2,195 – 2,347	400604	9	PC (5)	15.2	GB (309)	SS (141)	3.8	9	15.2
2,438 – 2,591	400607	9	PC (5)	15.2	GB (309)	SS (141)	4.6	9	15.2
2,713 – 2,865	400608	9.2	PC (5)	14.8	GB (309)	SS (141)	1.8 6	9.2	14.8
3,048 – 3,200	400606	9.1	PC (5)	14.8	GB (309)	SS (141)	4.3	9.1	14.8
3,322 – 3,627	400605	9	PC (5)	14.8	GB (309)	SS (141)		9	14.8

PENNSYLVANIA - SPS-6

Station (m)	Section	Original Construction					Rehabilitation		
		PCC		Base		Subgrade			
		Thickness	Type	Thickness	Type	Type	AC	PC	Base
0 305	420602	10.2	PC (5)	12	GB (303)	SS (141)		10.2	12
605 758	420659	10.3	PC (5)	10	GB (303)	SS (141)		10.3	10
765 918	420601	10.3	PC (5)	10	GB (303)	SS (141)		10.3	10
1,641 1,946	420605	10.1	PC (5)	11	GB (303)	SS (141)		10.1	11
2,030 2,182	420606	10.1	PC (5)	9	GB (303)	SS (141)	1.9 2.6	10.1	9
2,216 2,368	420603	10.1	PC (5)	10	GB (303)	SS (141)	1.8 2.4	10.1	10
2,399 2,552	420604	10.3	PC (5)	10	GB (303)	SS (141)	1.8 2.6	10.3	10
2,583 2,735	420607	10.1	PC (5)	10.4	GB (303)	SS (141)	1.7 2.4	10.1	10.4
3,006 3,159	420608	10.1	PC (5)	9.5	GB (303)	SS (141)	1.7 2.5 3 1.1	10.1	9.5
3,278 3,431	420660	10.6	PC (5)	10	GB (303)	SS (141)	1.4 2.5 4.5 1.1	10.6	10
3,513 3,666	420661	10	PC (5)	11	GB (303)	SS (141)	1.5 2.5 8 1.1	10	11
3,794 3,946	420662	10.2	PC (5)	10	GB (303)	SS (141)	1.2 2.5 3 1	10.2	10

SOUTH DAKOTA - SPS-6

Station (m)	Section	Original Construction: PCC Thickness	PCC Type	Base Thickness	Base Type	Subgrade Type	Rehabilitation: AC	PC	Base
0 – 152	460608	7.7	PC (4)	5.3	TB (331)	SS (148)	2 4.6	7.7	5.3
217 – 369	460660	7.3	PC (4)	5.5	TB (331)	SS (148)		7.3	5.5
425 – 577	460607	7.3	PC (4)	5.6	TB (331)	SS (148)	1.6 3.2	7.3	5.6
639 – 792	460662	7.3	PC (4)	5.5	TB (331)	SS (148)	1.3 2.7 0.1 (20)	7.3	5.5
859 – 1,011	460661	7.3	PC (4)	5.5	TB (331)	SS (148)	1.5 3.1	7.3	5.5
1,065 – 1,217	460606	7.2	PC (4)	4.4	TB (331)	SS (148)	1.6 2.7	7.2	4.4
1,284 – 1,436	460603	7.1	PC (4)	4.4	TB (331)	SS (148)	2.1 2.3	7.1	4.4
1,645 – 1,797	460604	7.1	PC (4)	3.6	TB (331)	SS (148)	2.2 2.2	7.1	3.6
2,013 – 2,318	460605							7.2	4
2,440 – 2,745	460602	7	PC (4)	4.4	TB (331)	SS (131)		7	4.4
2,803 – 2,955	460601	7	PC (4)	4	TB (331)	SS (131)			

TENNESSEE - SPS-6

Station (m)	Section	Original Construction: PCC Thickness	PCC Type	Base Thickness	Base Type	Subgrade Type	Rehabilitation: AC	PC	Base
0–152	470601	9	PC (4)	6	TB (339)	SS (204)		9	6
183–488	470602	8.9	PC (4)	6	TB (339)	SS (204)		8.9	6
701–1,006	470605	9	PC (4)	7.5	TB (339)	SS (102)		9	7.5
1,189–1,341	470603	9	PC (4)	7.5	TB (339)	SS (102)	1.2 0.4 (84) 2.8	9	7.5
1,372–1,524	470606	9.2	PC (4)	7.5	TB (339)	SS (102)	1.3 0.4 (84) 2.4	9.5	7.5
1,646–1,798	470604	9	PC (4)	6.6	TB (339)	SS (114)	1 0.4 (84) 2.8	9	6.6
2,195–2,347	470607	8.8	PC (4)	6.6	TB (339)	SS (114)	1.2 0.4 (84) 2.8	8.8	6.6
2,560–2,713	470608	8.6	PC (4)	6.6	TB (339)	SS (114)	1.4 0.4 (84) 6.9	8.6	6.6
2,743–2,896	470662	8.9	PC (4)	6.6	TB (339)	SS (114)	1.2 0.4 (84) 7	8.9	6.6
2,957–3,109	470661	9	PC (4)	6.6	TB (339)	SS (114)	1.3 0.4 (84) 6.6	9	6.6

Alabama (01)

STATE	YEAR	0601 to 0608			Average
		IRI	Rutting	Cracking	KESAL'S
1	1990				
	1991				
	1992				
	1993				
	1994				
	1995				
	1996				
	1997				
	1998		28-Jun-98	28-Jun-98	
	1999	24-Sep-99			
	2000		27-Sep-00	27-Sep-00	
	2001	21-Mar-01			
ESAL (thousands)					

Arizona (04)

STATE	YEAR	0601 to 0608			Average
		IRI	Rutting	Cracking	KESAL'S
4	1990		6-Oct-90		1,209
	1991	16-Sep-91		23-Sep-91	1,270
	1992				1,333
	1993				1,400
	1994				1,440
	1995				1,546
	1996				1,673
	1997				1,667
	1998				3,218
	1999				3,378
	2000		23-Aug-00	23-Aug-00	3,547
	2001	7-Feb-01			3,725
ESAL (thousands)		19,945	19,496	18,287	

Arkansas (05)

STATE	YEAR	0601 to 0608			Average
		IRI	Rutting	Cracking	KESAL'S
5	1990				
	1991				
	1992				
	1993				
	1994				
	1995				
	1996		20-Dec-96		
	1997	11-Aug-97			
	1998				
	1999	26-Jul-99			
	2000		19-Jun-00		
ESAL (thousands)					

California (06)

STATE	YEAR	0601 to 0608 and GPS 063005			Average
		IRI	Rutting	Cracking	KESAL'S
6	1989				1,560
	1990				1,781
	1991				1,700
	1992		1-Sep-92	7-Oct-92	2,257
	1993	6-Apr-93			2,605
	1994				1,774
	1995				1,249
	1996				1,669
	1997				2,089
	1998				2,338
	1999				2,455
	2000	10-Nov-00	16-Aug-00	16-Aug-00	2,578
ESAL (thousands)		15,704	16,542	16,317	

Illinois (17)

STATE	YEAR	0601 to 0608			Average
		IRI	Rutting	Cracking	KESAL'S
17	1990	13-Dec-90			820
	1991			17-Dec-91	861
	1992				255
	1993				1,056
	1994				1,001
	1995				534
	1996				67
	1997				428
	1998				1,275
	1999			18-Aug-99	1,339
	2000	16-Nov-00			1,406
ESAL (thousands)		8,087	69,006	5,493	

Indiana (18)

STATE	YEAR	0601 to 0608			Average
		IRI	Rutting	Cracking	KESAL'S
18	1990	14-Dec-90	30-Aug-90		286
	1991			26-Jun-91	300
	1992				333
	1993				388
	1994				447
	1995				618
	1996				742
	1997				415
	1998				694
	1999				729
	2000	22-Aug-00	12-Apr-00	13-Apr-00	765
ESAL (thousands)		5,170	4,976	4,737	

Iowa (19)

STATE	YEAR	0601 to 0608			Average
		IRI	Rutting	Cracking	KESAL'S
19	1989		16-Aug-89		914
	1990	17-Jun-90			932
	1991			30-Oct-91	941
	1992				854
	1993				907
	1994				724
	1995				607
	1996				373
	1997				138
	1998				145
	1999				153
	2000	20-Jul-00	4-Nov-00	4-Nov-00	160
ESAL (thousands)		5,433	6,252	4,196	

Michigan (26)

STATE	YEAR	0601 to 0608			Average
		IRI	Rutting	Cracking	KESAL'S
26	1989				225
	1990		16-May-90		269
	1991	28-Jun-91			269
	1992			25-Aug-92	192
	1993				377
	1994				292
	1995				364
	1996				471
	1997				243
	1998		14-Oct-98	14-Oct-98	196
	1999	14-Apr-99			206
	2000				216
ESAL (thousands)		2,332	2,532	1,970	

Missouri (29)

STATE	YEAR	0601 to 0608			Average
		IRI	Rutting	Cracking	KESAL'S
29	1989				839
	1990				852
	1991				873
	1992		2-Jun-92		846
	1993	13-Mar-93		4-Apr-93	817
	1994				685
	1995				536
	1996				591
	1997				768
	1998				498
	1999	10-Feb-99			523
	2000		2-Mar-00	2-Mar-00	549
ESAL (thousands)		3,788	5,002	4,300	

STATE	YEAR	0601 to 0608			Average
		IRI	Rutting	Cracking	KESAL'S
29A	1990				
	1991				
	1992				
	1993				
	1994				
	1995				
	1996				
	1997				
	1998		3-Sep-98		
	1999				
	2000		8-Feb-00		
ESAL (thousands)					

Oklahoma (40)

STATE	YEAR	0601 to 0608			Average
		IRI	Rutting	Cracking	KESAL'S
40	1989				1,071
	1990				1,130
	1991				1,178
	1992		28-Aug-92	5-Nov-92	758
	1993	16-Mar-93			337
	1994				664
	1995				719
	1996				742
	1997				690
	1998				1,035
	1999				1,087
	2000		14-Sep-00	14-Sep-00	1,141
	2001	8-Jan-01			1,198
ESAL (thousands)		6,368	6,335	6,194	

Pennsylvania (42)

STATE	YEAR	0601 to 0608			Average
		IRI	Rutting	Cracking	KESAL'S
42	1989				1,021
	1990				1,168
	1991				1,197
	1992	24-Nov-92	1-Oct-92		1,227
	1993				1,256
	1994			13-Jun-94	1,446
	1995				2,246
	1996				2,550
	1997				1,001
	1998				1,051
	1999				1,104
	2000	14-Nov-00	3-Aug-00	3-Aug-00	1,159
ESAL (thousands)		11,787	11,643	9,429	

South Dakota (46)

STATE	YEAR	0601 to 0608			Average
		IRI	Rutting	Cracking	KESAL'S
46	1989				17
	1990				16
	1991				18
	1992		29-Apr-92		64
	1993	20-Oct-93			60
	1994				20
	1995				18
	1996				20
	1997				94
	1998				101
	1999				110
	2000	10-May-00	24-Aug-00		118
ESAL (thousands)		417	543		

Tennessee (47)

STATE	YEAR	0601 to 0608			Average
		IRI	Rutting	Cracking	KESAL'S
47	1990				
	1991				
	1992				
	1993				
	1994				
	1995				
	1996		13-May-96	30-Oct-96	
	1997	30-Jan-97			
	1998				
	1999				
	2000		13-Jun-00	14-Jun-00	
	2001	16-May-01			
ESAL (thousands)					