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INFLUENCE OF DESIGN AND CONSTRUCTION FEATURES ON THE RESPONSE AND PERFORMANCE OF SPS-2 TEST SECTIONS

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INFLUENCE OF DESIGN AND CONSTRUCTION FEATURES ON THE RESPONSE AND PERFORMANCE OF SPS-2 TEST SECTIONS

By

Praveen Desaraju

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ABSTRACT

INFLUENCE OF DESIGN AND CONSTRUCTION FEATURES ON THE RESPONSE AND PERFORMANCE OF SPS-2 TEST SECTIONS

By

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This research was conducted to study the influence of design and construction features on the performance and response of jointed plain concrete pavements. The data used in this study were drawn from the Long Term Pavement Performance (LTPP) SPS-2 experiment. Pavement sections with undrained, dense-graded aggregate bases and undrained lean concrete bases have so far performed more poorly than sections with drained permeable asphalt-treated bases. Sections with thinner PCC slabs and lane width of 12 ft showed higher transverse cracking and pumping. The occurrence of transverse cracking in the sections seems to be a direct consequence of problems encountered during construction. It is too early to comment about the occurrence of faulting because of insignificant magnitudes of faulting in the test sections. A "Performance Index" was developed to evaluate the pavement sections due to the various limitations in the database and inconsistencies in the data collection process. Several statistical methods were used to validate the results obtained from the engineering analysis. It was also found that the individual deflections should be used in conjunction with load transfer efficiency (LTE) and edge support factor to completely understand the performance of the joints. In addition to the design and construction features, the effect of temperature is also an important factor to be considered in assessing the loss of support and in joint performance evaluation.

Dedicated to

My parents, D. Ramakrishna Rao and D. Ananta Lakshmi

and

My brothers, D. S. Kalyan and D. M. Srikiran

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CHAPTER 1

INTRODUCTION

For specific site conditions (e.g., traffic level, climatic conditions and subgrade type), the response and performance of rigid pavements will depend not only on the pavement layer thicknesses and material properties, but also on the design and construction features (e.g., drainage, base type, lane width etc.). The Long Term Pavement Performance (LTPP) Specific Pavement Studies (SPS) were designed to provide information on the relative merits of different design features on newly constructed pavements. These design features include thickness, base type, drainage types, flexural strength etc. In addition to this, instrumented sections were included in the SPS monitoring sites located in North Carolina and Ohio. The data available from the LTPP studies, including the instrumented SPS-2 test sections in Ohio and North Carolina, provide a unique opportunity to understand the effects of these features on pavement response and performance, and to develop conclusions regarding their influence.

RESEARCH OBJECTIVES

The objectives of this research are (1) to determine, for specific site conditions, the effects of design and construction features on pavement response and (2) to determine the contributions of design and construction features in achieving different levels of performance. The relationship between pavement performance and response has also been investigated in this project. The research is limited to new (i.e., non-rehabilitated) rigid pavements and is based on the data available from the LTPP SPS-2 experiment (Strategic study of structural factors for rigid pavements). The analysis is limited to using the data available in the LTPP Information Management System (IMS) database, classified as "Level E," as well as response data available from the LTPP instrumented test sections.

ORGANIZATION OF THE THESIS

The thesis is divided into 8 chapters including the introduction. Chapter 2 describes the SPS-2 experiment, its limitations, and identifies the experiment variables. Chapter 3 identifies the data types and details the data extraction process. Chapter 4 presents the extent and availability of design, construction, performance, response, and traffic data in the LTPP database. Chapter 5 presents the engineering analysis of the performance data. Chapter 6 presents the statistical analysis of the performance data. The relationship between the performance and response data is discussed in Chapter 7. A summary of the conclusions and recommendations resulting from the analyses performed in this study are contained in Chapter 8.

CHAPTER 2

DESCRIPTION OF THE SPS-2 EXPERIMENT

INTRODUCTION

This chapter describes the Specific Pavement Studies-2 (SPS-2) experiment in terms of its respective goals, experimental design, and associated design and construction factors.

SPS-2 EXPERIMENT

The SPS-2 experiment examines the effect of climatic region, subgrade soil (fine and coarse grained), and traffic on doweled jointed plain concrete pavement (JPCP) sections incorporating different levels of structural factors. These factors include drainage (presence or lack of it), concrete slab thickness (8 in. and 11 in.), base type (dense graded aggregate (DGAB), lean concrete (LCB) and permeable asphalt treated base (PATB)), concrete flexural strength of 550 psi and 900 psi at 14 days and lane width of 12 ft and 14 ft. This experiment requires that all the test sections be constructed with perpendicular joints at 15 ft spacing and stipulate a traffic load level in the lane in excess of 200,000 Equivalent Single Axle Loads (ESALs) per year (1). The data for this study has been obtained from Release 16.0 version of the LTPP database (2).

All sections with 12 ft lane width will be referred to as "12 ft sections" and all sections with 14 ft lane width will be referred to as "14 ft sections". All sections with 8 in. PCC slab will be referred to as "8 in. sections" and those with 11 in. PCC slab will be referred to as "11 in." sections throughout this thesis.

The LTPP SPS-2 experiment consists of 14 states, with each state having 12 sections. Comparisons can be made between these sections as combinations of base, subbase and wearing surface material are varied in 12 ft and 14 ft sections. The 12 sections in a given state are represented by either X-0201 through X-0212 or X-0213 through X-0224, where X denotes the state ID. The number 02 indicates the SPS experiment number and the last two digits represent the sequential numbering of the sections. Table 1 shows the proposed design matrix for the SPS-2 experiment. The matrix has 16 columns and 12 sections in each column. Hence, if the matrix was fully populated, then there should be 16 states (192 sections) in the experiment.

Table 1 SPS-2 experiment design matrix

Pavement Structure					Climatic Zones, Subgrade															
		PCC			Wet								Dry							
Drainage	Base type	Thickness (in)	14-day Flexural Strength, psi	Lane Width, ft	Freeze				No-Freeze				Freeze				No-Freeze			
					Fine		Coarse		Fine		Coarse		Fine		Coarse		Fine		Coarse	
					J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y
NO	DGAB	8	550	12	0201		0201		0201		0201		0201		0201		0201		0201	
				14		0213		0213		0213		0213		0213		0213		0213		0213
			900	12		0214		0214		0214		0214		0214		0214		0214		0214
				14	0202		0202		0202		0202		0202		0202		0202		0202	
		11	550	12		0215		0215		0215		0215		0215		0215		0215		0215
				14	0203		0203		0203		0203		0203		0203		0203		0203	
			900	12	0204		0204		0204		0204		0204		0204		0204		0204	
				14		0216		0216		0216		0216		0216		0216		0216		0216
NO	LCB	8	550	12	0205		0205		0205		0205		0205		0205		0205		0205	
				14		0217		0217		0217		0217		0217		0217		0217		0217
			900	12		0218		0218		0218		0218		0218		0218		0218		0218
				14	0206		0206		0206		0206		0206		0206		0206		0206	
		11	550	12		0219		0219		0219		0219		0219		0219		0219		0219
				14	0207		0207		0207		0207		0207		0207		0207		0207	
			900	12	0208		0208		0208		0208		0208		0208		0208		0208	
				14		0220		0220		0220		0220		0220		0220		0220		0220
YES	PATB DGAB	8	550	12	0209		0209		0209		0209		0209		0209		0209		0209	
				14		0221		0221		0221		0221		0221		0221		0221		0221
			900	12		0222		0222		0222		0222		0222		0222		0222		0222
				14	0210		0210		0210		0210		0210		0210		0210		0210	
		11	550	12		0223		0223		0223		0223		0223		0223		0223		0223
				14	0211		0211		0211		0211		0211		0211		0211		0211	
			900	12	0212		0212		0212		0212		0212		0212		0212		0212	
				14		0224		0224		0224		0224		0224		0224		0224		0224

Table 2 gives a description of the LTPP SPS-2 sites. From the table, it is evident that seven out of the 14 states are located in the Wet Freeze (WF) zone, 3 are in the Dry-Freeze (DF) zone and 2 states are located in each of the non-freeze regions. Hence the mber of sections available for analysis is 167(since there are only 11 sections in

)).

Table 2 Description of the LTPP SPS-2 sites

	AZ(4)	AR(5)	CA (6)	CO(8)	DE(10)	IA(19)	KS(20)
on	Western	Southern	Western	Western	North Atlantic	North Central	North Central
	Maricopa	Saline	Merced	Adams	Sussex	Polk	Dickinson
lder Type	PCC	AC	AC	PCC	AC	AC	PCC
ulder	PCC	AC	PCC	PCC	AC	AC	PCC
gion	Dry No Freeze	Wet No Freeze	Dry No Freeze	Dry Freeze	Wet Freeze	Wet Freeze	Wet Freeze
ı,mm	232	1380.6	300	370	1143.9	900.5	819.4
32 deg C	178	66	88	31	22	18	17

	MI(26)	NV(32)	NC(37)	ND(38)	OH(39)	WA(53)	WI(55)
on	North Central	Western	North Atlantic	North Central	North Central	Western	North Central
	Monroe	Lander	Davidson	Cass	Delaware	Adams	Marathon
lder Type	AC	PCC	PCC	AC	AC	AC	No Data
ulder	AC	PCC	PCC	AC	AC	AC	No Data
gion	Wet Freeze	Dry Freeze	Wet No Freeze	Wet Freeze	Wet Freeze	Dry Freeze	Wet Freeze
ı,mm	865.59	221.5	1150.8	545	971.6	308.4	815
32 deg C	13	61	31	14	10	26	5

ATIONS OF THE EXPERIMENT

S-2 experiment has the following limitations:

The 12 sections in a state are designed according to the SPS-2 factorial, regardless of the amount of traffic that the sections will experience during their design life. Hence, in states with relatively higher traffic levels, some sections could be "under-designed". This has been demonstrated using the AASHTO'98 supplemental design procedure (3) (to be discussed later). Therefore, test sections should have been constructed on routes with the same range of traffic in all the states. Also, only the lower limit of 200,000 ESALs was specified for traffic. If the upper limit were specified, then comparison of sections across the states would have been better.

The dataset is not balanced, as the number of years for which the data (level E) available for sections within a given state is not the same.

- The number of states assigned to each climatic zone is different. There are 2 states, each in the DNF and the WNF zone, 3 states in the DF zone and 7 states in the WF zone.
- The SPS-2 test sites in all the 14 states have not been opened to traffic at the same time. Hence the age of the sections is not the same. Figure 1 shows the age distribution amongst the SPS-2 sites.

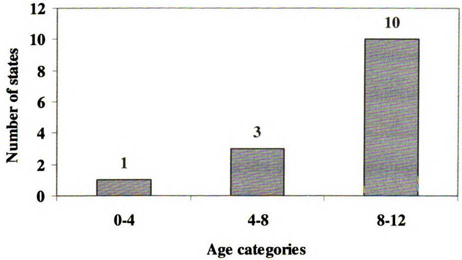


Figure 1 Age distribution in the SPS-2 sites

- While the SPS-2 experiment aims at evaluating the performance of new (i.e., non-rehabilitated) rigid pavements, rehabilitation was done in some states (AR (5), KS (20), ND (38) and NV (32). Every section is assigned a construction number of 1 when it is initially accepted into LTPP. The number is then incremented with each change to the layer structure.
- Some sections in a state have been deassigned and removed from the SPS-2 experiment due to the poor performance of the sections. Hence, no data will be available after the sections were deassigned from the experiment.

- There is inconsistency in the "type" of data collected. For example, monitored traffic data is collected over some years, after which the estimated data has been reported for subsequent years.

IDENTIFICATION OF EXPERIMENT VARIABLES

The variables in the SPS-2 experiment can be divided into two categories: (1) dependant and (2) independent.

The dependant variables are those used to describe pavement response and performance. Measures of pavement response are those measures that do not cumulate with time. The majority of pavement responses in this experiment are surface deflections from Falling Weight Deflectometer (FWD) testing.

The independent variables are those that describe design and construction factors. These can be divided into: (1) main variables, and (2) exogenous (or confounding) variables. Main variables are those used to specify the design matrices of the SPS experiment (e.g., base type). Exogenous variables are those that have potential impact on pavement response and performance but are not controlled in the experiment design. Exogenous variables that are independent of the main experiment variables are the actual cumulative traffic (KESALs) and age. All other exogenous variables are associated with the main design and construction variables. These include: (1) material properties of the various pavement layers, which constitute the structural factors in the design matrix, and (2) climatic factors, which describe the four climatic regions in the matrix. Table 3 lists the relevant independent and dependant variables identified for rigid pavements. Information on the availability and extent of these variables is discussed in later sections.

Table 3 Categorized list of variables for rigid pavements

Factor	Variables
Environmental factors	• No. of days with Freezing temperature • No. of days with temperature >32 deg C • Annual No. of days with precipitation • Annual No. of freeze-thaw cycles • FI, degree-days • Average Annual Precipitation • Environmental Zone • Average Max., Min. and Range of temperature, deg C
Concrete Material Properties	• PCC thickness • PCC Flexural Strength • PCC Compressive Strength • PCC Splitting tensile strength • PCC Mix gradation
Aggregate Base Material Properties	• Thickness of base • Base type (DGAB, LCB or PATB) • Density and OMC of the base material • Moduli, gradation and atterberg limits of the base material
Subgrade Material properties	• Subgrade soil type • Density and OMC of the material • Moduli, gradation and atterberg limits of the material
Traffic/Age	• Cumulative Annual Traffic in KESALs • Average Annual Traffic in KESALs • Age, years
Performance	• Dominant type of distresses o Transverse cracking o Longitudinal cracking o Faulting o Roughness o Pumping
Response	• Deflections • Various deflection basin parameters • Strains (DLR)

CHAPTER 3

SYNTHESIS OF DATABASE FOR ANALYSIS

INTRODUCTION

The data used in this study is a subpart of the LTPP Information Management System (IMS) database. This data is divided into the following categories: Inventory, Maintenance, Climatic, Monitoring, Traffic, Material Testing and Rehabilitation. Since the test sections in the LTPP SPS-2 experiment are new (i.e., not rehabilitated), maintenance and rehabilitation data are not relevant for this study and hence will not be discussed further. The Dynamic Load Response (DLR) data also will not be discussed because the offset distances for North Carolina are not available. The following is a brief description of the data elements contained in the categories that are relevant to this study.

Inventory data: Inventory tables contain information on the location of the section, section layout, drainage type, construction dates and any other static data (data that does not change with time).

Climatic data: Climatic data tables contain specific weather data collected from weather stations.

Monitoring data: These tables contain data collected through monitoring activities that are conducted at test sections. These include profile data, deflection (FWD) data, friction data, surface distress data and transverse profile data.

Traffic data: These tables contain historical traffic estimates from State Highway Agencies (SHA), and monitored traffic data (along with axle distribution data) collected using the weigh-in-motion (WIM) equipment.

Material testing data: These tables contain laboratory test data for pavement and subgrade materials as well as thickness data. This information is obtained from coring. Additional material, design and construction information for SPS sections are available in the specific SPS tables. The data for all the test sections undergoes quality control (QC) checks before being uploaded into the IMS database. The data that have satisfied these QC checks are referred to as "Level E" data. Only this type of data has been used in the analysis. The construction reports were obtained to review the detailed information on the construction of the sections.

IDENTIFICATION OF DATA ELEMENTS

The first step in this study is to identify variables that are available in Release 16.0 that may affect the response and performance of rigid pavements. This was done based on the information contained in the literature, past experience, and engineering judgment. The data tables within IMS that contain the relevant data elements were then identified, and systematically reviewed. Data from all the sections in the SPS-2 experiment were reviewed. Table 4 shows the data elements that were identified and included in the database for use in the analysis.

SYNTHESIS OF THE ANALYSIS DATABASE

The data used in this study are "Level E" data from the IMS database for the SPS-2 experiment and are extracted from Release 16.0. It might be noted that the performance data has been extracted from the Release 16.0 database while the response data has been extracted from the Release 15.0 database.

The flowchart describing the process of data extraction from the LTPP database is shown in Figure 2.

Table 4 Identified Data Elements

Description	Data Element
1. Inventory Data	
LTPP Experiment number	EXPERIMENT_SECTION
Construction date	INV_AGE
2. Traffic Data	
Historical ESALs	TRF_MON_EST_ESAL
Monitored ESALs	TRF_MON_BASIC_INFO
3. Climatic Data	
Annual precipitation	CLM_VWS_PRECIP_ANNUAL
Intense precipitation days	CLM_VWS_PRECIP_ANNUAL
Number of wet days/year	CLM_VWS_PRECIP_ANNUAL
Average maximum temperature	CLM_VWS_TEMP_ANNUAL
Average minimum temperature	CLM_VWS_TEMP_ANNUAL
Number of days below 0 oC/yr	CLM_VWS_TEMP_ANNUAL
Number of days above 32 oC/yr	CLM_VWS_TEMP_ANNUAL
Number of freeze thaw cycles /yr	CLM_VWS_TEMP_ANNUAL
Annual Freeze index	CLM_VWS_TEMP_ANNUAL
4. Subgrade Data	
Subgrade material code	TST_L05B
Subgrade resilient modulus	TST_SS07

Table 4 (cont'd).

Description	Data Element
Subgrade Data (continued)	
Subgrade moisture content	TST_SS01_UG01_UG02
Subgrade plastic limit	TST_UG04_SS03
Subgrade liquid limit	TST_UG04_SS03
Subgrade plasticity index	TST_UG04_SS03
Subgrade gradation properties	TST_SS01_UG01_UG02
% Greater than 2mm	TST_SS02_UG03
% Coarse sand	TST_SS02_UG03
% Fine sand	TST_SS02_UG03
% Silt	TST_SS02_UG03
% Clay	TST_SS02_UG03
5. Drainage Data	
Drainage type	INV_GENERAL
Drainage location	INV_GENERAL
6. Shoulder Information	
Shoulder surface type	INV_SHOULDER
Shoulder width	INV_SHOULDER
Shoulder paved width	INV_SHOULDER
Shoulder base type	INV_SHOULDER
Shoulder surface thickness	INV_SHOULDER
Shoulder base thickness	INV_SHOULDER

Table 4 (cont'd).

Description	Data Element
7. Pavement Layer Data	
PCC thickness	TST_L05B
Base thickness	TST_L05B
Subbase thickness	TST_L05B
Material code for base/subbase	TST_L05B
Base gradation	TST_SS01_UG01_UG02
Base moisture content	TST_SS01_UG01_UG02
Base/subbase liquid limit	TST_UG04_SS03
Base/subbase plastic limit	TST_UG04_SS03
Base/subbase plasticity index	TST_UG04_SS03
Moisture profiles through base/subbase and subgrade	SMP_GRAV_MOIST
Frost depth	SMP_FROST_PENETRATION
8. Pavement Layer Properties	
PCC elastic modulus	TST_PC04
PCC Poisson's ratio	TST_PC04
PCC compressive strength	TST_PC01
PCC split tensile strength	TST_PC02
PCC flexural strength	TST_PC09
PCC air content (hardened PCC)	TST_PC08

Table 4 (cont'd).

Description	Data Element
Pavement performance data	
1. Roughness data	
IRI value	MON_PROFILE_MASTER
Profile data	MON_PROFILE_DATA
2. Distress data	
PCC manual distress data	MON_DIS_JPCC_REV
PCC automated distress data, Longitudinal and transverse cracking, corner cracking, spalling, pumping, and joint sealant damage	MON_DIS_PADIAS_JPCC
PCC faulting data	MON_DIS_JPCC_FAULT MON_DIS_JPCC_FAULT_SECT
Pavement response data	
1. Surface deflection data	MON_DEFL_DROP_DATA
2. Deflection data with depth	DLR_LVDT_TRACE_SUM_AC
3. Strain data	DLR_STRAIN_TRACE_SUM_AC/PCC

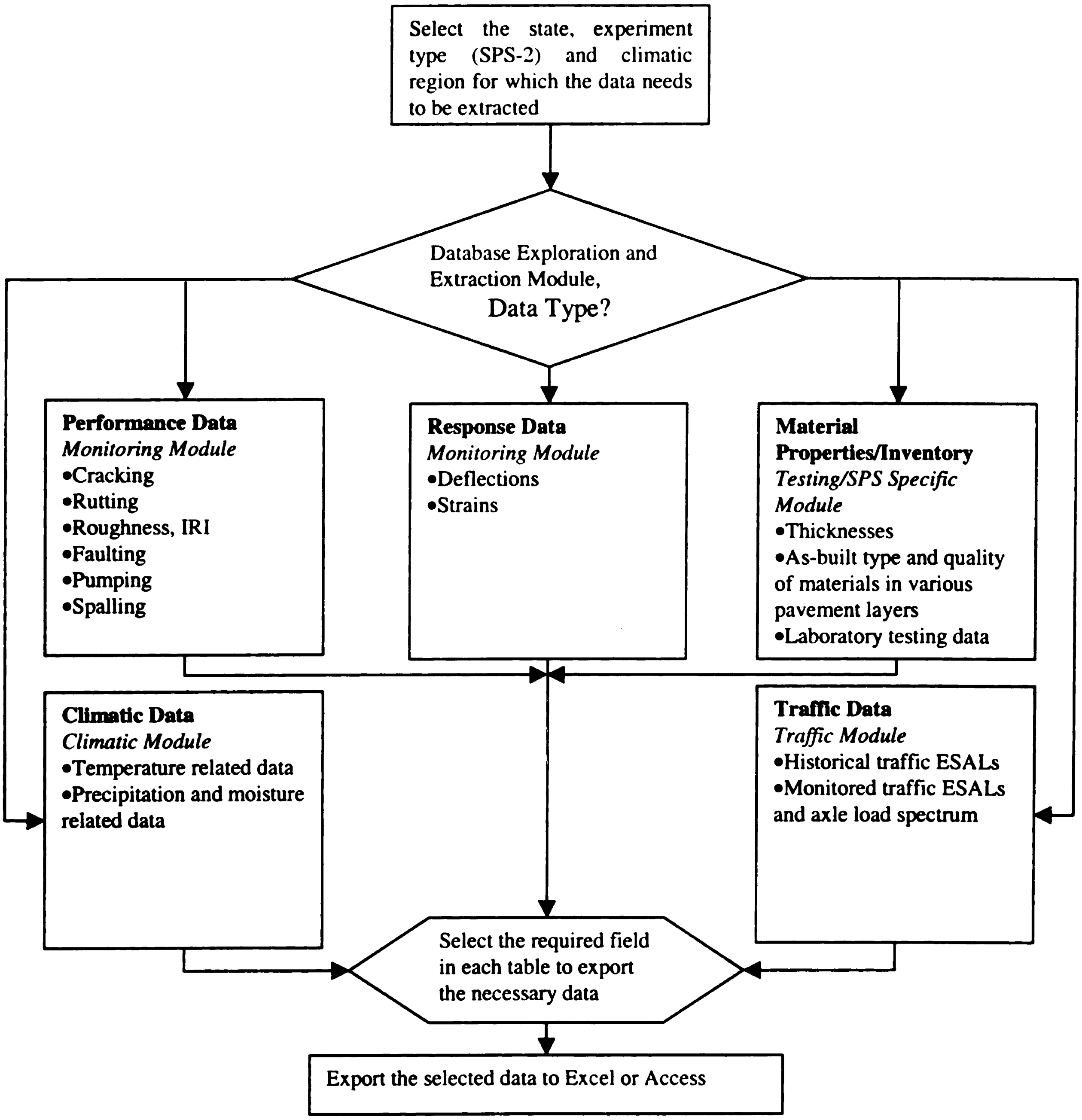


Figure 2 Flowchart for Data Extraction Process

To complement/cross-check the inventory data available in Release 16.0, construction reports (4) for all sections within the SPS-2 experiment were obtained. These reports were reviewed for the purpose of obtaining additional detailed information on construction and design features. They also include "problems" encountered during the construction of the SPS pavement sections. These have been discussed in Chapter 4.

CHAPTER 4

DATA AVAILABILITY IN THE SPS-2 EXPERIMENT

AVAILABILITY OF DESIGN AND CONSTRUCTION DATA

Construction information was obtained by reviewing the construction records for each of the SPS-2 test sites. The construction reports include (1) the location (climatic zone) and the layout of the test sections, (2) the process by which each layer within the pavement was constructed, (3) average daily traffic (ADT), percentage heavy trucks, estimated ESALs/year and the number of ESALs over the pavement design life, (4) problems encountered during the construction process, and (5) sampling plan and test data from field samples. In general, most of the test sections met the SPS-2 criteria of structural and material design. However some deviations were reported during construction at certain locations. Table A-1 of Appendix A summarizes the problems/deviations observed during the construction of the sections in all the 14 states. Some of the construction issues include inclement weather causing delay in the construction of sections in some states (CO, IA, DE, KS and NC). In general, it has been found that problems have been encountered during the construction of the LCB layers in most of the states. Shrinkage cracking was observed in the LCB layers at the time of the placement of the PCC slabs. These cracks appear to have reflected onto the PCC slabs in the form of transverse cracks in some states. Several problems were encountered during the construction of sections in NV (32), where the target strengths of 550 psi and 900 psi were changed to 475 psi and 750 psi respectively. Also, the construction of the sections in AR (5) did not conform to the SPS-2 factorial, with the LCB layers being constructed over a GB layer. All these construction deviations can have a potential impact on the performance and response of the pavement sections.

Deviations from the 14-day target flexural strengths (550 psi and 900 psi) were observed in some of the sections. The average flexural strength of the 550-psi sections was found to be 570 psi. However, the average flexural strength of the 900-psi sections was 819 psi. A summary of the sections, which did not meet the target strength requirements, is shown in Table 5. Compressive strength, flexural strength and splitting tensile strength data were available for all the states. The strength data of core specimens and those sampled during construction have been shown in Tables A-2 through A-14 in Appendix A. No mix design information was available for sections in WI (55).

Compressive and splitting tensile strength data for both the core specimens and the specimens sampled during construction were recorded at 14, 28 and 365 days. Flexural strength, measured only on specimens sampled during construction, was recorded at 14, 28 and 365 days.

A t-test was conducted to test the significance of deviations of the flexural strengths from their target strengths. As can be seen from Table 6, the deviation from the target flexural strengths is statistically significant because the absolute value of tcalc is greater than t0.05, n-1.

$$t_{calc} = \frac{x-\mu}{\frac{\sigma}{\sqrt{N}}}$$

Table 5 Deviations from the target flexural strengths for the SPS-2 test sites

State Code	SHRP ID	Target flexural strength, psi	Actual flexural strength, psi
5	0219	550	506
5	0221	550	521
8	0213	550	520
8	0215	550	510
8	0217	550	530
8	0219	550	515
8	0221	550	475
19	0213	550	500
19	0219	550	440
19	0223	550	460
32	0201	550	520
32	0207	550	490
53	0203	550	413
53	0205	550	487
53	0207	550	546
53	0211	550	494

State Code	SHRP ID	Target flexural strength, psi	Actual flexural strength, psi
4	0214	900	810
4	0216	900	790
4	0218	900	860
4	0220	900	810
4	0224	900	805
5	0218	900	825
5	0224	900	506
8	0218	900	810
8	0220	900	890
8	0224	900	815
10	0208	900	620
10	0212	900	730
19	0214	900	700
19	0220	900	770
19	0224	900	790
20	0202	900	803
20	0204	900	784
20	0206	900	829
20	0208	900	855
20	0212	900	865
32	0204	900	885
32	0206	900	730
32	0210	900	740
37	0212	900	850
39	0202	900	713
39	0208	900	690
39	0212	900	438
53	0202	900	823
53	0204	900	870
53	0206	900	801

Since tcalc is negative and the absolute value of tcalc is greater than t0.05, n-1, the deviation in the flexural strength from the target strengths (of 550 psi and 900 psi) are significant. Such a deviation is not desirable, as the sections did not achieve their target requirements. Not all the sections achieved their target 14-day strength at 28 days. Table 7 shows the sections, which achieved the 14-day target flexural strength at 28 days.

Table 6 Flexural strength deviations at the network level

	550-psi target strength	900-psi target strength
Average	495.7	773.6
N	18.0	30.0
Max	546.0	890.0
Min	413.0	438.0
Stdev	32.5	103.3
Cov	6.6	13.4
tcalc	-7.1	-6.7
t0.05,n-1	2.1	2.0

Table 7 Sections that met their target flexural strength at 28 days

State Code	Section ID	14-day target flexural strength, psi	Age, days	Actual 14-day Flexural Strength, psi
5	0221	550	28	555
8	0215	550	28	580
8	0217	550	28	560
8	0219	550	28	640
19	0213	550	28	590
32	0201	550	28	575
53	0203	550	28	622
53	0207	550	28	611
53	0211	550	28	709

State Code	Section ID	14-day target flexural strength, psi	Age, days	Actual 14-day Flexural Strength, psi
4	0218	900	28	925
8	0218	900	28	950
8	0220	900	28	1025
20	0202	900	28	911
20	0206	900	28	928
20	0208	900	28	1035
53	0202	900	28	1041
53	0204	900	28	915

Sections, which did not meet the 14-day target strengths at 28 days, met the target flexural strengths at 365 days. Most of the sections were constructed in accordance with the targeted PCC slab thicknesses of 8 in. and 11 in. The average thicknesses of the 8 in. and the 11 in. sections are 8.31 in. and 11.23 in. respectively. The average thickness of the DGAB layers (sections 0201-0204 and 0213-0216) is 6.42 in. (greater than the target thickness of 6 in.), while that of the LCB layers (0205-0208 and 0217-0220) is 6.32 in. (greater than the target thickness of 6 in.). The average thickness of the PATB layers (sections 0209-0212 and 0221-0224) was found to be 4.41 in. (greater than the target thickness of 4 in.). A t-test was conducted at the network level to determine if the layer thicknesses are significantly different from their target design values. Table 8 shows the results of the t-test. It has been found that there is a significant deviation in the thicknesses of the PCC and the LCB layer from their target thicknesses (tcalc > t0.05, n-1). However, even though there is a deviation in the thicknesses of the layers, the mean values of the thicknesses are greater than the target thicknesses. No significant deviation in the thickness of the DGAB layers is observed, as the tcalc is less than t0.05, n-1.

Table 8 Thickness deviations at the network level

	8" target PCC thickness	11" target PCC thickness	6" target DGAB thickness	6" target LCB thickness	4" target DGAB thickness	4" target PATB thickness
Average	8.3*	11.3*	6.1	6.3*	4.1	4.1
N	72	71	48	48	47	47
Max	10.1	12.4	9.3	7.5	5.0	5.6
Min	7.1	10.6	5.4	5.5	3.1	3.4
Stdev	0.5	0.3	0.7	0.4	0.4	0.5
Cov	5.7	3.1	11.3	6.3	8.8	11.1
t_{calc}	6.1	6.6	1.4	4.9	1.1	1.0
$t_{0.05,n-1}$	2.0	2.0	2.0	2.0	2.0	2.0

* Significantly different from the target thickness at a 0.05 level of significance

Figures B-1 through B-13 show the deviations in the layer thicknesses for all the states. It might be noted that the notation of the sections in AR (5) in Release 16.0 is different from the notation used in the construction reports. The sections were numbered from 5-0213 to 5-0224 in Release 16.0 and the sections were numbered from 5-0201 to 5-0212 in the construction reports. However the notation in Release 16.0 was used for the analysis. Also, a discrepancy in the cross sections was also observed in the LCB sections in AR (5). According to the SPS-2 factorial, the typical cross-section of all the LCB sections (5-0217 through 5-0220) is as shown in Figure 3, while the as-constructed cross sections are as shown in Figure 4.

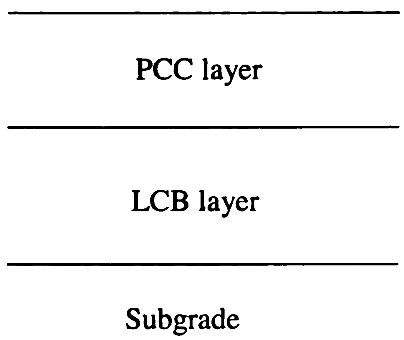


Figure 3 Cross section of LCB sections according to the SPS-2 factorial

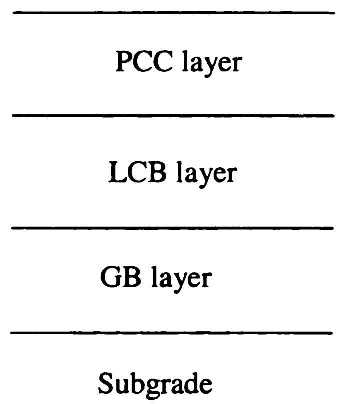


Figure 4 Cross section of LCB sections in AR (5)

The as-built cross section was used during the analysis. The thicknesses of the LCB and the DGAB layers were used in the thickness adequacy analysis using the AASHTO '98 procedure. The total structural capacity of the pavement was also used to evaluate the performance of sections in AR (5).

AVAILABILITY OF TRAFFIC DATA

Traffic data was assimilated from two sources (1) Release 16.0 database and (2) SPS-2 Construction Reports. The data is available in three forms (i) Monitored traffic data; (ii) Axle distribution data and (iii) Estimated traffic data. The three modules from which the data is obtained are described in Table 9.

Table 9 Location of traffic data in the LTPP database

Module Name	Description of the data
TRF_MONITOR_BASIC_INFO	Information on the monitored traffic data collection and site characteristics on a yearly basis
TRF_MONITOR_AXLE_DISTRIB	Information on the number of axles in each weight range for each axle group for monitoring data.
TRF_MON_EST_ESAL	Information on the estimated annual ESALs, truck volumes, and methods of estimation for the period after initiation of LTPP monitoring.

Table 10 and Table 11 show the monitored and estimated ESALs available in the Release 16.0 database. Shaded cells indicate missing data for that year.

Table 10 Average of Annual KESALs (Estimated data) for SPS-2 Experiment

STATE_CODE	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
4		900				1400	1300			
5					1969		8882			
8			395							
10						410				
19				94						
20	720	593	622	748	697	839	810	557	986	
32					492					
37					124	1342	1578	1578		
38				382	409	401	405	454	460	511
53					190	198				

Table 11 Average of Annual KESALs (Monitored data) for SPS-2 Experiment

STATE_CODE	1992	1993	1994	1995	1996	1997	1998	1999
4			1,344	726	1,091			
5					0		0	
8				478	240	224		
19					0	56		
20	732	53	212					
26		597	1,778	0	1,496	2,552	1,661	
32						813		
37			780	716	0	728	0	1,096
39							612	
53							462	

No traffic data is available for CA (6) or WI (55) in the monitored and estimated modules of the database. The respective construction reports of the states, however, provide information on the design ESALs of the sections.

Table 10 and Table 11 can be used to identify the states where the traffic data (estimated or monitored) are available. It is also possible to identify the extent of data availability, and to see if the missing data in one source can be supplemented from another available source.

There is a good agreement between the monitored and estimated ESALs for AZ (4) and CO (8). The monitored KESALs have been used for analysis in these states, since the monitored data is more accurate, as it is obtained from the WIM equipment. There is a discrepancy between the monitored and estimated KESALs for states AR (5), IA (19), KS (20), NV (32), NC (37) and WA (53). The remaining states have data available from either the monitoring or the estimated modules.

Inconsistency in the estimated traffic data was observed for AR (5) and NC (37), where the KESALs per year are significantly different. The estimated traffic information was available for only one year in the other states, viz., CO (8), DE (10), IA (19) and NV (32). The monitored KESALs for CO (8), IA (19), KS (20), MI (26) and NC (37) are inconsistent with time, as the KESALs per year are significantly different. Data was available only for one year for NV (32), OH (39) and WA (53). The monitored KESALs for AR (5) are zero and the estimated KESALs are inconsistent with time. Hence the data from the construction reports is used in the analysis.

The axle distribution data is available for states AR (5), CO (8), IA (19), MI (26), NV (32), NC (37), OH (39) and WA (53). The module reports the number of axles in each range for each axle group (1 through 4) for monitoring data.

Table 12 summarizes the extent of traffic data availability for all the states in the SPS-2 experiment. The table also shows the source from which the data is obtained. No monitoring data is available for the year 2001 for any of the states in the Release 16.0 database.

Table 12 Traffic data availability in Release 16.0

STATE CODE	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
4		E	M	M	M	E	E	NO	NO	NO
5				NO	E,M	A	E,M	A	NO	A
6	NO TRAFFIC DATA AVAILABLE,SECTION OPENED TO TRAFFIC IN 2000									
8		NO	E	M,A	M,A	M	NO	NO	NO	NO
10					NO	E	NO	NO	NO	NO
19			NO	E	M	E,A	NO	NO	A	A
20	E,M	E,M	E,M	E	E	E	E	E	E	NO
26		M,A	M,A	M	M	M	M	NO	A	A
32				NO	E	M	NO	A	A	NO
37			M	M	E,M	E,M	E,M	E,M	A	A
38			NO	E	E	E	E	E	E	E
39					NO	NO	M,A	NO	A	A
53				NO	E	E	M,A	A	NO	NO
55						NO	NO	NO	NO	NO

E : Data available from the Estimated Module, TRF_MON_EST_ESAL
M: Data available from the Monitored Module, TRF_MONITOR_BASIC_INFO
A: Data available from the Axle Distribution Module, TRF_MONITOR_AXLE_DISTRIB
NO : Data not available from any source

Table 13 shows the estimated (design) ESALs from the construction reports. This data is presented in the form of: (1) Average Daily Traffic (ADT), (2) Percent of heavy trucks, (3) ESALs/year, and (4) Projected ESALs over the design life of the pavement section. The table shows that the design traffic information is available for 13 out of the 14 states. Because there is a high variability in the traffic data available from the three sources and due to the missing data for some states, the KESALs per year have been proposed for each state based on the monitored and estimated data and the traffic data information from the construction reports, as shown in Table 14. This was done by giving priority to the monitored ESAL data (wherever available) followed by the estimated ESALs and the ESAL information from the construction report. Table 15, describes in detail, how the KESALs per year have been proposed for each state. The proposed rate of KESALs was used as a covariate in the statistical analysis (to be discussed in Chapter 6) to determine the effects of design and construction features on the occurrence of various distresses.

Table 13 Traffic Information from the construction reports for SPS-2 Experiment

State	Design Traffic Information
Arizona, AZ (4)	ADT (1992)=15,900; ADT (2002)=20,400
Arkansas, AR (5)	ESALs/year=1,700,000, 45% heavy trucks
California, CA (6)	AADT in two directions= 89000 vehicles with 24.6 % trucks, Total 18k ESALs in the 20 year design period = 48,100,000
Colorado, CO (8)	ADT=8,400; 16% heavy trucks; 20 year design ESALs=15.6 million
Delaware, DE (10)	ADT=10,708; 10% heavy trucks; 15 year design ESALs=3.048 million
Iowa, IA (19)	ADT=17,400, 16% heavy trucks; 30 year design ESALs=9.9 million
Kansas, KS (20)	ADT=13,750,21.4 % heavy trucks; 20 year design ESALs=26 million
Michigan, MI (26)	AADT=35,000; 22% heavy trucks; 20 year design ESALs=26.6 million (4% growth rate)
Nevada, NV (32)	ESALs/year=799,000; 51% heavy trucks
North Carolina, NC (37)	N/A
North Dakota, ND (38)	ADT = 8,310; 12% heavy trucks; 30 year design ESALs=2.15 million
Ohio, OH (39)	ADT (1994)=20,210, 12 heavy trucks
Washington, WA (53)	AADT (1993)=18,000; 40 year design ESALs=35 million
Wisconsin, WI (55)	ADT (1995)=6,650;ADT (2015)=8,700; 20 % heavy trucks

Table 14 KESALs per year for SPS-2 Experiment

State ID	KESALs/year				Remarks
	Monitored	Construction reports	Estimated	Proposed	
Arizona, AZ (4)	1054	-	1200	1054	
Arkansas, AR (5)	-	1700	1969	1700	
California, CA (6)	-	2405	-	2405	
Colorado, CO (8)	350	454*	395	400	*TF used from FHWA
Delaware, DE (10)	-	300*	410	350	*Based on KESAL from flexible pavements times 1.5
Iowa, IA (19)	56	330	94	330	
Kansas, KS (20)	732**	870*	670	870	*Based on TF from FHWA **Ignored data for 93 and 94
Michigan, MI (26)	1872	1330	-	1500	
Nevada, NV (32)	813	799	492	800	
North Carolina, NC (37)	830	-	1499	1164	
North Dakota, ND (38)	-	419*	432	420	*TF used from FHWA
Ohio, OH (39)	612	797*	-	612	*TF used from FHWA
Washington, WA (53)	462	875	194	462	
Wisconsin, WI (55)	-	180*	-	180	*TF used from FHWA

Table 15 Calculation of KESALs per year

State ID	Calculation of KESALs/year
AZ (4)	• Estimated traffic data is available for 3 years. The KESALs for the three years (1993,1997 and 1998) are 900, 1400 and 1300 respectively and hence the average KESALs/year was calculated to be 1200 KESALs/year • Monitored traffic data was available for 1994, 1995 and 1996. The KESALs were 1344, 726 and 1091 and the average KESALs/year was found to be 1054 KESAL/s year • Information from both the estimated data can be used to supplement the missing information in the Monitored data, as the magnitudes of KESALs are within the same range. The proposed KESALs/year is 1054 as the information from the monitored traffic data is more accurate.
AR (5)	• The estimated traffic data is 1969 KESALs for year 1996 and 8882 for 1998. This data is questionable as the KESALs for both the years are significantly different. • The monitored traffic data is zero for 1996 and 1998 • However, the design KESAL (from the construction report) for the sections is 1700. The proposed KESALs/year is 1700
CA (6)	• No information about the traffic data is available from the monitored and estimated modules. The proposed KESALs/ year is 2405 obtained from the construction reports.
CO (8)	• Estimated KESALs for 1994 is 395 • Monitored KESALs for 1995, 1996 and 1997 are 478, 240 and 224 respectively. Average Monitored KESALs/year are 350 • Design KESALs (from the construction reports) are 454 The proposed KESALs/year is 400 (average of 395,350 and 454)
DE (10)	• Estimated traffic is 410 for year 1997. • Design KESALs from the construction reports are 300 The proposed KESALs/year is 350 (average of KESALs from the 2 sources)
IA (19)	• Estimated traffic data is 94 for year 1995 • Monitored traffic data is 56 for year 1997 • Design KESALs from the construction reports are 330 The proposed KESALs/year is 330
KS (20)	• Estimated traffic data is available from 1992 through 2000. Average estimated KESALs/year is 670 • Monitored traffic data is 732 (1992), 53 (1993) and 212 (1994). Data from 1993 and 1994 are ignored as there are significantly lower than the other values • Design KESALs is 870 The proposed KESAL/s year is 870

Table 15 (cont'd).

State ID	Calculation of KESALs/year
MI (26)	• Estimated KESAL data is not available • Monitored KESALs are available from 1993 through 1998. Data for 1993 and 1995 can be ignored, as they are significantly lower than the other values. Average monitored KESALs/s year is 1872 • Design KESAL is 1330 The proposed KESALs/year is 1500 (average from both the sources)
NV (32)	• Estimated KESALs is 492 for 1996 • Monitored KESALs is 813 for 1997 • Design KESALs is 799 The proposed KESALs/year is 800
NC (37)	• Estimated traffic data is available from 1996 through 1999. However, since the KESALs in 1996 was comparatively very low (124), it has been ignored when computing the average estimated KESALs (1499) • Monitored traffic information is available from 1994 through 1999. Ignoring the data from 1996 and 1998 as they are zero, the average monitored KESALs was calculated as 830 The proposed KESAL/s year (1164) was reported as the average of the KESALs from the two sources.
ND (38)	• Estimated traffic information is available from 1995 through 2001. Average estimated KESALs is 432 • Monitored KESALs/ year is not available • Design KESALs is 419 The proposed KESAL/s year is 420
OH (39)	• No estimated traffic data information is available • Monitored traffic data is available for 612 for year 1998. • Design KESALs is 797 from construction reports The proposed KESALs/year is 612 (from the monitored module)
WA (53)	• Estimated traffic data is available for 1996 and 1998. Average estimated KESALs is 194 • Monitored KESALs/year is 462 for year 1998. • Design KESALs is 875 from the construction reports The proposed KESALs/year is 462 as the data is available from the monitoring module
WI (55)	• No information is available from the monitored and estimated modules in the database • Design KESALs/year is 180 The proposed KESALs/year is 180.

RESPONSE AND PERFORMANCE DATA

Figure 5 illustrates the extent of performance data available by showing the distribution of the data by their level at the latest survey year. The figure also shows the age distribution of the SPS-2 sections. Table 16 through Table 20 summarize the availability of the performance and response data. There are a number of sections that have exhibited various levels of response and performance. For example, 11% of the faulting data falls in the range of –0.02-0.00 in. (-0.5-0 mm), 15% falls in the range of 0.00-0.02 in (0-0.5 mm), 72 % falls in the range of 0.02-0.04 in (0.5-1 mm) and 2% of the data falls in the range of 0.06-0.08 in (1.5-2 mm), respectively.

Table 16 Average number of Transverse cracks in the SPS-2 test sites

Pavement Structure					Climatic Zones, Subgrade															
Drainage	Base type	PCC		Lane Width, ft	Wet								Dry							
		Thickness (in)	14-day Flexural Strength, psi		Freeze				No-Freeze				Freeze				No-Freeze			
					Fine		Coarse		Fine		Coarse		Fine		Coarse		Fine		Coarse	
					J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y
NO	DGAB	8	550	12	4		0		0.1		X		X		17		X		6	
				14		0.2		X		X		0.8		0		X		X		0
			900	12		0.3		X		X		0		X		0		X		0
				14	2.7		0		0		X		53		0		X		6	
		11	550	12		0.1		X		X		0		0		0		X		0
				14	0		0		0		X		139		0		X		1.3	
			900	12	0.4		0		0		X		19		0		X		0	
				14		0		X		X		0		X		X		X		0
NO	LCB	8	550	12	3.9		6.2		4.8		X		X		78		X		9.7	
				14		2.2		X		X		1		0		X		X		6.3
			900	12		1.7		X		X		20		1		X		X		8.3
				14	1.8		0		0		X		111		2.1		X		6.3	
		11	550	12		0		X		X		0		X		0		X		0.8
				14	0		0		0		X		7.3		2.3		X		0.7	
			900	12	0		0		0		X		36		0		X		1	
				14		0		X		X		0		0		X		X		0.7
YES	PATB/DGAB	8	550	12	0		0		0		X		0.6		0		X		0	
				14		0		X		X		0		0		X		X		0
			900	12		0		X		X		0		0		X		X		0
				14	0.4		0		0.8		X		25		0		X		0	
		11	550	12		0		X		X		0		X		0		X		0
				14	0		0		0		X		3.5		0		X		0	
			900	12	0.1		0		0		X		X		0		X		0	
				14		0		X		X		0		X		0		X		0

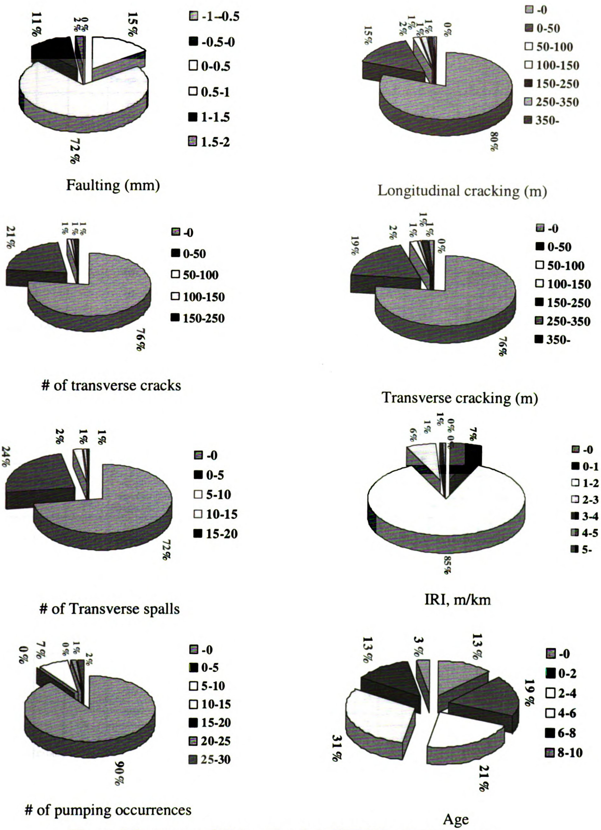


Figure 5 Summary of distress levels in SPS-2 for the latest year

Table 17 Average joint faulting in the SPS-2 sites

Pavement Structure					Climatic Zones, Subgrade															
		PCC			Wet								Dry							
Drainage	Base type	Thickness (in)	14-day Flexural Strength, psi	Lane Width, ft	Freeze				No-Freeze				Freeze				No-Freeze			
					Fine		Coarse		Fine		Coarse		Fine		Coarse		Fine		Coarse	
					J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y
NO	DGAB	8	550	12	0.16		0.32		0.29		X		X		0.42		X		0.29	
				14		0.25		X		X		0.96		0.22		X		X		0.28
			900	12		0.32		X		X		0.45		X		0.23		X		0.26
				14	0.1		0.27		0.27		X		0.6		0.29		X		0.16	
		11	550	12		0.56		X		X		0.95		0.17		X		X		0.29
				14	0.12		0.15		0.23		X		0.41		0.34		X		0	
			900	12	0.16		0.12		0.31		X		0.49		0.32		X		0.12	
				14		0.26		X		X		0.34		X		0.19		X		0.26
NO	LCB	8	550	12	0.2		0.74		0.27		X		X		0.35		X		0.12	
				14		0.18		X		X		0.21		0.37		X		X		0.18
			900	12		0.28		X		X		0.28		0.4		X		X		0.23
				14	0.16		0.36		0.22		X		0.24		0.24		X		0.14	
		11	550	12		0.26		X		X		0.36		X		0.32		X		X
				14	0.13		0.08		0.09		X		0.51		0.14		X		0.09	
			900	12	0.04		0.15		0.12		X		0.4		0.25		X		0.15	
				14		0.21		X		X		0.44		0.3		X		X		X
YES	PATB / DGAB	8	550	12	0.12		0.4		0.12		X		0.41		0.27		X		0.1	
				14		0.23		X		X		0.47		0.19		X		X		X
			900	12		0.27		X		X		0.42		0.14		X		X		X
				14	0.19		0.18		0.3		X		0.39		0.27		X		0.11	
		11	550	12		0.17		X		X		0.36		X		0.53		X		X
				14	0.07		0.05		0.33		X		0.39		0.27		X		0.02	
			900	12	0.14		0.27		0.51		X		X		0.36		X		0.14	
				14		0.19		X		X		0.52		X		0.39		X		X

Note: Numbers in cells are in mm. (1 in. = 25.4 mm)

Table 18 Total number of pumping occurrences in the SPS-2 sites

Pavement Structure					Climatic Zones, Subgrade															
		PCC			Wet								Dry							
Drainage	Base type	Thickness (in)	14-day Flexural Strength, psi	Lane Width, ft	Freeze				No-Freeze				Freeze				No-Freeze			
					Fine		Coarse		Fine		Coarse		Fine		Coarse		Fine		Coarse	
					J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y
NO	DGAB	8	550	12	1		0		0		X		X		3		X		0	
				14		6		X		X		8		0		X		X		0
			900	12		16		X		X		51		X		0		X		0
				14	0		0		0		X		0		0		X		0	
		11	550	12		14		X		X		11		0		X		X		0
				14	0		0		0		X		0		0		X		0	
			900	12	0		0		0		X		23		0		X		0	
				14		31		X		X		18		X		0		X		0
NO	LCB	8	550	12	7		0		0		X		X		1		X		0	
				14		105		X		X		53		0		X		X		0
			900	12		31		X		X		40		0		X		X		0
				14	22		0		0		X		0		0		X		0	
		11	550	12		17		X		X		57		X		0		X		X
				14	0		35		0		X		0		0		X		0	
			900	12	0		0		0		X		18		0		X		0	
				14		38		X		X		14		0		X		X		X
YES	PATB / DGAB	8	550	12	0		0		0		X		0		0		X		0	
				14		0		X		X		0		0		X		X		X
			900	12		0		X		X		32		0		X		X		X
				14	0		0		0		X		16		0		X		0	
		11	550	12		0		X		X		0		X		0		X		X
				14	0		0		0		X		0		0		X		0	
			900	12	0		0		0		X		X		0		X		0	
				14		4		X		X		0		X		0		X		X

Table 19 Average midslab deflection (in microns) at sensor 1(based on last year) for SPS-2 Experiment

PCC Thickness, in.	PCC Slab		Zone / Subgrade		WF		WNF		DF		DNF	
	Flexural Strength (psi)	Lane Width, ft	Base Type	Drainage	F	C	F	C	F	C	F	C
8	550	12	DGAB	ND	124.86	91.63	97.61			128.43		
			LCB		92.52	91.85	89.34			90.26		
			PATB	D	103.88	86.65	90.00		86.08	88.62		
		14	DGAB	ND	140.56					95.07		85.15
			LCB		123.13				93.29			55.31
			PATB	D	111.22				148.21			81.67
	900	12	DGAB	ND	122.99					209.59		111.09
			LCB		115.94					152.31		92.95
			PATB	D	99.49					102.87		81.34
		14	DGAB	ND	125.19	87.82	114.24			160.29		
			LCB		90.71	62.87	80.07			75.04		
			PATB	D	106.45	110.50	94.59			78.00		
11	550	12	DGAB	ND	88.73				68.47			75.72
			LCB		70.33					71.24		52.36
			PATB	D	65.80					79.42		57.14
		14	DGAB	ND	75.96	60.64	77.85		70.68	79.96		
			LCB		61.13	60.58	62.59		59.70	53.28		
			PATB	D	67.19	51.22	73.35		66.59	68.58		
	900	12	DGAB	ND	70.45	67.26	92.13			66.22		
			LCB		55.90	60.95	60.62			45.83		
			PATB	D	63.64	56.83	62.55			59.61		
		14	DGAB	ND	81.26					64.00		92.17
			LCB		61.18				75.22			44.88
			PATB	D	72.51				127.03	82.11		55.27

Table 20 Average midslab deflection at sensor 7(based on last year) for SPS-2 Experiment

PCC Thickness, in.	PCC Slab		Zone		WF		WNF		DF		DNF	
			Subgrade		F	C	F	C	F	C	F	C
	Flexural Strength (psi)	Lane Width ft	Base Type	Drainage								
8	550	12	DGAB	ND	44.06	38.19	52.65			41.41		
			LCB		35.82	33.87	61.45			37.28		
			PATB	D	36.41	36.32	47.37		32.86	29.22		
		14	DGAB	ND	53.07					37.77		31.44
			LCB		54.26				42.61			21.09
			PATB	D	44.30				58.17			34.95
	900	12	DGAB	ND	50.93					89.72		40.94
			LCB		49.42					58.63		29.34
			PATB	D	39.39					40.79		32.04
		14	DGAB	ND	43.61	38.90	67.98			57.59		
			LCB		38.12	33.32	57.49			24.88		
			PATB	D	34.93	43.65	56.22			30.27		
11	550	12	DGAB	ND	44.38				29.96			35.14
			LCB		35.02					43.25		45.17
			PATB	D	33.05					37.15		31.08
		14	DGAB	ND	32.01	30.28	52.15		34.31	37.46		
			LCB		26.83	31.08	49.09		32.39	27.27		
			PATB	D	28.71	25.77	50.73		34.03	28.98		
	900	12	DGAB	ND	32.22	39.58	63.06			29.44		
			LCB		26.97	33.09	45.05			21.49		
			PATB	D	31.29	27.13	38.72			26.66		
		14	DGAB	ND	44.11					35.57		43.80
			LCB		34.47				48.54			26.19
			PATB	D	35.52				41.98	44.17		28.29

The quantity of data available till date was found sufficient for analysis. The dataset gives us an opportunity to make preliminary conclusions regarding the effects of construction features on the performance of JPCP sections. Most of the cracks that manifested in the SPS-2 test sections so far could be a direct consequence of the shrinkage cracks that occurred in the LCB layer at the time of construction. As the sections get older, it is expected from the knowledge of the distresses that more load-related and material-related distresses would be manifested. These aspects could thus be analyzed in a few years from now, when most of the sections exhibit higher distress with age. The SPS-2 experiment being first of its kind and analysis of its data to study the effects of design and construction features is being done for the first time, the approach suggested in this thesis could be of use for future researchers to understand the behavior of Jointed Plain Concrete Pavements.

CHAPTER 5

ENGINEERING ANALYSIS OF SPS-2 DATA

This chapter presents the engineering analysis of the SPS-2 data. The analysis consists of the thickness adequacy analysis using the AASHTO '98 procedure, and the performance data (cracking, pumping and faulting) analysis. The performance data analysis was done at both the network level and state level. The network level analysis deals with evaluating the sections in all states in terms of various performance measures. This allows for comparing the performance of various designs under varying climatic conditions, subgrade types and traffic loads. The state level analysis deals with evaluating the sections within each state. This allows for comparing the performance of various designs within a state for constant climatic conditions, subgrade type and traffic loads. The response data analysis has been dealt with in Chapter 7.

THICKNESS ADEQUACY ANALYSIS USING AASHTO '98 DESIGN PROCEDURE

The amount of traffic that each of the 12 sections within a state can withstand during their design life has been theoretically calculated (3). To investigate the influence of construction deviations on the load carrying capacity of the sections, the ESAL levels of the as built and the as-designed sections were compared. It has been found that most of the 8-in sections cannot withstand the design traffic. However, this could be because of the under-design of the sections and not the construction deviations. The assumptions made in the analysis are shown in Table 21.

All the other inputs required for the analysis have been obtained from Release 16.0. The results of the analysis are summarized in Tables A-15 through A-25 in Appendix A. It might be noted that no analysis was done for states AR (5), CA (6) (due to non-availability of flexural strength data) and WI (55) (due to non-availability of thickness data). Table 22 shows the projected traffic (obtained from the construction reports) during the design period. Data for the other states is not available in the construction reports. The average ESALs for the as designed and as-built cross sections (both 8 in. and 11 in. sections) are also shown in Table 22. The average ESALs of all the 8 in. and 11 in. sections are computed for states where the design ESALs information is available. This allows us to verify if the 8 in. and 11 in. sections have met their target ESALs. It was found that most of the 8 in. sections did not meet their target ESALs while all the 11 in. sections can withstand the design ESALs.

Table 21 Assumptions in the AASHTO '98 analysis

Design reliability	95 %
Overall standard deviation	0.38
Mean 28-day concrete elastic modulus	4000000 psi
Concrete Poisson's ratio	0.15
Base elastic modulus	DGAB layer: 30000 psi
	LCB layer: 2000000 psi
	PATB layer: 3000000 psi
Slab/base friction coefficient	DGAB layer: 1.35
	LCB layer: 35
	PATB layer: 6.85
□PSI	2.0
Edge support adjustment factor	1.00 for 12-ft lane and AC shoulder
	0.94 for 12-ft lane and tied PCC shoulder
	0.92 for widened PCC slab
Mean annual temperature	Obtained from the climatic data in the supplemental guide
Mean annual precipitation	
Mean annual wind speed	

Table 22 Comparison of ESALs for SPS-2 sites

State ID	Projected design ESALs, millions	ESALs for the as-designed cross section (8-in. sections)	ESALs for the as-built cross section (8-in. sections)	ESALs for the as-designed cross section (11-in. sections)	ESALs for the as-built cross section (11-in. sections)
CO (8)	15.6	2.92	3.81	21.66	28.78
DE (10)	3.05	17.31	21.94	63.28	115.04
IA (19)	9.9	1.41	1.75	12.34	18.40
KS (20)	26.1	10.1	9.7	34.78	37.51
MI (26)	26.6	22.8	42.35	106.9	116.9
ND (38)	2.16	8.2	9.9	48.8	50.4
WA (53)	35	10.3	12.3	32.96	35.96

Performance data analysis

All the distresses that manifested in the SPS-2 test sections have been recorded in the MON_DIS_JPCC_REV and MON_DIS_JPCC_FAULT modules of the Release 16.0 database. The occurrence of the distresses in each of the test sections has been summarized in Tables A-26 through A-38 in Appendix A. The most commonly occurring distresses include: longitudinal and transverse cracking, longitudinal and transverse joint sealant damage, longitudinal and transverse joint spalling, pumping, scaling and corner breaks. It should be noted that the data set is not balanced, as the number of years for which data is available for sections is inconsistent.

General observations from these tables include:

- Transverse cracking was found mainly in sections constructed on non-drainable bases.
- DGAB sections, in general, exhibited more transverse cracking than sections constructed on other base types.

- Transverse cracking in the LCB sections could be due to the problems encountered during construction.
- Within a base type, 8 in. sections had greater amount of transverse cracking than 11 in. sections.
- For a given base type and slab thickness, sections with a conventional 12 ft lane exhibited more transverse cracking than 14 ft sections.
- Transverse and longitudinal joint sealant damage was observed in most of the states, irrespective of the climatic region in which they are located.
- 'D' cracking was observed in states located in the WF zone (KS and ND),
- Faulting was observed in almost all the states. However, higher levels of faulting (0.39- 0.55 in) were observed in sections located in WF zones (DGAB sections in MI). The magnitudes of faulting in the other states ranged from 0-0.19 in. The relationship between faulting and dowel diameter is not obvious as the thicker sections have 1.5 in. dowels whereas the thinner sections have 1.25 in. dowels.
- Relatively higher faulting was observed in sections constructed on a DGAB than those constructed on an LCB or a PATB.
- Pumping was observed only in the regions located in the wet zones (rainfall greater than 20 in.) except for NV (32), which is located in DF zone, the reason(s)for this observation is (are) not clear from the data.

A detailed discussion of the occurrence of distresses is presented in the subsequent sections.

CRACKING IN SPS-2 SECTIONS

Figure 6 shows the number of sections with 8 in. and 11 in. PCC slabs in the SPS-2 experiment that exhibited transverse cracking. Transverse cracking manifested within 0-3 years after the sections were opened to traffic in both categories of sections. The total number of 8 in. and 11 in. sections constructed is 84 and 83 respectively. About 93 % of the 8 in. and the 11 in. sections exhibited transverse cracking, the number of sections that exhibited cracking within the two levels of PCC thickness being almost the same (77 and 78 respectively). Table 23 shows the sections, which exhibited transverse cracking, after 3 years of opening to traffic. Figure 6 also shows the number of sections within different base types and different lane widths, which exhibited transverse cracking. Within the different base types and lane widths, it was found that the number of sections, which exhibited transverse cracking, is almost the same. Hence, it was deemed necessary to further investigate the magnitudes of transverse cracking in each of these categories to completely understand the occurrence of transverse cracking in the SPS-2 sections.

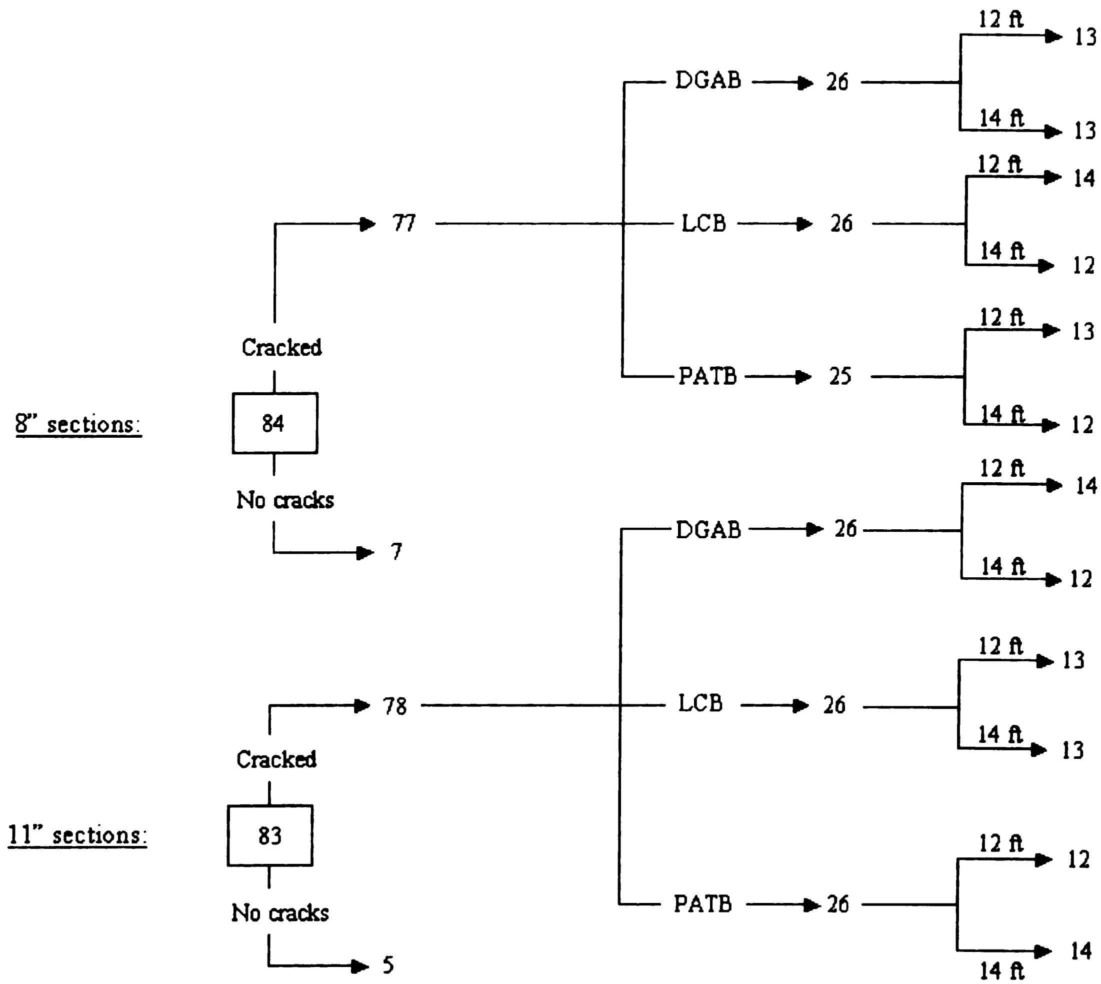


Figure 6 Occurrence of transverse cracks in the SPS-2 sites

Table 23 Sections with late occurrence of transverse cracking

8 in. sections				11 in. sections			
Section ID	Base type	Lane Width, ft	Time to first crack, years	Section ID	Base type	Lane Width, ft	Time to first crack, years
4-0217	LCB	14	4	4-0219	LCB	12	8
4-0218	LCB	12	4	4-0220	LCB	14	4
5-0217	LCB	14	6	26-0215	DGAB	12	6
5-0218	LCB	12	5	32-0207	LCB	14	3
20-0201	DGAB	12	5	39-0204	DGAB	12	5
20-0202	DGAB	14	5	53-0207	LCB	14	5
26-0213	DGAB	14	5				
26-0214	DGAB	12	9				
32-0209	LCB	12	4				
37-0201	DGAB	12	8				
37-0205	LCB	12	6				
39-0202	DGAB	14	5				

Table 24 and Table 25 show the cumulative number of transverse cracks in the SPS-2 sites, with and without the inclusion of NV (32). The SPS-2 sections in NV have been deassigned from the experiment because of some problems encountered during the construction of the sections (Table A-1 of Appendix A). Hence, the occurrence of transverse cracking in the sections was investigated with and without the inclusion of sections in NV (32).

Table 24 Total number of transverse cracks in the SPS-2 sites

Target PCC	Base type	Lane width	Low severity cracks	Medium severity cracks	High severity cracks	Total
8	DGAB	12	63	64	141	268
		14	53	57	27	137
	LCB	12	320	185	698	1203
		14	186	110	19	315
	PATB	12	4	0	0	4
		14	4	0	0	4
11	DGAB	12	165	14	57	236
		14	73	121	644	838
	LCB	12	68	81	68	217
		14	34	16	14	64
	PATB	12	0	0	0	0
		14	78	48	72	198

Table 25 Total number of transverse cracks in the SPS-2 sites (without NV)

Target PCC	Base type	Lane width	Low severity cracks	Medium severity cracks	High severity cracks	Total
8	DGAB	12	32	8	10	50
		14	14	15	2	31
	LCB	12	141	45	15	201
		14	46	38	9	93
	PATB	12	0	0	0	0
		14	4	0	0	4
11	DGAB	12	3	0	0	3
		14	4	0	0	4
	LCB	12	4	0	0	4
		14	20	0	0	20
	PATB	12	0	0	0	0
		14	0	0	0	0

The tables show the total number of low, medium and high severity transverse cracks in the SPS-2 sections till date. Table 24 shows that the 8 in. sections showed more number of transverse cracks than the 11 in. sections. The effect of lane width is predominant in the 8 in. sections than in the 11 in. sections. Sections with a 12 ft lane, in general, showed more number of transverse cracks than those with a 14 ft lane. All these observations have been statistically validated and the analysis is presented in Chapter 6 of the thesis. The same trends were also observed, when the sections in NV were not considered, as shown in Table 25. 38% of the data in Table 25 belongs to the WF zone (DE, IA, KS, MI, ND, OH), 28 % from the DNF zone (AZ and CA), 24% from the DF zone (CO and WA) and 10% from the WNF zone (AR and NC). None of the sections in WI exhibited transverse cracking till date.

The 11 in. sections, in general, exhibited lesser number of transverse cracks. Table 25 shows that, for a given base type and lane width, the 11 in. sections had significantly less transverse cracking than the 8 in. sections. For example, consider the DGAB sections with a 12 ft lane in Table 25. The total number of low, medium and high severity cracks are 3,0 and 0 respectively for the 11 in. sections, whereas the 8 in. sections exhibited 32,8 and 10 cracks respectively. The same trends were also observed in the LCB sections, with the 11 in sections exhibiting lesser number of transverse cracks (low, medium and high) than the 8 in. sections. It has also been observed from the AASHTO analysis (Tables A-15 through A-25) that sections with 11 in. PCC slab, lane width of 14 ft and constructed on an LCB layer can withstand the ESALs for which they have been designed.

The occurrence of transverse cracking will largely depend on the interaction between the various structural factors and the location of the sections (climatic region and subgrade). Hence the analysis was done for each state to completely understand the occurrence of transverse cracking. Tables A-26 through A-38 in Appendix A show that transverse cracking (TC) was not observed in any of the sections constructed on a drainable base. Except for the PATB section in NC (37-0210) and those in NV (32), none of the PATB sections exhibited cracking, which could be due to the drainage provision in these sections. Cracking in the PATB sections in NV could be due to the problems encountered during construction. In NC, the embankment experienced slope failure, which may cause failure in the shoulder and driving lane (according to the construction report). Example plots illustrating the cracks in non-drainable sections are shown in Figure 7 through Figure 10. Transverse cracks in the CA (6) sections have manifested within two years after the completion of construction.

Within the non-drainable sections, transverse cracks were prevalent in sections founded on DGAB layers in CA (6), KS (20), MI (26), NV (32), NC (37) and OH (39). This could be explained by the fact that the DGAB layers typically have lesser stiffness (15,000 to 45,000 psi) than the LCB layers (1 x 106 to 3 x 106 psi) and PATB layers (300,000 to 600,000 psi). Hence, they provide less load carrying support to the PCC slab, when compared to the other base types.

Within the DGAB sections, the 8 in. sections exhibited higher transverse cracking than the 11 in. sections, which indicates the greater structural capacity of the pavement. This trend is evident in CA (6), KS (20) and MI (26). However, the relationship between the lane width and transverse cracking is not evident within the DGAB sections. Figure 7 through Figure 10 and Figures B-14 through B-21 suggest that transverse cracks were also prevalent in most of the sections founded on LCB layer in almost all the states except KS (20) and WI (55).

In general, the 8 in sections exhibited higher transverse cracks than the 11 in. sections, which could be due to the lower structural capacity of these sections. In most of the states, transverse cracks were observed in sections with a 12-ft lane. In WA (53), shrinkage cracks (observed during construction) may have caused transverse cracks in 14 ft lane sections. In IA (19), counter intuitive trends were observed with the 14 ft lane sections showing more transverse cracks than 12 ft sections. This could be because of the fact that section 19-0217 (LCB section) was constructed 0.3 in. thinner than its target thickness, while 19-0218 (LCB section) was constructed 0.2 in. thicker than its target thickness. The transverse cracks in all the other states could be attributed to the shrinkage cracking (as indicated in the construction reports), which might have manifested onto the PCC layer. Table 26 summarizes the possible reasons for the occurrence of transverse cracking in all the states.

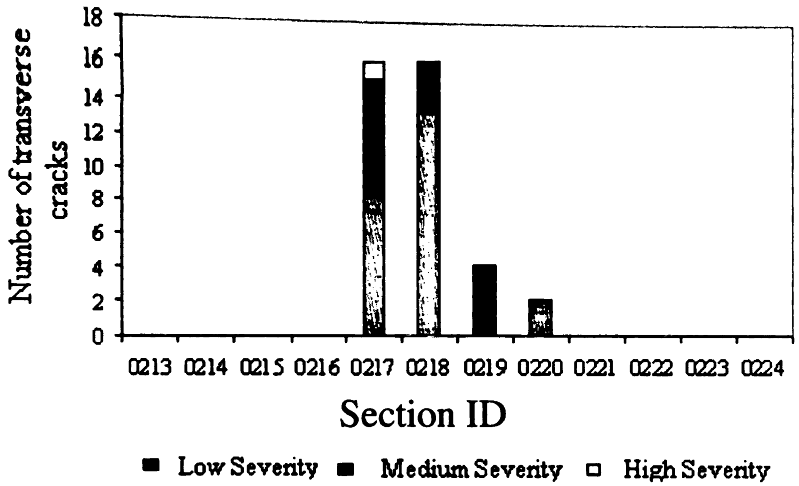


Figure 7 Transverse cracks in AZ (4)*

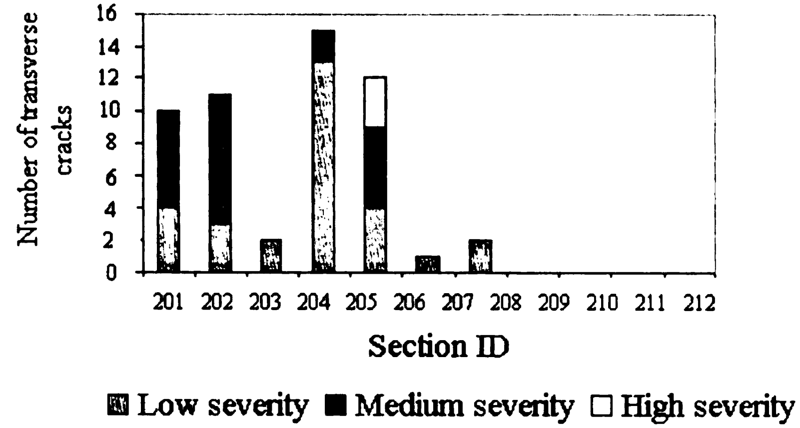


Figure 8 Transverse cracks in CA (6)**

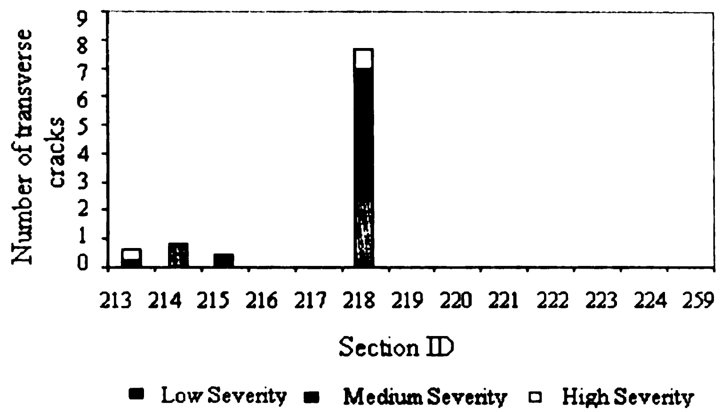


Figure 9 Transverse cracks in MI (26)+

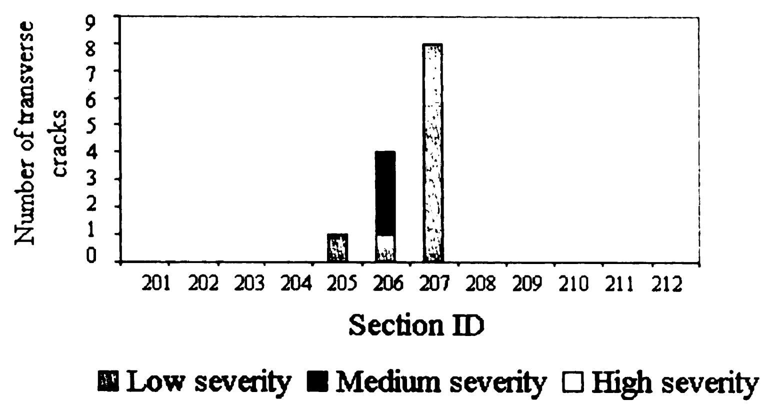


Figure 10 Transverse cracks in WA (53)++

* Age of the AZ (4) sections is 9 years
**Age of the CA (6) sections is 2 years
+Age of the MI (26) sections are: 0213-6 years, 0214-10 years, 0215-7 years, 0218-3 years, ++Age of the WA (53) sections is 6 years

Table 26 Occurrence of transverse cracking in the SPS-2 sites

State Code	Climatic zone	Comments
AZ (4)	DNF	• Out of the 3 base types, cracking was found only in the sections founded on an LCB layer. This could be due to the mat defects (refer to Table A-1 in Appendix A) • Higher levels of cracking occurred in the 8 in. sections. 11 in. sections showed cracking 9 years after opening to traffic. • The effect of lane width on cracking is inconclusive. • Since there were no thickness deviations observed in the cracked sections, cracking may be due to the defects during construction.
AR (5)	WNF	• The occurrence of cracking in LCB sections is inconclusive as there is no indication of any cracks in the LCB layer during construction. • Most of the cracking occurred in the 8 in. sections. • High severity cracking was observed in the 12-ft section. (5-0218) • Since there was no thickness deviations observed in the cracked sections and no defects were observed during construction, the occurrence of cracking in these sections is not explicit.
CA (6)	DNF	• Transverse cracks were predominant in the LCB sections, which could be due to the shrinkage cracks observed during construction. • Intensity of Transverse cracks was high in the 8 in. sections.11 in. sections showed low severity cracking 2 years after the pavement was opened to traffic. • The effect of lane width on cracking is inconclusive. • Since there were no thickness deviations observed in the cracked sections, cracking may not be due to thickness deviations.
CO (8)	DF	• One transverse crack was observed in section 8-0218. • Transverse cracks in the LCB section (8-0218) could be due to the design of the section (8 in. and 12-ft) • Since there were no thickness deviations observed in the cracked sections, cracking may not be due to thickness deviations.

Table 26 (cont'd).

State Code	Climatic zone	Comments
DE (10)	WF	• Transverse cracks in the LCB section (10-0205) could be due to the design of the section (8 in. and 12-ft) and also due to the serious shrinkage cracking observed during construction. • Since there were no thickness deviations observed in the cracked sections, cracking may not be due to thickness deviations.
IA (19)	WF	• Transverse cracks were observed only in the 8 in. LCB sections. • Effect of lane width is inconclusive. • 19-0217 was constructed 0.3 in. thinner than its target thickness, which could have resulted in greater transverse cracks than 19-0218, which is 8.2 in. thick, and hence the effect of lane width could not be studied.
KS (20)	WF	• Cracking was observed in 8 in. sections constructed on DGAB. This could be attributed to the fact that the DGAB layers typically have lesser stiffness (15,000 to 45,000 psi) than the LCB layers (1 x 106 to 3 x 106 psi) and PATB layers (300,000 to 600,000 psi).
MI (26)	WF	• Transverse cracks exhibited in three out of the four DGAB sections. One explanation for this could be that the DGAB layers typically have lesser stiffness (15,000 to 45,000 psi) than the LCB layers (1 x 106 to 3 x 106 psi) and PATB layers (300,000 to 600,000 psi). • Within the DGAB sections, however, section 26-0216 did not experience cracking. This could be attributed to the fact that the section has a thicker slab (11 in.), which adds to the structural capacity of the pavement, and also a widened lane (14 ft.), which creates a pseudo-interior loading condition. • 26-0218 was the only section among LCB sections that exhibited transverse cracks, which may be due to transverse shrinkage cracks that appeared immediately after construction. • 11 in. sections showed cracking 7 years after the sections were opened to traffic.

Table 26 (cont'd).

State Code	Zone	Comments
NV (32)	DF	• Extensive cracking was observed in all the sections • The cracking could be mainly due to severe construction problems. Most 750-psi mix was stiff and would tear during placement. To attain 750-psi strength the water-cement ratio was lowered to 0.3. High slump was adjusted by addition of water reducing agents and lowering of water content. Flash set occurred prior to placement and finishing.
NC (37)	WNF	• Transverse cracks occurred in all the base types • In 37-0210, which is a PATB section, transverse cracks may be due to the slope failure which affected the driving lane and the shoulder • Transverse cracks were observed mainly in 8 in. sections with 12 ft lane width.
ND (38)	WF	• Transverse cracks were observed only in 38- 0217 which may be due to the reflection cracks that were observed during construction
OH (39)	WF	• In general, 8 in. sections showed more cracking than 11 in. sections. • More cracking was observed in sections with a 12 ft lane width.
WA(53)	WF	• Cracking was exhibited only in the LCB sections. • Both the 8 in. sections showed extensive cracking. Shrinkage cracks were found during the construction of section 53-0206. • 11 in. sections showed cracking 6 years after the sections were opened to traffic.
WI (55)	WF	• No transverse cracks were found in any of these sections.

PUMPING

Pumping can be defined as the forceful displacement of a mixture of soil and water that occurs under slab joints, cracks and pavement edges which are depressed and released quickly by high-speed heavy vehicle loads.

However, pumping in the LCB sections is just the ejection of water trapped between the PCC and the LCB layers. Figure 11 through Figure 14 illustrate the number of pumping occurrences in the SPS-2 sites. Pumping was observed in states AR (5), DE (10), IA (19) and OH (39). Pumping was observed only in the regions located in the wet zones (rainfall greater than 508 mm). Pumping is mainly concentrated in sections founded on a non-drainable base (sections 0201 through 0208 or sections 0213 through 0220), confirming the intuition that pumping is directly related to the drainage condition of the sections.

It was also found that LCB sections experienced higher pumping than DGAB sections. One explanation could be that although both DGAB and LCB sections are non-drainable sections, LCB could be considered as an impermeable layer resulting in a poor drainage condition (trapping of interfacial water), when compared with DGAB sections, supporting the higher number of pumping occurrences in the LCB sections. For example, higher pumping was observed in LCB sections in DE (10), IA (19) and OH (39) than those constructed on DGAB, as illustrated in Figure 11 through Figure 14. Table 27 summarizes the occurrence of pumping in the SPS-2 sites.

Another explanation for the occurrence of pumping could be the joint sealant damages observed in these sections. Figure 15 through Figure 18 illustrate the number of transverse joint sealant damages in sections AR (5), DE (10), MI (26) and NV (32). Since the length of the sections is 500 ft and the joint spacing is 15 ft, the total possible number of joints (excluding the construction joints) is approximately 34. The sealants of all the joints in the four states shown are damaged and this could have aggravated the occurrence of pumping in most of the sections.

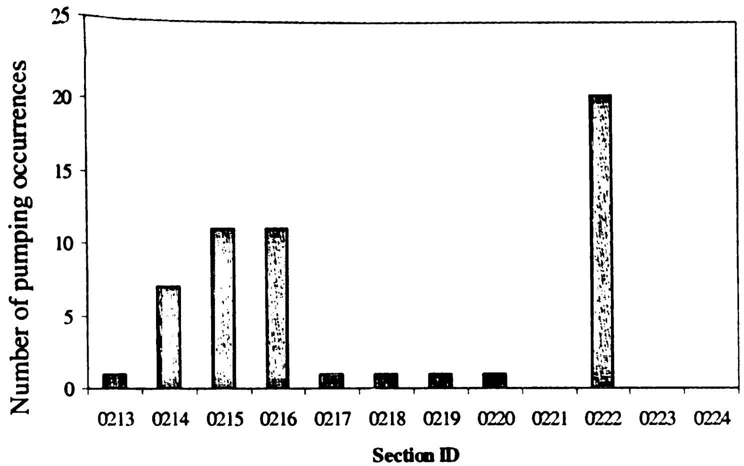


Figure 11 Number of pumping occurrences for AR (5)

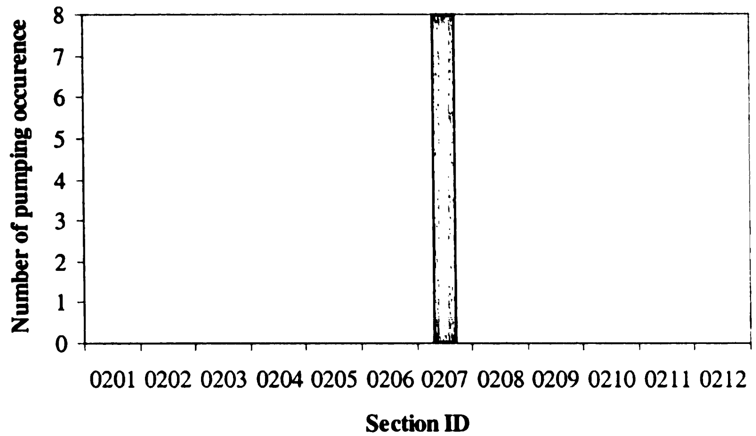


Figure 12 Number of pumping occurrences for DE (10)

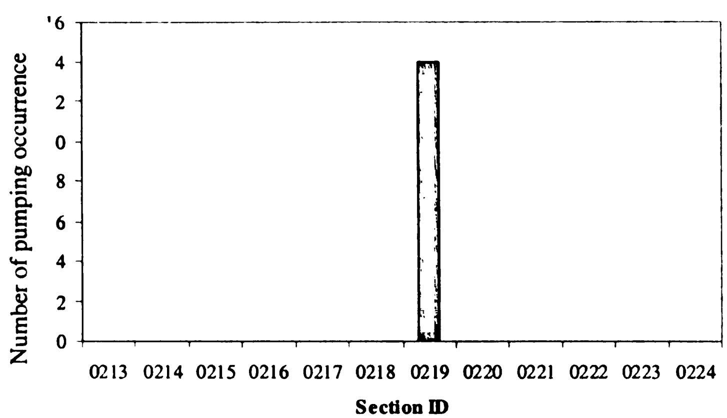


Figure 13 Number of pumping occurrences for IA (19)

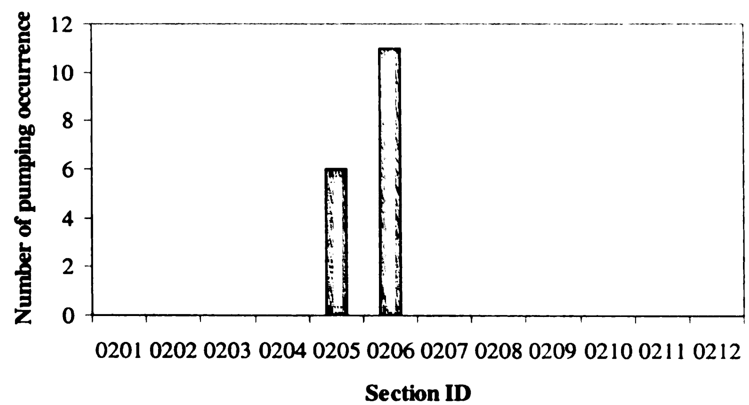


Figure 14 Number of pumping occurrences for OH (39)

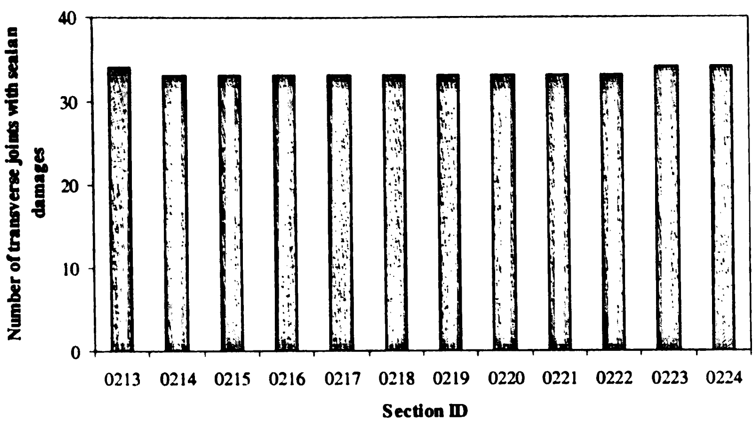


Figure 15 Number of transverse joint sealant damages in AR (5)

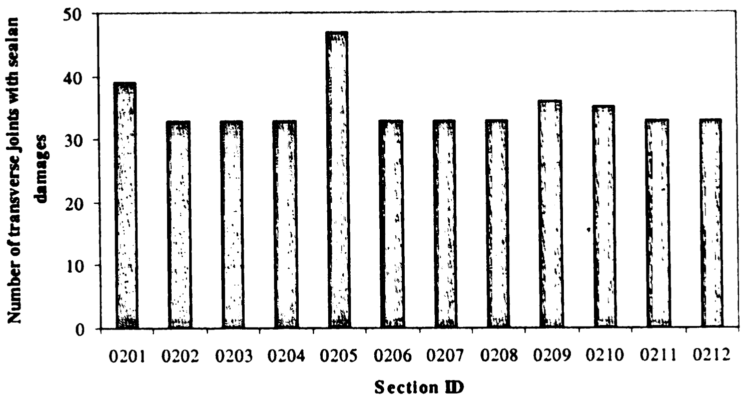


Figure 16 Number of transverse joint sealant damages in DE (10)

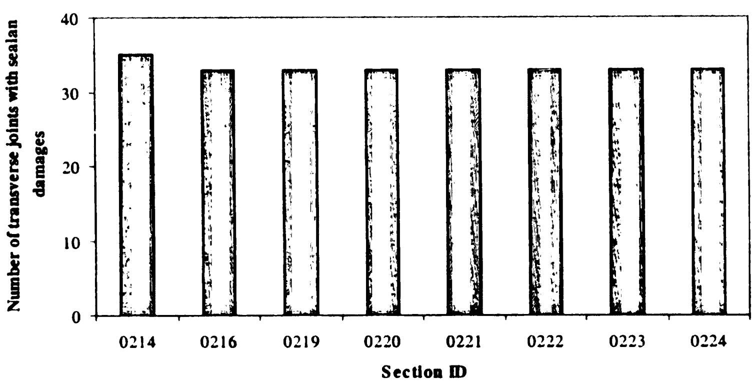


Figure 17 Number of transverse joint sealant damages in IA (19)

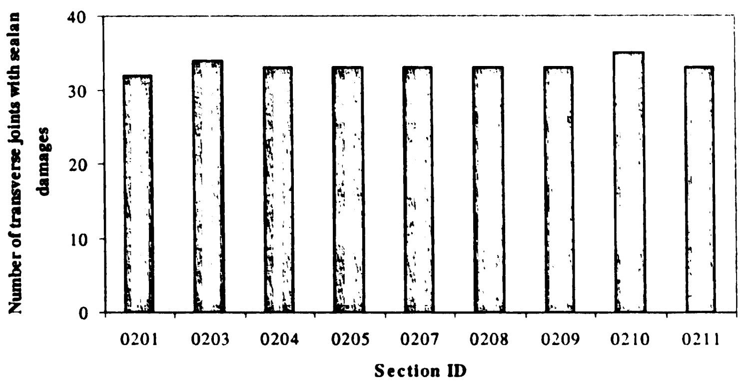


Figure 18 Number of transverse joint sealant damages in OH (39)

Table 27 Pumping occurrences in the SPS-2 sites

State Code	Climatic region	Comments
AZ (4)	DNF	• No pumping was observed, as the region is dry (rainfall <508 mm)
AR (5)	WNF	• Pumping was observed in all the DGAB and LCB sections. Higher pumping was observed in the DGAB than in the LCB sections. Pumping was also observed in 5-0222, the reason(s) for which are not clear from the data. • Pumping in all the sections could have been aggravated due to the extensive joint sealant damages.
CA (6)	DNF	• No pumping was observed, as the region is dry (rainfall <508 mm)
CO (8)	DF	• No pumping was observed, as the region is dry (rainfall <508 mm)
DE (10)	WF	• Pumping was observed only in the LCB sections. • Section 10-0207 showed pumping, which might be aggravated due to the presence of longitudinal cracking and joint sealant damages.
IA (19)	WF	• Pumping was observed only in the LCB sections. • Section 19-0219 showed pumping, which might be aggravated due to the presence of longitudinal and transverse spalls.
KS (20)	WF	• No pumping occurrences were observed.
MI (26)	WF	• No pumping occurrences were observed.
NV (32)	DF	• No pumping occurrences were observed.
NC (37)	WNF	• No pumping occurrences were observed.
ND (38)	WF	• No pumping occurrences were observed.
OH (39)	WF	• Insignificant pumping occurrences observed.
WA (53)	WF	• No pumping occurrences

PROGRESSION OF DISTRESSES WITH TIME

The severity levels of transverse cracks have been obtained from literature (5) as follows:

Low severity: Crack widths < 3mm, no spalling and no measurable faulting, or well sealed and the width cannot be determined.

Medium severity: Crack widths ≥ 3 mm and < 6 mm, or with spalling <75 mm, or faulting up to 6 mm.

High severity: Crack widths ≥ 6 mm, or with spalling ≥ 75 mm or faulting ≥ 6 mm.

It has been observed that the severity levels of the distresses and/or magnitude increase with time for almost all the states. Figure 19 shows the severity levels of transverse cracking with time for SPS-2 sections in AZ (4). For example, in section 4-0217, 4 low severity cracks and 2 high severity cracks were observed in 1997 and 1999. The medium severity cracks developed into high severity cracks in 2000 and 2001. There was an increase in the number of low severity cracks from 2000 to 2001.

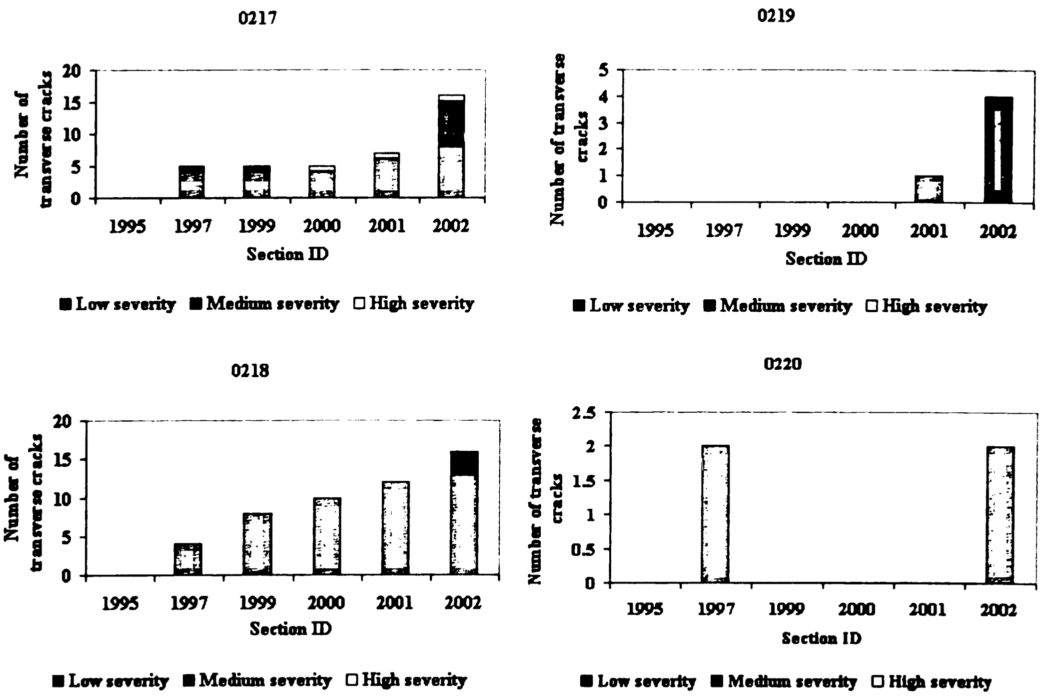


Figure 19 Progression of transverse cracking with time for AZ (4)

The progression of transverse cracking in the other states is shown in Figures B-22 through B-36. It might be noted that cracking and spalling are reported in three levels viz., low, medium and high severities while the other distresses are recorded in magnitude. Hence the progression of the other distresses is reported in terms of the increase or decrease in magnitude with time. The progression of these distresses with time for the other SPS-2 sites is shown in Table 28.

Table 28 Progression of distresses in the SPS-2 sites

State Code	Climatic region	Comments
AR (5)	WNF	• Insignificant cracking occurred in the section 05-0217 compared to that of 05-0218. Both the sections have 8 in. thick PCC slabs. • Section 05- 0218 has shown early cracking and also quicker progression in cracks. This may be due to the lane width of 12 ft.
CA (6)	DNF	• Cracking was observed very early (within two years) in all the sections. • Transverse cracks in 11 in. sections were much lower in magnitude than 8 in.. • Medium and High severity cracks were observed only in 8 in. sections.
CO (8)	DF	• No significant cracking was observed
DE (10)	WF	• Cracking occurred the very next year of opening to traffic, only in 10- 0205 • This 8 in. LCB section showed all severities of cracks • All the sections met the target design ESALs (3.05 million)
IA (19)	WF	• Cracks, though low in number, occurred in the very next year of opening to traffic in the two LCB sections • Cracks of higher severity were observed in 19- 0217 than in 19- 0218 • Both the sections that showed cracking did not meet the target design ESALs
KS (20)	WF	• High severity cracking occurred only in 20-0201 • Initially both the sections, which showed cracking, had only low severity cracks. • Both the sections that showed cracking did not meet the target design ESALs

Table 28 (cont'd).

State Code	Climatic region	Comments
MI (26)	WF	• Cracks appeared only after five years of opening the sections in most of the sections. • Only 8 in. sections showed medium or high severity cracks which can be due to the less structural capacity of the sections. • Based on the 10-year data, medium and high severity cracks are exhibited in the two sections, which had the least computed allowable ESALs (26-0213 and 26-0218)
NV (32)	DF	• Very high number of cracks of all severities were observed in almost all the sections, from the very next year of opening the sections to traffic • Problems during construction in these sections could have caused the extensive cracking. • A very high number of cracks occurred in the non-drainable base types
NC (37)	WNF	• Insignificant number of cracks exhibited in DGAB sections. • A few medium severity cracks were found in the section 37- 0205, which is a LCB section. • Cracks occurred six years after opening to traffic in both the sections
ND (38)	WF	• Cracks appeared only in 38- 0217 immediately after the sections were opened to traffic • Reflection cracks that appeared in the section 38-0217 (as per the construction report) would have caused the Transverse cracks • Cracks of all severities were observed in the section
OH (39)	WF	• Cracks appeared in the sections three years after the sections were opened to traffic • More number of cracks appeared in section 39-0205 • Medium severity cracks occurred only in the section 39- 0205
WA (53)	WF	• Cracks appeared in the sections after two years of opening to traffic • All the cracks appeared only in the following LCB sections: 0205, 0206, and 0207. • Medium severity cracks appeared only in 0206 which may be due to the shrinkage cracks that appeared during construction

MISCELLANEOUS DISTRESSES

Other distresses include joint spalling, D-crack, map cracking and scaling. Spalling usually results from excessive stresses at the joint or cracks, caused by the infiltration of incompressible materials and by subsequent expansion or traffic loading. It can also be caused by disintegration of concrete, by weak concrete at the joint caused by overworking or by poorly designed or constructed load transfer devices. D cracking is caused by freeze-thaw expansive pressures of certain types of coarse aggregates. D cracking was observed only in two states located in the Wet freeze zones viz., KS (20) and ND (38) as shown in Table 29 below.

Table 29 D-cracking in SPS-2 test sites

STATE_CODE	SHRP_ID	SURVEY_DATE	Low severity	Medium severity	High severity
20	0204	5/27/1997	1	0	0
38	0217	6/18/1999	0	1	0

The severity levels for D-cracking have been obtained from literature (5) as follows:

Low severity: "D" cracks are tight, with no loose or missing pieces and no patching is in the affected area

Medium severity: "D" cracks are well defined, and some small pieces are loose or have been displaced.

High severity: "D" cracking has a well-developed pattern, with a significant amount of loose or missing material. Displayed pieces, up to 0.1 m2, may have been patched.

Scaling can be caused by deicing salts, by traffic, by improper construction or by freeze thaw cycles. The occurrence of scaling in the SPS-2 sites is shown in Figure 20. Map cracking is caused by over finishing of the concrete and can lead to scaling of the surface.

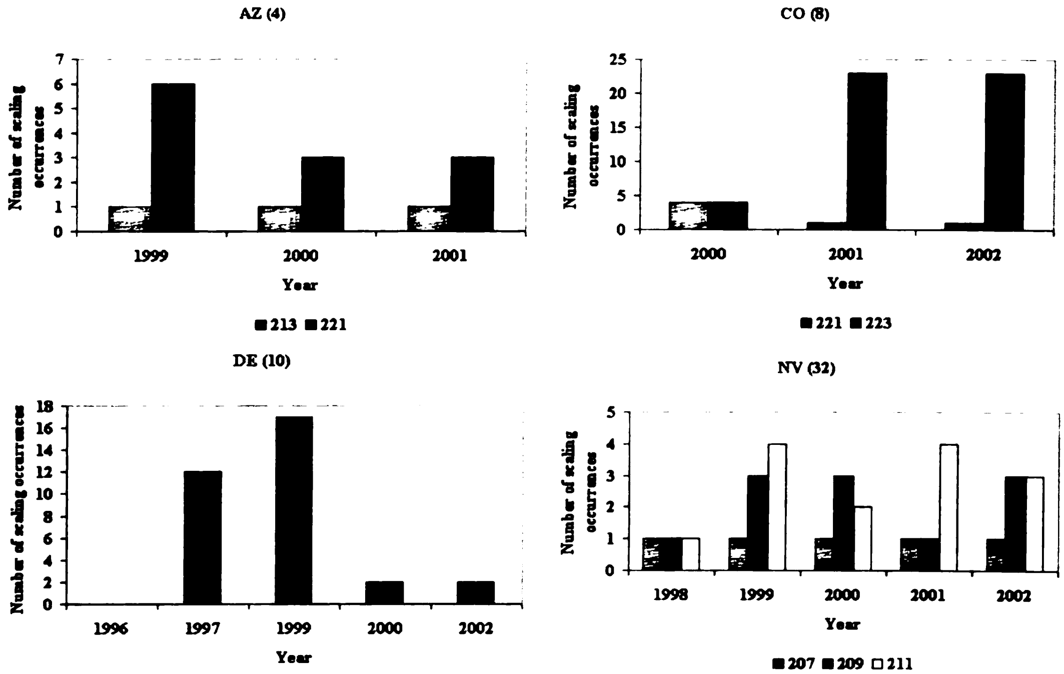


Figure 20 Scaling occurrences in the SPS-2 sites

Tables A-26 through A-38 show that D-cracking and scaling was prevalent in the wet freeze zones. It can also be seen that map cracking was prevalent in the wet freeze zones, which could have led to scaling in these regions.

TRANSVERSE JOINT FAULTING

Figure 21 shows the number of sections, which exhibited faulting in the SPS-2 experiment. Even though the number of sections in both the categories of PCC thickness is the same, the magnitudes of faulting are different. About 70 % of the 8 in. sections and 65% of the 11 in. sections exhibited faulting.

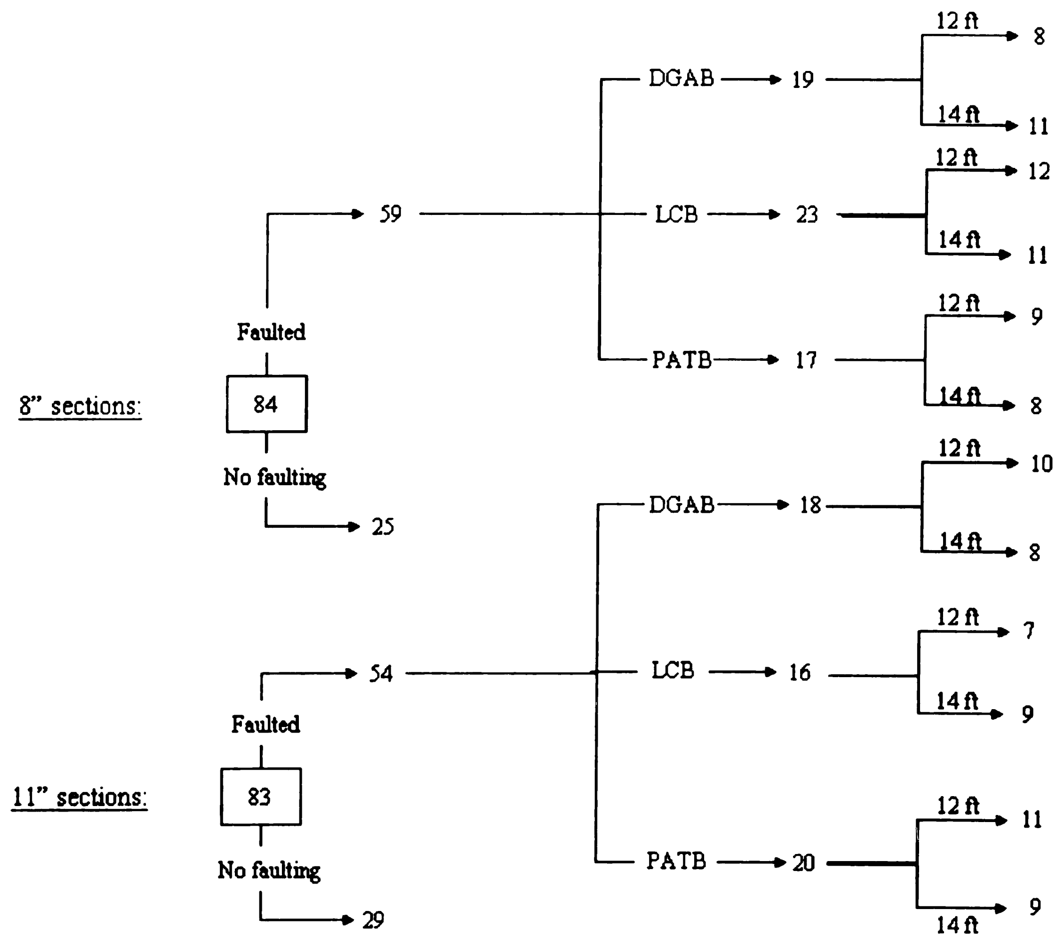


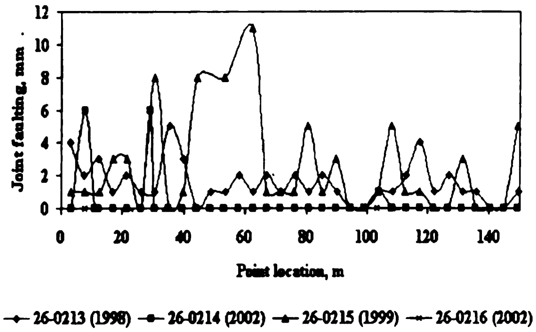
Figure 21 Occurrence of faulting in the SPS-2 sites

Within the different base types and lane widths, the number of sections that exhibited faulting are almost the same and hence it was deemed necessary to investigate the magnitudes of faulting. According to literature (6), three severity levels of faulting have been established. Faulting is classified as low (<3mm), medium (>3mm and <7 mm) and high (>7mm).Table 30 shows the number of cracks and joints faulted in the SPS-2 sites. Most of the cracks and joints have low severity faulting (<3mm).

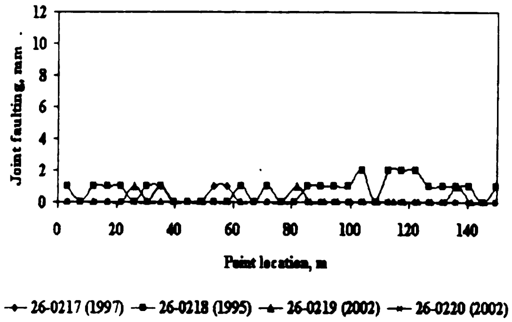
Table 30 Number of joints and cracks faulted in the SPS-2 sites

Target PCC	Base type	Lane Width, ft	C		J		
			Low	Medium	Low	Medium	High
8	DGAB	12	10		2044	7	
		14	15		1645	7	
	LCB	12	97	6	1813	20	
		14	51	2	1509	9	
	PATB	12			1958	7	
		14			1784	4	
11	DGAB	12	2	1	2182	25	5
		14	1		1497		
	LCB	12	2		1715		
		14			1750		1
	PATB	12			1746	7	1
		14			1715	8	

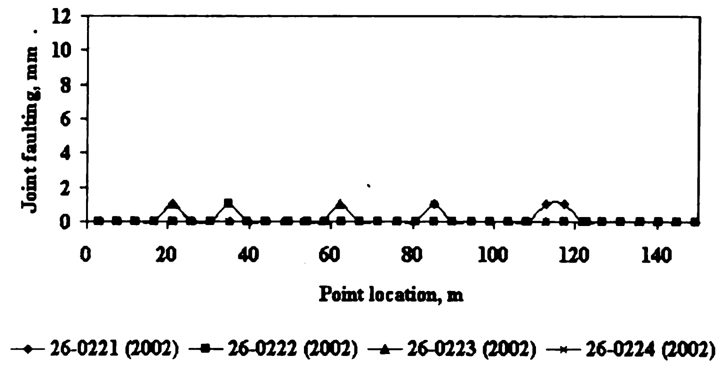
Also, the number of joints and cracks faulted in the non-drainable sections (DGAB and LCB sections) are higher than those in the drainable sections (PATB sections). Transverse cracks in the states of DE, IA, KS and MI and transverse joints in the states of AZ, CO, DE, KS, MI, NV, NC, OH, WA and WI experienced medium severity faulting (between 3 mm and 7 mm). High severity faulting (>7 mm) at the joints was found in the states of AZ, CO and MI. Figure 22 below illustrates the magnitude of faulting at all the joints for the latest year for the MI (26) SPS-2 sites. In general, it appears that sections without drainage (DGAB and LCB) exhibited relatively higher faulting compared to the drained sections (PATB). However, among the non-drainable sections, the DGAB sections experienced higher magnitudes of faulting. This could be explained through the fact that shear transfer provided by LCB is higher than what is provided by DGAB since LCB is stiffer (higher elastic modulus) than DGAB layers.



(a) DGAB sections.



(b) LCB section



(c) PATB sections.

Figure 22 Average joint faulting in the MI (26) SPS-2 sites

The occurrence of faulting in sections could also be associated with pumping. For most of the sections, the joint faulting ranged from 0 to 0.19 in. (0 to 5 mm), with some joints in the MI (26) sections showing about 0.38 to 0.47 in. (10 to 12mm) of faulting. It might be noted that the dowel diameters of the sections are either 1.25 inch or 1.5 inch. According to the SPS-2 factorial, 1.25-inch diameter dowel bars are provided in the 8 in. sections, and 1.5-inch diameter dowel bars are provided in the 11 in. sections. Figure 22 shows that sections with a greater dowel diameter had relatively higher levels of faulting. The relationship between faulting and dowel diameter is not obvious as the thicker sections have 1.5” dowels whereas the thinner sections have 1.25” dowels. Based on this example and the ones summarized in the appendix (Figures B-37 through B-57 of

Appendix B), it can be concluded that faulting is not significantly reducing the structural capacity of the pavement sections. The observations made from the data are summarized in Table 31 below.

Table 31 Occurrence of faulting in the SPS-2 test sites

State	Comments
AZ (4)	• The 8 in. DGAB sections have the maximum number of faulting occurrences • Faulting at almost all the joints is <3 mm. 2 joints in 4-0215 exhibited 4 mm and 10 mm faulting. Section 4-0223 exhibited faulting of 9 mm.
AR (5)	• The DGAB sections have more occurrences of faulting than the others, which may be due to their low stiffness. It could also be due to the high number of pumping occurrences in these sections. • Within the DGAB sections, the 8 in. sections have shown more faulting • All the joints to date have faulting <3 mm
CA (6)	• In all the sections, faulting was <3 mm and all sections on all types of bases had almost same number of faulting occurrences
CO (8)	• Most of the sections have shown faulting less than 3 mm. Faulting for sections 8-0217,8-0218 and 8-0224 ranged from 3-4 mm. One joint in section 8-0220 had a faulting of 9 mm.
DE (10)	• 3 joints in section 10-0201 exhibited 3-4 mm faulting. • 9 joints in section 10-0205 exhibited 3-4 mm faulting to date. • 1 joint in section 10-0206 exhibited 3 mm faulting. • 4 joints in section 10-0209 exhibited 3-4 mm faulting. • 1 joint in section 10-0210 and 10-0212 exhibited 3 mm faulting. • Except the above-mentioned joints, the remaining joints exhibited faulting <3 mm to date.

Table 31 (cont'd).

State	Comments
IA (19)	• The magnitude of faulting is less than 3 mm in most of the joints. • Only one joint in section 19-0217 at point location 136.9 m exhibited 3 mm faulting.
KS (20)	• Except for 2 joints (at 67.5 m and 72 m) in section 20-0206 and 1 joint (at 131.9 m) in section 20-0212 where the faulting ranged from 3-4 mm, the faulting has been less than 3 mm at all the joints in all the sections.
NV (32)	• Faulting was observed in all the non-drainable sections. Faulting ranged from 3-5 mm in these sections, with one joint (at point location of 79.9 m) showing a faulting of 7 mm. • The remaining joints showed faulting less than 3 mm.
NC (37)	• The usage of 1" diameter dowels instead of 1.25" bars in the sections can have an impact on faulting. So far the magnitudes of faulting have been less than 7 mm. • The faulting has been less than 3 mm in all the joints except for one joint in section 37-0202 (at point location 72.1 m) and one joint in section 37-0205 (at point location 115.7 m) where the magnitudes of faulting are 3mm and 5 mm respectively.
ND (38)	• The magnitudes of faulting are less than 3 mm in all the sections. Sections are yet to exhibit consistently higher faulting trends.
OH (39)	• Insignificant faulting observed
WA (53)	• Most of the joints exhibited either zero faulting or less than 3 mm • 7mm faulting was observed at 7.6 m in section 53-0201 • 6mm faulting was observed at 62 m in section 53-0202 • Faulting of 6mm and 3 mm were observed at 81 m and 108.5 m respectively, in section 53-0204 • 3mm faulting was observed at 44.2 m in section 53-0209. • 3mm faulting was observed at 71.8 m in section 53-0210. • Faulting of 3-4 mm was observed at 4 joints in section 53-0212.
WI (55)	• Except for 2 joints at 75.8m and 103.1m which exhibited 3 mm faulting, all the other sections exhibited zero faulting or less than 3 mm.

CHAPTER 6

STATISTICAL ANALYSIS OF SPS-2 DATA

Several statistical methods can and have been employed to establish performance criteria, to study the effect of design and construction methods on pavement response and performance. The statistical methods range from trend plotting to complex regression analysis.

The simpler statistical methods include Univariate and Bivariate analysis of data. These methods include (1) determination of data statistics such as mean, standard deviation and data variability and (2) degree of dependence between variables. Such an analysis can also provide summary statistics such as the coefficient of correlation. Bivariate analysis can also assist in identifying outliers.

Hypothesis testing is a tool that allows one to determine if a specific numerical value is equal to, less or greater than a specified number or means of two sets of data are equal or significantly different. The mean response values for each group can be determined and then compared using hypothesis testing for a certain level of confidence. If this relationship is significant, then the impact of the given factor on the response should be further investigated.

Some of the multivariate statistical methods include:

- Analysis of Variance (ANOVA)
- Regression Analysis

The ANOVA is a tool that allows one to compare the relationship between one dependant variable and one or more independent variables. For example, the relationship between the number of transverse cracking (dependant variable) and base type are ideal candidates for such an analysis. This method can be applied at both the network and the project level analyses.

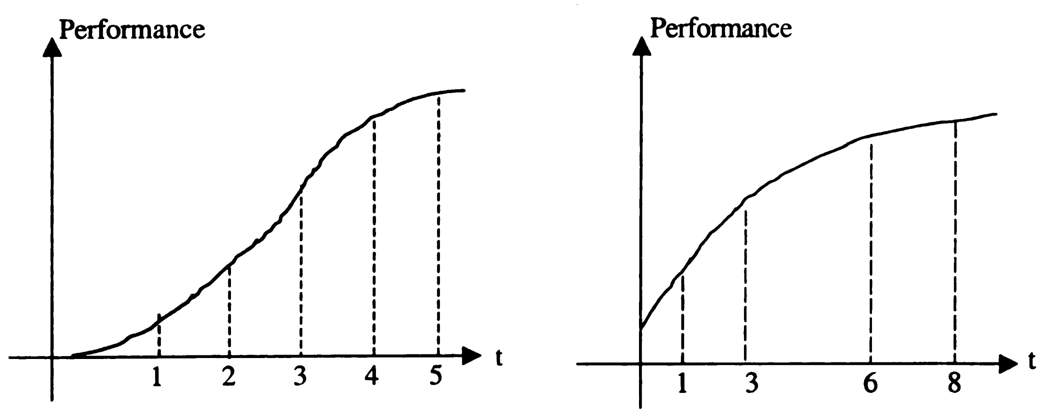
Regression Analysis attempt to explain some dependent variable, y, in terms of many independent (explanatory) variables, x's. The model (equation) can either be linear or non-linear and with actual, transformed, or interaction clusters of variables. The model coefficients can be estimated using best (least squares) fitting techniques.

The normal density function will provide the basis for most of the statistical inferences regarding the investigation of treatment effects on continuous random response variables. For a normally distributed random variable, the z-transformation transforms a normal distribution with any mean μ and variance $\sigma 2$ to that of the standard normal distribution. All the statistical analysis will be done at an α= 5 % level of significance (7,8).

Performance Index and Relative Performance Index

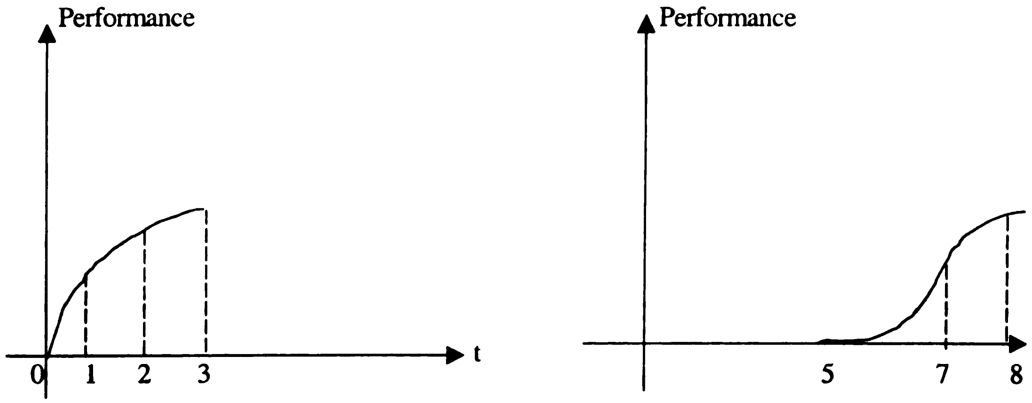
It might be noted that since the sections were not all opened to traffic at the same time, the age of all the sections in the SPS-2 experiment is not the same. Moreover, as mentioned before, the dataset is not balanced, as the number of years for which data is available for sections within a state is also inconsistent. A direct comparison of sections is not possible as the age of the sections is different. Hence, it was deemed necessary to develop an index, such that comparisons can be made across different states without the need for age.

Figure 23 shows a hypothetical (typical) performance curve over time for a pavement section. The response/performance for the majority of SPS-2 test sections is not measured continuously i.e., at every year or over the same period necessarily. The area under the performance curve represents the overall performance of a particular section but it cannot be used for comparing two sections having the same performance at different ages. Figure 24 shows two typical sections; the first section shows an early deterioration over time (0-3 years) whereas the second section exhibits signs of distress at a later age (5-8 years). The performance curves for sections in CA (6) are similar to Figure 24a, while the performance curves for sections in MI (26) follow the pattern shown in Figure 24b. Hence a direct comparison of sections in CA (6) and MI (26) is not possible due to the difference in the age of the sections. The area under the performance curves for both the sections might have the same value, however the second section is performing better since the same distress level was accumulated at a much later time.



(a) Continuous Response Measurement (b) Discontinuous Response Measurement

Figure 23 Typical performance curves



(a) Poor performance over time (b) Good performance with time

Figure 24 Measure of performance with time

Therefore, a Performance Index was calculated for each section with respect to different performance measures such as cracking, faulting, spalling, pumping and roughness. This was calculated by summing the product of the performance over years (performance value multiplied by the survey year for all the survey years) divided by the sum of the survey years for a particular section as shown below:

$$Y = \frac{\sum_i y_i t_i}{\sum_i t_i}$$

where Y is the performance index , and yi and ti are the performance value and the pavement age, respectively, at survey year i. It might be noted that the Performance Index of any distress will have the units of that distress. If the Performance Index is calculated for the two sections shown in Figure 24, the second section will have a lower value (indicating better performance) than the first one.

After the performance index is calculated for all the sections, the main factors in the experiment design were compared to investigate the relative performance. Hence a relative performance index was calculated. The relative performance index is defined as the ratio of the average performance index at that level to the average of all the performance indices at all levels of that factor. An example calculation is shown in the subsequent sections. The sum of relative performance indices for a given category is equal to the number of levels in that category. For paired comparisons (e.g., PCC thickness, lane width etc.), the ratio ranges from "0" to "2", with a value of "1" indicating that there is no significant difference in the performance between the two levels (i.e., on an average, the amount of distress for the two levels of a given factor is almost the same). A value less than "1" indicates lower distress (better performance) and a value greater than "1" indicates higher distress (worse performance). The best possible performance translates to "0" and the worst possible performance translates to "2". It might be noted that, for cases where there is no distress for both levels of a given factor, the relative performance index cannot be defined.

For the effect of base type, the ratio varies from "0" to "3", since there are three base types, with a value of "1" for all base types indicating that the amount of distresses is the same (on an average) for all the base types. Values close to "1" indicate no significant effect of base type. A value higher than 1 indicates more distress (worse performance) for a particular base type. The worst possible performance translates to 3 (all other base types would show "0", indicating no distress), and the best possible performance translates to "0".

The relative performance index for various levels of the main factors was calculated for all the states in the SPS-2 experiment and for each performance measure; the effects of climatic zone and subgrade type were compared across the states. The concept of relative performance index can be utilized across the states without considering the traffic because it is a dimensionless quantity. The summary tables for factor comparison were prepared for each performance measure for all the states.

All the afore mentioned techniques have been used in this research to identify the factors that contribute to the occurrence of transverse cracking, faulting and pumping in the SPS-2 sections, thus validating the results obtained from the engineering analysis (presented in Chapter 5). The subsequent sections in this Chapter present the statistical analysis for the three distresses (transverse cracking, faulting and pumping).

CRACKING IN SPS-2 SITES

As mentioned before, the performance index and the relative performance index were calculated for transverse cracking. Then the univariate and the multivariate analysis were done to identify the factors contributing to the occurrence of transverse cracking.

Performance Index and Relative Performance Index

Table 32 shows the example calculation of performance index and relative performance index with time for number of transverse cracks with respect to drainage type (presence or lack of it) for the state of Kansas KS (20).

Table 32 Example calculation of average normalized performance over time (State- KS (20), Number of transverse cracks)

Non-drainable sections		Drainable sections	
SHRP ID	Performance Index	SHRP ID	Performance Index
0201	6.34	0209	0.00
0202	1.81	0210	0.00
0203	0.00	0211	0.00
0204	0.00	0212	0.00
0205	0.00		
0206	0.00		
0207	0.00		
0208	0.00		
Average	1.02	Average	0.00
Mean performance	$\frac{(1.02+0)}{2} = 0.51$	Mean performance	$\frac{(1.02+0)}{2} = 0.51$
Relative performance index	$\frac{1.02}{0.51} = 2$	Relative performance index	$\frac{0.00}{0.51} = 0$

In the above example, comparing the performance indices indicates that the pavement sections founded on a drainable base are performing better than those founded on non-drainable bases, since the relative performance index is lower.

Table 33 and Table 34 show an example of factors' comparison for number and length of transverse cracks at the network level respectively. As can be seen from the table, the sum of the relative performance indices for factors with two levels (PCC thickness and drainage type) is "2" and "3" for factors with three levels (base type). The table compares the effect of PCC thickness, drainage type and base type on the occurrence of transverse cracking. For example, consider the effect of base type on the number of transverse cracks. All the LCB sections in the DF region and founded on a coarse subgrade had high relative performance indices (2.60, 3.00 and 3.00). Such high values (close to 3.00) indicate the poor performance of the sections constructed on LCB layers, which could be due to the transverse shrinkage cracks observed during construction in most of the states. As mentioned before, most of the cracks in these sections were contributed by sections in NV (32).

Table 35 and Table 36 show the comparisons for the relative performance index at the state level for number and length of transverse cracks at all the levels of the main factors in the SPS-2 experiment. Also, the effect of climatic zone and the subgrade type were compared across the states.

Table 33 Overall factor comparisons summary for number of transverse cracks at the network level

PCC thickness

Zone	Subgrade Type	ND								D			
		DGAB				LCB				PATB			
		12'		14'		12'		14'		12'		14'	
		8"	11"	8"	11"	8"	11"	8"	11"	8"	11"	8"	11"
DF	Coarse	2.00	0.00	X	X	2.00	0.00	0.83	1.17	X	X	X	X
	Fine	X	X	0.08	1.92	0.05	1.95	1.35	0.65	X	X	1.51	0.49
DNF	Coarse	2.00	0.00	1.66	0.34	1.79	0.21	1.83	0.17	X	X	X	X
WF	Coarse	X	X	X	X	2.00	0.00	X	X	X	X	X	X
	Fine	1.79	0.21	2.00	0.00	2.00	0.00	2.00	0.00	0.00	2.00	2.00	0.00
WNF	Coarse	X	X	2.00	0.00	2.00	0.00	2.00	0.00	X	X	X	X
	Fine	2.00	0.00	X	X	2.00	0.00	X	X	X	X	2.00	0.00

Drainage type

Zone	Subgrade Type	8"				11"			
		12'		14'		12'		14'	
		D	ND	D	ND	D	ND	D	ND
DF	Coarse	0.00	2.00	0.00	2.00	X	X	0.00	2.00
	Fine	0.50	1.50	1.21	0.79	X	X	0.15	1.85
DNF	Coarse	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00
WF	Coarse	0.00	2.00	X	X	X	X	X	X
	Fine	0.00	2.00	0.16	1.84	0.46	1.54	X	X
WNF	Coarse	0.00	2.00	0.00	2.00	X	X	X	X
	Fine	0.00	2.00	2.00	0.00	X	X	X	X

Base type

Zone	Subgrade Type	8"						11"					
		12'			14'			12'			14'		
		D	ND		D	ND		D	ND		D	ND	
		PATB	DGAB	LCB	PATB	DGAB	LCB	PATB	DGAB	LCB	PATB	DGAB	LCB
DF	Coarse	0.00	0.40	2.60	0.00	0.00	3.00	X	X	X	0.00	0.00	3.00
	Fine	X	X	X	1.32	0.74	0.93	X	X	X	0.07	2.85	0.07
DNF	Coarse	0.00	0.18	2.82	0.00	0.25	2.75	0.00	0.00	3.00	0.00	0.51	2.49
WF	Coarse	0.00	0.00	3.00	X	X	X	X	X	X	X	X	X
	Fine	0.00	1.58	1.42	0.13	1.04	1.83	0.39	2.61	0.00	X	X	X
WNF	Coarse	0.00	0.00	3.00	0.00	1.34	1.66	X	X	X	X	X	X
	Fine	0.00	0.10	2.90	3.00	0.00	0.00	X	X	X	X	X	X

Table 34 Overall factor comparisons summary for length of transverse cracks at the network level

Length of transverse cracks

PCC thickness

Zone	Subgrade Type	ND								D			
		DGAB				LCB				PATB			
		12'		14'		12'		14'		12'		14'	
		8"	11"	8"	11"	8"	11"	8"	11"	8"	11"	8"	11"
DF	Coarse	2.00	0.00	X	X	2.00	0.00	1.42	0.58	X	X	X	X
	Fine	X	X	0.14	1.86	0.08	1.92	1.24	0.76	X	X	1.79	0.21
DNF	Coarse	2.00	0.00	1.80	0.20	1.76	0.24	1.92	0.08	X	X	X	X
WF	Coarse	X	X	X	X	2.00	0.00	X	X	X	X	X	X
	Fine	1.62	0.38	2.00	0.00	2.00	0.00	2.00	0.00	0.00	2.00	2.00	0.00
WNF	Coarse	X	X	2.00	0.00	2.00	0.00	2.00	0.00	X	X	X	X
	Fine	2.00	0.00	X	X	2.00	0.00	X	X	X	X	2.00	0.00

Drainage type

Zone	Subgrade Type	8"				11"			
		12'		14'		12'		14'	
		D	ND	D	ND	D	ND	D	ND
DF	Coarse	0.00	2.00	0.00	2.00	X	X	0.00	2.00
	Fine	0.18	1.82	1.37	0.63	X	X	0.11	1.89
DNF	Coarse	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00
WF	Coarse	0.00	2.00	X	X	X	X	X	X
	Fine	0.00	2.00	0.19	1.81	0.46	1.54	X	X
WNF	Coarse	0.00	2.00	0.00	2.00	X	X	X	X
	Fine	0.00	2.00	2.00	0.00	X	X	X	X

Base type

Zone	Subgrade Type	8"						11"					
		12'			14'			12'			14'		
		D	ND		D	ND		D	ND		D	ND	
		PATB	DGAB	LCB	PATB	DGAB	LCB	PATB	DGAB	LCB	PATB	DGAB	LCB
DF	Coarse	0.00	0.63	2.37	0.00	0.00	3.00	X	X	X	0.00	0.00	3.00
	Fine	X	X	X	1.55	0.75	0.69	X	X	X	0.05	2.83	0.12
DNF	Coarse	0.00	0.38	2.62	0.00	0.45	2.55	0.00	0.00	3.00	0.00	0.98	2.02
WF	Coarse	0.00	0.00	3.00	X	X	X	X	X	X	X	X	X
	Fine	0.00	1.11	1.89	0.15	1.08	1.78	0.39	2.61	0.00	X	X	X
WNF	Coarse	0.00	0.00	3.00	0.00	1.05	1.95	X	X	X	X	X	X
	Fine	0.00	0.06	2.94	3.00	0.00	0.00	X	X	X	X	X	X

Note: Cells marked in "X" indicate that the magnitudes of distress at that level of the factor are zero. In such a case, the value of relative performance cannot be defined

It is evident from Table 35 that sections with 11 in. PCC thickness showed lesser number of transverse cracks than the 8 in sections. Sections with a lane width of 14 ft showed lesser number of transverse cracks than those with a lane width of 12 ft. Sections founded on a drainable base (PATB) performed better since the relative performance indices are lower.

Table 35 State Level factor comparison for Number of transverse cracks

NUMBER OF TRANSVERSE CRACKS													
Zone	Subgrade	State ID	Drainage		Base Type			PCC Thickness		Flexural Strength		Lane Width	
			D	ND	DGAB	LCB	PATB	8"	11"	550 psi	900 psi	12'	14'
WF	C	10	0.00	2.00	0.00	3.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00
	F	19	0.00	2.00	0.00	3.00	0.00	2.00	0.00	1.90	0.10	0.10	1.90
	F	20	0.00	2.00	3.00	0.00	0.00	2.00	0.00	1.56	0.44	1.56	0.44
	F	26	0.00	2.00	0.73	2.27	0.00	1.89	0.11	0.27	1.73	1.84	0.16
	F	38	0.00	2.00	0.00	3.00	0.00	2.00	0.00	2.00	0.00	0.00	2.00
	F	39	0.11	1.89	0.99	1.84	0.17	1.90	0.10	0.96	1.04	1.06	0.94
WNF	C	5	0.00	2.00	0.12	2.88	0.00	2.00	0.00	0.18	1.82	1.82	0.18
	F	37	0.16	1.84	0.09	2.67	0.24	2.00	0.00	1.84	0.16	1.84	0.16
DF	F+C	8	0.00	2.00	0.00	3.00	0.00	2.00	0.00	0.00	2.00	2.00	0.00
	F+C	32	0.10	1.90	1.22	1.58	0.20	1.21	0.79	1.22	0.78	0.89	1.11
	C	53	0.00	2.00	0.00	3.00	0.00	1.08	0.92	1.34	0.66	0.42	1.58
DNF	C	4	0.00	2.00	0.00	3.00	0.00	1.81	0.19	0.90	1.10	1.15	0.85
	C	6	0.00	2.00	1.28	1.72	0.00	1.81	0.19	1.10	0.90	1.05	0.95

Table 36 State Level factor comparison for Length of transverse cracks

LENGTH OF TRANSVERSE CRACKS													
Zone	Subgrade	State ID	Drainage		Base Type			PCC Thickness		Flexural Strength		Lane Width	
			D	ND	DGAB	LCB	PATB	8"	11"	550 psi	900 psi	12'	14'
WF	C	10	0.00	2.00	0.00	3.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00
	F	19	0.00	2.00	0.00	3.00	0.00	2.00	0.00	1.99	0.01	0.01	1.99
	F	20	0.00	2.00	3.00	0.00	0.00	2.00	0.00	1.24	0.76	1.24	0.76
	F	26	0.00	2.00	0.72	2.28	0.00	1.87	0.13	0.34	1.66	1.78	0.22
	F	38	0.00	2.00	0.00	3.00	0.00	2.00	0.00	2.00	0.00	0.00	2.00
	F	39	0.12	1.88	0.99	1.83	0.18	1.91	0.09	0.90	1.10	0.99	1.01
WNF	C	5	0.00	2.00	0.07	2.93	0.00	2.00	0.00	0.14	1.86	1.86	0.14
	F	37	0.04	1.96	0.06	2.88	0.06	2.00	0.00	1.96	0.04	1.96	0.04
DF	F+C	8	0.00	2.00	0.00	3.00	0.00	2.00	0.00	0.00	2.00	2.00	0.00
	F+C	32	0.16	1.84	1.27	1.41	0.32	1.23	0.77	0.99	1.01	0.72	1.28
	C	53	0.00	2.00	0.00	3.00	0.00	1.48	0.52	0.71	1.29	0.19	1.81
DNF	C	4	0.00	2.00	0.00	3.00	0.00	1.84	0.16	1.09	0.91	1.00	1.00
	C	6	0.00	2.00	1.51	1.49	0.00	1.85	0.15	0.97	1.03	0.92	1.08

The above factor comparisons at both the network and the state level have been repeated for all the other performance measures.

The overall statistical analysis involves the use of independent data (inventory, construction, performance and response) from all the states in the SPS-2 experiment. The advantage of this approach is that the wealth of data from all states combined is used. This data is also conducive for performing formal statistical analysis as outlined below. Figure 25 shows the general framework of overall analysis for the SPS-2 experiment.

The data that actually populate the experimental design matrix have been thoroughly reviewed and it is known, for example, which cells of the matrix contain data that can be used in the analysis. A typical matrix is shown in Table 37. In this example, the dependant variables are those used to describe the pavement performance (e.g. transverse cracking); independent design variables are those used to specify the design matrix (e.g., PCC thickness); and independent exogenous variables are those which have potential impacts on pavement performance but are not controlled in the experiment design (e.g., actual cumulative ESALs).

In this particular instance, the dependant variable is the performance index for number of transverse cracks. Number in a cell in Table 37 indicates the average of the performance indices of all the sections that belong to that cell.

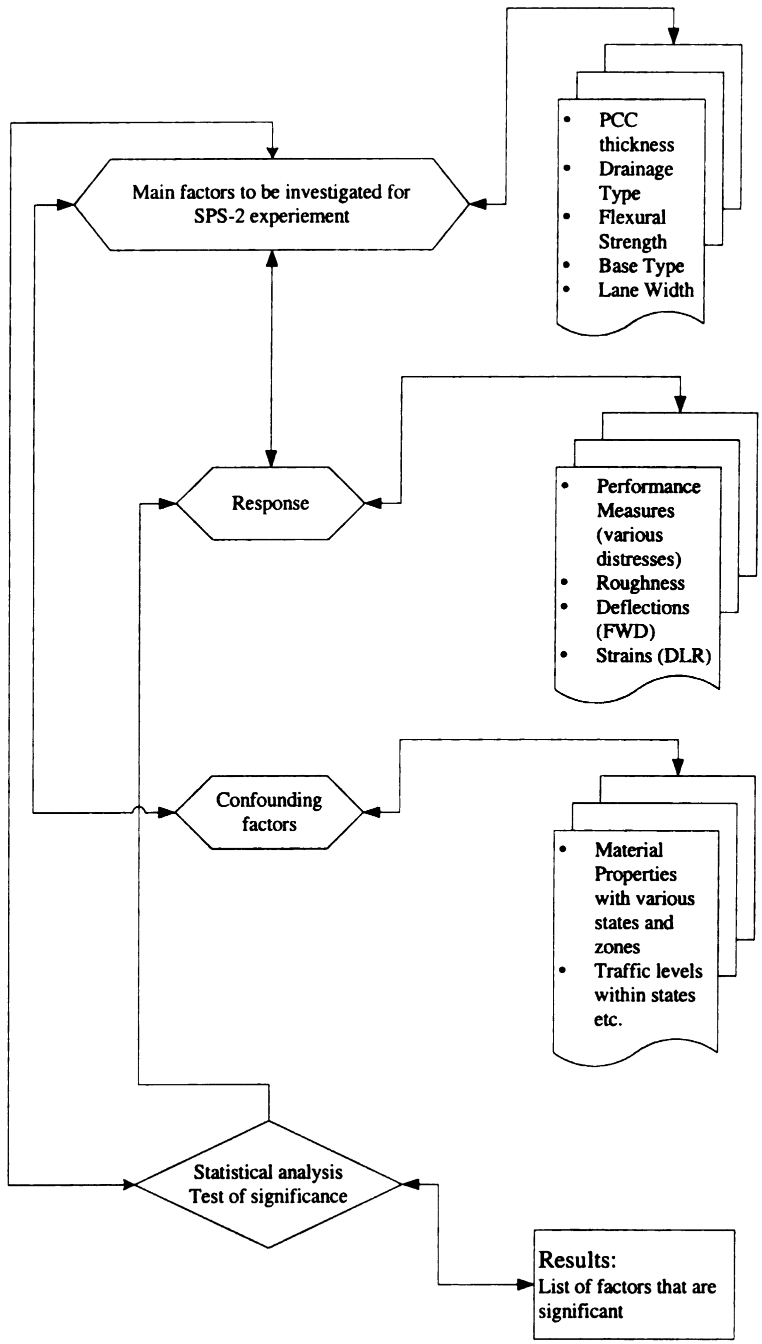


Figure 25 Framework for overall analysis

Table 37 Performance Indices for Number of transverse cracks

Pavement Structure					Climatic Zones, Subgrade																Row Number
Drainage	Base type	PCC		Lane Width, ft	Wet								Dry								
		Thickness (in)	14-day Flexural Strength, psi		Freeze				No-Freeze				Freeze				No-Freeze				
					Fine		Coarse		Fine		Coarse		Fine		Coarse		Fine		Coarse		
					J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	
NO	DGAB	8	550	12	5.31		0		0.2		X		X		20.8		X		9		*1*
				14		0.4		X		X		1.11		X		X		X		0	*2*
			900	12		0.6		X		X		0		X		0		X		0	*3*
				14	4.26		0		0		X		X		0		X		9.67		*4*
		11	550	12		0.3		X		X		0		X		X		X		0	*5*
				14	0		0		0		X		X		0		X		2		*6*
			900	12	0.72		0		0		X		X		0		X		0		*7*
				14		0		X		X		0		X		0		X		0	*8*
NO	LCB	8	550	12	6.93		8.54		6.1		X		X		96.5		X		14.7		*9*
				14		2.1		X		X		1.37		X		X		X		7.92	*10*
			900	12		3.9		X		X		25.6		X		X		X		10.4	*11*
				14	4.67		0		0		X		X		2.7		X		10.3		*12*
		11	550	12		0		X		X		0		X		0		X		1.22	*13*
				14	0		0		0		X		X		3.78		X		1		*14*
			900	12	0		0		0		X		X		0		X		1.67		*15*
				14		0		X		X		0		X		X		X		0.72	*16*
YES	PATB / DGAB	8	550	12	0		0		0		X		X		0		X		0		*17*
				14		0		X		X		0		X		X		X		0	*18*
			900	12		0		X		X		0		X		X		X		0	*19*
				14	0.86		0		0.55		X		X		0		X		0		*20*
		11	550	12		0		X		X		0		X		0		X		0	*21*
				14	0		0		0		X		X		0		X		0		*22*
			900	12	0.21		0		0		X		X		0		X		0		*23*
				14		0		X		X		0		X		0		X		0	*24*
Column letter					*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*K*	*L*	*M*	*N*	*O*	*P*	

Each cell in the matrix has a row (a number from 1 to 24) and a column (a letter from A to P) designation for ease of reference. These labels are shown in the last column and bottom row, respectively of Table 37.

Independent Design and Construction Variables

The matrix is defined by independent design variables. Here, there are two (2) drainage conditions, three (3) base types, two (2) PCC thickness, two (2) flexural strength values, two (2) lane widths, four (4) zone conditions, and two (2) subgrade types. All these variables are treated as nominal. Variables like P200 (percent passing # 200 sieve), as-constructed PCC thickness, base thickness etc. have been treated as interval (or continuous) variables. The main effects of these design variables on pavement performance and the interaction effects among independent variables has been thoroughly investigated and the analysis is presented in the subsequent sections. As mentioned before, the experiment matrix is not fully populated. Also the sample sizes are unequal and hence the straightforward ANOVA analysis cannot be done.

The analysis will begin at the simplest/grossest level, considering the effects of only one design variable, and proceed to more detailed levels, considering (as the data permits) additional design variables and their interactions. All the statistical analyses were done at a 5% level of significance.

Simple Univariate Comparisons for Transverse cracking

With reference to Table 37, the first step is to consider the effect of PCC thickness on Transverse Cracking, ignoring the effects of other variables. This is a simple comparison of the mean value of the transverse cracking data with PCC thickness=8 in. with the mean value of transverse cracking data with PCC thickness=11 in.. The statistical comparison is a basic t-test of the equality of two means.

The actual hypothesis being tested is:

$H\text{-}1_{\text{over columns A-P:}}$

[average (transverse cracking) for all data with PCC thickness=8 in.] =

[average (transverse cracking) for all data with PCC thickness=11 in.]

Figure 26 shows that the 8 in. sections, in general, experienced more number of transverse cracks than the 11 in. sections. From the Univariate analysis, the overall significance of the model is P= 0.209 which is greater than 0.05 (significance level). Also, the P-value for PCC thickness is 0.209, which is greater than 5 % level of significance. Hence it appears that PCC thickness does not seem to be significant according to the simple univariate analysis. The high number of transverse cracks in these sections is mostly contributed by NV (32). The extensively high transverse cracking in NV is because of the problems encountered during construction.

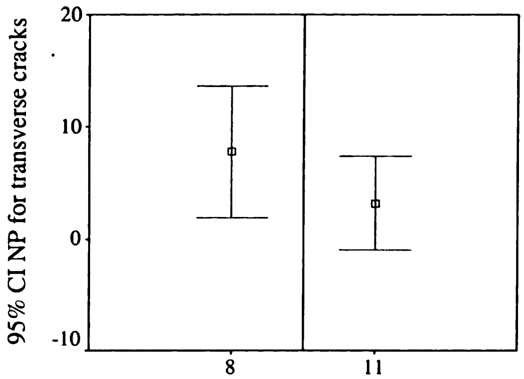


Figure 26 Example hypothesis testing – PCC thickness

Table 38 Example hypothesis testing – PCC thickness

Tests of Between-Subjects Effects

Dependent Variable: NP

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	818.662[a]	1	818.662	1.591	.209
Intercept	4664.026	1	4664.026	9.065	.003
PCC_THIC	818.662	1	818.662	1.591	.209
Error	78716.376	153	514.486		
Total	84224.507	155			
Corrected Total	79535.038	154			

a. R Squared = .010 (Adjusted R Squared = .004)

The analysis was also done by excluding the sections from NV and the results are as shown in Figure 27. This analysis shows that the PCC thickness seems to be significant in the occurrence of transverse cracking. Since there was extensive cracking in both the 8 in. and the 11 in. sections in NV because of the shrinkage cracking, the PCC thickness was not significant in Figure 26.

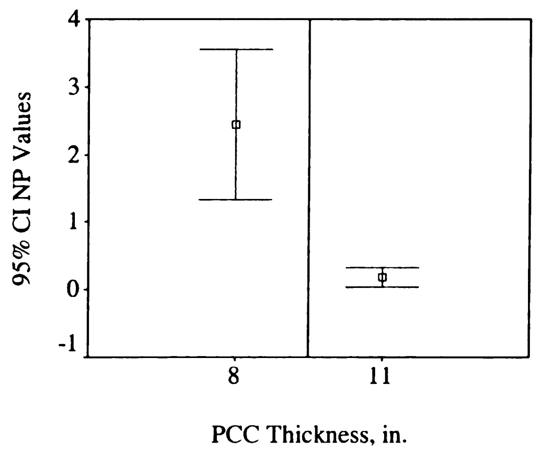


Figure 27 Hypothesis testing –PCC thickness (without NV)

The second step is to consider only the data in columns A-H because the data in that half of the overall matrix belongs to the wet zones in the SPS-2 experiment. The same test was repeated for sections located in the dry zones (columns I-P). The results of both the tests are shown in Figure 28 and Figure 29 respectively.

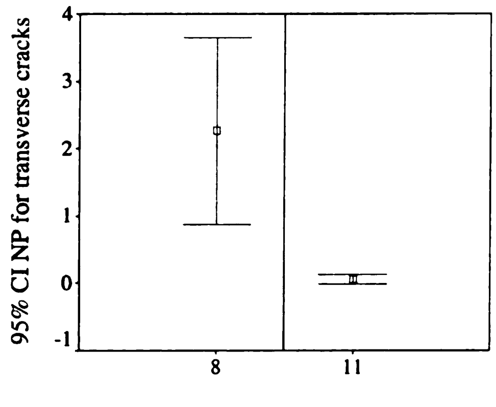


Figure 28 Transverse cracking-Wet Zones

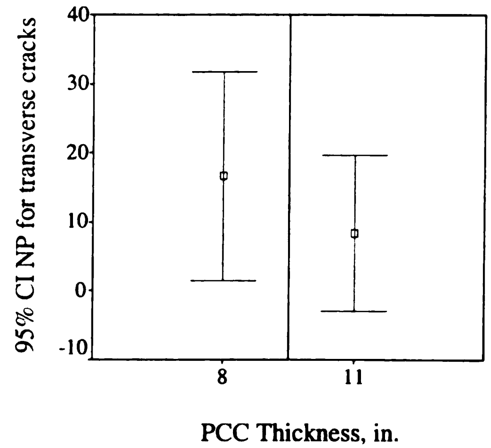


Figure 29 Transverse cracking-Dry Zones

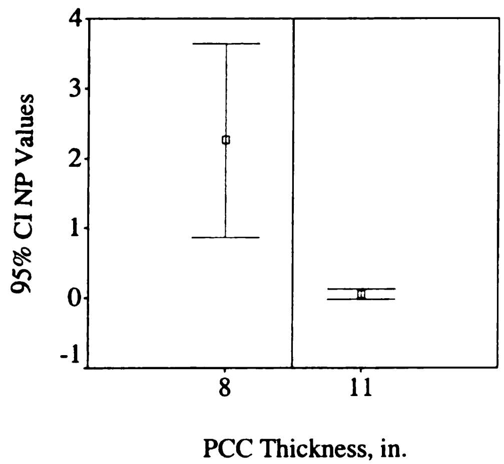


Figure 30 Transverse cracking-Wet Zones (without NV)

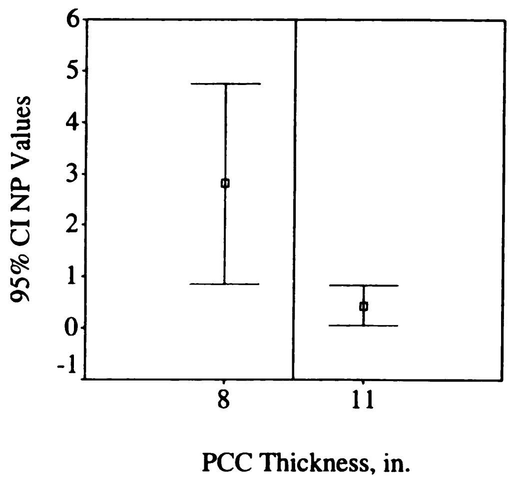


Figure 31 Transverse cracking-Dry Zones (without NV)

Figure 28 and Figure 29 show that sections located in the Dry zones had significantly greater amount of transverse cracking than those in the Wet zones. It might be noted that most of the transverse cracking in the dry zones was contributed by sections located in Nevada, NV (32). The same trends were observed in Figure 30 and Figure 31 which show the comparison without the inclusion of NV. It might be noted that the dependant variable throughout this analysis is the total number of transverse cracks. The severity levels of the cracks are not considered here.

A similar comparison can also be done for sections located in the Freeze (columns A-D and I-L) and No-Freeze (columns E-H and M-P) climates as shown in Figure 32 and Figure 33. The sections located in the Freeze zones have higher transverse cracking than those located in the non-freeze zones. The same analysis was done for sections without the inclusion of NV as shown in Figure 34 and Figure 35, where the same trends were observed. Figure 36 shows an example of hypothesis testing (for effect of PCC thickness) considering the various climatic zones separately. The 8 in. sections located in the DF zone have higher transverse cracking than the other sections. Figure 37 shows the same comparison done without the inclusion of NV. The 8 in. sections located in the DNF region had higher transverse cracking.

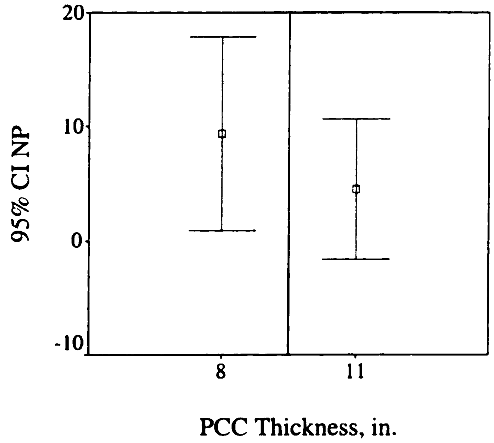


Figure 32 Transverse cracking -Freeze zones

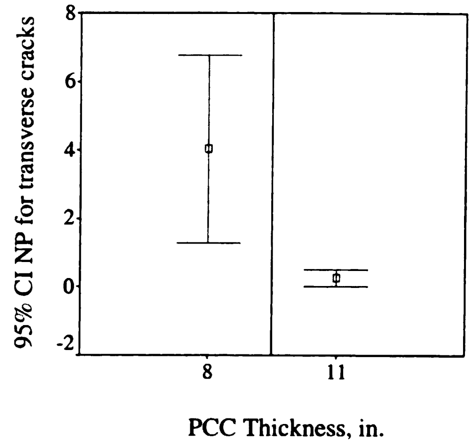


Figure 33 Transverse Cracking -Non-Freeze zones

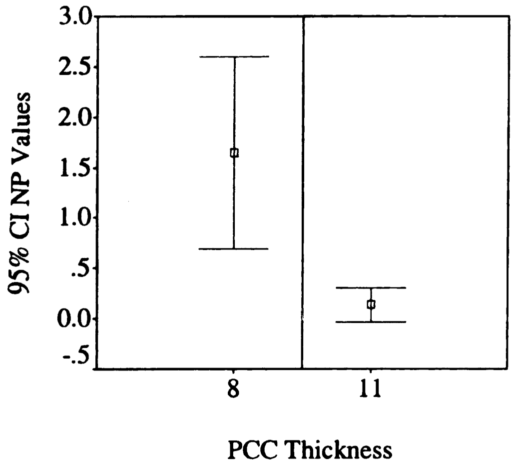


Figure 34 Transverse cracking -Freeze zones (without NV)

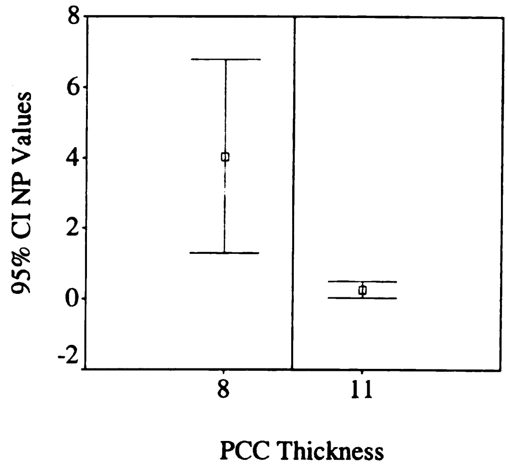


Figure 35 Transverse Cracking -Non-Freeze zones (without NV)

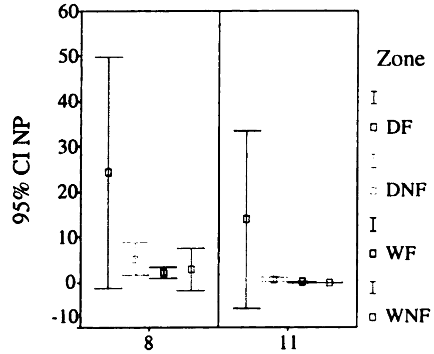


Figure 36 Example hypothesis testing for PCC thickness by climatic zones

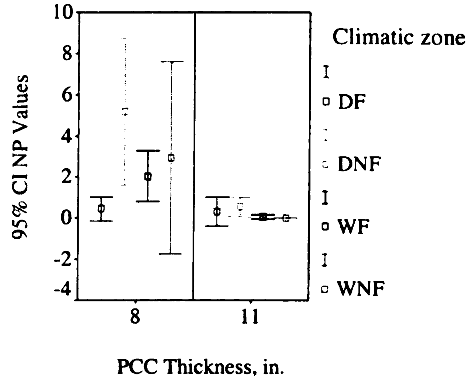


Figure 37 Example hypothesis testing for PCC thickness by climatic zones (without NV)

Similar hypothesis testing can also be done with the subgrade type, base type, drainage type and lane width. The results are shown in Figure 38 through Figure 41. The non-drainable (LCB) 8 in. sections constructed on a coarse subgrade, have significantly greater transverse cracking. Also sections with a 12 ft lane exhibited higher transverse cracking than those with a 14 ft lane width. The same analysis was done for sections excluding NV as shown in Figure 42 through Figure 45.

The third step consists of testing the data from columns A-H on the left half of the matrix, which has the effect of controlling the effect of zone=wet-freeze/no-freeze and subgrade conditions=fine/coarse.

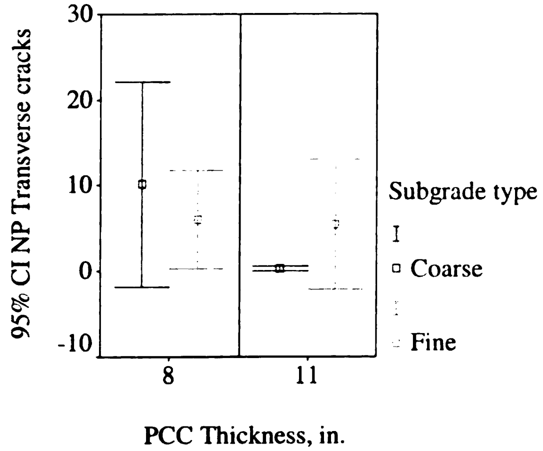


Figure 38 Transverse cracks-Subgrade type

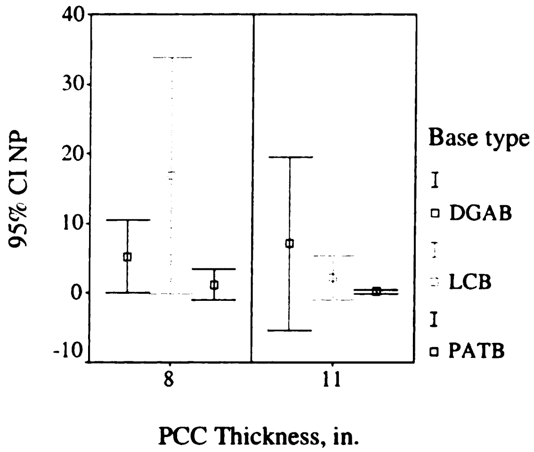


Figure 39 Transverse cracks-Base type

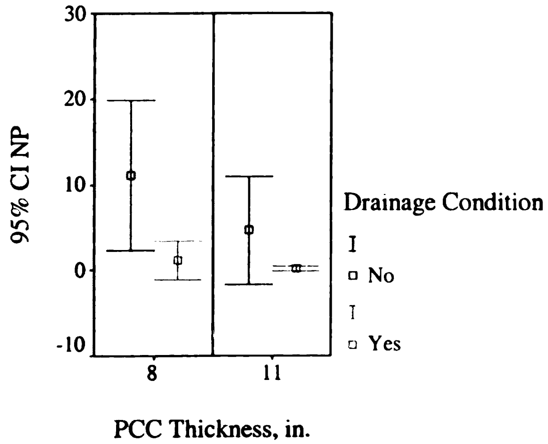


Figure 40 Transverse cracks-Drainage type

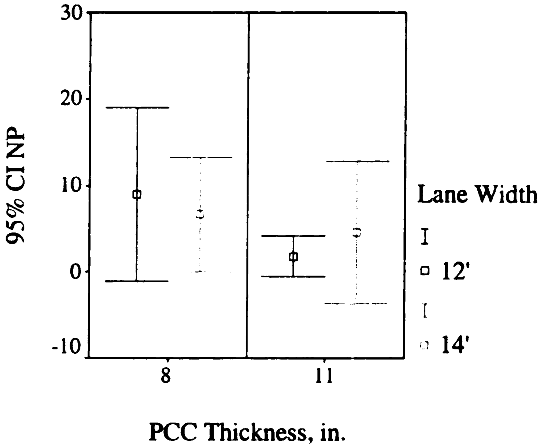


Figure 41 Transverse cracks-Lane Width

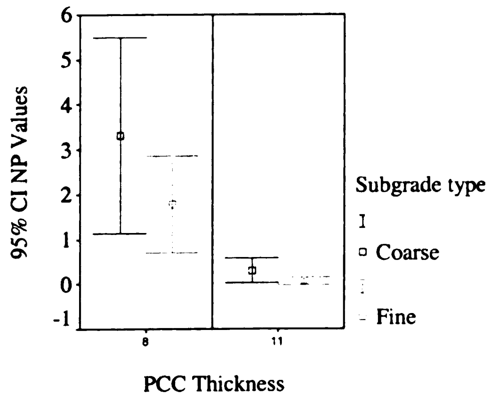


Figure 42 Transverse cracks-Subgrade type (without NV)

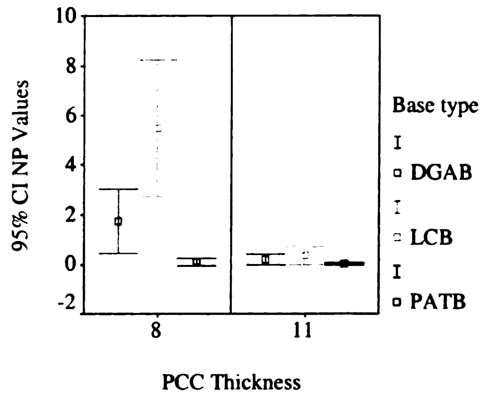


Figure 43 Transverse cracks -Base type (without NV)

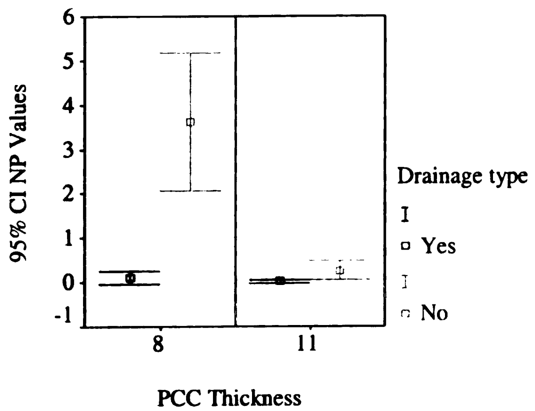


Figure 44 Transverse cracks-Drainage type (without NV)

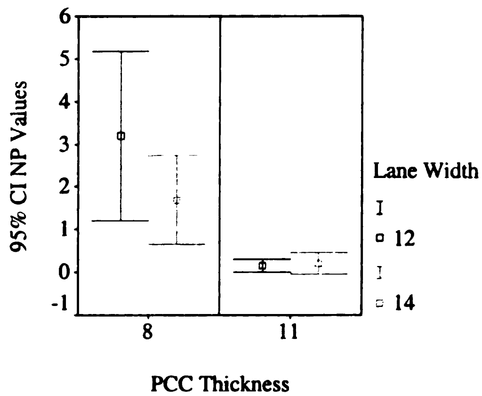


Figure 45 Transverse cracks-Lane Width (without NV)

Figure 46 shows an example of the above hypothesis by subgrade type for sections in the WF zone.

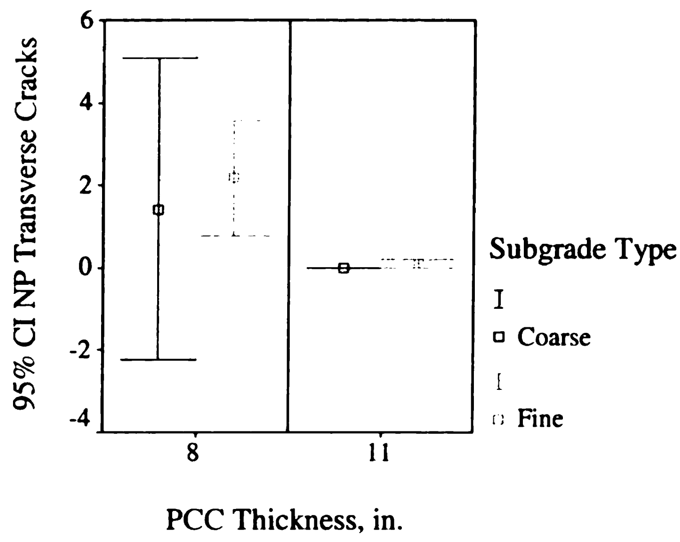


Figure 46 Example hypothesis testing for PCC thickness by Subgrade Type (WF).

This comparison is repeated for the other three climatic zones with three other similar hypotheses being tested. These comparisons basically reveal whether there are differences in transverse cracking between pavements with PCC = 8 in. and PCC=11 in. for the various combinations of zone=wet-freeze/no-freeze and subgrade conditions. It might be noted that there are differences in the base type, lane width, and the drainage type between the two sets of data. Figures B-58 through B-60 show these graphs.

It can be concluded from the univariate analysis that sections with an 8 in. PCC slab, founded on an LCB layer and a coarse subgrade with a 12 ft lane width exhibit higher transverse cracking. The same trends have also been observed in the engineering analysis (presented in Chapter 5). The occurrence of cracks in the 8 in. LCB sections could be because of the transverse shrinkage cracks during construction. The occurrence of transverse cracking in the 8 in DGAB sections could be because of the low structural capacity of the sections. Also, the 8 in. sections with a 12 ft lane could not withstand the target design ESALs for which they have been designed (as obtained from the thickness adequacy analysis using AASHTO '98).

Multivariate Analysis for Transverse cracking

The data in the matrix also allows for multivariate testing- e.g. testing for the main effects of two or more design variables and their interactions. Since the experiment design matrix for transverse cracking has empty cells, the main and the interaction effects cannot be considered in their entirety. Rather, the multivariate relationships were considered with some constraints (as defined by the available data).

The fifth step in the analysis is to consider all the design variables in the multivariate analysis, while treating the effects of traffic and PCC thickness variability as covariates. (It might be noted that the proposed KESALs/ year in Table 14 has been used in this analysis due to non-availability of traffic data). Hence, the multivariate analysis was done at the network level to determine the effects of the various factors and all possible interactions between them. Table 39 shows the multivariate analysis for all SPS-2 sections with the normalized performance value of transverse cracking as the dependant variable.

The overall model is not significant as the P-value (0.224) is greater than 0.05. None of the variables seem to show any effect (since the significance values are greater than 0.05) on the occurrence of transverse cracking in the sections. Most of the sections have very low magnitudes of transverse cracking. Hence, it was deemed necessary to perform the same analysis at a state level to determine the factors that contribute to transverse cracking.

At the state level, it was necessary to calculate the z-scores of the normalized performance values. The reason for using the z-scores is to remove the effect of the age of the sections. The z-score for each section in a given state is calculated as follows:

$$z - score(for\ a\ given\ section) =$$

$$\frac{(Performance\ index\ of\ section - Average\ of\ Performance\ Indices\ of\ all\ sections\ in\ that\ state)}{(Standard\ deviation\ of\ Performance\ Indices\ values\ of\ all\ sections\ in\ that\ state)}$$

Table 40 shows the multivariate analysis done at the state level. It has been found that base type, PCC thickness, variability in the PCC thickness, the interaction between base type & PCC thickness, and PCC thickness & lane width are statistically significant (as their respective P-values are less than 5 % level of significance) and hence contribute to the occurrence of transverse cracking in these sections.

Table 39 Multivariate ANOVA for SPS-2 sections-Transverse cracking

Tests of Between-Subjects Effects

Dependent Variable: NP VALUES

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	24997.360[a]	42	595.175	1.201	.224
Intercept	2056.585	1	2056.585	4.148	.044
DRAINAGE	911.291	1	911.291	1.838	.178
NBASETYP	192.384	1	192.384	.388	.535
PCC_THIC	1050.555	1	1050.555	2.119	.148
FLEX_COD	21.252	1	21.252	.043	.836
LW_CODE	86.428	1	86.428	.174	.677
ZONE	3061.981	3	1020.660	2.059	.110
SUBGRADE	.350	1	.350	.001	.979
RECENTER	178.903	1	178.903	.361	.549
V26	192.007	1	192.007	.387	.535
DRAINAGE * PCC_THIC	25.373	1	25.373	.051	.821
DRAINAGE * FLEX_COD	156.979	1	156.979	.317	.575
DRAINAGE * LW_CODE	138.031	1	138.031	.278	.599
DRAINAGE * ZONE	1946.693	3	648.898	1.309	.275
DRAINAGE * SUBGRADE	651.550	1	651.550	1.314	.254
NBASETYP * PCC_THIC	1887.916	1	1887.916	3.808	.054
NBASETYP * FLEX_COD	24.521	1	24.521	.049	.824
NBASETYP * LW_CODE	988.158	1	988.158	1.993	.161
NBASETYP * ZONE	296.925	3	98.975	.200	.896
NBASETYP * SUBGRADE	1007.139	1	1007.139	2.031	.157
PCC_THIC * FLEX_COD	23.187	1	23.187	.047	.829
PCC_THIC * LW_CODE	268.580	1	268.580	.542	.463
PCC_THIC * ZONE	241.578	3	80.526	.162	.921
PCC_THIC * SUBGRADE	573.386	1	573.386	1.157	.285
FLEX_COD * LW_CODE	193.196	1	193.196	.390	.534
FLEX_COD * ZONE	255.773	3	85.258	.172	.915
FLEX_COD * SUBGRADE	488.093	1	488.093	.985	.323
LW_CODE * ZONE	739.035	3	246.345	.497	.685
LW_CODE * SUBGRADE	1177.852	1	1177.852	2.376	.126
ZONE * SUBGRADE	1020.507	2	510.254	1.029	.361
Error	54534.729	110	495.770		
Total	84161.058	153			
Corrected Total	79532.089	152			

a. R Squared = .314 (Adjusted R Squared = .052)

Table 40 Multivariate ANOVA at the state level-Transverse cracking

Tests of Between-Subjects Effects

Dependent Variable: Z-SCORES

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	72.857[a]	15	4.857	9.720	.000
Intercept	1.485	1	1.485	2.971	.087
DRAINAGE	1.603	1	1.603	3.207	.076
BASETYP	10.627	1	10.627	21.265	.000
PCC_THIC	19.453	1	19.453	38.928	.000
FLEX_COD	.354	1	.354	.709	.401
LW_CODE	.825	1	.825	1.651	.201
PCC_thick_var	3.694	1	3.694	7.392	.007
DRAINAGE * PCC_THIC	.329	1	.329	.658	.419
DRAINAGE * FLEX_COD	.400	1	.400	.801	.372
DRAINAGE * LW_CODE	.075	1	.075	.150	.699
NBASETYP * PCC_THIC	11.611	1	11.611	23.235	.000
NBASETYP * FLEX_COD	.061	1	.061	.121	.728
NBASETYP * LW_CODE	.762	1	.762	1.524	.219
PCC_THIC * FLEX_COD	.011	1	.011	.022	.882
PCC_THIC * LW_CODE	2.208	1	2.208	4.418	.037
FLEX_COD * LW_CODE	.036	1	.036	.073	.787
Error	68.462	137	.500		
Total	141.326	153			
Corrected Total	141.319	152			

a. R Squared = .516 (Adjusted R Squared = .463)

Having known the factors within which interaction is present, the marginal means were then compared at different levels of the factors. The term Marginal Mean implies a mean taken over all other factors in the experiment. For example, since it was concluded that interaction exists between base type and PCC thickness, the marginal means were obtained as shown in Figure 47.

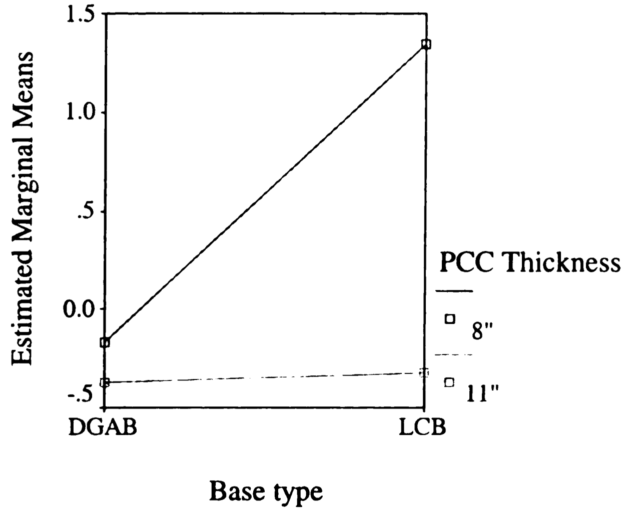


Figure 47 Estimated marginal means at all levels of base type and PCC thickness

Figure 47 shows that PCC thickness was found to be more significant for sections constructed on an LCB than those constructed on a DGAB, since the marginal means for both the levels of the PCC thickness are significantly different. This could be because of the fact that, since most of the LCB sections had transverse shrinkage cracking during construction, which reflected onto the PCC surface. However, this was observed mostly in the 8 in. sections and not in the 11 in. sections (to be discussed later). Hence, PCC thickness was found to be significant in the LCB sections than in the DGAB sections. Since there are two base types with no drainage (DGAB and LCB) and one base type with drainage (PATB), it will not be possible to compare the effect of drainage. Hence, all PATB sections were considered to be DGAB sections with drainage provision.

Figure 48 shows the estimated marginal means at all levels of PCC thickness and lane width. From the analysis, it appears that the lane width seems to have a significant effect for 8 in. sections. This could be because of the fact that sections constructed with 11 in. PCC will have lower transverse cracking than 8 in. sections. Hence, within the 8 in. sections, lower transverse cracking is found in 14 ft sections, because of the pseudo interior loading condition. Hence, the effect of lane width would be more significant in 8 in. sections than in 11 in. sections.

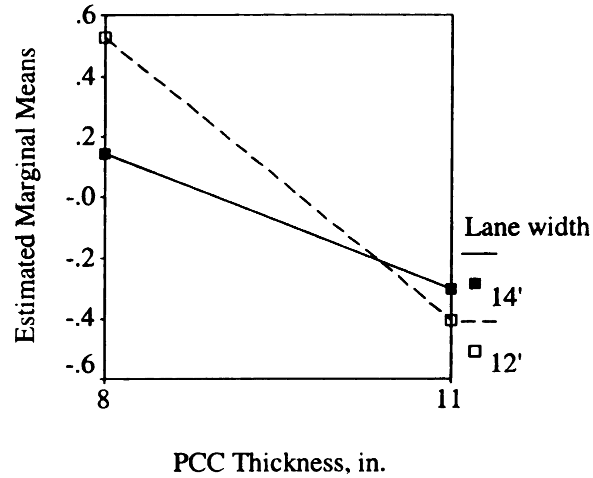


Figure 48 Estimated marginal means at all levels of PCC thickness and lane width

PUMPING

The performance index and the relative performance index were calculated for the number of pumping occurrences. Then the univariate and the multivariate analysis were done to identify the factors contributing to the occurrence of transverse cracking.

Performance Index and Relative Performance Index

The overall factor comparisons were done at both the network level and at the state level to study the effect of various design factors on pumping. This has been illustrated in Table 41 and 42. Consider the effect of base type on the number of pumping occurrences in Table 41. For sections located in the WNF zone and constructed on a coarse subgrade, all the non-drainable sections had higher values of performance index than the drainable sections. Within the non-drainable sections, the LCB sections had higher performance indices than DGAB sections. This could be because the LCB layer can be considered to be a relatively impermeable layer than the DGAB sections. The sum of factors is 2 because the number of levels in drainage type is two (drainage and no-drainage). Sections constructed on a drainable base perform relatively better than those constructed on a non-drainable base. Also, sections constructed on a DGAB and sections with 8 in. PCC slab perform better, since their relative performance indices are lower. A similar analysis was done at the state level. The response variable is the z score of the normalized performance of pumping occurrences (as discussed before for transverse cracks). The analysis has been shown in Tables 43 and 44. It can be observed that the non-drainable sections founded on LCB have high performance indices in all the states, indicating the poor performance of these sections.

Simple Univariate Comparisons for pumping

The first step is to consider the effect of drainage condition on the occurrence of pumping, ignoring the effects of other variables. This is a comparison of the mean of the number of pumping occurrences of cells with no drainage, to those with drainage. The statistical comparison is a t-test of the equality of the two means. The hypothesis being tested is:

H-1 [average (number of pumping occurrences) for all sections with no drainage] =

[average (number of pumping occurrences) for all sections with drainage]

Table 41 Overall factor comparisons summary for number of pumping occurrences at the network level

Number of pumping occurrences — PCC thickness

Zone	Subgrade Type	ND								D			
		DGAB				LCB				PATB			
		12'		14'		12'		14'		12'		14'	
		8"	11"	8"	11"	8"	11"	8"	11"	8"	11"	8"	11"
DF	Coarse	2.00	0.00	X	X	2.00	0.00	X	X	X	X	X	X
	Fine	X	X	X	X	0.00	2.00	X	X	X	X	2.00	0.00
DNF	Coarse	X	X	X	X	X	X	X	X	X	X	X	X
WF	Coarse	X	X	X	X	X	X	0.00	2.00	X	X	X	X
	Fine	1.33	0.67	0.85	1.15	1.37	0.63	1.73	0.27	X	X	0.00	2.00
WNF	Coarse	1.57	0.43	0.62	1.38	0.86	1.14	1.59	0.41	2.00	0.00		
	Fine	X	X	X	X	X	X	X	X	X	X	X	X

Number of pumping occurrences — Drainage type

Zone	Subgrade Type	8"				11"			
		12'		14'		12'		14'	
		D	ND	D	ND	D	ND	D	ND
DF	Coarse	0.00	2.00	X	X	X	X	X	X
	Fine	X	X	2.00	0.00	X	X	X	X
DNF	Coarse	X	X	X	X	X	X	X	X
WF	Coarse	X	X	X	X	X	X	0.00	2.00
	Fine	0.00	2.00	0.00	2.00	0.00	2.00	0.14	1.86
WNF	Coarse	0.92	1.08	0.00	2.00	0.00	2.00	0.00	2.00
	Fine	X	X	X	X	X	X	X	X

Number of pumping occurrences — Base type

Zone	Subgrade Type	8"						11"					
		12'			14'			12'			14'		
		D	ND		D	ND		D	ND		D	ND	
		PATB	DGAB	LCB	PATB	DGAB	LCB	PATB	DGAB	LCB	PATB	DGAB	LCB
DF	Coarse	0.00	2.05	0.95	X	X	X	X	X	X	X	X	X
	Fine	X	X	X	3.00	0.00	0.00	X	X	X	X	X	X
DNF	Coarse	X	X	X	X	X	X	X	X	X	X	X	X
WF	Coarse	X	X	X	X	X	X	X	X	X	0.00	0.00	3.00
	Fine	0.00	1.20	1.80	0.00	0.12	2.88	0.00	1.25	1.75	0.11	0.80	2.10
WNF	Coarse	0.90	1.19	0.91	0.00	0.44	2.56	0.00	0.64	2.36	0.00	1.79	1.21
	Fine	X	X	X	X	X	X	X	X	X	X	X	X

Table 42 Overall factor comparisons summary for length of pumping at the network level

Length of pumping — PCC thickness

Zone	Subgrade Type	ND								D			
		DGAB				LCB				PATB			
		12'		14'		12'		14'		12'		14'	
		8"	11"	8"	11"	8"	11"	8"	11"	8"	11"	8"	11"
DF	Coarse	2.00	0.00	X	X	2.00	0.00	X	X	X	X	X	X
	Fine	X	X	X	X	0.00	2.00	X	X	X	X	2.00	0.00
DNF	Coarse	X	X	X	X	X	X	X	X	X	X	X	X
WF	Coarse	X	X	X	X	X	X	0.00	2.00	X	X	X	X
	Fine	0.74	1.26	1.97	0.03	1.32	0.68	1.64	0.36	X	X	0.00	2.00
WNF	Coarse	1.49	0.51	1.36	0.64	0.99	1.01	0.95	1.05	2.00	0.00	X	X
	Fine	X	X	X	X	X	X	X	X	X	X	X	X

Length of pumping — Drainage type

Zone	Subgrade Type	8"				11"			
		12'		14'		12'		14'	
		D	ND	D	ND	D	ND	D	ND
DF	Coarse	0.00	2.00	X	X	X	X	X	X
	Fine	X	X	2.00	0.00	X	X	X	X
DNF	Coarse	X	X	X	X	X	X	X	X
WF	Coarse	X	X	X	X	X	X	0.00	2.00
	Fine	0.00	2.00	0.00	2.00	0.00	2.00	0.02	1.98
WNF	Coarse	0.59	1.41	0.00	2.00	0.00	2.00	0.00	2.00
	Fine	X	X	X	X	X	X	X	X

Length of pumping — Base type

Zone	Subgrade Type	8"						11"					
		12'			14'			12'			14'		
		D	ND		D	ND		D	ND		D	ND	
		PATB	DGAB	LCB	PATB	DGAB	LCB	PATB	DGAB	LCB	PATB	DGAB	LCB
DF	Coarse	0.00	0.36	2.64	X	X	X	X	X	X	X	X	X
	Fine	X	X	X	3.00	0.00	0.00	X	X	X	X	X	X
DNF	Coarse	X	X	X	X	X	X	X	X	X	X	X	X
WF	Coarse	X	X	X	X	X	X	X	X	X	0.00	0.00	3.00
	Fine	0.00	0.44	2.56	0.00	0.48	2.52	0.00	1.09	1.91	0.01	0.04	2.95
WNF	Coarse	0.52	1.02	1.46	0.00	1.04	1.96	0.00	0.57	2.43	0.00	0.54	2.46
	Fine	X	X	X	X	X	X	X	X	X	X	X	X

Note: Cells marked in "X" indicate that the magnitudes of distress at that level of the factor are zero. In such a case, the value of relative performance cannot be defined.

Table 43 State level factor comparisons for number of pumping occurrences

Zone	Subgrade	State ID	Drainage		Base Type			PCC Thickness		Flexural Strength		Lane Width	
			D	ND	DGAB	LCB	PATB	8"	11"	550 psi	900 psi	12'	14'
WF	C	10	0.00	2.00	0.00	3.00	0.00	0.00	2.00	2.00	0.00	0.00	2.00
	F	19	0.00	2.00	0.00	3.00	0.00	0.00	2.00	2.00	0.00	2.00	0.00
	F	20	0.00	2.00	1.50	1.50	0.00	2.00	0.00	1.00	1.00	1.00	1.00
	F	26	0.00	2.00	0.41	2.59	0.01	1.74	0.26	1.24	0.76	0.78	1.22
	F	38	0.00	2.00	0.00	3.00	0.00	2.00	0.00	1.75	0.25	0.25	1.75
	F	39	0.00	2.00	0.00	3.00	0.00	2.00	0.00	0.42	1.58	0.42	1.58
WNF	C	5	0.27	1.73	0.97	1.63	0.40	1.31	0.69	0.88	1.12	1.35	0.65
	F	37	X	X	X	X	X	X	X	X	X	X	X
DF	F+C	8	X	X	X	X	X	X	X	X	X	X	X
	F+C	32	0.50	1.50	1.25	0.82	0.93	0.65	1.35	0.23	1.77	1.50	0.50
	C	53	X	X	X	X	X	X	X	X	X	X	X
DNF	C	4	X	X	X	X	X	X	X	X	X	X	X
	C	6	X	X	X	X	X	X	X	X	X	X	X

Table 44 State level factor comparisons for length of pumping

Zone	Subgrade	State ID	Drainage		Base Type			PCC Thickness		Flexural Strength		Lane Width	
			D	ND	DGAB	LCB	PATB	8"	11"	550 psi	900 psi	12'	14'
WF	C	10	0.00	2.00	0.00	3.00	0.00	0.00	2.00	2.00	0.00	0.00	2.00
	F	19	0.00	2.00	0.00	3.00	0.00	0.00	2.00	2.00	0.00	2.00	0.00
	F	20	0.00	2.00	2.90	0.10	0.00	2.00	0.00	1.93	0.07	1.93	0.07
	F	26	0.00	2.00	0.95	2.05	0.00	1.31	0.69	1.33	0.67	1.12	0.88
	F	38	0.00	2.00	0.00	3.00	0.00	2.00	0.00	1.01	0.99	0.99	1.01
	F	39	0.00	2.00	0.00	3.00	0.00	2.00	0.00	0.96	1.04	0.96	1.04
WNF	C	5	0.11	1.89	0.83	2.01	0.16	1.15	0.85	0.91	1.09	1.02	0.98
	F	37	X	X	X	X	X	X	X	X	X	X	X
DF	F+C	8	X	X	X	X	X	X	X	X	X	X	X
	F+C	32	0.21	1.79	0.68	1.92	0.40	0.38	1.62	0.23	1.77	1.79	0.21
	C	53	X	X	X	X	X	X	X	X	X	X	X
DNF	C	4	X	X	X	X	X	X	X	X	X	X	X
	C	6	X	X	X	X	X	X	X	X	X	X	X

Note: Cells marked in "X" indicate that the magnitudes of distress at that level of the factor are zero. In such a case, the value of relative performance cannot be defined.

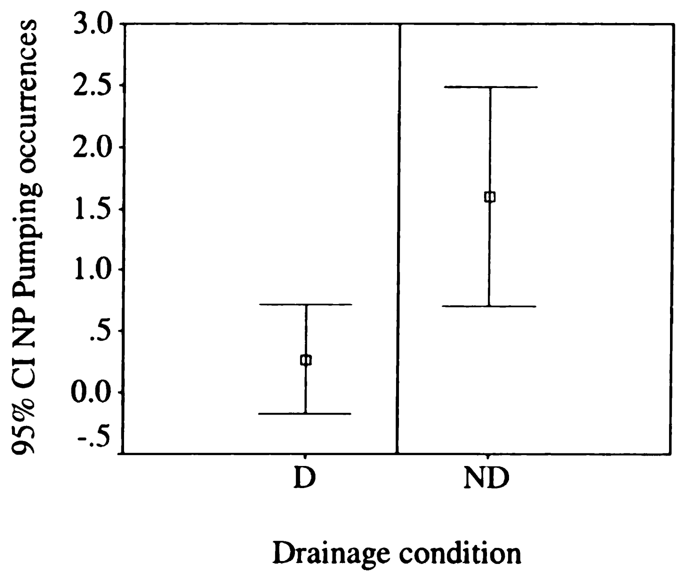


Figure 49 Hypothesis testing – Drainage condition

Table 45 Hypothesis testing – Drainage condition

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	60.514[a]	1	60.514	4.072	.045
Intercept	119.186	1	119.186	8.019	.005
DRAINAGE	60.514	1	60.514	4.072	.045
Error	2273.953	153	14.862		
Total	2543.214	155			
Corrected Total	2334.467	154			

a. R Squared = .026 (Adjusted R Squared = .020)

Figure 49 shows that sections with no drainage have significantly high levels of pumping occurrences than those constructed on a drainable base as is suggested from the significance values (0.045). Also the model is significant (P-value= 0.045) at a 5 % level of significance.

The second step is to consider only the data in columns A-H because the data in that half of the overall matrix belongs to the wet zones in the matrix.

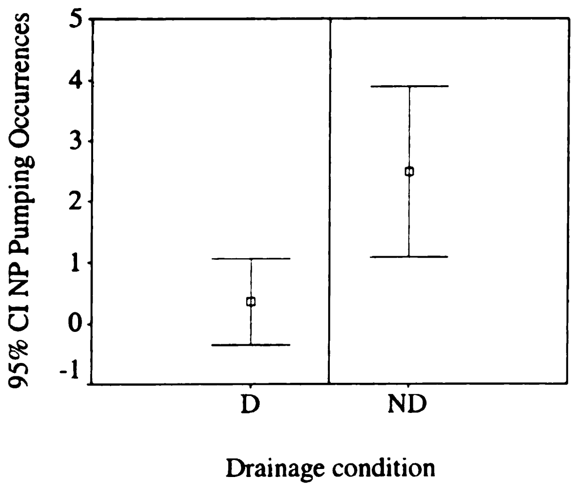


Figure 50 Pumping-Wet Zones

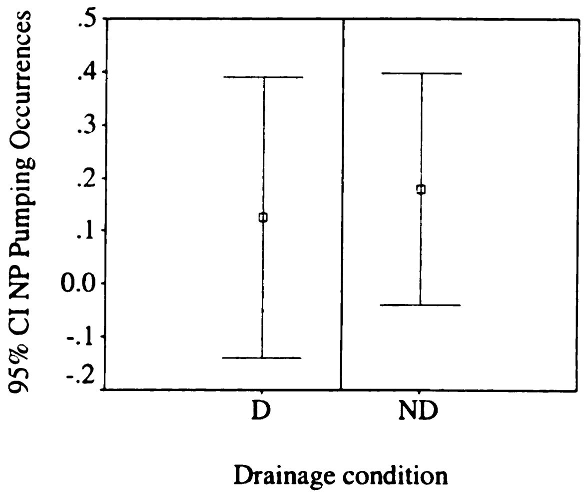


Figure 51 Pumping-Dry Zones

Figure 50 shows that, for sections located in the Wet zones, sections founded on a non-drainable base have significantly higher number of pumping occurrences than those founded on a drainable base. The same test can be repeated for sections located in the dry zones (Figure 51). The effect of drainage is not significant in the dry zones, as the number of pumping occurrences in the dry zones is significantly low.

A similar comparison can also be done for sections located in the Freeze zone (columns A-D and I-L) and No-Freeze (columns E-H and M-P) climates as shown in Figure 52 and Figure 53.

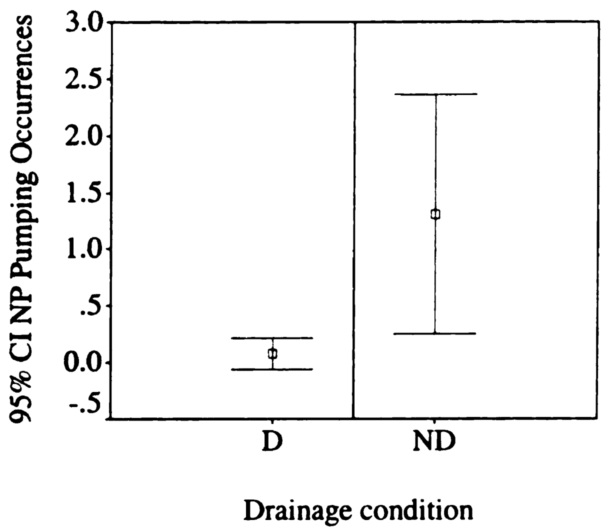


Figure 52 Pumping –Freeze zone

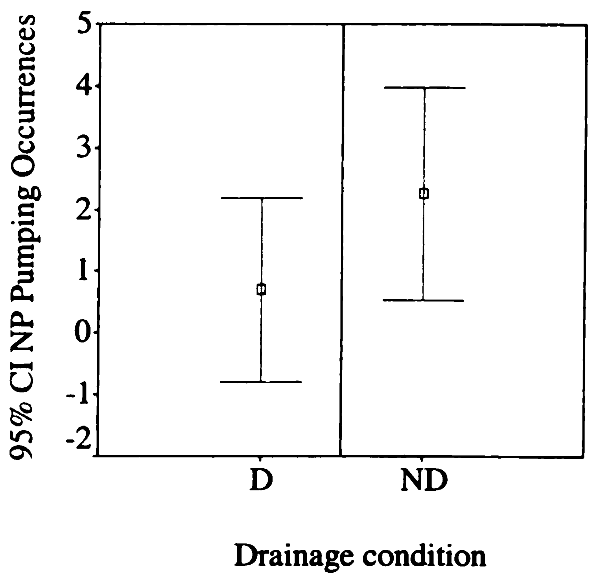


Figure 53 Pumping-Non-freeze zone

From the analysis, pumping appears to be prevalent in the non-drainable sections in both the zones. Figure 54 shows an example of hypothesis testing (for effect of drainage) considering the various climatic zones separately. Sections located in the wet zones have significantly high pumping occurrences than the others.

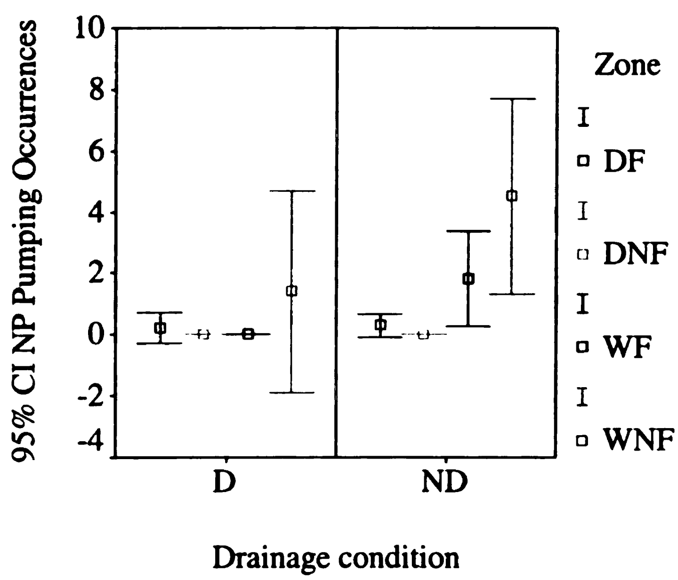


Figure 54 Hypothesis testing for drainage condition by climatic zones

The effect of base type and subgrade type have also been investigated and shown in Figure 55 and Figure 56.

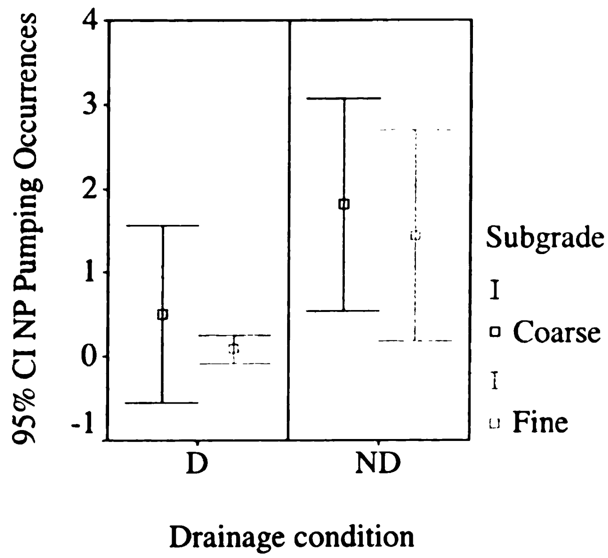


Figure 55 Pumping –Subgrade type

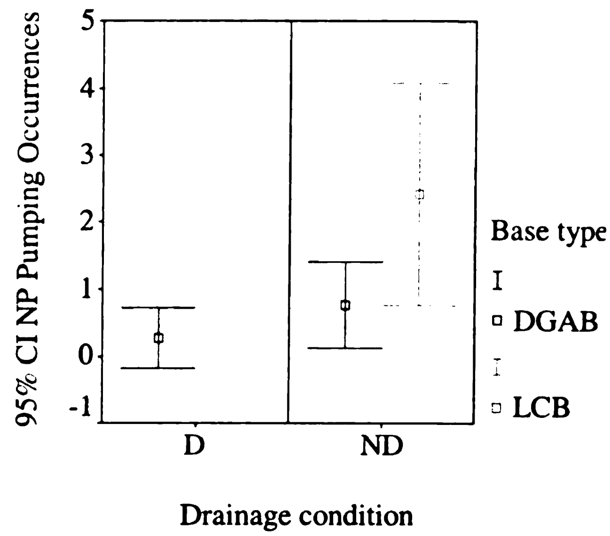


Figure 56 Pumping –Base type

The third step consists of testing the data from columns A-H on the left half of the matrix, which has the effect of controlling the effect of zone=wet-freeze/no-freeze and subgrade conditions=fine/coarse.

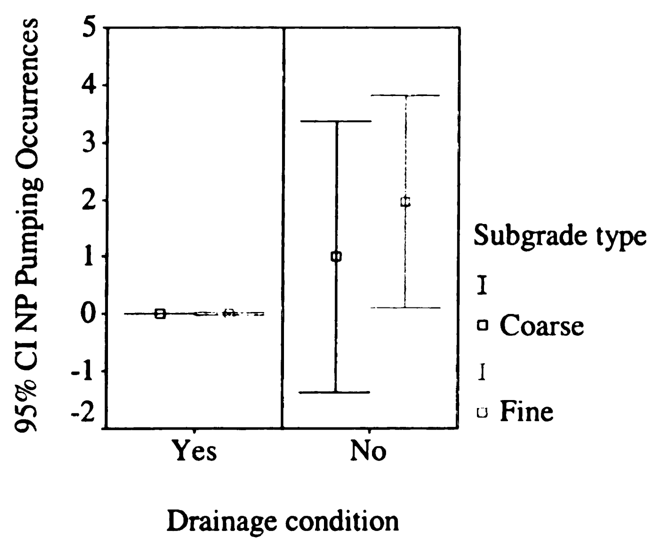


Figure 57 Hypothesis testing for drainage condition by Subgrade type (WF)

Figure 57 shows an example of the above hypothesis by subgrade type for sections located in the WF zone.

This comparison is repeated for the other three climatic zones with three other similar hypotheses being tested. These comparisons will basically reveal whether there are differences in pumping occurrences between pavements with and without drainage provision for the various combinations of zone=wet-freeze/no-freeze and subgrade conditions. It might be noted that there are differences in the base type, lane width, and the drainage type between the two sets of data. Figures B-61 through B-63 show these graphs.

It can be concluded from the univariate analysis that sections located in the wet zones with no drainage provision and founded on a coarse subgrade show more number of pumping occurrences. The same trends were observed in the engineering analysis (presented in Chapter 5).

Multivariate Analysis for pumping

The fifth step in the analysis is to consider all the design variables in the multivariate analysis, while treating the effects of traffic and PCC thickness variability as covariates. (It might be noted that the proposed KESALs/ year in Table 14 has been used in this analysis due to non-availability of traffic data). Hence, the multivariate analysis was done at the network level to determine the effects of the various factors and all possible interactions between them. Table 46 shows the multivariate analysis for all SPS-2 sections with the performance index of pumping occurrences as the dependant variable. The overall model is significant (at 0.05 level) with zone and subgrade type showing significant contribution to pumping. The interaction between these two variables also seems to be significantly contributing to pumping occurrences.

The state level analysis was done by calculating the z-scores of all the sections (explained before). From Table 47, the overall model is significant with the base type significantly contributing to the occurrence of pumping. Knowing that the base type affects pumping, the marginal means were compared at different levels of the base type. From Table 48, the mean difference is significant at the 0.05 level of significance.

Table 46 Multivariate ANOVA for SPS-2 sections- Pumping

Tests of Between-Subjects Effects

Dependent Variable: NP

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	984.183[a]	42	23.433	1.913	.004
Intercept	73.964	1	73.964	6.038	.016
ZONE	138.894	3	46.298	3.779	.013
DRAINAGE	6.774	1	6.774	.553	.459
SUBGRADE	51.607	1	51.607	4.213	.042
PCC_THIC	29.811	1	29.811	2.433	.122
NBASETYP	31.213	1	31.213	2.548	.113
FLEX_COD	.001	1	.001	.000	.991
LW_CODE	.523	1	.523	.043	.837
RECENTER	4.367	1	4.367	.356	.552
PCC_VAR	3.138	1	3.138	.256	.614
ZONE * DRAINAGE	13.206	3	4.402	.359	.782
ZONE * SUBGRADE	164.712	2	82.356	6.723	.002
ZONE * PCC_THIC	28.099	3	9.366	.765	.516
ZONE * NBASETYP	43.965	3	14.655	1.196	.315
ZONE * FLEX_COD	15.869	3	5.290	.432	.731
ZONE * LW_CODE	42.758	3	14.253	1.163	.327
DRAINAGE * SUBGRADE	2.616	1	2.616	.214	.645
DRAINAGE * PCC_THIC	2.611E-06	1	2.611E-06	.000	1.000
DRAINAGE * NBASETYP	.000	0	.	.	.
DRAINAGE * FLEX_COD	.001	1	.001	.000	.994
DRAINAGE * LW_CODE	.145	1	.145	.012	.913
SUBGRADE * PCC_THIC	.035	1	.035	.003	.958
SUBGRADE * NBASETYP	2.378	1	2.378	.194	.660
SUBGRADE * FLEX_COD	2.266	1	2.266	.185	.668
SUBGRADE * LW_CODE	3.757	1	3.757	.307	.581
PCC_THIC * NBASETYP	26.126	1	26.126	2.133	.147
PCC_THIC * FLEX_COD	3.612	1	3.612	.295	.588
PCC_THIC * LW_CODE	1.490	1	1.490	.122	.728
NBASETYP * FLEX_COD	20.651	1	20.651	1.686	.197
NBASETYP * LW_CODE	15.113	1	15.113	1.234	.269
FLEX_COD * LW_CODE	33.121	1	33.121	2.704	.103
Error	1347.555	110	12.251		
Total	2543.214	153			
Corrected Total	2331.738	152			

a. R Squared = .422 (Adjusted R Squared = .201)

Table 47 Multivariate ANOVA at the state level

Tests of Between-Subjects Effects

Dependent Variable: ZNP

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	23.782[a]	15	1.585	1.939	.032
Intercept	.235	1	.235	.287	.593
DRAINAGE	.832	1	.832	1.018	.316
PCC_THIC	1.981	1	1.981	2.423	.124
NBASETYP	6.399	1	6.399	7.827	.007
FLEX_COD	.140	1	.140	.171	.680
LW_CODE	.562	1	.562	.687	.410
PCC_VAR	.069	1	.069	.085	.771
DRAINAGE * PCC_THIC	.016	1	.016	.019	.890
DRAINAGE * NBASETYP	.000	0	.	.	.
DRAINAGE * FLEX_COD	.093	1	.093	.113	.737
DRAINAGE * LW_CODE	.879	1	.879	1.076	.303
PCC_THIC * NBASETYP	.490	1	.490	.599	.441
PCC_THIC * FLEX_COD	.313	1	.313	.383	.538
PCC_THIC * LW_CODE	1.309	1	1.309	1.601	.210
NBASETYP * FLEX_COD	1.144	1	1.144	1.399	.240
NBASETYP * LW_CODE	3.139	1	3.139	3.840	.054
FLEX_COD * LW_CODE	.288	1	.288	.353	.554
Error	62.951	77	.818		
Total	86.739	93			
Corrected Total	86.733	92			

a. R Squared = .274 (Adjusted R Squared = .133)

Table 48 Effect of Base type on Pumping

Pairwise Comparisons

Dependent Variable: ZNP

(I) NBASETYP	(J) NBASETYP	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
0	1	-.769[*,b]	.201	.000	-1.169	-.369
1	0	.769[*,c]	.201	.000	.369	1.169

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Adjustment for multiple comparisons: Bonferroni.

b. An estimate of the modified population marginal mean (J).

c. An estimate of the modified population marginal mean (I).

Table 48 (cont'd).

Univariate Tests

Dependent Variable: ZNP

	Sum of Squares	df	Mean Square	F	Sig.
Contrast	11.980	1	11.980	14.654	.000
Error	62.951	77	.818		

The F tests the effect of NBASETYP. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

FAULTING

The performance index and the relative performance index were calculated for faulting. Then the univariate and the multivariate analysis were done to identify the factors contributing to the occurrence of faulting.

Performance Index and Relative Performance Index

The overall factor comparisons were done at both the network and the state level to study the effects of various design factors on faulting. From Table 49 and Table 50, it can be inferred that sections constructed on a drainable base perform better, as indicated by the relative performance indices of the sections. For example, consider the effect of base type on faulting for sections located in the DNF zone and on a coarse subgrade. For 8 in. sections with a 12 ft lane width, the DGAB sections had the highest value of relative performance index (1.55) followed by LCB (1.32) and PATB (0.13). The same trends were observed at both the state level as shown in Table 50. For any given state, sections with no drainage and constructed on an 8 in. PCC slab showed higher performance indices, indicating poor performance. For example, consider the state of DE (10). The non-drainable sections had a higher performance index (of 1.09) than the drainable sections (0.91). Also, sections with 8 in. PCC slab thickness had higher performance index (1.43) compared to sections constructed with 11 in. PCC slab, indicating worse performance of the 8 in. thick sections.

Simple Univariate Comparisons for Faulting

The first step is to consider the effect of drainage condition on the occurrence of faulting, ignoring the effects of other variables. This is a comparison of the mean of faulting of cells with no drainage in the matrix, to those with drainage. The statistical comparison is a t-test of the equality of the two means.

Table 49 Overall factor comparisons for faulting at the network level

Zone	Subgrade Type	PCC thickness											
		ND								D			
		DGAB				LCB				PATB			
		12'		14'		12'		14'		12'		14'	
		8"	11"	8"	11"	8"	11"	8"	11"	8"	11"	8"	11"
DF	Coarse	0.95	1.05	1.06	0.94	1.10	0.90	1.28	0.72	0.74	1.26	0.93	1.07
	Fine	X	X	0.86	1.14	1.08	0.92	1.01	0.99	X	X	0.92	1.08
DNF	Coarse	1.03	0.97	1.02	0.98	1.67	0.33	1.73	0.27	0.50	1.50	0.68	1.32
WF	Coarse	1.31	0.69	1.38	0.62	1.59	0.41	1.59	0.41	1.14	0.86	1.56	0.44
	Fine	0.80	1.20	0.99	1.01	1.01	0.99	1.00	1.00	1.11	0.89	1.17	0.83
WNF	Coarse	0.63	1.37	1.47	0.53	0.81	1.19	0.67	1.33	1.10	0.90	0.94	1.06
	Fine	1.04	0.96	1.14	0.86	1.42	0.58	1.48	0.52	0.43	1.57	1.06	0.94

Zone	Subgrade Type	Drainage type							
		8"				11"			
		12'		14'		12'		14'	
		D	ND	D	ND	D	ND	D	ND
DF	Coarse	0.88	1.12	1.10	0.90	1.19	0.81	1.24	0.76
	Fine	0.73	1.27	0.90	1.10	X	X	0.94	1.06
DNF	Coarse	0.17	1.83	0.10	1.90	0.44	1.56	0.17	1.83
WF	Coarse	0.88	1.12	0.82	1.18	1.25	0.75	0.71	1.29
	Fine	0.92	1.08	1.03	0.97	0.71	1.29	0.85	1.15
WNF	Coarse	1.12	0.88	0.88	1.12	0.69	1.31	1.14	0.86
	Fine	0.63	1.37	1.15	0.85	1.45	0.55	1.35	0.65

Zone	Subgrade Type	Base type											
		8"						11"					
		12'			14'			12'			14'		
		D	ND		D	ND		D	ND		D	ND	
		PATB	DGAB	LCB	PATB	DGAB	LCB	PATB	DGAB	LCB	PATB	DGAB	LCB
DF	Coarse	0.84	1.05	1.11	1.14	1.15	0.71	1.24	0.99	0.78	1.43	1.12	0.44
	Fine	X	X	X	0.89	0.92	1.19	X	X	X	0.92	1.07	1.01
DNF	Coarse	0.13	1.55	1.32	0.08	1.92	0.99	0.56	2.07	0.36	0.22	2.57	0.22
WF	Coarse	0.81	0.66	1.52	0.76	1.05	1.19	1.36	0.77	0.87	0.65	1.42	0.93
	Fine	0.90	1.22	0.88	1.04	0.99	0.97	0.64	1.60	0.77	0.81	1.12	1.07
WNF	Coarse	1.15	1.20	0.65	0.85	1.74	0.41	0.62	1.74	0.64	1.20	0.79	1.01
	Fine	0.59	1.36	1.05	1.21	1.01	0.78	1.69	0.97	0.34	1.53	1.08	0.39

Table 50 State level comparisons for faulting

Zone	Subgrade	State ID	Drainage		Base Type			PCC Thickness		Flexural Strength		Lane Width	
			D	ND	DGAB	LCB	PATB	8"	11"	550 psi	900 psi	12'	14'
WF	C	10	0.91	1.09	0.87	1.25	0.89	1.43	0.57	1.04	0.96	1.23	0.77
	F	19	0.83	1.17	1.34	0.87	0.79	1.15	0.85	0.89	1.11	1.09	0.91
	F	20	0.81	1.19	1.24	1.00	0.76	1.02	0.98	1.03	0.97	1.03	0.97
	F	26	0.70	1.30	1.67	0.69	0.64	0.91	1.09	1.10	0.90	1.27	0.73
	F	38	0.88	1.12	1.00	1.15	0.84	0.88	1.12	1.35	0.65	1.21	0.79
	F	39	1.18	0.82	0.84	0.91	1.25	1.41	0.59	0.95	1.05	1.13	0.87
WNF	C	5	0.94	1.06	1.42	0.66	0.92	0.96	1.04	1.16	0.84	0.95	1.05
	F	37	1.19	0.81	1.09	0.63	1.27	1.02	0.98	0.85	1.15	1.04	0.96
DF	F+C	8	1.08	0.92	0.69	1.21	1.11	0.92	1.08	1.07	0.93	1.03	0.97
	F+C	32	0.91	1.09	1.14	0.89	0.97	0.97	1.03	1.00	1.00	0.99	1.01
	C	53	1.01	0.99	1.18	0.81	1.01	1.03	0.97	1.02	0.98	1.14	0.86
DNF	C	4	#N/A	#N/A	#N/A	#N/A	#N/A	0.94	1.06	0.92	1.08	1.03	0.97
	C	6	0.56	1.44	1.87	0.65	0.49	1.50	0.50	0.97	1.03	1.24	0.76

Figure 58 and Table 51 show that sections with no drainage have significantly high levels of faulting than those constructed on a drainable base. However, drainage seems to have no effect on the occurrence of faulting at step 1. (P-value of 0.408 is higher than 0.05 level of significance).

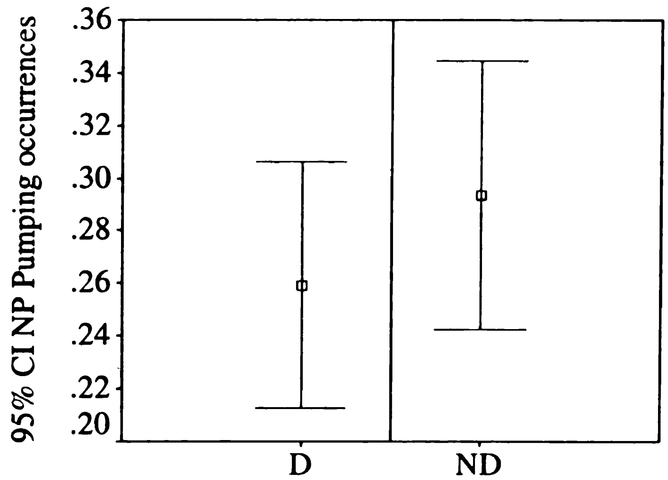


Figure 58 Hypothesis testing – Drainage condition

Table 51 Hypothesis testing – Drainage condition

Tests of Between-Subjects Effects

Dependent Variable: NP

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.037[a]	1	.037	.689	.408
Intercept	9.821	1	9.821	181.105	.000
DRAINAGE	.037	1	.037	.689	.408
Error	7.971	147	.054		
Total	19.902	149			
Corrected Total	8.009	148			

a. R Squared = .005 (Adjusted R Squared = -.002)

The second step considers only the data in columns A-H because the data in that half of the overall matrix belongs to the wet zones in the matrix.

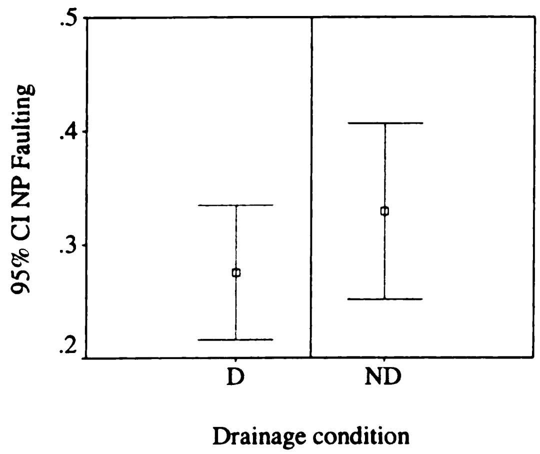


Figure 59 Faulting -Wet Zones

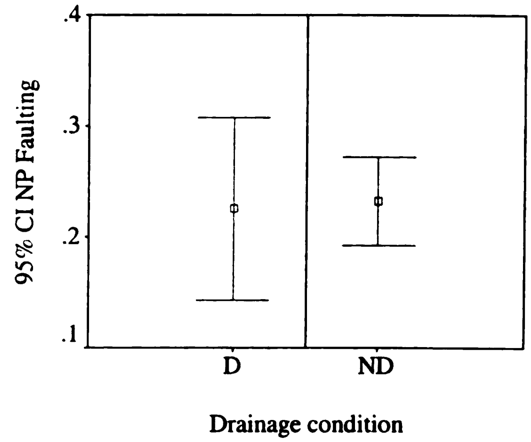


Figure 60 Faulting-Dry Zones

Figure 59 shows that, for sections located in the Wet zones, sections founded on a non-drainable base have higher faulting than those founded on a drainable base. The same test can be repeated for sections located in the dry zones (Figure 60). A similar comparison can also be done for sections located in the Freeze zone (columns A-D and I-L) and No-Freeze (columns E-H and M-P) climates as shown in Figure 61 and Figure 62.

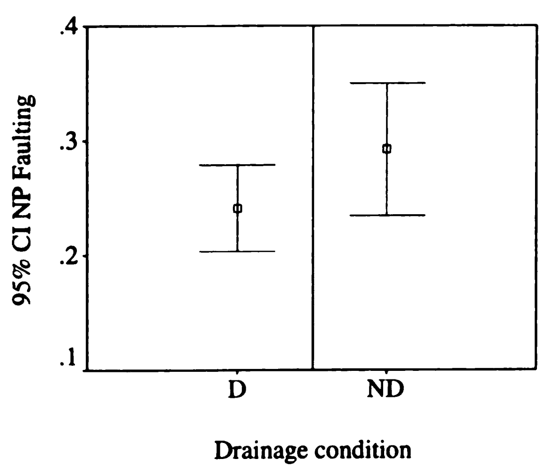


Figure 61 Faulting –Freeze zone

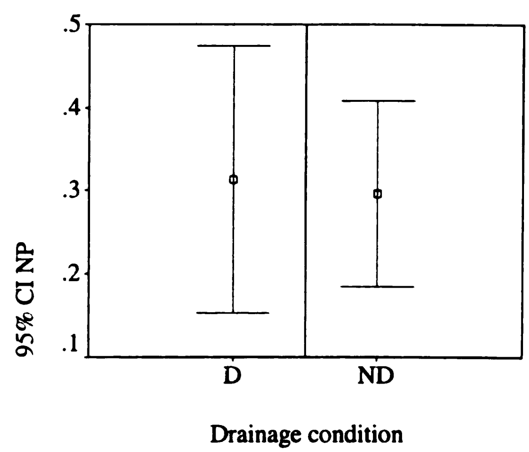


Figure 62 Faulting-Non-freeze zone

Figure 63 shows an example of hypothesis testing (for effect of drainage) considering the various climatic zones separately. Sections located in the wet zones have higher faulting occurrences than the others.

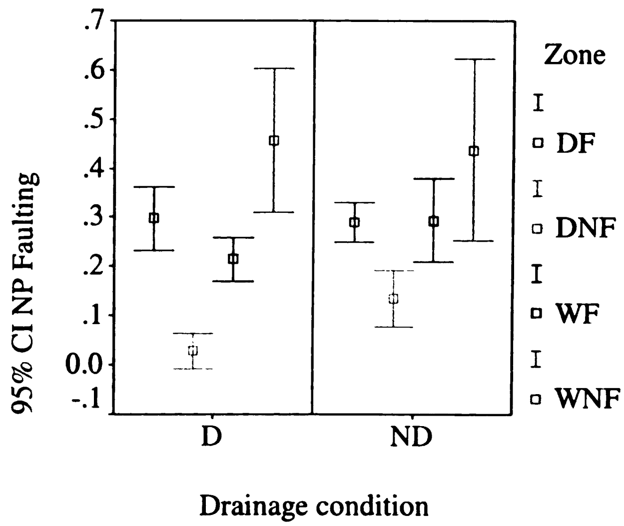


Figure 63 Hypothesis testing for drainage condition by climatic zones

The effect of base type and subgrade type have also been investigated and shown in Figure 64 and Figure 65.

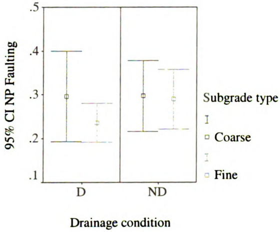


Figure 64 Faulting –Subgrade type

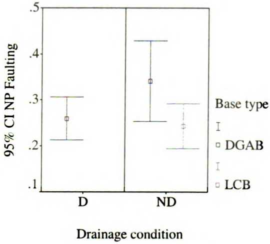


Figure 65 Faulting –Base type

The third step consists of testing the data from columns A-H on the left half of the matrix, which has the effect of controlling the effect of zone=wet-freeze/no-freeze and subgrade conditions=fine/coarse. Figure 66 shows an example of the above hypothesis by subgrade type for sections located in the WF zone. This comparison is repeated for the other three climatic zones with three other similar hypotheses being tested.

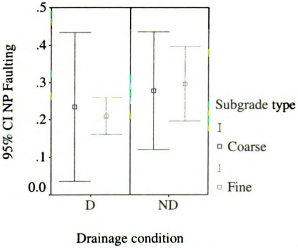


Figure 66 Hypothesis testing for drainage condition by Subgrade type (WF)

These comparisons will basically reveal whether there are differences in the levels of faulting between pavements with and without drainage provision for the various combinations of zone=wet-freeze/no-freeze and subgrade=fine/coarse conditions. It might be noted that there are differences in the base type, lane width, and the drainage type between the two sets of data. Figures B-64 through B-66 show these graphs. It can be concluded from the univariate analysis that sections located in the wet zones with no drainage provision and founded on a coarse subgrade tend to exhibit higher faulting.

Multivariate Analysis for Faulting

The fifth step in the analysis is to consider all the design variables in the multivariate analysis, while treating the effects of traffic and PCC thickness variability as covariates. (It might be noted that the proposed KESALs/ year in Table 14 has been used in this analysis due to non-availability of traffic data). Hence, the multivariate analysis was done at the network level to determine the effects of the various factors and all possible interactions between them. Table 52 shows the multivariate analysis for all SPS-2 sections with the performance index of faulting as the dependant variable. The overall model is significant (P-value of 0.001 is less than 0.05 level of significance) with drainage, base type and climatic zone showing significant contribution to faulting, as indicated by the respective P-value. There also seems to be an interaction of drainage and flexural strength towards faulting.

The state level analysis was done by calculating the z-scores of all the sections (explained before). From Table 53, the overall model is significant with the base type and drainage significantly contributing to the occurrence of faulting. Knowing that the base type and drainage affect faulting, the marginal means were compared at different levels of both the variables as shown in Table 54 and Table 55. From the mean difference, both the factors are significant (at the 0.05 level) at all the levels. As can be seen from Figure 67, there is significant effect of lane width at the 550-psi flexural strength, since the marginal means for both the levels of the lane width are significantly different.

Table 52 Multivariate ANOVA for SPS-2 sections- Faulting

Tests of Between-Subjects Effects

Dependent Variable: NP

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3.654[a]	42	.087	2.113	.001
Intercept	3.726	1	3.726	90.489	.000
DRAINAGE	.174	1	.174	4.225	.042
PCC_THIC	.001	1	.001	.033	.855
FLEX_COD	.019	1	.019	.460	.499
LW_CODE	.004	1	.004	.092	.762
NBASETYP	.304	1	.304	7.383	.008
ZONE	.664	3	.221	5.379	.002
SUBGRADE	.129	1	.129	3.134	.080
RECENTER	.169	1	.169	4.094	.046
V24	.005	1	.005	.121	.728
DRAINAGE * PCC_THIC	.008	1	.008	.202	.654
DRAINAGE * FLEX_COD	.212	1	.212	5.155	.025
DRAINAGE * LW_CODE	.038	1	.038	.921	.340
DRAINAGE * NBASETYP	.000	0	.	.	.
DRAINAGE * ZONE	.088	3	.029	.710	.548
DRAINAGE * SUBGRADE	6.844E-06	1	6.844E-06	.000	.990
PCC_THIC * FLEX_COD	.001	1	.001	.035	.852
PCC_THIC * LW_CODE	.057	1	.057	1.391	.241
PCC_THIC * NBASETYP	.014	1	.014	.334	.564
PCC_THIC * ZONE	.089	3	.030	.724	.540
PCC_THIC * SUBGRADE	.015	1	.015	.372	.544
FLEX_COD * LW_CODE	.083	1	.083	2.027	.158
FLEX_COD * NBASETYP	.116	1	.116	2.825	.096
FLEX_COD * ZONE	.053	3	.018	.426	.735
FLEX_COD * SUBGRADE	.030	1	.030	.737	.393
LW_CODE * NBASETYP	.004	1	.004	.103	.749
LW_CODE * ZONE	.092	3	.031	.744	.528
LW_CODE * SUBGRADE	.001	1	.001	.029	.864
NBASETYP * ZONE	.183	3	.061	1.478	.225
NBASETYP * SUBGRADE	.002	1	.002	.059	.808
ZONE * SUBGRADE	.246	2	.123	2.992	.055
Error	4.282	104	.041		
Total	19.880	147			
Corrected Total	7.936	146			

a. R Squared = .460 (Adjusted R Squared = .243)

Table 53 Multivariate ANOVA at the state level

Tests of Between-Subjects Effects

Dependent Variable: ZNP

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	29.592[a]	15	1.973	2.444	.004
Intercept	.142	1	.142	.175	.676
DRAINAGE	4.618	1	4.618	5.721	.018
PCC_THIC	.413	1	.413	.512	.476
FLEX_COD	.073	1	.073	.090	.765
LW_CODE	1.764	1	1.764	2.185	.142
NBASETYP	8.433	1	8.433	10.448	.002
V24	1.299	1	1.299	1.610	.207
DRAINAGE * PCC_THIC	1.708	1	1.708	2.116	.148
DRAINAGE * FLEX_COD	2.896	1	2.896	3.588	.061
DRAINAGE * LW_CODE	1.194	1	1.194	1.479	.226
DRAINAGE * NBASETYP	.000	0	.	.	.
PCC_THIC * FLEX_COD	.058	1	.058	.071	.790
PCC_THIC * LW_CODE	1.468	1	1.468	1.818	.180
PCC_THIC * NBASETYP	.006	1	.006	.008	.929
FLEX_COD * LW_CODE	3.584	1	3.584	4.440	.037
FLEX_COD * NBASETYP	.055	1	.055	.068	.794
LW_CODE * NBASETYP	.066	1	.066	.082	.775
Error	100.897	125	.807		
Total	130.493	141			
Corrected Total	130.489	140			

a. R Squared = .227 (Adjusted R Squared = .134)

Table 54 Effect of Drainage type on Faulting

Pairwise Comparisons

Dependent Variable: ZNP

(I) DRAINAGE COI	(J) DRAINAGE CO	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
D	ND	-.143[b]	.162	.378	-.464	.178
ND	D	.143[c]	.162	.378	-.178	.464

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

b. An estimate of the modified population marginal mean (I).

c. An estimate of the modified population marginal mean (J).

Univariate Tests

Dependent Variable: ZNP

	Sum of Squares	df	Mean Square	F	Sig.
Contrast	.631	1	.631	.782	.378
Error	100.897	125	.807		

The F tests the effect of DRAINAGE CODE. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

Table 55 Effect of Base type on Faulting

Pairwise Comparisons

Dependent Variable: ZNP

(I) NBASETYP	(J) NBASETYP	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
.00	1.00	.383*,b	.163	.020	.061	.705
1.00	.00	-.383*,c	.163	.020	-.705	-.061

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Adjustment for multiple comparisons: Bonferroni.

b. An estimate of the modified population marginal mean (J).

c. An estimate of the modified population marginal mean (I).

Univariate Tests

Dependent Variable: ZNP

	Sum of Squares	df	Mean Square	F	Sig.
Contrast	4.462	1	4.462	5.528	.020
Error	100.897	125	.807		

The F tests the effect of NBASETYP. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

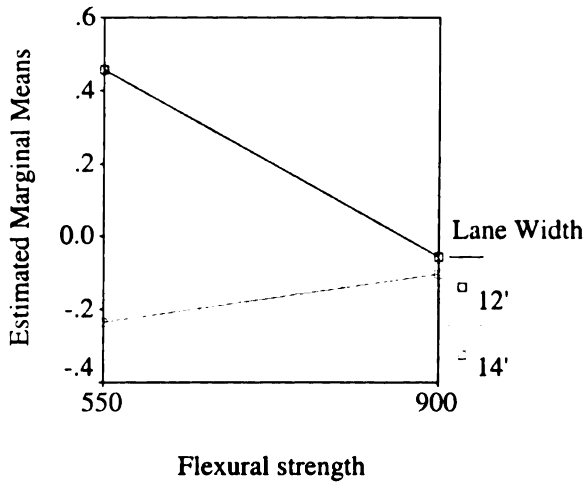


Figure 67 Estimated Marginal means at all levels of flexural strength and lane width

From the statistical analysis, it can be inferred that sections with 8 in. PCC slab, resting on a DGAB and with a 12 ft lane tend to exhibit more number of transverse cracks than the other designs. Sections located in the wet zones with no drainage provision and founded on a coarse subgrade show more number of pumping occurrences. Sections located in the wet zones with no drainage provision and founded on a coarse subgrade tend to exhibit higher faulting. The statistical analysis helped to validate the results obtained from the engineering analysis.

CHAPTER 7

RELATIONSHIP BETWEEN PERFORMANCE AND RESPONSE

This chapter presents the analysis of the response data and the relationship between the performance and response data. The performance of the transverse and the longitudinal joints was studied in terms of load transfer efficiency (LTE), edge support factor and void potential. The midslab deflection data is also analyzed for consistency with time. The relationship between LTE, void potential and edge support factor was also studied to completely understand the performance of the sections.

FWD TESTING

The location of each of the FWD testing is as shown in Figure 68 below (9). The use of the FWD testing done at various locations has been summarized in Table 56.

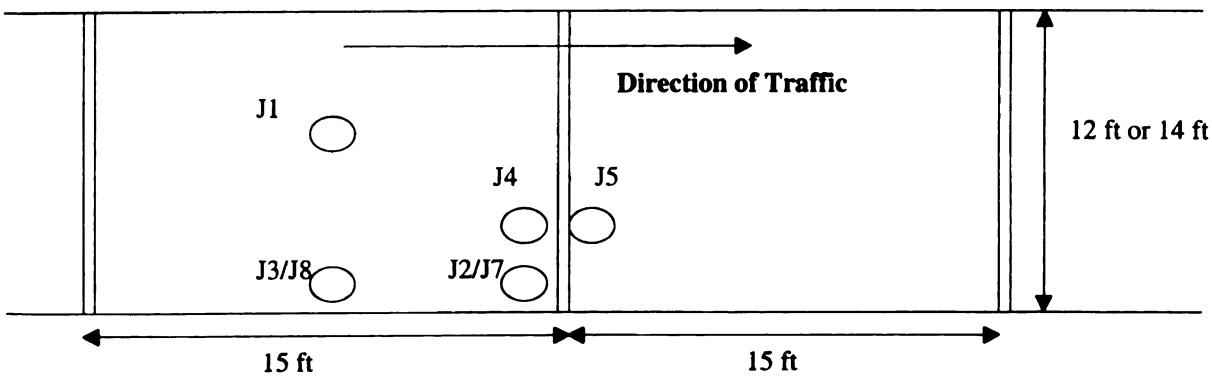


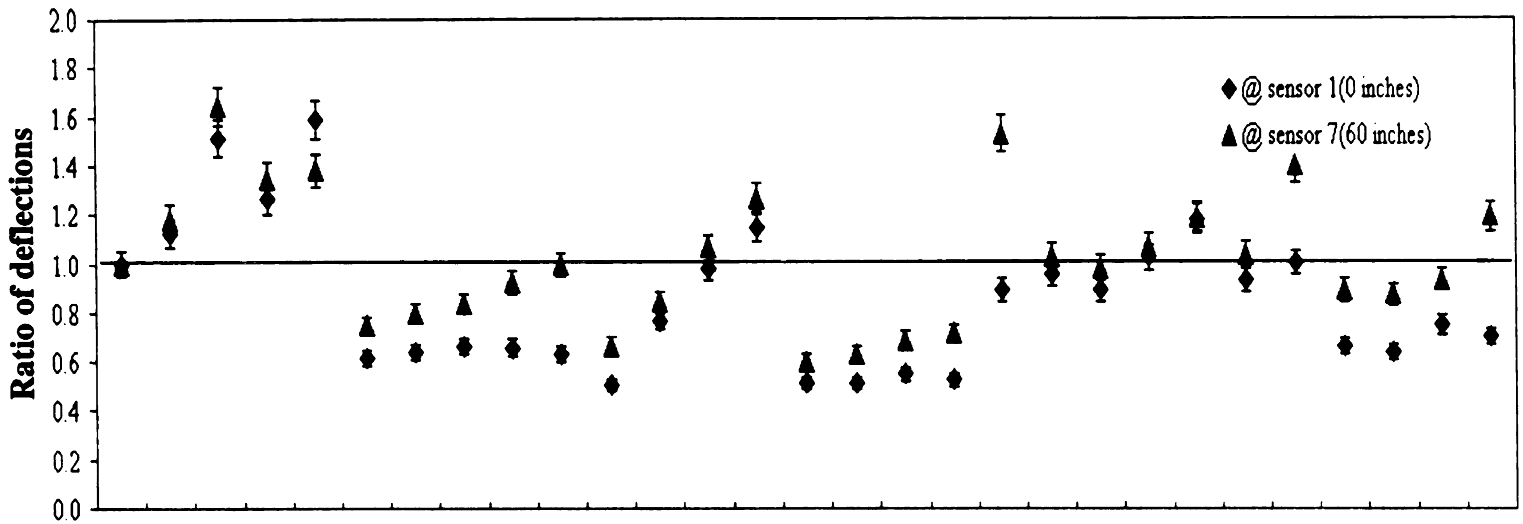
Figure 68 Deflection test location of the pavement slab

Table 56 Use of the FWD data (9)

Lane No.	Location tested	Lane Width	Use of the data
J1	Midslab	For both 12 ft and 14 ft sections	• Used with J3 to compute the D-ratio or the edge support factor • Used to analyze the response of the PCC layer
J2	Corner	For 12 ft wide sections only	• Used to estimate void potential
J3	Edge	For 12 ft wide sections only	• Used with J1 to compute the D-ratio or the edge support factor
J4	Leave Slab	For both 12 ft and 14 ft sections	• Used with J5 to compute LTE
J5	Approach slab	For both 12 ft and14 ft sections	• Used with J4 to compute LTE
J7	Corner	For 14 ft wide sections only	• Used to estimate void potential
J8	Edge	For 14 ft wide sections only	• Used with J1 to compute the D-ratio or the edge support factor

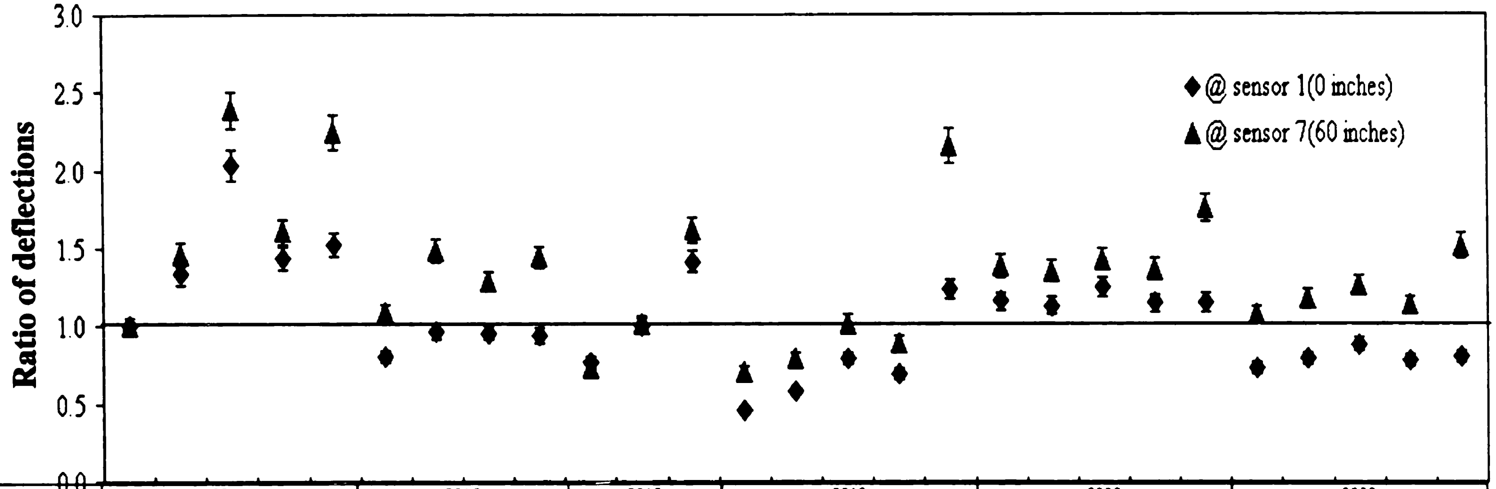
VARIATION OF DEFLECTION DATA WITH TIME

Variation of the midslab deflection data (J1) was analyzed using the deflections at sensors 1 and 7 (at 0 and 60 in. from drop load, respectively) .The example calculations shown are for the state of Michigan, MI (26). Figures 58 and 59 illustrate the midslab deflection data with time for the sections with 12-ft lane and 14-ft lane respectively. The midslab deflection data has been converted and expressed as a ratio with respect to the deflections at the first data point in the data series. For example, within the 12 ft sections, the average deflection at sensor 1 (or sensor 7) for any given section was expressed as a ratio of the average deflection at sensor 1 (or sensor 7) for section 0213 at age 0. Hence the first data point at sensors 1 and 7 are equal to 1. As expected, all the 11-in. sections in general experienced lower deflections than 8-in. sections. Figure 69 shows that the deflection ratios for 0215, 0219 and 0223 are close to 1. This means that the magnitudes of deflections at the 11 in. sections are quite close to the deflections at the 8 in. section (26-0214). Moreover, less variation in the deflection data was observed over time for these 11-in. sections, regardless of thermal curling during the FWD tests. Among the six 8-in sections, less variation in the deflection data over time was observed only in the two PATB sections. The variation in the deflection data in sections 26-0213, 26-0214, and 26-0218 in the latest year indicates low structural capacity, which is supported by the presence of transverse cracking in these sections. Although section 26-0215 has low severity transverse cracking and the FWD testing was done under a positive thermal gradient, less variation in the deflection data was observed in the section because of higher slab thickness of 11 in. Variation in the deflection data in section 26-0217 could be caused by thermal curling of the slab as the deflection test was conducted under high positive thermal gradients. It can also be seen that, regardless of the thermal gradient, the deflections at sensor 7 are quite consistent (since the ratio is close to 1.00) indicating a uniform response of the subgrade with time.



Section ID	0213					0216					0217				0220					0221						0224			
Age of pavement, years	0	1	2	4	5	0	1	2	5	8	0	1	2	4	0	1	2	5	8	0	1	2	4	5	8	0	1	2	8
Surface Temp, °C	8.314	5.2	33.78	16.86	10.28	5.4	0.375	15.02	8.45	23.15	8.678	2.34	23.75	20.92	6.057	6.1	16.24	9.675	30.33	5.043	0.45	21.83	28.82	5.3	22.86	6.55	4.1	33.2	30.34
Temp at the middepth, °C	8.629	4.45	27.05	13.4	8.375	6.1	-0.65	15.72	7.3	20.45	8.811	1.92	19.83	16.36	6.414	3.225	16.1	9.025	23	5.386	-0.35	19.03	26.08	4.3	21.36	6.85	2.45	23.64	27.04
Temp at the bottom of the slab, °C	8.786	3.6	22.98	11.04	8.25	7.243	0.475	16.44	7.55	20.5	8.722	1.94	19.2	14.34	6.843	2.275	16.6	9.875	21.23	5.771	-0.33	18.98	23.08	4.15	19.54	7.433	1.85	20.44	21.06
Temp gradient, °C/mm	0.00	0.01	0.06	0.03	0.01	-0.01	0.00	-0.01	0.01	0.01	0.00	0.00	0.03	0.04	0.00	0.02	0.00	0.00	0.05	0.00	0.00	0.02	0.03	0.01	0.02	0.00	0.01	0.07	0.05

Figure 69 Deflections at sensors 1 and 7 for 14-ft wide sections in MI (26)



Section ID	0214					0215				0218			0219					0222					0223				
Age of pavement, years	0	1	2	5	9	0	1	2	5	0	1	2	0	1	2	5	9	0	1	2	5	8	0	1	2	5	8
Surface Temp, °C	4.06	7.175	36.95	8.133	27.3	6.32	3.325	29.75	13.6	5.1	10.85	25.75	5.267	12.17	32.63	10.93	39.56	6.74	10.03	23.63	13.07	23.23	1.76	8.7	34.53	7.7	20.2
Temp at the middepth, °C	3.94	7.8	32.18	8.6	26.64	6.94	1.775	23.75	12.1	4.68	9.775	24.48	5.083	10.53	26.03	9.8	30.64	4.16	8.533	22.8	11.07	21.87	1.72	5.367	27.2	7.1	20.33
Temp at the bottom of the slab, °C	4.08	8.125	28.28	9.533	26.68	7.44	2.05	22.4	11.1	4.66	8.75	24.58	5.45	8.933	24.1	10.03	27.66	3.84	7.1	23.1	9.767	21.57	2.86	4.467	22.13	6.667	21
Temperature gradient, °C/mm	-0	-0.01	0.049	-0.01	0.003	-0.01	0.007	0.041	0.014	0.002	0.012	0.007	-0	0.018	0.048	0.005	0.067	0.016	0.016	0.003	0.019	0.009	-0.01	0.024	0.07	0.006	-0

Figure 70 Deflections at sensors 1 and 7 for 12-ft wide sections in MI (26)

Figures B-67 through B-92 illustrate the variation in the deflection data for the other 13 states in the SPS-2 experiment. Table 57 below summarizes the observations from these figures.

Table 57 Variation of deflection data with time in the SPS-2 sites

State	Comments
AZ (4)	• PCC o The effect of thermal gradient on the ratio of deflections is inconclusive. All the sections, except 0213 and 0214, have less variability in the ratio of deflections irrespective of their thermal gradients. The ratio of deflections for the 8 in. and the 11 in. sections are close to each other. • Subgrade o Irrespective of the thermal gradient the ratio of deflections at sensor 7 is close to 1.0, except in 0213 and 0214.
AR (5)	o PCC o High variability in the ratio of deflections was observed in the 8 in. sections (5-0214) than the 11 in. sections. The ratio of deflections is close to 1 in the 11 in. sections. The ratio of deflections is 3.0 in 2001, which might be because of the presence of transverse cracking. • Subgrade o Both the DGAB sections, 0214 and 0216, show variability in the J1 deflection data, which could be due to the low stiffness of the DGAB. All the other sections have almost constant deflections at sensor 7. The ratio of deflections at sensor 7 is consistent with time and close to 1, indicating that all sections showed the same deflections at sensor 7. This indicates consistency in subgrade response.
CA (6)	o PCC o Variability in the ratio of deflections at sensor 1 was observed in almost all the sections except for sections 0211 and 0212. This variability might be attributed to the transverse cracking in these sections. Cracks of all severities manifested, 2 years after the pavement was opened to traffic. The effect of thermal gradient on the deflections is inconclusive. • Subgrade o No significant variability in the deflections at sensor 7 was observed in any of the sections.

Table 57 (cont'd).

State	Comments

CO (8)	• PCC
	  o Variability in the ratio of deflections was observed in sections 0213 and 0214 (both 8 in. sections). The variability might be attributed to the positive thermal gradient.
	• Subgrade
	  o Except for the sections 0213, 0214, and 0217 all the other sections showed no significant variability in the values of the ratio of deflections. The positive thermal gradient in the section 0217 could be the reason for the behavior.

DE (10)	o PCC
	  o Sections 0201, 0202, 0204, 0205 and 0210 showed variability in the ratio of deflections at sensor 1. Low stiffness of DGAB could be a cause for the behavior of the 0201,0202 and 0204. The variations in the deflection ratios in section 0205 can be due to the transverse cracks in the section.
	• Subgrade
	  o Sections 0201 and 0202 showed high variability in the ratio of deflections at sensor 7. This could be due to the fact that the sections are constructed on DGAB, are 8 in. thick and a positive thermal gradient. The other sections showed less variability in the deflection ratios.

IA (19)	o PCC
	  o Ratio of deflections was very low in the 11 in. sections than in the 8 in. sections. The ratio of deflections is decreasing with time for the 8 in. thick slab sections 0213 and 0214. This could be attributed to the stiffness of the DGAB layers. The decrease in the ratio for section 0217 could be due to the transverse cracks. Also, this section was constructed 0.3" thinner than its target thickness. High variability in ratio of deflections at sensor 1 were observed in section 0221, which could be because of the high positive thermal gradient at the time of FWD testing.
	• Subgrade
	  o Subgrade response has been consistent with time.

Table 57 (cont'd).

State	Comments

KS (20)	o PCC
	    o Ratio of deflections is low for 11 in. sections as the deflections at the 8 in. section are high. However, the ratio of deflections is constant for 11 in. sections.
	    o Variability in sections 0201 and 0202 could be due to the design of the sections (8 in. PCC slab), high positive thermal gradient at the time of FWD testing, and transverse cracks in these sections. Also these sections did not meet the target thickness requirements. The variability in the other sections could be due to the positive thermal gradient at the time of FWD testing.
	• Subgrade
	    o No significant variability in the ratio of deflection data at sensor 7 was observed in any of the sections.

NV (32)	o PCC
	    o 0201 and 0202 have shown significant variability in the ratio of deflections at sensor 1 which may be because of the extensive cracking in these sections. Several problems encountered during construction (refer to table A-1 in Appendix A) and high positive thermal gradient also might have contributed to the variability.
	• Subgrade
	    o Fairly constant deflection ratios were observed at sensor 7 for all the sections regardless of age and temperature at the time of FWD testing.

NC (37)	• PCC
	    o Variability in the ratio of the deflections was observed in sections 0201,0202, 0205, and 0210. Variability in sections 0201,0205 and 0210 could be due to the transverse cracking in these sections. The slope failure that occurred in 0210 (according to the construction report) also might have contributed to the variability in the deflections at sensor 1. Variability in 0202 could be due to the positive thermal gradient at the time of FWD testing.
	• Subgrade
	    o Slight variability in the ratio of deflections at sensor 7 were observed in sections 0202 and 0203

Table 57 (cont'd).

State	Comments
ND (38)	• PCC o Sections 0213, 0214, 0217, and 0221 showed variability in the ratio of deflections. The transverse cracking and reflection cracking in the 0217 section could be one of the reasons for the variability. Variability in all these sections could also be due to the positive thermal gradient, with the deflections increasing with an increase in the thermal gradient. • Subgrade o Variability was observed only in sections 0213 and 0214 (8 in. sections resting on a DGAB layer), which could be due to the low stiffness of the DGAB layers. No significant variability was observed in the other sections.
OH (39)	• PCC o Sections 0201, 0202, 0205 and 0209 have shown variability in the ratio of deflections at sensor 1. Transverse cracking in 0202 and 0205 together with a high positive thermal gradient could be the cause of the variability in these sections. Very high positive thermal gradients at the time of testing could be the causes of variability in sections 0201 and 0209. • Subgrade o Variability in the ratio of deflections was found in the same sections identified above.
WA (53)	• PCC o Sections 0201, 0202, 0209, 0206, and 0210 have shown variability in the ratio of deflection data. The transverse cracking in 0201, 0202, 0206, and 0210 could be the reasons for variability in these sections. Shrinkage cracks also manifested in section 0206. Surface voids also occurred on the slabs and bleeding occurred in the base and subbase courses. • Subgrade o Almost all sections showed consistency in the ratio of the deflection data at sensor 7.

Table 57 (cont'd).

State	Comments

WI (55)	• PCC
	  o Sections 0213, 0214, and 0222 have shown inconsistency in the ratio of deflections. This could be due to the 8 in. slab thickness. In 0213 and 0214 it may also be due to the DGAB layer and high temperature gradients. Excessively high deflections at sensor 1 in sections 0222 could be due to the high positive thermal gradient
	• Subgrade
	  o The same sections identified above showed variability in the ratio of deflections at sensor 7.

TRANSVERSE JOINT PERFORMANCE EVALUATION

Besides faulting, the performance of transverse joints is evaluated through the following factors:

- Load transfer efficiency and total deflection (or sum of deflections, SD)
- Void potential
- D-ratio or the Edge support factor

Load transfer efficiency and Sum of deflections (SD)

The load transfer efficiency is defined as the ratio of the deflections of the unloaded slab to the deflections of the loaded slab as shown below (9):

$$LTE = \frac{\delta_{UL}}{\delta_L} X\ 100$$

As shown in Figure 68 and Table 56, the deflection data obtained from the J4 and J5 testing will be used to evaluate the performance of the transverse joint. The parameters of interest in J4 and J5 are defined in Table 58 and Figure 71.

Table 58 Deflection parameters in J4 and J5

J4	Loaded slab deflection: D1
	Unloaded slab deflection: D3
J5	Loaded slab deflection: D1
	Unloaded slab deflection: D2

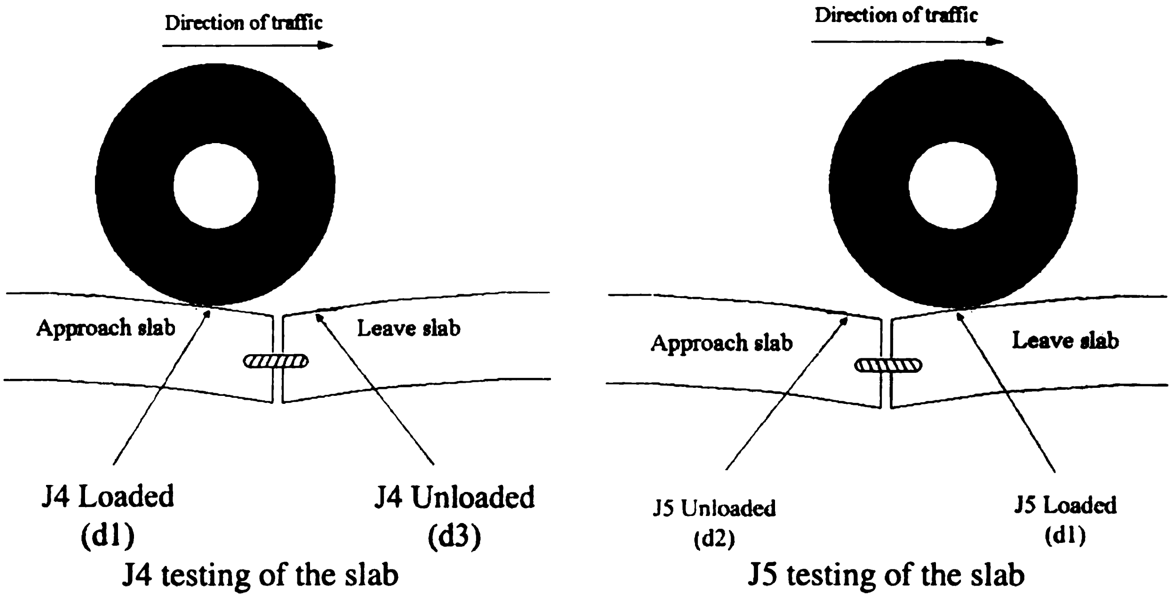


Figure 71 Definition of J4 and J5 tests

The performance of a joint is unsatisfactory under one of the following circumstances:

- *Problems under the approach slab:* These problems can be identified by the loaded deflection (d1) from J4 and unloaded deflection (d2) from J5. If the magnitudes of these deflections are high, then it indicates that there is a possibility of non-uniform support under the approach slab.
- *Problems under the leave slab:* These problems can be identified by the unloaded deflection (d3) from J4 and loaded deflection (d1) from J5. If the magnitudes of these deflections are high, then it indicates that there is a possibility of non-uniform support under the leave slab.

Figure 73 through Figure 76 show the magnitudes of deflections for the loaded and the unloaded slab at various locations for section 26-0214 in MI (26). Table 59 below shows the deflections of the loaded and the unloaded slab at 18 ft (5.2 m) from the start of the section.

Table 59 J4 and J5 deflections at 18 ft (5.2 m) in 26-0214 for the year 1998

	Approach Slab	Leave Slab
J4	600 microns (24 mils)	450 microns (18 mils)
J5	500 microns (20 mils)	650 microns (26 mils)

High deflections on the loaded and the unloaded side of the joint on both the approach and the leave side indicate a poor performance of the joint. Also, the faulting data indicates that there is a faulting of 6mm at this location, indicating that the joint is deteriorating with time.

RELATIONSHIP BETWEEN SUM OF DEFLECTIONS (SD) AND LOAD TRANSFER EFFICIENCY (LTE)

Realizing the importance of the magnitudes of deflections on either side of the joint, Guo (2001) (10) suggested that the sum of deflections (SD) on the two sides of the joint be used in transverse joint performance evaluation. Guo and Marsey (2001) found that the SDs remain almost constant on both the sides of the joint although the corresponding LTEs were found to be significantly different.

From Table 59 above, the sum of deflections can be calculated as:

Table 60 Sum of deflections at 18 ft (5.2 m) in 26-0214

	Approach Slab	Leave Slab	SD
J4	600 microns (24mils)	450 microns (18 mils)	1050 microns (42 mils)
J5	500 microns (20 mils)	650 microns (26 mils)	1150 microns (46 mils)

The SDs and the LTE values on both the sides of the joint are almost the same within a given year. Not significant variations were found in the LTEs or the SD values for J4 and

J5. The SDs on both the approach and the leave slab are almost constant at a given point location.

Traditionally, the performance of transverse joints is evaluated based on the value of load transfer efficiency (LTE), calculated through the ratio of the deflection of the unloaded slab to the loaded slab during the deflection tests run at the approach slab (J4) and leave slab (J5). Considering the example shown in Table 60 above, the LTE values at that location are calculated as shown in Table 61 below:

Table 61 LTE at 18ft (5.2 m) in 26-0214

	Approach Slab	Leave Slab	LTE
J4	d1 = 600 microns (24 mils)	d3 = 450 microns (18 mils)	450/600 = 75 %
J5	d2 = 500 microns (20 mils)	d1 = 650 microns (26 mils)	500/650 = 77 %

Even though the joint has an average LTE of 76%, the magnitudes of the individual deflections, and hence the value of SD is significantly high. Also, the joint has a faulting of 6mm. Hence even though the LTE value is good, the SD values indicate a poor performing joint with a faulting of 6 mm. Hence, the LTE value alone does not necessarily reflect the performance of the transverse joint. The magnitude of deflections on both the loaded and unloaded sides of the joint should also be considered in addition to the LTE value to evaluate the performance of the transverse joint. Table 62 below shows another example from the state of AZ (4) at point location 180 ft (53.9 m)

Table 62 SDs and LTEs at 180 ft (53.9 m) in 4-0214

	Approach Slab	Leave Slab	SD	LTE
J4	dl = 538 microns (22 mils)	d3 = 458 microns (18 mils)	996 microns (40 mils)	458/538 = 85 %
J5	d2 = 460 microns (23 mils)	dl = 562 microns (18 mils)	1022 microns (41 mils)	460/562 = 82 %

Even though the average value of LTE is 83.5 %, the magnitudes of deflections and hence the SD values are significantly high indicating the poor performance of the joint. Hence SD needs to be used in conjunction with the LTE values to completely understand the performance of the transverse joint.

An example of LTE and SD using MI (26) data

Consider the example of SPS-2 sections located in MI (26). It was observed that the LTE values could be ranked from highest to lowest in the order of LCB, PATB to DGAB sections, respectively. Sections 26-0213 and 26-0215 were found to have relatively low LTE values (≤ 50%). As illustrated in Figure 72, the significant decrease in the LTE values in sections 26-0213 and 26-0215 from about 90% in 1993 to less than 50% in 1998 could be explained by high deflections at the joints as there was no evidence of thermal curling or high distress levels (only one high severity transverse crack was observed).

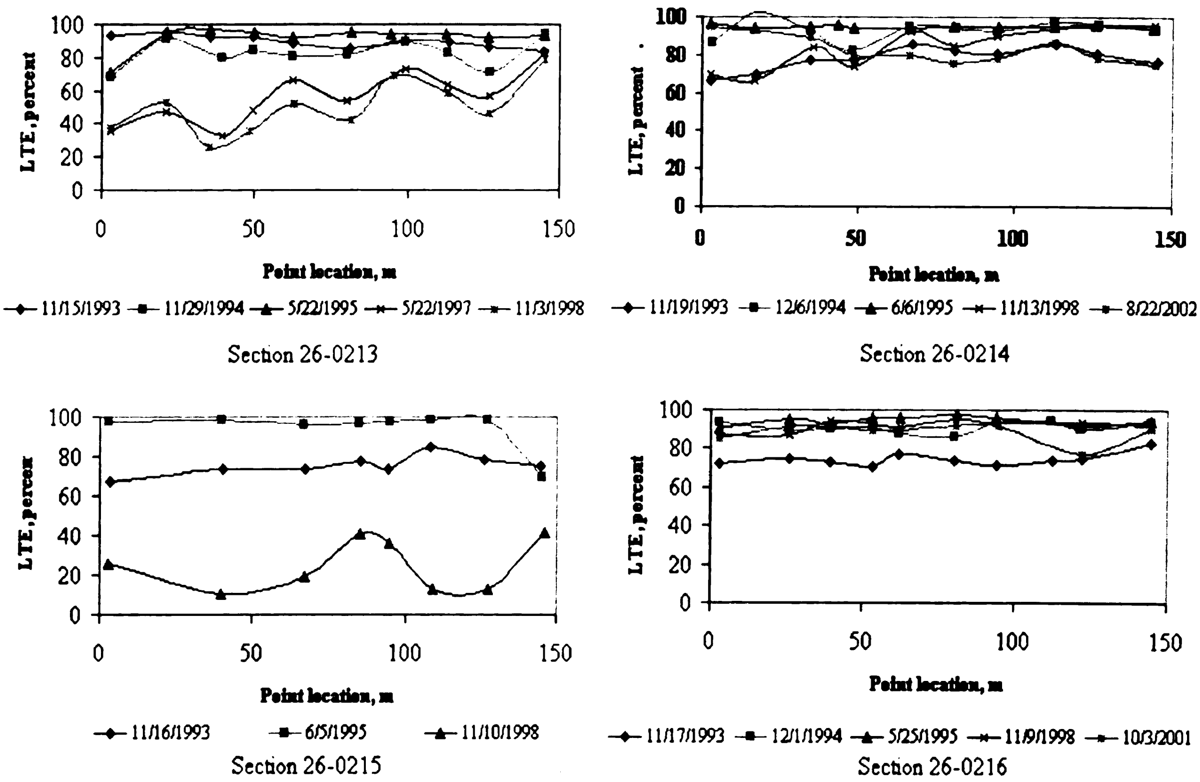


Figure 72 LTE for DGAB sections in MI SPS-2 sites

As observed from section 26-0214, such high LTE values resulted from high deflections (300 to 600 □m) on the loaded and unloaded sides as illustrated in Figures 62 through 65, indicating a poor performance of the joint. Note that transverse joints in section 26-0216 were found to have good performance, indicated by high LTE values (70 to 90%) along with low deflections at the joints (< 200 µm). One explanation for this could be the combination of 11-in. PCC slab, 14-ft lane, and 1.5-in. dowel bar for the section. A lower LTE on the approach side of the joint at several point locations, especially at location 10.2 ft in section 26-0213, is caused by relatively high loaded deflection (about 1,500 µm) on the approach side of the joint. One explanation could be that faulting began on the approach side of the joint. Note that thermal gradient has a significant impact on the deflection test results, also including LTE. Not only was a high positive thermal gradient found to result in low void potential, but it was also found to result in high LTE due to slab downward curling. The opposite trend was observed for negative thermal gradient.

To investigate the impact of base type on performance of the transverse joint, three pavement sections with the same design except for the base type (sections 26-0215, 26-0219, and 26-0223) were chosen for comparison as illustrated in Figure 77. It can be seen that the values of LTE (J4) from the PATB and LCB sections are higher than those observed from the DGAB section, while there was no significant difference among the values of LTE (J5) observed from the three sections. However, since the magnitudes of the deflections in these two sections were lower, it is clear that the transverse joints in the LCB and PATB sections performed better than those in the DGAB section. As mentioned before that the SD values are highly related to the curling of the slab, it is important to eliminate the impact of thermal gradient to study the impact of base type on the performance of the transverse joint. Hence, in this comparison, the deflections at approximately zero thermal gradients were used.

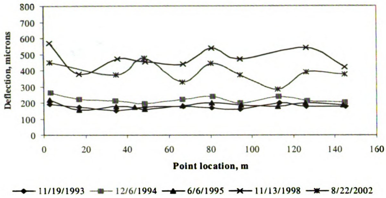


Figure 73 Deflections on the loaded side of the approach slab for section 26-0214

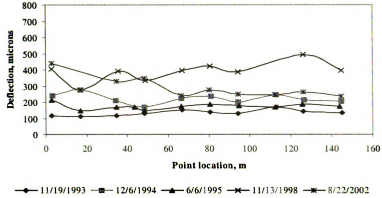


Figure 74 Deflections on the unloaded side of the approach slab for section 26-0214

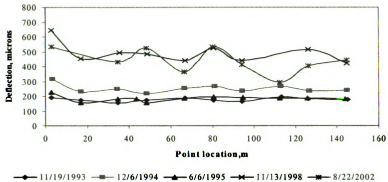


Figure 75 Deflections on the loaded side of the leave slab for section 26-0214

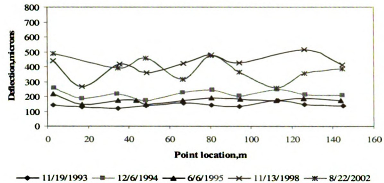


Figure 76 Deflections on the unloaded side of the leave slab for section 26-0214

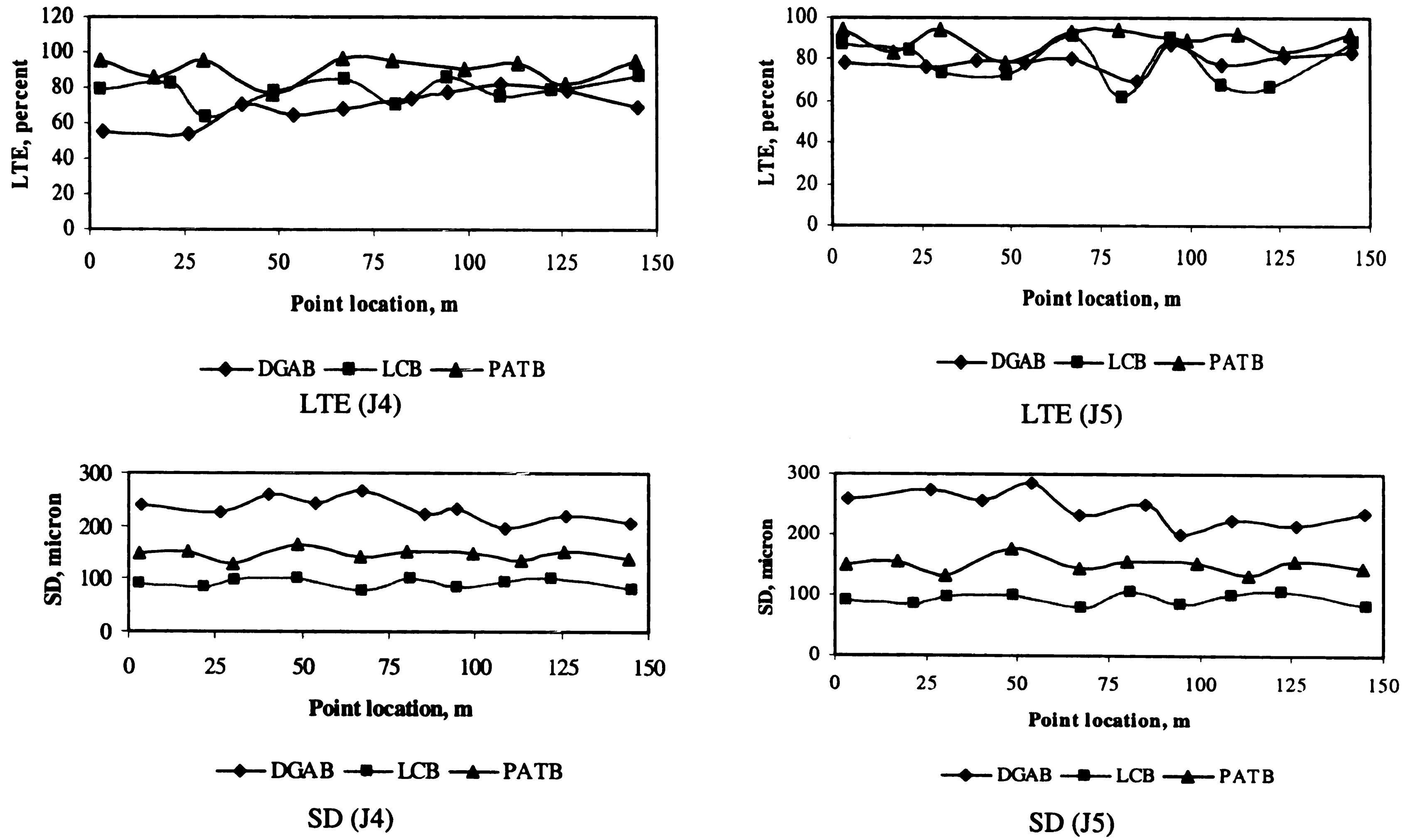


Figure 77 Impact of base type on transverse joint performance in MI SPS-2 sites

Figures B-93 through B-105 illustrate the effect of base type on the transverse joint performance for the other SPS-2 sites. Table 63 summarizes the effect of base type on transverse joint performance for all the SPS-2 sites.

Table 63 Effect of base type on transverse joint performance for SPS-2 sites

State	Comments
AZ (4)	• LTE o Most of the joints in the PATB sections have the least LTE among the base types at both J4 and J5. However, LTEs range from 60-90% • SD o SD (J4) and SD (J5) at the joints in all the base types are close to each other and are not high. PATB sections have the least SDs while the LCB sections have the highest SDs. Even though LTE values at both J4 and J5 are close to each other, SDs for the LCB sections are relatively much higher.
AR (5)	• LTE o LCB sections have the least LTE at both J4 and J5 • SD o SD (J4) and SD (J5) at the joints in all the base types are close to each other and are not high. Low LTE and high SD at J4, and, low LTE and medium SD at J5 in the LCB section may indicate problems in the approach side of the joint
CA (6)	• LTE o LTE for all the three base types are close to each other. • SD o SDs, in general, are ranked from high to low in the order of PATB, DGAB and LCB sections. Even though the LTE values are close to each other, the SD values at the PATB joints are almost double to that of LCB sections. LTE and SD values at J4 and J5 are close to each other.
CO (8)	• LTE o LTE for all the three base types are close to each other. • SD o SDs at most of the PATB joints are highest. Even though the LTE values are close to each other, the SD values at the PATB joints higher than that those at the joints in the other sections. LTE and SD values at J4 and J5 are close to each other.

Table 63 (cont'd).

State	Comments
DE (10)	• LTE o LTE for all the three base types are quite close to each other. • SD o SDs at most of the PATB joints is highest. Even though the LTE values are close to each other, the SD values at the PATB joints higher than that those at the joints in the other sections. LTE and SD values at J4 and J5 are close to each other.
IA (19)	• LTE o LTEs for the PATB sections are slightly lower than those in the other base types. • SD o SDs at the DGAB joints are highest Even though the SDs are relatively higher in the DGAB sections, the LTE values are not significantly different from those of the other base types. LTE and SD values at J4 and J5 are close to each other.
KS (20)	• LTE o Most of the DGAB joints have the least LTE at J4, while most of the LCB joints have the least LTE at J5 • SD o SD values for the DGAB joints are highest. High SDs at J4 together with low LTEs at J4 may indicate problems at the approach side of the joint. However, high LTE values at J5 are observed inspite of the relatively high SDs at J5 in DGAB sections.
NV (32)	• LTE o Most of the joints in the LCB sections have the least LTE • SD o PATB joints have the highest LTE Joints in all the sections are performing reasonably well. LTE and SD values at J4 and J5 are close to each other.
NC (37)	• LTE o LTEs of most of the LCB joints are low • SD o LCB joints have the highest SD values. The above observations indicate that the LCB joints have shown relatively poor performance.
ND (38)	• LTE o Most of the LCB joints have the least LTE values • SD o Most of the LCB joints have the highest SD values The above observations indicate that the LCB joints are performing relatively worse than the other sections.

Table 63 (cont'd).

State	Comments
OH (39)	• LTE o LTE values at all the joints in all the sections are close to each other • SD o SD values at the DGAB joints are highest. Even though the LTE values are close to each other, the SDs values indicate that the LCB sections are the worst performing sections.
WA (53)	• LTE o Most of the PATB joints have the least LTE values • SD o DGAB joints have relatively much higher SDs than the other sections. The SD values for most of the DGAB joints are more than 4 times than those of the other sections. Even though most of the DGAB sections have the highest LTE values, the outstandingly high SD values indicate poorly performing joints.
WI (55)	• LTE o LTE values of the joints in all the base types are close to each other • SD o SD values at the joints in all the base types are reasonably low. The above observations indicate that all the joints are performing satisfactorily.

RELATIONSHIP BETWEEN LTE, VOID POTENTIAL AND D-RATIO

This section deals with evaluating the pavement sections in terms of the various response parameters like load transfer efficiency (LTE), void potential (VP) and D-ratio. It was deemed necessary to analyze these parameters together because the occurrence of one parameter is affected by one or both of the other parameters.

The corner deflection data (J2 for 12-ft lanes and J7 for 14-ft lanes) is used in void potential (VP) analysis to assess the potential loss of support near the slab corner. The FWD loading is graphed with the peak deflection and the intercept of the line on the deflection axis is noted. As suggested by Darter et al (11), a threshold value of 50 □m has been used in the analysis. Note that the positive results from void potential analysis do not necessarily ensure the presence of the voids, since the high corner deflections could also occur due to thermal curling of the slab. We know that a positive thermal gradient (slab surface is warmer than the bottom) will cause the slab to curl downward, while a negative thermal gradient will cause the slab to curl upward, which could be associated with the loss of support of the slab.

D-ratio is a measure of the performance of the lateral support, calculated through the ratio of the peak deflection at the edge of the slab (J3 or J8) to the peak deflection at the center of the slab (J1) as shown below (9):

$$D-ratio = \frac{\delta 1\,(J3\;or\;J8)}{\delta 1\,(J1)}$$

Consider the example of SPS-2 test sections located in MI (26). Figure 78 shows the LTE, VP and D-ratio for 26-0213 using the latest year of FWD data available. The X-axis shows the LTE (in the increasing order) at various point locations indicated below the scale. The Y-axes represent the void potential and the D-ratio respectively. A horizontal line is drawn at the threshold value for void potential (50 to 70 microns).

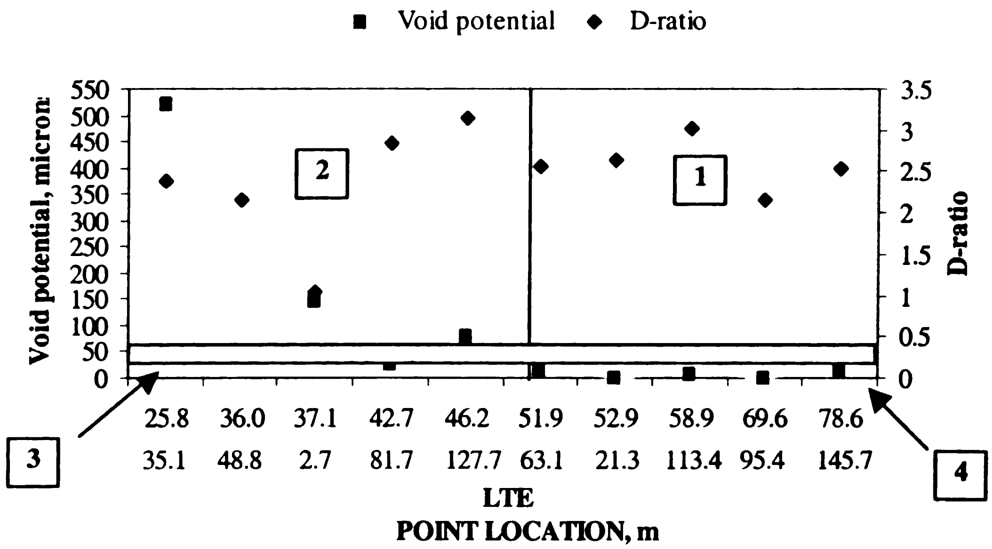


Figure 78 LTE, VP and D-ratio in 26-0213 for the latest year

5 out of the 10 joints at which the FWD measurements were done have LTE values >50%. The deflections on both the unloaded and the loaded side at these locations (21.3m, 63.1m, 95.4m, 113.4m and 145.7m) are low as shown in Figure 79 through Figure 82. Also none of the locations showed any potential for voids as the intercept on the deflection axis is less than the threshold values. However, high D-ratios (>2) were recorded at all these joints. High D-ratios at these locations are because of the high deflections at the edges as shown in Figure 83 and Figure 84. Also, high deflections on the edge could be attributed to the fact that the sections have an AC shoulder.

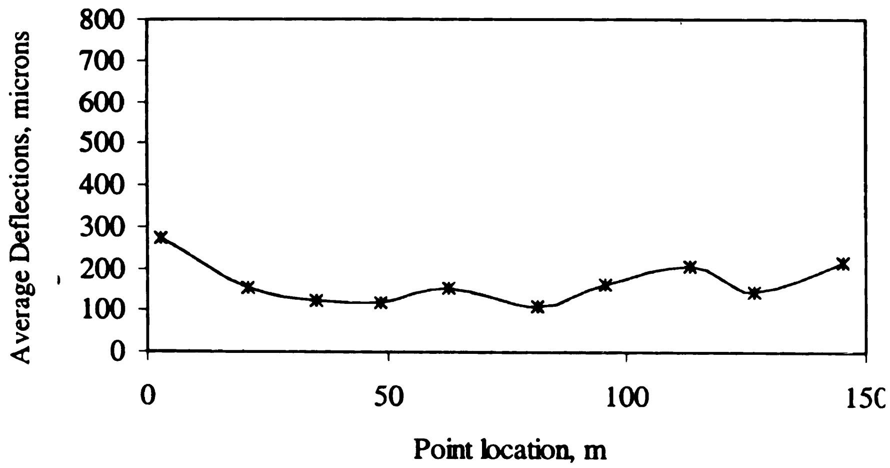


Figure 79 Deflections on the unloaded side for 26-0213 (J4 unloaded)

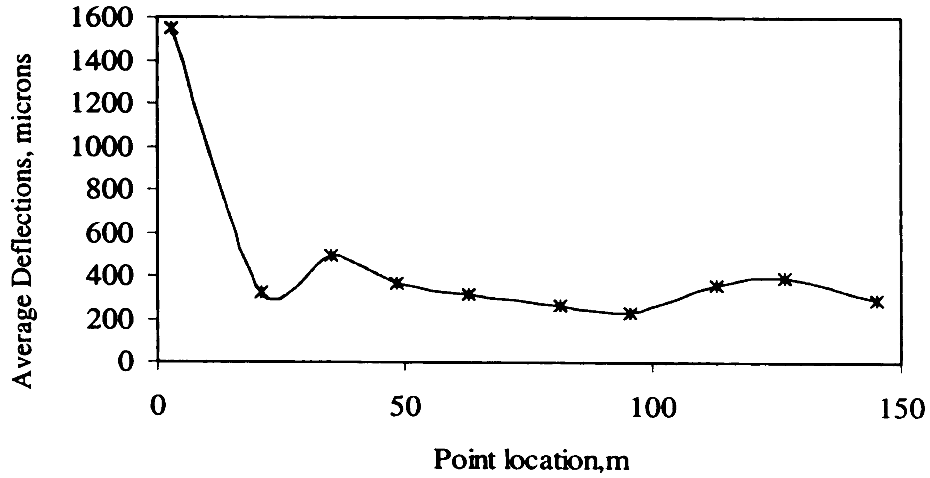


Figure 80 Deflections on the loaded side for 26-0213 (J4 loaded)

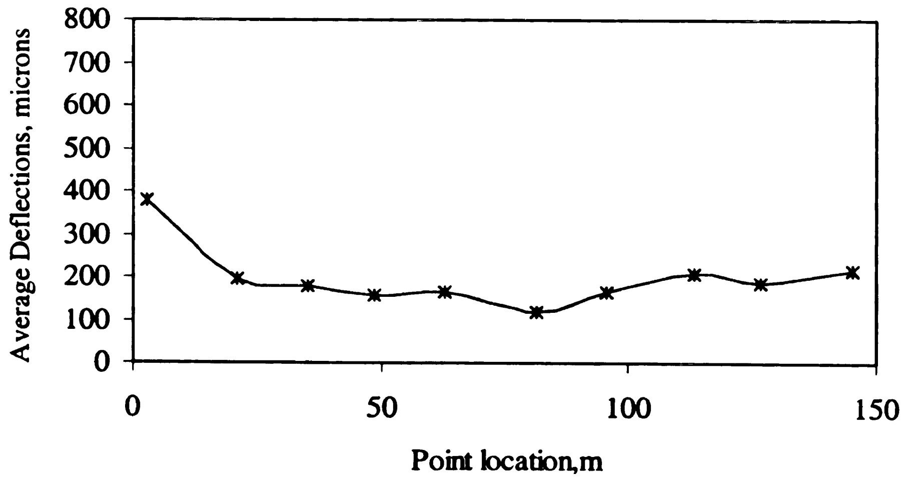


Figure 81 Deflections on the unloaded side for 26-0213 (J5 unloaded)

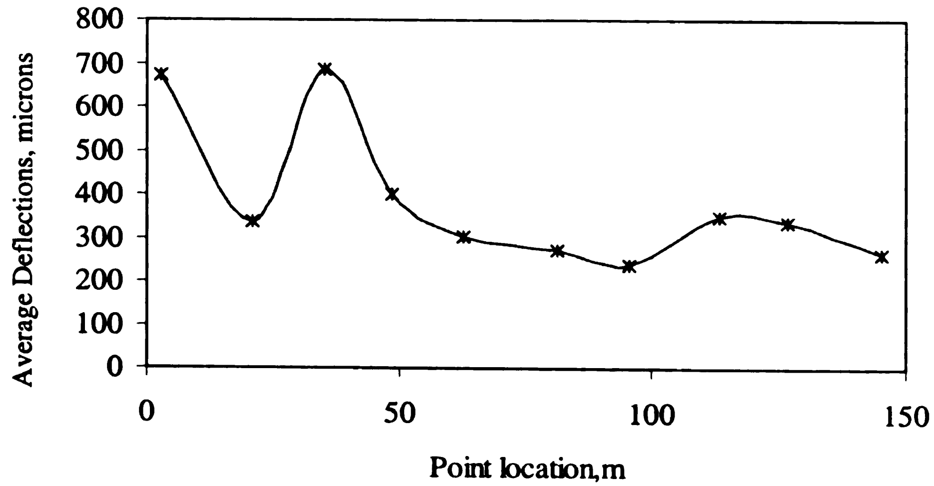


Figure 82 Deflections on the loaded side for 26-0213 (J5 loaded)

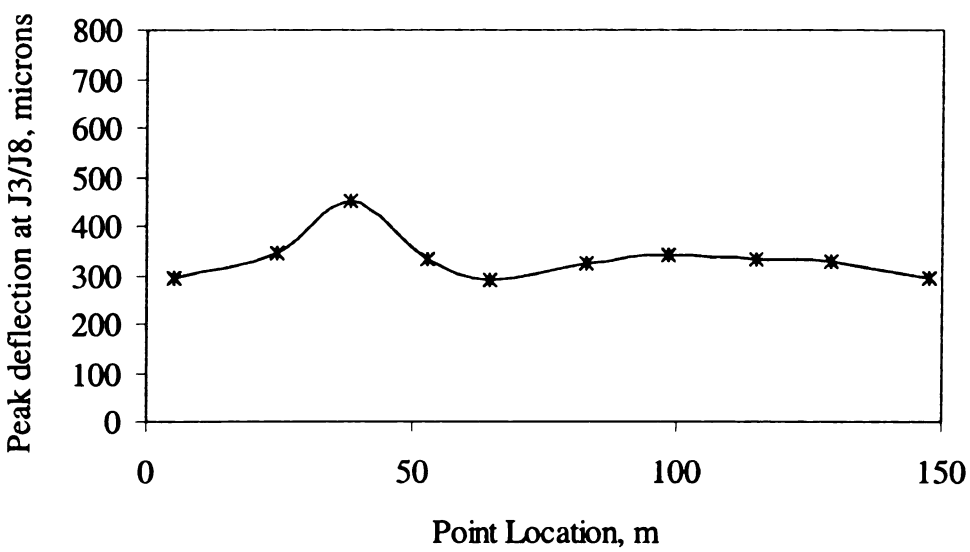


Figure 83 Peak deflection at the edge of the slab

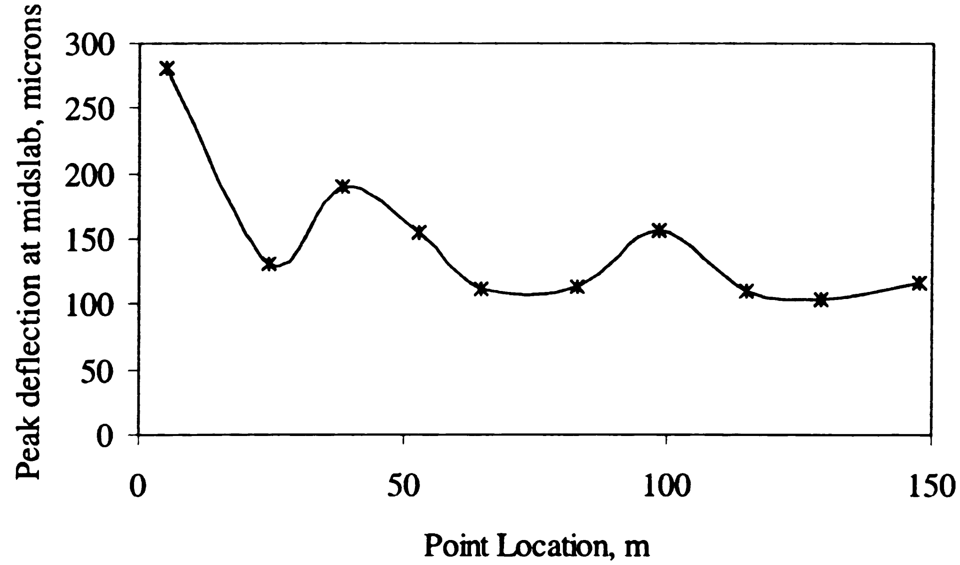


Figure 84 Peak deflection at the center of the slab

Low LTEs at the joints (2.7m, 35.1m, 48.8m, 81.7m and 127.7m) are because of the excessively high deflections on the loaded side of the joint as shown in Figure 79 through Figure 82. Void potential was detected at 2.7m and 35.1m. Even though the joint had a D-ratio of 1, the occurrence of voids at 2.7m could be because of the fact that the joint experienced excessively high deflections on the loaded side of the joint and low LTEs as shown in Figure 80 and Figure 82. Void potential at 35.1m could be due to the extremely low load transfer efficiencies and high D-ratio (>2.00). High D-ratio at this location could be because of the high edge deflections at the joints, which could be attributed to the provision of an AC shoulder. However, void potential was not observed at the other three locations. This could be because of the fact that even though the LTE values are low, the magnitudes of deflections are very low. However high D-ratios at these locations could be because of the high deflections at the edges.

Based on the deflection data available, void potential is also found in sections 26-0214,26-0215, 26-0218 and 26-0222. It can be observed that out of the three base types, the DGAB sections have a higher potential for voids followed by PATB and LCB. Void potential was exhibited in 2 out of the 4 PATB sections. Effect of slab thermal curling could explain the void potential in section 26-0223, but not for section 26-0222. This is because the deflection test was done under a positive thermal gradient for section 26-0222, while section 26-0223 experienced negative thermal gradient. The VP in section 26-0222 could be explained by the low LTE at the transverse joints, supported by the design features of the sections. (8 in. thick and 1.25 in dowel diameter). Excessively low LTEs (<50%) in sections 0215 and 0222 are because of the high deflections at the joints.

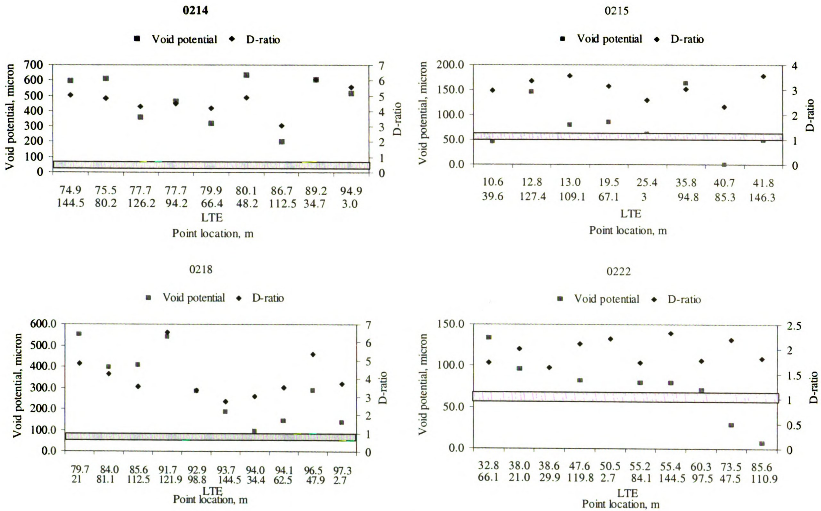


Figure 85 LTE, VP and D-ratio for the other SPS-2 sections in MI (26)

It was observed that DGAB sections were found to have relatively higher D-ratio than the other sections, indicating that DGAB layers do not provide as good of a lateral support as the other base types. One explanation could be that the DGAB layer is less stiff than LCB and PATB, hence providing lesser shear transfer across the longitudinal joint than LCB and PATB. Figure 86 illustrates the shear transfer across the longitudinal joint provided by the base layer.

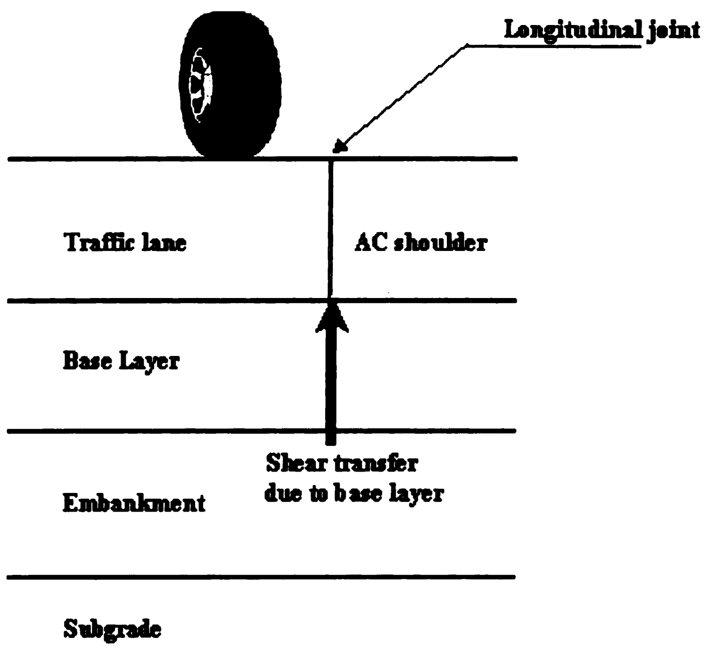


Figure 86 Illustration of the shear transfer across the longitudinal joint

Within the DGAB sections, it can be observed that sections 26-0214 and 26-0215 have relatively higher D-ratio than the other two sections. This could be explained through the advantage of having the widened lane (14-ft lane) as compared to the standard lane (12-ft). However, as can be seen from Figure 87 through Figure 90, the magnitude of deflections in these sections are significantly different. For example, the D-ratio for section 26-0214 at point location 123 ft (36.9 m), is computed as:

D-ratio = 800/140 = 5.17

In this case, the edge deflections are high indicating a poor performance of the lane-shoulder joint.D-ratio for section 26-0214 at location 488.6 ft (146.6 m), in the latest year, is 250/55 = 4.54.

Even though both the values of D-ratio are fairly close to each other, the magnitudes of deflections that make up the D-ratio are significantly different. Hence, section 26-0214 should be considered to be performing worse than section 26-0215, since the magnitude of deflections is high. Hence it is important that the magnitudes of deflections need to be considered in conjunction with the D-ratio to assess the performance of the lateral support.

High D-ratio was also observed in section 26-0218 despite the fact that this section is an LCB section with a 14-ft lane. This is related to the cracking in the LCB layer during the construction as a result of which the layer cannot provide the shear transfer, expected for an LCB layer. In addition, it was observed that within the 12-ft DGAB sections, section 26-0214 (8-in.) had a higher D-ratio than section 26-0215 (11-in.), indicating that a wider lane, a stiffer base layer and a thicker PCC slab provide a better lateral support condition.

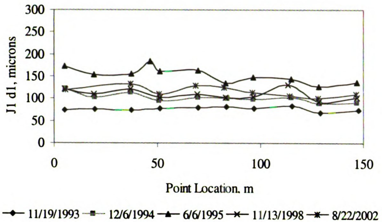


Figure 87 Peak deflection at the center of the slab, 26-0214

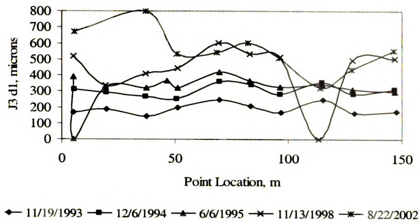


Figure 88 Peak deflection at the edge of the slab, 26-0214

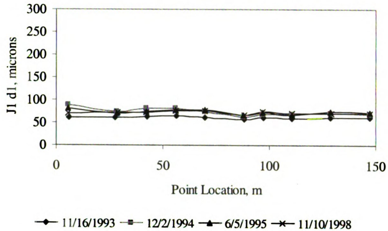


Figure 89 Peak deflection at the center of the slab, 26-0215

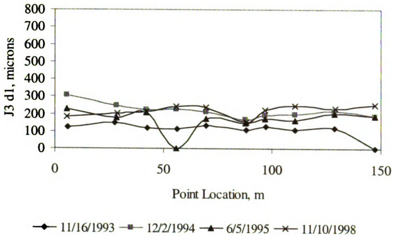


Figure 90 Peak deflection at the edge of the slab, 26-0215

CHAPTER 8

SUMMARY AND CONCLUSIONS

The effects of climatic region, subgrade soil and traffic on the performance of doweled jointed concrete pavement test sections incorporating different levels of structural factors have been analyzed in this research. The data for this study are drawn from the LTPP SPS-2 database. A summary of the influence of all these factors has been prepared as shown in Table A-54. The table explains in detail the reasons for behavior of test sections in each of the 14 states in SPS-2 experiment.

There is sufficient data in the SPS-2 experiment to study the effects of construction features on the performance of JPCP sections. The performance and response data have been obtained from the Release 16.0 database. The construction reports provide information on construction and design features. They also include "problems" encountered during the construction of the SPS pavement sections. Some major problems like excessive shrinkage cracking in the LCB sections, problems with the PCC mix design and deviations in the layer thicknesses are indicative of non-standard construction practices. The various limitations identified in the experiment and the database suggests that the data collection process needs to be consistent and care needs to be taken in the construction of the LCB sections to prevent shrinkage cracks.

The AASHTO '98 Supplemental Procedure for Concrete Pavement Thickness Design has been used to theoretically verify if the sections can withstand the design ESALs. It was found from this analysis that most of the 8 in. sections could not withstand the design ESALs. In general, sections with 8 in. PCC slab and lane width of 12 ft showed higher transverse cracking. It is too early to comment about the occurrence of faulting because of insignificant magnitudes. Pavement sections with undrained dense-graded aggregate bases or undrained lean concrete bases have so far shown more distresses than sections with drained permeable asphalt-treated bases.

A "Performance Index" was developed to enable the comparison of sections across different states without the need for age. The results obtained from the engineering analysis have been validated by using various statistical methods like univariate and multivariate analysis.

It was also found that the magnitudes of deflections on either side of the joints needs to be used in conjunction with the load transfer efficiency (LTE) and edge support factor to completely understand the behavior of the transverse and longitudinal joint. In addition to the design and construction features, the effect of temperature is also an important factor to be considered in assessing the loss of support and in joint performance evaluation.

Since the SPS-2 test sections have been monitored from the traffic open date, the SPS-2 database gives us a unique opportunity to record the initiation of distress. As the sections get older, it is expected from the knowledge of the distresses that more load-related and material-related distresses would be manifested. These aspects could thus be analyzed in a few years from now, when most of the sections exhibit higher distress with age. The SPS-2 experiment being first of its kind and analysis of its data to study the effects of design and construction features is being done for the first time, the approach suggested in this thesis could be of use for future researchers to understand the behavior of Jointed Plain Concrete Pavements.

Appendix A
Tables

Table A- 1 Construction deviations in the SPS-2 sites

State ID	Construction Issues
AZ (4)	• Base and sub base o Very coarse mix in DGAB o Mat defects led to group patching and hand finishing in LCB o Transverse drains installed perpendicular o Insufficient Filter fabric around PATB mat • PCC construction o Hydraulic liquid leakage caused 20 min delay o Delay in homogeneous placement due to rolling of material
AR (5)	• Three sections built on fills • Six sections constructed in 'cut' sections of original roadway • Dowel assembly replaced after the arrangement got disturbed
CA (6)	• LCB had developed cracks after placement because the curing compound was not placed properly. • The sides of the PATB material were completely covered by the overlaying PCC material and the cement paste rendering the PCC almost ineffective.
CO (8)	• Subgrade o Six sections on cut and six sections of fill • Base and Subbase o Pumping and rise in ground water table observed during heavy rains o PATB constructed in trenching of DGAB • PCC o Weather and equipment breakdown disrupted placement of slabs
DE (10)	• Subgrade o Delayed beginning in construction due to wet weather • Subbase o Some DGAB removed during testing o Depressions in LCB due to tamping bars of paver o Serious shrinkage cracks observed o Spalling occurred while testing • PCC o Paving operations rescheduled due to wet weather and poor concrete

Table A-1 (cont'd).

State ID	Construction Issues
IA (19)	• Construction delayed due to wet weather • Section 0222 shifted to new location after incorrect placement of dowel bars • Cement content increased by 50 lbs in sections which did not achieve target strength of 900 psi • 1" of filter fabric removed to improve permeability
KS (20)	• Construction delayed due to wet weather • Excess PATB was placed and removed • Existing granular subbase material and shoulder material retained • Subgrade was dried up prior to construction using Type C Fly Ash
MI (26)	• Base and subbase o Embankment clay dried out and desiccation cracks appeared o Rutting developed from 0-15 to 0+15 near the inner wheel path and 0-02 to 0+15 in the outer wheel path of 0221 o Transverse shrinkage cracks appeared in LCB soon after construction o Extra amount of water entered the pavement structure since this section is located on superelevation, which drains toward the outside shoulder. • PCC o Concreting delayed by a month in 0216
NV (32)	• Subgrade o Existing AC layer, cement treated base, embankment, and DGAB removed before construction of lime-stabilized subgrade • PCC o Section 0205 was removed after severe shrinkage cracking o Random block cracking observed in 0208 within 16 ft of inner edge prior to PCC work o Section 0212 removed and repaved (using state standard mix design) after severe cracking o Target 14-day strength changed to 475 and 750 psi • Most 750 psi mix was stiff and would tear during placement • To attain 750 psi strength the water-cement ratio was lowered to 0.3 • High slump was adjusted by addition of water reducing agents and lowering of water content • Flash set occurred prior to placement and finishing • Sections 0201 and 0209 had high variations in deflection during FWD testing

Table A-1 (cont'd).

State ID	Construction Issues
NC (37)	• Subgrade o Heavy rains caused problems for sections 0207 and 0204, which were either lime-stabilized or aggregate stabilized • Base and subbase o DGAB thickness was increased at the transition point of 0201 and 0209 as water entered through PATB layer o DGAB extended only to 2' beyond pavement edge o 1" dowel bars were used instead of 1.25" dowels o Non-uniform pavement structure across the lanes o Embankment at 0210 had a slope failure which may cause failure in shoulder and driving lane o Construction joint present in 0204 o DGAB at 0201, near TRB instrumentation, was not compacted and may thus lead to settlement
ND (38)	• Base and subbase o LCB was hard to be placed o Forms were used to contain concrete with high proportion of fines, from collapsing at edges o Mix was adjusted to avoid migration of water o PATB being very fluid was not rolled properly and it lost its shape • PCC o Reflection cracks appeared in section 0217
OH (39)	• Two types of mixes were used-odd numbered sections are different from even numbered sections
WA (53)	• Subgrade o Average moisture content was 5.8% below optimum o Construction traffic provided compaction effort • Base and subbase o Traffic during construction caused bleeding to surface o Tracking occurred in prime coat o Patching was done to the fabric of edge drains in 0209 and 0212 o Initially contamination of rock occurred because fabric was short o High water reducing agent used in first 300' • PCC o Surface voids appeared immediately due to the mix being unconsolidated o First 300' had a uniform appearance o Shrinkage cracks appeared on 0206

Table A- 2 Mix design summary for AZ (4) SPS-2 sites

Description	550-psi flexural strength at 14-day	900-psi flexural strength at 14-day	Lean Concrete Base
Mix Design			
Cement	400 lbs	811.1 lbs	234 lbs
Fly Ash	100 lbs	-	50 lbs
Water	232 lbs	292 lbs	250 lbs
Fine Aggregate	1285 lbs	1207 lbs	-
Coarse Aggregate	1939 lbs	1826 lbs	3345 lbs
Water reducer	25 oz/cu.yd	40 oz/cu.yd	5.5 oz/cu.yd
Air entraining admixture	2 oz/cu.yd	-	3.5 oz/cu.yd
Compressive Strength (Core), psi			
14-day	3570-4580	5870-6800	-
28-day	3780-4570	6330-7100	-
365-day	5390-6970	6490-8270	-
Compressive Strength (Fresh), psi			
14-day	3400-3840	6100-6350	495-575
28-day	4330-4670	6460-6700	850-950
365-day	6050-6210	7200-8100	-
Split Tensile Strength (Core), psi			
14-day	370-530	530-640	-
28-day	365-490	480-645	-
365-day	605-735	553-670	-
Split Tensile Strength (Fresh), psi			
14-day	350-400	470-505	-
28-day	365-385	520-590	-
365-day	460-550	680-860	-
Flexural Strength, psi			
14-day	560-580	790-860	-
28-day	630-685	825-950	-
365-day	805-945	890-1085	-

Table A- 3 Mix design summary for AR (5) SPS-2 sites

Description	550-psi flexural strength at 14-day	900-psi flexural strength at 14-day	Lean Concrete Base
Mix Design			
Cement	400 lbs	811.1 lbs	234 lbs
Fly Ash	100 lbs	-	50 lbs
Water	232 lbs	292 lbs	250 lbs
Fine Aggregate	1285 lbs	1207 lbs	-
Coarse Aggregate	1939 lbs	1826 lbs	3345 lbs
Water reducer	25 oz/cu.yd	40 oz/cu.yd	5.5 oz/cu.yd
Air entraining admixture	2 oz/cu.yd	-	3.5 oz/cu.yd
Compressive Strength (Core), psi			
14-day			
28-day	No information about the age of testing the specimens is available		
365-day			
Compressive Strength (Fresh), psi			
14-day			
28-day	No information about the age of testing the specimens is available		
365-day			
Split Tensile Strength (Core), psi			
14-day			
28-day	No information about the age of testing the specimens is available		
365-day			
Split Tensile Strength (Fresh), psi			
14-day			
28-day	No information about the age of testing the specimens is available		
365-day			
Flexural Strength, psi			
14-day			
28-day	No information about the age of testing the specimens is available		
365-day			

Table A- 4 Mix design summary for CA (6) SPS-2 sites

Description	550-psi flexural strength at 14-day	900-psi flexural strength at 14-day	Lean Concrete Base
Mix Design			
Cement	400 lbs	811.1 lbs	234 lbs
Fly Ash	100 lbs	-	50 lbs
Water	232 lbs	292 lbs	250 lbs
Fine Aggregate	1285 lbs	1207 lbs	-
Coarse Aggregate	1939 lbs	1826 lbs	3345 lbs
Water reducer	25 oz/cu.yd	40 oz/cu.yd	5.5 oz/cu.yd
Air entraining admixture	2 oz/cu.yd	-	3.5 oz/cu.yd
Compressive Strength (Core), psi			
14-day	2570-3180	5454-5520	-
28-day	2960-3930	4460-6090	-
365-day	3500-4490	4960-6310	-
Compressive Strength (Fresh), psi			
14-day	2340-3310	900-4530	-
28-day	3050-3690	1340-5060	-
365-day	3370-5450	1670-6630	-
Split Tensile Strength (Core), psi			
14-day	119-444	466-617	-
28-day	326-409	374-606	-
365-day	224-401	501-608	-
Split Tensile Strength (Fresh), psi			
14-day			
28-day		No data is available	
365-day			
Flexural Strength, psi			
14-day			
28-day		No data is available	
365-day			

Table A- 5 Mix design summary for CO (8) SPS-2 sites

Description	550-psi flexural strength at 14-day	900-psi flexural strength at 14-day	Lean Concrete Base
Mix Design			
Cement	400 lbs	811.1 lbs	234 lbs
Fly Ash	100 lbs	-	50 lbs
Water	232 lbs	292 lbs	250 lbs
Fine Aggregate	1285 lbs	1207 lbs	-
Coarse Aggregate	1939 lbs	1826 lbs	3345 lbs
Water reducer	25 oz/cu.yd	40 oz/cu.yd	5.5 oz/cu.yd
Air entraining admixture	2 oz/cu.yd	-	3.5 oz/cu.yd
Compressive Strength (Core), psi			
14-day	2190-3380	4290-5390	850-1120
28-day	2280-3300	4670-7030	800-1450
365-day	1200-5580	7360-8390	1500-1920
Compressive Strength (Fresh), psi			
14-day	2085-4315	4070-6540	390-570
28-day	2460-4990	5800-6810	500-660
365-day	3500-6430	7430-9000	870-1250
Split Tensile Strength (Core), psi			
14-day	380-510	570-680	-
28-day	410-900	390-820	-
365-day	550-744	680-860	-
Split Tensile Strength (Fresh), psi			
14-day	290-375	300-550	-
28-day	210-510	510-650	-
365-day	415-605	540-720	-
Flexural Strength, psi			
14-day	475-625	810-960	-
28-day	470-640	7080-950	-
365-day	620-710	840-1050	-

Table A- 6 Mix design summary for DE (10) SPS-2 sites

Description	550-psi flexural strength at 14-day	900-psi flexural strength at 14-day	Lean Concrete Base
Mix Design			
Cement	400 lbs	811.1 lbs	234 lbs
Fly Ash	100 lbs	-	50 lbs
Water	232 lbs	292 lbs	250 lbs
Fine Aggregate	1285 lbs	1207 lbs	-
Coarse Aggregate	1939 lbs	1826 lbs	3345 lbs
Water reducer	25 oz/cu.yd	40 oz/cu.yd	5.5 oz/cu.yd
Air entraining admixture	2 oz/cu.yd	-	3.5 oz/cu.yd
Compressive Strength (Core), psi			
14-day	3980-4710	3670-6410	-
28-day	3880-5050	4540-6020	-
365-day	4570-6820	5110-8790	-
Compressive Strength (Fresh), psi			
14-day	3570-3920	4060-5730	-
28-day	3920-4370	4300-7250	-
365-day	4010-5920	4960-7920	-
Split Tensile Strength (Core), psi			
14-day	505-716	489-627	-
28-day	437-438	502-552	-
365-day	612-705	406-692	-
Split Tensile Strength (Fresh), psi			
14-day	-	442-516	-
28-day	-	461-518	-
365-day	-	434-639	-
Flexural Strength, psi			
14-day	550-750	620-920	-
28-day	650-930	730-1190	-
365-day	680-970	680-1120	-

Table A- 7 Mix design summary for IA (19) SPS-2 sites

Description	550-psi flexural strength at 14-day	900-psi flexural strength at 14-day	Lean Concrete Base
Mix Design			
Cement	400 lbs	811.1 lbs	234 lbs
Fly Ash	100 lbs	-	50 lbs
Water	232 lbs	292 lbs	250 lbs
Fine Aggregate	1285 lbs	1207 lbs	-
Coarse Aggregate	1939 lbs	1826 lbs	3345 lbs
Water reducer	25 oz/cu.yd	40 oz/cu.yd	5.5 oz/cu.yd
Air entraining admixture	2 oz/cu.yd	-	3.5 oz/cu.yd
Compressive Strength (Core), psi			
14-day	2560-3430	4930-5900	310-430
28-day	2860-3820	4810-6070	750-940
365-day	3050-5080	5050-7390	1000-1280
Compressive Strength (Fresh), psi			
14-day	2500-3080	5570-6620	310-340
28-day	3080-3930	6470-7450	600-620
365-day	4060-4580	7690-9530	1110-1130
Split Tensile Strength (Core), psi			
14-day	260-380	410-510	
28-day	350-460	500-580	
365-day	350-500	520-600	
Split Tensile Strength (Fresh), psi			
14-day	280-380	450-530	-
28-day	290-400	490-570	-
365-day	350-450	565-660	-
Flexural Strength, psi			
14-day	440-500	700-790	-
28-day	520-590	720-770	-
365-day	520-590	770-930	-

Table A- 8 Mix design summary for KS (20) SPS-2 sites

Description	550-psi flexural strength at 14-day	900-psi flexural strength at 14-day	Lean Concrete Base
Mix Design			
Cement	400 lbs	811.1 lbs	234 lbs
Fly Ash	100 lbs	-	50 lbs
Water	232 lbs	292 lbs	250 lbs
Fine Aggregate	1285 lbs	1207 lbs	-
Coarse Aggregate	1939 lbs	1826 lbs	3345 lbs
Water reducer	25 oz/cu.yd	40 oz/cu.yd	5.5 oz/cu.yd
Air entraining admixture	2 oz/cu.yd	-	3.5 oz/cu.yd
Compressive Strength (Core), psi			
14-day	-	-	-
28-day	-	-	-
365-day	-	-	-
Compressive Strength (Fresh), psi			
14-day	3641-5074	5702-7387	586-729
28-day	4360-5859	6454-8613	901-1022
365-day	5748-7352	6487-10534	1232-1251
Split Tensile Strength (Core), psi			
14-day	-	-	-
28-day	-	-	-
365-day	-	-	-
Split Tensile Strength (Fresh), psi			
14-day	435-536	486-630	-
28-day	463-624	536-657	-
365-day	460-526	504-751	-
Flexural Strength, psi			
14-day	568-702	784-924	-
28-day	576-706	839-1035	-
365-day	667-752	816-1002	-

Table A- 9 Mix design summary for MI (26) SPS-2 sites

Description	550-psi flexural strength at 14-day	900-psi flexural strength at 14-day	Lean Concrete
Mix Design			
Cement	376 lbs	750 lbs	165 lbs
Fine Aggregate	1485 lbs (SSD)	1370 lbs (SSD)	1370 lbs (SSD)
Coarse Aggregate	1827 lbs (SSD)	1605 lbs (SSD)	1605 lbs (SSD)
Water	211 lbs	285 lbs	285 lbs
Air	1.0 oz/cwt	1.7 oz/cwt	1.7 oz/cwt
WRDA Concrete admixture	3.0 oz/cwt	3.0 oz/cwt	3.0 oz/cwt
Total	3899 lbs	4019 lbs	4010 lbs
Compressive Strength (Core), psi			
14-day	4000-5060	5990-6130	-
28-day	3265-5070	5610-6300	-
365-day	4790-7030	8660-9340	1030-1470
Compressive Strength (Fresh), psi			
14-day	3870-4080	5890	580-700*
28-day	4120-4400	6400-6600	720-830
365-day	5020-5690	8130-9370	740-1040
Split Tensile Strength (Core), psi			
14-day	480-514	526-645	-
28-day	370-530	470-645	-
365-day	484-713	698-761	-
Split Tensile Strength (Fresh), psi			
14-day	390-415	505-525	-
28-day	345-460	490-570	-
365-day	345-513	398-464	-
Flexural Strength, psi			
14-day	585-645	840-975	-
28-day	760-1040	980-1015	-
365-day	835-915	875-1000	-

* indicates 7-day strength

Table A- 10 Mix design summary for NV (32) SPS-2 sites

Description	550-psi flexural strength at 14-day	900-psi flexural strength at 14-day	Lean Concrete Base
Mix Design			
Cement	400 lbs	811.1 lbs	234 lbs
Fly Ash	100 lbs	-	50 lbs
Water	232 lbs	292 lbs	250 lbs
Fine Aggregate	1285 lbs	1207 lbs	-
Coarse Aggregate	1939 lbs	1826 lbs	3345 lbs
Water reducer	25 oz/cu.yd	40 oz/cu.yd	5.5 oz/cu.yd
Air entraining admixture	2 oz/cu.yd	-	3.5 oz/cu.yd
Compressive Strength (Core), psi			
14-day	2130-3420	3110-3570	430-670
28-day	2550-3770	4000-4350	570-820
365-day	4560-5110	6740-8410	990-1510
Compressive Strength (Fresh), psi			
14-day	2600-4000	5390-6400	340-510
28-day	3200-4440	6380-6880	600-820
365-day	4200-6010	9410-9940	1260-1620
Split Tensile Strength (Core), psi			
14-day			
28-day		No data is available for testing	
365-day			
Split Tensile Strength (Fresh), psi			
14-day	285-445	455-518	325-445
28-day	325-370	505-560	345-480
365-day	438-528	544-684	442-610
Flexural Strength, psi			
14-day	490-555	730-885	-
28-day	525-585	785-890	-
365-day	575-715	845-920	-

Table A- 11 Mix design summary for NC (37) SPS-2 sites

Description	550-psi flexural strength at 14-day	900-psi flexural strength at 14-day	Lean Concrete Base
Mix Design			
Cement	400 lbs	811.1 lbs	234 lbs
Fly Ash	100 lbs	-	50 lbs
Water	232 lbs	292 lbs	250 lbs
Fine Aggregate	1285 lbs	1207 lbs	-
Coarse Aggregate	1939 lbs	1826 lbs	3345 lbs
Water reducer	25 oz/cu.yd	40 oz/cu.yd	5.5 oz/cu.yd
Air entraining admixture	2 oz/cu.yd	-	3.5 oz/cu.yd
Compressive Strength (Core), psi			
14-day	2250-4170	3435-6369	-
28-day	2884-4495	3478-6766	-
365-day	4990-7340	6070-10680	-
Compressive Strength (Fresh), psi			
14-day	3880-4340	2967-6630	-
28-day	4590-5224	3770-7847	-
365-day	6840-7960	5590-10050	-
Split Tensile Strength (Core), psi			
14-day	270-450	522-634	-
28-day	357-496	541-660	-
365-day	429-794	600-761	-
Split Tensile Strength (Fresh), psi			
14-day	326-413	446-550	-
28-day	473-497	510-575	-
365-day	543-675	550-744	-
Flexural Strength, psi			
14-day	650-736	-	-
28-day	564-736	912-1075	-
365-day	824-972	1010-1065	-

Table A- 12 Mix design summary for ND (38) SPS-2 sites

Description	550-psi flexural strength at 14-day	900-psi flexural strength at 14-day	Lean Concrete Base
Mix Design			
Cement	400 lbs	811.1 lbs	234 lbs
Fly Ash	100 lbs	-	50 lbs
Water	232 lbs	292 lbs	250 lbs
Fine Aggregate	1285 lbs	1207 lbs	-
Coarse Aggregate	1939 lbs	1826 lbs	3345 lbs
Water reducer	25 oz/cu.yd	40 oz/cu.yd	5.5 oz/cu.yd
Air entraining admixture	2 oz/cu.yd	-	3.5 oz/cu.yd
Compressive Strength (Core), psi			
14-day			
28-day		No information is available for testing	
365-day			
Compressive Strength (Fresh), psi			
14-day			
28-day		No information is available for testing	
365-day			
Split Tensile Strength (Core), psi			
14-day	443-555	-	-
28-day	487-506	-	-
365-day	616-673	-	-
Split Tensile Strength (Fresh), psi			
14-day			
28-day		No information is available for testing	
365-day			
Flexural Strength, psi			
14-day			
28-day		No information is available for testing	
365-day			

Table A- 13 Mix design summary for OH (39) SPS-2 sites

Description	550-psi flexural strength at 14-day	900-psi flexural strength at 14-day	Lean Concrete Base
Mix Design			
Cement	400 lbs	811.1 lbs	234 lbs
Fly Ash	100 lbs	-	50 lbs
Water	232 lbs	292 lbs	250 lbs
Fine Aggregate	1285 lbs	1207 lbs	-
Coarse Aggregate	1939 lbs	1826 lbs	3345 lbs
Water reducer	25 oz/cu.yd	40 oz/cu.yd	5.5 oz/cu.yd
Air entraining admixture	2 oz/cu.yd	-	3.5 oz/cu.yd
Compressive Strength (Core), psi			
14-day	3942-6254	6494-7853	1048-1105
28-day	4263-6342	4810-8165	1968-2215
365-day	6520-8710	8120-11350	1965-1995
Compressive Strength (Fresh), psi			
14-day	4665-5362	7029-7661	676-711
28-day	5234-6599	7491-8179	1072-1111
365-day	6500-8210	9310-10510	1420-1460
Split Tensile Strength (Core), psi			
14-day	353-407	387-686	-
28-day	382-580	413-705	-
365-day	523-775	517-676	-
Split Tensile Strength (Fresh), psi			
14-day	333-399	387-686	-
28-day	162-452	413-705	-
365-day	524-612	490-804	-
Flexural Strength, psi			
14-day	645-749	438-713	-
28-day	702-880	784-890	-
365-day	850-945	930-955	-

Table A- 14 Mix design summary for WA (53) SPS-2 sites

Description	550-psi flexural strength at 14-day	900-psi flexural strength at 14-day	Lean Concrete Base
Mix Design			
Cement	400 lbs	811.1 lbs	234 lbs
Fly Ash	100 lbs	-	50 lbs
Water	232 lbs	292 lbs	250 lbs
Fine Aggregate	1285 lbs	1207 lbs	-
Coarse Aggregate	1939 lbs	1826 lbs	3345 lbs
Water reducer	25 oz/cu.yd	40 oz/cu.yd	5.5 oz/cu.yd
Air entraining admixture	2 oz/cu.yd	-	3.5 oz/cu.yd
Compressive Strength (Core), psi			
14-day	2368-2970	5926-7158	587-963
28-day	3088-3613	6681-8078	783-1368
365-day	3890-5040	7660-8600	1370-1930
Compressive Strength (Fresh), psi			
14-day	5926-7158	5906-6651	290-930
28-day	6671-8078	6685-7544	570-1820
365-day	7660-8600	5000-6340	1520-2800
Split Tensile Strength (Core), psi			
14-day	405-475	732-798	-
28-day	418-527	738-844	-
365-day	511-691	895-728	-
Split Tensile Strength (Fresh), psi			
14-day	349-449	544-608	-
28-day	420-465	599-670	-
365-day	496-576	582-707	-
Flexural Strength, psi			
14-day	413-546	801-870	-
28-day	524-709	880-1041	-
365-day	597-772	738-880	-

Table A- 15 Comparison of ESALs using AASHTO '98 for AZ (4)

		As-Design			As-Built		
Section ID	Average MR, psi	PCC thickness, in.	Base thickness, in.	ESAL, million	PCC thickness, in.	Base thickness, in.	ESAL, million
4-0213	633	8	6	1.2	7.9	5.9	1.1
4-0214	868	8	6	4.7	8.3	6.1	5.4
4-0215	633	11	6	4.4	11.3	6.1	5.1
4-0216	868	11	6	21.82	11.2	6.2	23.95
4-0217	633	8	6	1.05	8.1	6.1	1.07
4-0218	868	8	6	4.21	8.3	6.2	4.64
4-0219	633	11	6	3.47	10.8	6.2	3.13
4-0220	868	11	6	17.34	11.3	6.1	21.06
4-0221	633	8	4	1.1	8.2	4	1.25
4-0222	868	8	4	4.01	8.6	4.2	6.2
4-0223	633	11	4	4.41	11.1	3.6	4.8
4-0224	868	11	4	22.02	10.7	3.8	19.54

Table A- 16 Comparison of ESALs using AASHTO '98 for CO (8)

	As-Designed				As-Built		
Section ID	PCC thickness, in.	Base thickness, in.	Average MR, psi	ESALs	PCC thickness, in.	Base thickness, in.	ESALs
8-0213	8	6	630	0.98	8.7	5.9	1.55
8-0214	8	6	900	4.8	8.4	5.9	6.31
8-0215	11	6	630	6.3	11.4	6	7.96
8-0216	11	6	900	25.93	11.8	5.8	37.16
8-0217	8	6	630	1.1	8.6	6.3	1.56
8-0218	8	6	900	5.03	7.7	6.2	4.65
8-0219	11	6	630	3.4	11.1	6.1	3.64
8-0220	11	6	900	46.89	11.1	6.3	52.79
8-0221	8	4	630	0.95	8.3	4.1	1.21
8-0222	8	4	900	4.7	8.7	4	7.56
8-0223	11	4	630	4.31	11.8	4.7	6.53
8-0224	11	4	900	43.15	11.7	3.1	64.57

Table A- 17 Comparison of ESALs using AASHTO '98 for DE (10)

			As-Design			As-Built		
Section ID	e MR, psi	Width, ft	PCC thickness, in.	Base thickness, in.	ESAL, million	PCC thickness, in.	Base thickness, in.	ESAL, million
10-0201	790	12	8	6	3.98	8.3	6.2	4.84
10-0202	960	14	8	6	15.01	8.8	6.5	25.06
10-0203	790	14	11	6	34.61	11.7	6.1	49.94
10-0204	960	12	11	6	58.92	11	6.3	59.2
10-0205	790	12	8	6	11.89	9.2	5.5	13.75
10-0206	960	14	8	6	44.84	8.9	6.1	56.49
10-0207	790	14	11	6	63.87	11.3	6.9	93.68
10-0208	960	12	11	6	108.72	12.1	6	223.95
10-0209	790	12	8	4	5.89	8.2	4.7	10.88
10-0210	960	14	8	4	22.23	8.3	3.8	20.64
10-0211	790	14	11	4	42.03	11.8	3.7	69.95
10-0212	960	12	11	4	71.53	12.4	3.7	193.57

Table A- 18 Comparison of ESALs using AASHTO '98 for IA (19)

			As-Design			As-Built		
Section ID	Average MR, psi	Lane Width, ft	PCC thickness, in.	Base thickness, in.	ESAL, million	PCC thickness, in.	Base thickness, in.	ESAL, million
19-0213	555	14	8	6	0.74	8.5	6.1	1.05
19-0214	745	12	8	6	2.03	8.4	6.3	2.69
19-0215	555	12	11	6	3.32	11.8	5.8	5.14
19-0216	745	14	11	6	20.09	11.6	5.9	27.99
19-0217	555	14	8	6	0.99	7.7	6.5	1.08
19-0218	745	12	8	6	2.71	8.2	6.4	3.32
19-0219	555	12	11	6	4.30	11.2	6.8	5.56
19-0220	745	14	11	6	26.04	11.4	6.9	39.46
19-0221	555	14	8	4	0.52	9.4	3.6	1.09
19-0222	745	12	8	4	1.43	8.3	3.4	1.29
19-0223	555	12	11	4	2.88	11.7	3.6	4.73
19-0224	745	14	11	4	17.42	11.6	3.8	27.52

Table A- 19 Comparison of ESALs using AASHTO '98 for KS (20)

			As-Design			As-Built		
Section ID	Average MR, psi	Lane Width, ft	PCC thickness, in.	Base thickness, in.	ESAL, million	PCC thickness, in.	Base thickness, in.	ESAL, million
20-0201	641	12	8	6	1.26	7.7	6.1	1.04
20-0202	937	14	8	6	11.46	7.4	5.9	7.76
20-0203	641	14	11	6	10.94	11.1	5.7	11.49
20-0204	937	12	11	6	44.92	11.3	5.5	52.25
20-0205	641	12	8	6	3.15	7.8	6	3.14
20-0206	937	14	8	6	28.64	7.9	6	28.52
20-0207	641	14	11	6	17.95	11.3	5.9	21.40
20-0208	937	12	11	6	73.71	11	6	73.71
20-0209	641	12	8	4	1.59	8.5	3.9	1.72
20-0210	937	14	8	4	14.50	8.3	3.7	12.81
20-0211	641	14	11	4	11.97	11.1	4.2	13.77
20-0212	937	12	11	4	49.16	10.9	4.4	52.47

Table A- 20 Comparison of ESALs using AASHTO '98 for MI (26)

			As-Design			As-Built		
Section ID	Average MR, psi	Lane Width, ft	PCC thickness, in.	Base thickness, in.	ESALs	PCC thickness, in.	Base thickness, in.	ESALs
26-0213	900	14	8	6	16.94	8.6	6.1	16.94
26-0214	1000	12	8	6	12.85	8.9	5.8	22.48
26-0215	900	12	11	6	45.43	11.2	6.2	50.67
26-0216	1000	14	11	6	111.72	11.4	5.9	137.67
26-0217	900	14	8	6	36.63	8.5	6.2	42.96
26-0218	1000	12	8	6	40.67	7.1	6.9	135.39
26-0219	900	12	11	6	87.11	10.9	6.3	87.71
26-0220	1000	14	11	6	214.24	11.1	5.8	218.43
26-0221	900	14	8	4	14.06	8.2	4.2	16.14
26-0222	1000	12	8	4	15.62	8.4	4.2	20.19
26-0223	900	12	11	4	54.61	11	4.1	54.93
26-0224	1000	14	11	4	134.31	11.2	4.3	152.49

Table A- 21 Comparison of ESALs using AASHTO '98 for NV (32)

			As-Design			As-Built		
Section ID	Average MR, psi	Lane Width, ft	PCC thickness, in.	Base thickness, in.	ESAL, million	PCC thickness, in.	Base thickness, in.	ESAL, million
32-0201	562	12	8	6	0.67	9.2	5.9	1.41
32-0202	839	14	8	6	6.76	8.2	5.8	7.65
32-0203	562	14	11	6	5.84	11.9	5.7	9.28
32-0204	839	12	11	6	26.53	11.8	6.2	40.32
32-0205	562	12	8	6	1.61	8.5	6.8	2.64
32-0206	839	14	8	6	16.91	7.8	6.6	24.46
32-0207	562	14	11	6	9.59	10.9	6.8	10.68
32-0208	839	12	11	6	43.53	11	7.5	60.58
32-0209	562	12	8	4	0.85	8.9	4	1.16
32-0210	839	14	8	4	8.56	10.1	3.7	20.53
32-0211	562	14	11	4	6.39	11.3	4.1	8.26

Table A- 22 Comparison of ESALs using AASHTO '98 for NC (37)

			As-Design			As-Built		
Section ID	Average MR, psi	Lane Width, ft	PCC thickness, in.	Base thickness, in.	ESAL, million	PCC thickness, in.	Base thickness, in.	ESAL, million
37-0201	650	12	8	6	1.35	9	9.3	2.64
37-0202	1006	14	8	6	16.07	8.9	9	29.57
37-0203	650	14	11	6	11.69	11.2	5.6	12.92
37-0204	1006	12	11	6	63.03	11.2	5.4	69.46
37-0205	650	12	8	6	3.37	8	6.5	4.43
37-0206	1006	14	8	6	40.19	8.4	6.7	59.34
37-0207	650	14	11	6	19.18	11.6	5.6	26.52
37-0208	1006	12	11	6	103.44	11.2	5.9	115.47
37-0209	650	12	8	4	1.70	8.6	5.6	7.09
37-0210	1006	14	8	4	20.35	9.1	5.3	67.28
37-0211	650	14	11	4	12.80	11.4	3.6	15.29
37-0212	1006	12	11	4	68.99	10.9	4.3	71.08

Table A- 23 Comparison of ESALs using AASHTO '98 for ND (38)

			As-Design			As-Built		
Section ID	Average MR, psi	Lane Width, ft	PCC thickness, in.	Base thickness, in.	ESAL, million	PCC thickness, in.	Base thickness, in.	ESAL, million
38-0213	668	14	8	6	2.28	8.2	5.7	2.57
38-0214	945	12	8	6	8.02	7.9	6.2	7.55
38-0215	668	12	11	6	8.85	11	6.4	9.00
38-0216	945	14	11	6	69.61	11.2	6.1	77.51
38-0217	668	14	8	6	5.70	7.9	6.5	7.59
38-0218	945	12	8	6	20.04	7.9	6.6	28.40
38-0219	668	12	11	6	14.68	10.9	6.5	15.30
38-0220	945	14	11	6	114.24	10.9	6.7	124.38
38-0221	668	14	8	4	2.89	8.1	4.4	4.03
38-0222	945	12	8	4	10.14	8.2	3.8	9.24
38-0223	668	12	11	4	9.79	11.1	4.1	10.90
38-0224	945	14	11	4	76.19	10.8	4	65.87

Table A- 24 Comparison of ESALs using AASHTO '98 for OH (39)

			As-Design			As-Built		
Section ID	Average MR, psi	Lane Width, ft	PCC thickness, in.	Base thickness, in.	ESAL, million	PCC thickness, in.	Base thickness, in.	ESAL, million
39-0201	791	12	8	6	3.43	7.9	6.1	3.23
39-0202	837	14	8	6	6.69	8.3	5.8	8.05
39-0203	791	14	11	6	29.81	10.9	6.2	28.33
39-0204	837	12	11	6	26.23	11.1	5.8	27.58
39-0205	791	12	8	6	8.58	8	6.2	9.54
39-0206	837	14	8	6	16.72	7.9	5.9	15.78
39-0207	791	14	11	6	48.92	11.1	6.3	55.37
39-0208	837	12	11	6	43.04	11	6.3	45.74
39-0209	791	12	8	4	4.35	8.1	4	4.43
39-0210	837	14	8	4	8.47	8	4.1	9.15
39-0211	791	14	11	4	32.63	11.4	3.9	42.71
39-0212	837	12	11	4	28.71	10.6	4.4	24.93

Table A- 25 Comparison of ESALs using AASHTO '98 for WA (53)

			As-Design			As-Built		
Section ID	Average MR, psi	Lane Width, ft	PCC thickness, in.	Base thickness, in.	ESAL, million	PCC thickness, in.	Base thickness, in.	ESAL, million
53-0201	617	12	8	6	1.05	8.2	5.7	1.18
53-0202	945	14	8	6	11.93	7.9	6.2	11.24
53-0203	617	14	11	6	9.12	11	6.4	9.17
53-0204	945	12	11	6	46.78	11.2	6.1	52.08
53-0205	617	12	8	6	2.63	7.9	6.5	3.49
53-0206	945	14	8	6	29.82	7.9	6.6	42.26
53-0207	617	14	11	6	3.91	10.9	6.5	15.59
53-0208	945	12	11	6	76.76	10.9	6.7	83.58
53-0209	617	12	8	4	1.33	8.1	4.4	1.85
53-0210	945	14	8	4	15.10	8.2	3.8	13.76
53-0211	617	14	11	4	9.98	11.1	4.1	11.10
53-0212	945	12	11	4	51.20	10.8	4	44.26

Table A- 26 Occurrence of distresses in AZ (4)

STATE CODE	SHRP ID	YEAR	LC	TC	MAP CRACK	LONG.JT.SEAL DAMAGE	LONG. SPALL	TRANS. SPALL	PUMPING	SCALING	CORNER BREAKS	TRANS.JT.SEAL DAMAGE	D-CRACK	FAULT
4	0213	1995					X					X		X
		1997				X	X	X				X		X
		1999	X		X	X		X		X		X		X
		2000	X			X				X		X		X
		2001	X		X	X	X	X		X		X		X
	0214	1995										X		X
		1997			X	X	X	X				X		
		1999			X	X	X					X		X
		2000			X	X	X					X		X
		2001			X	X	X					X		
	0215	1995			X	X						X		X
		1996			X	X						X		X
		1997				X	X	X				X		
		1998				X						X		X
		1999			X	X						X		X
		2000				X	X					X		X
		2001				X	X					X		
		2002				X						X		
	0216	1995												X
		1997			X	X						X		X
		1999			X	X						X		X
		2000			X	X						X		X
		2001			X	X						X		
	0217	1995										X		X
		1997	X	X	X	X		X				X		
		1999	X	X	X	X		X				X		X
		2000	X	X		X		X				X		X
		2001	X	X	X	X	X	X				X		X
	0218	1995				X						X		X
		1997	X	X	X	X	X	X				X		X
		1999	X	X	X	X		X				X		X
		2000	X	X		X	X	X				X		X
		2001	X	X	X	X	X					X		
	0219	1995												X
		1997	X		X	X	X	X				X		
		1999			X	X	X	X				X		X
		2000			X	X	X	X				X		X
		2001		X	X	X	X	X				X		X
	0220	1995												X
		1997	X	X	X	X						X		X
		1999			X	X						X		X
		2000			X	X						X		X
		2001			X	X						X		
	0221	1995			X	X	X					X		X
		1997	X		X	X	X	X				X		X
		1999	X		X	X		X		X		X		X
		2000	X			X		X		X		X		X
		2001	X		X	X	X			X		X		
	0222	1995				X								X
		1997	X		X	X	X	X				X		
		1999			X	X	X					X		X
		2000	X			X	X					X		X
		2001	X		X	X						X		X
	0223	1995												X
		1997				X		X				X		X
		1999			X	X						X		X
		2000				X						X		X
		2001				X						X		X
	0224	1995					X					X		X
		1997			X	X	X	X				X		
		1999			X	X	X	X				X		X
		2000	X		X	X						X		X
		2001			X	X		X				X		

Table A- 27 Occurrence of distresses in AR (5)

STATE CODE	SHRP ID	YEAR	LC	TC	MAP CRACK	LONG.JT.SEAL DAMAGE	LONG. SPALL	TRANS. SPALL	PUMPING	SCALING	CORNER BREAKS	TRANS.JT.SEAL DAMAGE	D-CRACK	FAULT
5	0213	1996				X	X					X		
		2000	X			X	X				X	X		X
		2001	X			X	X		X			X		X
	0214	1996				X	X		X			X		
		2000				X			X			X		X
		2001				X	X		X			X		X
	0215	1996				X	X					X		
		2000				X						X		X
		2001				X						X		X
	0216	1996				X	X	X	X			X		
		2000				X			X			X		X
		2001				X			X			X		X
	0217	1996				X	X	X	X			X		
		2000	X			X			X			X		X
		2001	X	X		X			X			X		X
	0218	1996				X	X		X			X		X
		2000	X	X		X		X	X			X		X
		2001	X	X		X		X	X			X		X
	0219	1996				X	X	X	X			X		X
		2000				X			X			X		X
		2001				X			X			X		
	0220	1996				X	X	X	X			X		
		2000				X		X	X			X		X
		2001				X		X	X		X	X		X
	0221	1996				X	X	X				X		
		2000				X						X		X
		2001				X						X		X
	0222	1996				X	X	X				X		X
		2000				X						X		X
		2001				X	X		X			X		
	0223	1996					X					X		
		2000				X	X					X		X
		2001				X	X					X		X
	0224	1996				X	X	X				X		
		2000				X		X			X	X		X
		2001				X					X	X		X

Table A- 28 Occurrence of distresses in CO (8)

STATE CODE	SHRP ID	YEAR	LC	TC	MAP CRACK	LONG.JT.SEAL DAMAGE	LONG. SPALL	TRANS. SPALL	PUMPING	SCALING	CORNER BREAKS	TRANS.JT.SEAL DAMAGE	D-CRACK	FAULT
8	0213	1996				X						X		X
		1998				X						X		X
		1999				X						X		X
		2000				X						X		X
	0214	1996				X						X		X
		1998				X						X		X
		1999				X						X		X
		2000				X	X	X				X		
	0215	1996				X	X	X				X		X
		1998				X	X	X				X		
		1999			X	X	X	X				X		X
		2000				X	X					X		X
	0216	1996				X						X		X
		1998				X						X		
		1999				X						X		
		2000			X	X						X		X
	0217	1996	X			X		X				X		X
		1998	X			X	X	X				X		X
		1999	X			X	X	X		X		X		X
		2000	X			X	X	X				X		X
		2001	X			X	X	X				X		X
		2002	X			X	X	X				X		X
	0218	1996		X		X						X		X
		1998		X		X	X	X				X		
		1999		X		X	X	X				X		X
		2000		X		X		X				X		X
		2001		X		X	X	X				X		X
		2002		X		X	X	X				X		X
	0219	1996				X						X		X
		1998				X	X					X		X
		1999				X	X			X		X		X
		2000				X	X	X				X		X
		2001				X	X	X				X		X
		2002				X	X	X				X		
	0220	1996				X						X		X
		1998				X						X		
		1999				X					X	X		
		2000				X		X			X	X		X
		2001				X					X	X		X
		2002				X	X	X				X		
	0221	1996				X						X		X
		1998	X			X	X	X				X		X
		1999				X	X					X		X
		2000	X			X	X			X		X		X
		2001				X	X	X		X		X		X
		2002				X	X	X		X		X		
	0222	1996				X						X		X
		1998				X		X				X		X
		1999	X			X						X		
		2000	X			X		X				X		X
		2001				X		X				X		X
		2002				X		X				X		X
	0223	1996				X						X		X
		1998				X						X		X
		1999				X						X		X
		2000				X				X		X		X
		2001				X				X		X		X
		2002				X				X		X		X
	0224	1996				X		X				X		X
		1998				X		X				X		X
		1999				X						X		X
		2000				X		X				X		X
		2001				X		X				X		X
		2002				X		X				X		X

Table A- 29 Occurrence of distresses in DE (10)

STATE CODE	SHRP ID	YEAR	LC	TC	MAP CRACK	LONG.JT.SEAL DAMAGE	LONG. SPALL	TRANS. SPALL	PUMPING	SCALING	CORNER BREAKS	TRANS.JT.SEAL DAMAGE	D-CRACK	FAULT
10	0201	1996				X		X				X		
		1997				X	X	X				X		X
		1998				X	X	X				X		X
		1999				X	X	X				X		X
		2000				X	X	X				X		X
		2001			X	X	X	X				X		X
	0202	1996				X		X				X		
		1997				X	X	X		X		X		X
		1999				X	X	X		X		X		X
		2000				X	X	X				X		X
		2001				X	X	X				X		X
	0203	1996				X		X				X		X
		1997				X	X	X				X		
		1999				X	X	X				X		X
		2000				X	X	X				X		X
		2001			X	X	X					X		X
	0204	1996				X						X		
		1997				X	X					X		
		1999				X	X					X		X
		2000				X	X					X		X
		2001			X	X	X					X		X
	0205	1996						X				X		X
		1997	X	X		X	X	X				X		X
		1999		X		X		X				X		X
		2000	X	X		X		X				X		X
		2001		X		X	X	X				X		X
	0206	1996				X		X				X		
		1997				X	X	X		X		X		X
		1999				X	X	X		X		X		X
		2000				X	X	X		X		X		X
		2001				X	X	X		X		X		X
	0207	1996	X			X		X				X		
		1997	X			X	X	X	X			X		X
		1999	X			X	X	X				X		
		2000	X			X	X	X	X			X		X
		2001	X		X	X	X	X	X			X		X
	0208	1996				X		X				X		
		1997				X	X					X		
		1999			X	X						X		X
		2000				X	X					X		X
		2001			X	X	X					X		X
	0209	1996				X	X	X				X		X
		1997				X	X	X				X		X
		1998				X	X	X				X		X
		1999				X	X	X				X		
		2000				X	X					X		X
		2001	X			X	X	X				X		X
	0210	1996				X		X				X		
		1997				X	X	X				X		
		1999				X				X		X		
		2000				X						X		
		2001				X	X	X		X		X		X
	0211	1996				X	X	X				X		
		1997				X	X					X		
		1999				X		X				X		X
		2000				X	X	X				X		X
		2001			X	X	X					X		
	0212	1996				X		X				X		X
		1997				X	X					X		X
		1999				X	X					X		X
		2000				X	X					X		X
		2001			X	X	X	X				X		X

Table A- 30 Occurrence of distresses in IA (19)

STATE CODE	SHRP ID	YEAR	LC	TC	MAP CRACK	LONG.JT.SEAL DAMAGE	LONG. SPALL	TRANS. SPALL	PUMPING	SCALING	CORNER BREAKS	TRANS.JT.SEAL DAMAGE	D-CRACK	FAULT
19	0213	1994				X						X		
		1997	X			X		X				X		X
		1999	X			X						X		
		2000				X						X		
		2001	X			X						X		X
		2002	X			X						X		X
	0214	1994				X						X		
		1999				X						X		X
		2000				X						X		X
		2001				X						X		X
		2002				X						X		X
	0215	1994				X						X		
		1997				X						X		
		1999				X						X		X
		2000				X						X		
		2001				X						X		X
		2002				X						X		X
	0216	1994				X		X				X		
		1997				X		X				X		
		1999				X						X		X
		2000				X						X		
		2001				X						X		X
		2002				X						X		X
	0217	1994		X		X		X				X		
		1997		X		X		X				X		X
		1999		X		X						X		X
		2000		X		X						X		X
		2001		X		X						X		X
		2002		X		X						X		X
	0218	1994				X						X		
		1997		X		X						X		
		1999				X	X					X		X
		2000				X	X					X		X
		2001				X	X					X		X
		2002				X	X					X		X
	0219	1994				X						X		
		1997				X						X		
		1999				X	X					X		X
		2000				X	X	X				X		
		2001				X	X	X	X			X		X
		2002				X	X	X	X			X		X
	0220	1994										X		
		1997				X						X		
		1999				X						X		X
		2000				X						X		
		2001				X						X		X
		2002				X						X		X
	0221	1994				X	X					X		
		1997				X	X	X				X		
		1999				X						X		X
		2000				X						X		
		2001				X						X		X
		2002				X						X		X
	0222	1994				X						X		
		1999				X						X		X
		2000	X			X						X		
		2001	X			X						X		X
		2002				X						X		X
	0223	1994						X				X		
		1999				X						X		X
		2000				X						X		
		2001				X						X		X
		2002				X						X		X
	0224	1994				X						X		
		1999				X						X		X
		2000	X			X		X				X		
		2001	X			X		X				X		X
		2002	X			X		X				X		X

Table A- 31 Occurrence of distresses in KS (20)

STATE CODE	SHRP ID	YEAR	LC	TC	MAP CRACK	LONG.JT.SEAL DAMAGE	LONG. SPALL	TRANS. SPALL	PUMPING	SCALING	CORNER BREAKS	TRANS.JT.SEAL DAMAGE	D-CRACK	FAULT
20	0201	1993				X	X	X				X		X
		1997	X	X		X	X					X		X
		1999	X	X		X	X					X		X
		2001	X	X		X	X					X		X
		2002	X	X		X	X		X			X		X
	0202	1993				X						X		X
		1997		X		X	X					X		X
		1999				X						X		X
		2001		X		X						X		X
		2002		X		X						X		
	0203	1993				X						X		X
		1997				X	X					X		X
		1999				X						X		X
		2001				X						X		X
		2002				X						X		X
	0204	1993				X	X	X				X		X
		1997				X	X					X	X	X
		1999				X	X					X		X
		2001				X	X					X		X
		2002				X	X					X		X
	0205	1993				X	X	X				X		X
		1997				X	X					X		X
		1999				X	X	X				X		
		2001	X			X	X	X				X		X
		2002	X			X	X	X				X		X
	0206	1993				X						X		X
		1997	X			X	X		X			X		X
		1999	X			X	X					X		X
		2001	X			X						X		X
		2002	X			X						X		X
	0207	1993				X						X		X
		1997				X	X					X		X
		1999				X	X					X		X
		2001				X	X					X		X
		2002				X	X					X		X
	0208	1993				X	X					X		X
		1997				X	X					X		X
		1999				X		X				X		X
		2001				X		X				X		
		2002				X		X				X		
	0209	1993				X						X		X
		1997				X	X					X		X
		1999				X	X					X		X
		2001				X	X					X		X
		2002				X	X					X		
	0210	1993				X	X					X		X
		1997				X	X					X		X
		1999				X	X	X				X		X
		2001				X	X	X				X		X
		2002				X	X	X				X		
	0211	1993				X	X					X		X
		1997				X	X					X		X
		1999				X	X					X		X
		2001				X	X					X		X
		2002				X	X					X		X
	0212	1993				X	X					X		X
		1997				X	X					X		X
		1999				X	X	X				X		X
		2001				X	X	X				X		X
		2002				X	X	X				X		X

Table A- 32 Occurrence of distresses in MI (26)

STATE CODE	SHRP ID	YEAR	LC	TC	MAP CRACK	LONG.JT.SEAL DAMAGE	LONG. SPALL	TRANS. SPALL	PUMPING	SCALING	CORNER BREAKS	TRANS.JT.SEAL DAMAGE	D-CRACK	FAULT
26	0213	1993				X								
		1994				X						X		X
		1995				X			X			X		X
		1997				X		X	X			X		
		1998		X		X			X			X		X
	0214	1993				X					X	X		
		1994				X					X	X		X
		1995				X		X	X			X		X
		1998				X		X	X			X		X
		1999				X		X	X			X		X
		2002	X	X		X	X					X		X
	0215	1993				X								
		1994				X			X			X		X
		1995				X			X			X		X
		1998				X			X			X		X
		1999		X		X			X			X		X
	0216	1993				X								
		1994				X			X			X		X
		1995				X						X		X
		1998				X						X		X
		1999				X						X		
		2001				X						X		X
		2002				X						X		
	0217	1993				X								
		1994				X			X			X		X
		1995				X			X			X		X
		1997	X			X			X			X		X
	0218	1993				X								
		1994	X	X		X		X	X			X		X
		1995	X	X		X		X	X		X	X		X
	0219	1993				X								
		1994				X						X		X
		1995				X			X			X		X
		1998				X			X			X		X
		1999				X			X			X		
		2002				X		X				X		
	0220	1993				X								
		1994				X			X			X		X
		1995				X			X			X		X
		1998				X			X			X		X
		1999				X						X		X
		2001				X						X		X
		2002				X						X		
	0221	1993				X								
		1994				X	X					X		X
		1995				X						X		X
		1997				X		X				X		
		1998				X						X		X
		1999				X						X		
		2001				X						X		X
		2002				X		X				X		X
	0222	1993				X								
		1994				X						X		X
		1995				X						X		X
		1998				X						X		X
		1999				X						X		
		2001				X						X		X
		2002				X						X		
	0223	1993				X								
		1994				X						X		X
		1995				X						X		X
		1998				X						X		X
		1999				X						X		
		2001				X						X		X
		2002				X		X				X		X
	0224	1993				X								
		1994				X			X			X		X
		1995				X						X		X
		1998				X						X		X
		1999				X						X		

Table A- 33 Occurrence of distresses in NV (32)

STATE CODE	SHRP ID	YEAR	LC	TC	MAP CRACK	LONG.JT.SEAL DAMAGE	LONG. SPALL	TRANS. SPALL	PUMPING	SCALING	CORNER BREAKS	TRANS.JT.SEAL DAMAGE	D-CRACK	FAULT
32	0201	1996		X		X						X		X
		1998	X	X		X	X	X				X		X
		1999	X	X		X						X		X
		2000	X	X		X						X		X
		2001	X	X		X		X				X		X
		2002	X	X		X	X	X	X			X		X
	0202	1996	X	X		X						X		X
		1997	X	X		X						X		X
	0203	1996	X	X	X	X						X		X
		1998	X	X		X	X	X				X		X
		1999	X	X		X		X				X		X
		2000	X	X		X						X		X
		2001	X	X		X		X				X		X
		2002	X	X	X	X		X				X		X
	0204	1996	X	X	X	X		X				X		X
		1997	X	X	X	X		X		X		X		X
		1998	X	X		X			X			X		X
		1999	X	X		X			X			X		X
		2000	X	X	X	X			X			X		X
		2001		X	X	X			X			X		X
		2002	X	X	X	X			X			X		X
	0205	1996	X	X		X					X	X		X
		1998	X	X		X		X			X	X		X
		1999	X	X		X		X			X	X		X
		2000	X	X	X	X		X		X		X		X
		2001	X	X	X	X		X		X		X		X
		2002	X	X	X	X	X	X	X	X		X		
	0206	1996	X	X		X						X		X
		1997	X	X		X						X		X
	0207	1996				X						X		X
		1998	X	X		X				X		X		X
		1999	X	X		X				X		X		X
		2000	X	X		X				X		X		X
		2001	X	X		X				X		X		X
		2002	X	X		X				X		X		X
	0208	1996	X	X		X						X		X
		1998	X	X		X	X		X			X		X
		1999	X	X	X	X	X	X	X			X		X
		2000	X	X	X	X	X	X	X	X		X		X
		2001	X	X		X	X	X	X	X		X		X
		2002	X	X		X	X	X	X	X		X		X
	0209	1996				X						X		X
		1997				X						X		X
		1998				X				X		X		X
		1999		X		X				X		X		X
		2000	X	X		X				X		X		X
		2001	X	X		X				X		X		X
		2002	X	X		X				X		X		
	0210	1996		X		X						X		X
		1997	X	X		X						X		X
		1998	X	X		X	X		X			X		X
		1999	X	X		X			X			X		X
		2000	X	X		X	X	X	X			X		X
		2001	X	X		X	X	X	X			X		X
		2002	X	X	X	X	X	X	X			X		X
	0211	1996	X	X		X						X		X
		1998	X	X		X				X		X		X
		1999	X	X		X				X		X		X
		2000	X	X		X				X		X		X
		2001	X	X		X				X		X		X
		2002	X	X	X	X				X		X		X

Table A- 34 Occurrence of distresses in NC (37)

STATE CODE	SHRP ID	YEAR	LC	TC	MAP CRACK	LONG.JT.SEAL DAMAGE	LONG. SPALL	TRANS. SPALL	PUMPING	SCALING	CORNER BREAKS	TRANS.JT.SEAL DAMAGE	D-CRACK	FAULT
37	0201	1995				X	X					X		X
		1996				X	X	X				X		X
		1997				X	X					X		X
		1998	X			X	X	X				X		X
		1999				X	X					X		X
		2000				X	X					X		X
		2001			X	X	X			X		X		X
		2002		X	X	X	X			X		X		X
	0202	1997				X						X		X
		1999				X						X		X
		2000				X	X					X		
		2001				X	X					X		X
		2002	X			X	X					X		X
	0203	1997				X	X					X		X
		1999				X						X		
		2000				X						X		X
		2001				X						X		X
	0204	1997				X	X	X			X	X		X
		1999				X	X	X				X		X
		2000				X	X	X				X		X
		2001				X		X				X		X
	0205	1997				X	X					X		X
		1999				X		X		X		X		X
		2000	X	X	X	X	X	X		X		X		X
		2001	X	X	X	X	X			X	X	X		X
	0206	1997				X						X		X
		1999				X						X		X
		2000				X		X				X		
		2001				X	X					X		X
	0207	1997				X						X		X
		1999				X				X		X		
		2000				X				X		X		X
		2001				X						X		X
	0208	1997				X	X					X		X
		1999				X						X		
		2000				X						X		X
		2001				X	X					X		X
	0209	1995				X	X					X		
		1997				X	X					X		X
		1998				X	X			X		X		X
		1999				X				X		X		
		2000				X	X					X		X
		2001				X	X			X		X		X
		2002				X	X			X		X		X
	0210	1997	X	X		X	X				X	X		X
		1999	X	X		X				X		X		
		2000				X	X	X		X		X		X
		2001				X	X	X				X		X
		2002	X			X	X	X				X		X
	0211	1997				X						X		X
		1999				X						X		
		2000				X						X		X
		2001				X						X		X
	0212	1997				X					X	X		X
		1999				X	X					X		X
		2000				X		X				X		X
		2001				X		X				X		X

Table A- 35 Occurrence of distresses in ND (38)

STATE CODE	SHRP ID	YEAR	LC	TC	MAP CRACK	LONG.JT.SEAL DAMAGE	LONG. SPALL	TRANS. SPALL	PUMPING	SCALING	CORNER BREAKS	TRANS.JT.SEAL DAMAGE	D-CRACK	FAULT
38	0213	1994				X		X				X		
		1997				X		X				X		
		1999				X	X					X		X
		2000				X						X		X
		2001				X						X		X
		2002				X						X		X
	0214	1994				X		X				X		X
		1999				X	X					X		
		2000				X						X		X
		2001				X						X		X
		2002	X			X		X				X		X
	0215	1994				X		X				X		X
		1999				X						X		X
		2000				X						X		X
		2001				X						X		X
		2002	X			X						X		X
	0216	1994				X		X				X		X
		1999				X						X		X
		2000				X						X		X
		2001				X		X				X		
		2002	X			X		X				X		X
	0217	1994		X		X					X	X		X
		1997	X	X		X		X			X	X		X
		1999	X	X		X	X		X		X	X	X	X
		2000	X	X		X	X		X			X		X
		2001	X	X		X			X			X		X
		2002	X	X		X		X				X		X
	0218	1994				X		X				X		X
		1999				X	X					X		
		2000	X			X	X		X			X		
		2001	X			X	X		X			X		X
		2002	X			X	X					X		X
	0219	1994				X		X				X		X
		1999				X						X		X
		2000				X	X					X		X
		2001				X						X		X
		2002				X						X		X
	0220	1994				X		X				X		X
		1999				X						X		X
		2000				X	X					X		
		2001				X						X		X
		2002				X						X		X
	0221	1994				X						X		X
		1997				X						X		X
		1999				X						X		
		2000				X	X					X		X
		2001				X						X		X
		2002				X						X		X
	0222	1994				X						X		X
		1999				X		X				X		
		2000				X	X					X		X
		2001				X						X		X
		2002				X		X				X		
	0223	1994				X		X				X		X
		1999				X						X		X
		2000				X	X					X		X
		2001				X						X		X
		2002				X						X		X
	0224	1994				X		X				X		X
		1999	X			X						X		X
		2000	X			X	X					X		
		2001	X			X						X		X
		2002				X						X		

Table A- 36 Occurrence of distresses in OH (39)

STATE CODE	SHRP ID	YEAR	LC	TC	MAP CRACK	LONG.JT.SEAL DAMAGE	LONG. SPALL	TRANS. SPALL	PUMPING	SCALING	CORNER BREAKS	TRANS.JT.SEAL DAMAGE	D-CRACK	FAULT
39	0201	1996				X						X		
		1999				X						X		
		2001				X						X		
	0202	1996				X	X					X		
		1999				X						X		X
		2001		X		X						X		X
	0203	1996				X						X		
		1999				X						X		X
		2001				X						X		
	0204	1996				X	X					X		
		1998				X						X		X
		1999				X	X					X		X
		2001		X		X						X		X
	0205	1996				X						X		
		1999		X		X						X		X
		2001		X		X			X			X		X
	0206	1996				X						X		
		1999	X			X	X		X			X		X
	0207	1996				X						X		
		1999				X						X		
		2001				X						X		
	0208	1996				X						X		
		1999				X						X		
		2001				X						X		
	0209	1996				X						X		
		1999				X						X		X
		2001				X						X		X
	0210	1996				X	X					X		
		1999				X						X		X
		2001				X						X		
	0211	1996				X						X		
		1999				X						X		X
		2001				X						X		X
	0212	1996				X						X		
		1999				X						X		
		2001				X						X		

Table A- 37 Occurrence of distresses in WA (53)

STATE CODE	SHRP ID	YEAR	LC	TC	MAP CRACK	LONG JT SEAL DAMAGE	LONG SPALL	TRANS SPALL	PUMPING	SCALING	CORNER BREAKS	TRANS JT SEAL DAMAGE	D-CRACK	FAULT
53	0201	1995												X
		1997			X	X						X		
		1998				X						X		X
		1999				X						X		X
		2000				X						X		X
		2001				X						X		X
		2002				X						X		
	0202	1995												X
		1997			X	X						X		
		1998				X						X		X
		1999				X						X		
		2000				X						X		X
		2001				X	X					X		X
		2002				X						X		
	0203	1995				X						X		X
		1997				X						X		X
		1998				X						X		X
		1999				X						X		X
		2000				X						X		X
		2001				X						X		X
		2002				X						X		
	0204	1995												X
		1997				X						X		
		1998				X						X		X
		1999				X						X		
		2000				X						X		X
		2001				X						X		X
		2002				X						X		
	0205	1995				X								X
		1997		X	X	X						X		
		1998		X	X	X						X		X
		1999		X	X	X						X		X
		2000		X	X	X						X		X
		2001		X	X	X						X		X
		2002		X	X	X						X		X
	0206	1995			X	X						X		X
		1997		X	X	X						X		X
		1998		X	X	X						X		X
		1999		X	X	X						X		X
		2000	X	X	X	X								X
		2001		X	X	X						X		X
		2002	X	X	X	X						X		X
	0207	1995				X						X		X
		1997				X						X		
		1998			X	X						X		
		1999			X	X						X		X
		2000		X	X	X						X		X
		2001		X	X	X		X				X		
		2002		X	X	X						X		
	0208	1995												X
		1997			X	X						X		
		1998				X						X		X
		1999				X						X		X
		2000				X						X		X
		2001			X	X						X		X
		2002			X	X						X		
	0209	1995												X
		1997				X						X		X
		1998				X						X		X
		1999				X						X		X
		2000				X						X		X
		2001				X						X		X
		2002				X						X		X
	0210	1995												X
		1997			X							X		X
		1998				X						X		X
		1999				X						X		X
		2000				X						X		X
		2001				X						X		X
		2002				X						X		X
	0211	1995												X
		1997				X						X		X
		1998				X						X		X
		1999				X						X		X
		2000				X						X		X
		2001				X						X		X
		2002				X						X		X
	0212	1995												X
		1997				X						X		X
		1998				X						X		X
		1999				X						X		
		2000				X						X		X
		2001				X						X		X
		2002				X						X		X

Table A- 38 Occurrence of distresses in WI (55)

STATE CODE	SHRP ID	YEAR	LC	TC	MAP CRACK	LONG.JT.SEAL DAMAGE	LONG. SPALL	TRANS. SPALL	PUMPING	SCALING	CORNER BREAKS	TRANS.JT.SEAL DAMAGE	D-CRACK	FAULT
55	0213	1998					X					X		
		2000				X						X		X
		2002				X						X		X
	0214	1998				X	X	X				X		
		2000				X	X					X		X
		2002				X	X					X		
	0215	1998				X	X	X				X		
		2000				X	X					X		X
		2002				X	X					X		
	0216	1998				X						X		X
		2000										X		
		2002				X						X		X
	0217	1998				X						X		
		2000				X						X		
		2002				X						X		X
	0218	1998				X	X	X				X		
		2000				X	X	X				X		
		2002				X	X	X				X		
	0219	1998				X	X					X		
		2000				X	X					X		X
		2002				X	X					X		X
	0220	1998				X	X					X		
		2000				X						X		X
		2002				X						X		
	0221	1998				X						X		X
		2000				X						X		
		2002				X						X		X
	0222	1998				X	X					X		X
		2000				X	X	X				X		
		2002				X	X	X				X		X
	0223	1998				X	X					X		
		2000				X	X					X		
		2002				X						X		X
	0224	1998				X	X					X		
		2000				X	X					X		
		2002				X	X					X		

Table A- 39 Overall factor comparison for longitudinal joint sealant damage at the network level

Longitudinal Joint Sealant Damage — PCC thickness

Zone	Subgrade Type	ND								D			
		DGAB				LCB				PATB			
		12'		14'		12'		14'		12'		14'	
		8"	11"	8"	11"	8"	11"	8"	11"	8"	11"	8"	11"
DF	Coarse	1.06	0.94	1.27	0.73	0.18	1.82	1.36	0.64	0.44	1.56	1.07	0.93
	Fine			2.00	0.00	1.56	0.44	1.11	0.89			1.99	0.01
DNF	Coarse	1.27	0.73	1.84	0.16	0.96	1.04	0.02	1.98	1.17	0.83	1.07	0.93
WF	Coarse	0.96	1.04	1.00	1.00	0.93	1.07	0.94	1.06	1.22	0.78	1.00	1.00
	Fine	1.62	0.38	0.69	1.31	0.78	1.22	1.02	0.98	1.04	0.96	0.95	1.05
WNF	Coarse	1.26	0.74	0.58	1.42	0.69	1.31	0.70	1.30	1.09	0.91	0.90	1.10
	Fine	0.05	1.95	1.11	0.89	1.18	0.82	1.00	1.00	0.94	1.06	1.00	1.00

Longitudinal Joint Sealant Damage — Drainage type

Zone	Subgrade Type	8"				11"			
		12'		14'		12'		14'	
		D	ND	D	ND	D	ND	D	ND
DF	Coarse	0.75	1.25	1.11	0.89	1.02	0.98	1.26	0.74
	Fine	0.44	1.56	1.02	0.98			0.01	1.99
DNF	Coarse	0.56	1.44	0.76	1.24	0.54	1.46	0.64	1.36
WF	Coarse	1.27	0.73	0.96	1.04	1.00	1.00	0.93	1.07
	Fine	0.89	1.11	1.17	0.83	1.21	0.79	1.09	0.91
WNF	Coarse	0.97	1.03	1.08	0.92	0.81	1.19	0.83	1.17
	Fine	1.44	0.56	0.70	1.30	1.03	0.97	0.76	1.24

Longitudinal Joint Sealant Damage — Base type

Zone	Subgrade Type	8"						11"					
		12'			14'			12'			14'		
		D	ND		D	ND		D	ND		D	ND	
		PATB	DGAB	LCB	PATB	DGAB	LCB	PATB	DGAB	LCB	PATB	DGAB	LCB
DF	Coarse	0.76	1.95	0.30	1.15	1.40	0.45	1.10	0.70	1.20	1.48	1.20	0.31
	Fine				1.13	0.36	1.51				0.02	0.00	2.98
DNF	Coarse	0.48	1.44	1.08	0.70	2.28	0.02	0.44	1.07	1.49	0.57	0.19	2.24
WF	Coarse	1.40	0.82	0.78	0.95	1.09	0.96	1.00	1.00	1.00	0.91	1.05	1.04
	Fine	0.89	1.68	0.43	1.23	0.58	1.20	1.30	0.63	1.07	1.13	0.92	0.95
WNF	Coarse	0.95	1.15	0.89	1.11	0.68	1.21	0.76	0.64	1.60	0.78	0.94	1.28
	Fine	1.25	0.04	1.72	0.64	1.45	0.91	1.04	1.09	0.87	0.70	1.29	1.01

Table A- 40 Overall factor comparison for longitudinal spalling at the network level

Longitudinal Spalling — PCC thickness

Zone	Subgrade Type	ND								D			
		DGAB				LCB				PATB			
		12'		14'		12'		14'		12'		14'	
		8"	11"	8"	11"	8"	11"	8"	11"	8"	11"	8"	11"
DF	Coarse	2.00	0.00	2.00	0.00	0.04	1.96						
	Fine			0.00	2.00	0.63	1.37	1.96	0.04			2.00	0.00
DNF	Coarse	1.13	0.87	0.99	1.01	0.28	1.72	0.83	1.17	1.42	0.58	1.38	0.62
WF	Coarse	1.17	0.83	1.68	0.32	0.51	1.49	0.98	1.02	1.02	0.98	0.52	1.48
	Fine	0.95	1.05	1.10	0.90	1.55	0.45	1.34	0.66	0.85	1.15	1.12	0.88
WNF	Coarse	1.49	0.51	0.87	1.13	0.51	1.49	0.86	1.14	0.36	1.64	0.57	1.43
	Fine	1.22	0.78	0.55	1.45	0.28	1.72	2.00	0.00	1.94	0.06	2.00	0.00

Longitudinal Spalling — Drainage type

Zone	Subgrade Type	8"				11"			
		12'		14'		12'		14'	
		D	ND	D	ND	D	ND	D	ND
DF	Coarse	0.00	2.00	0.00	2.00	0.00	2.00		
	Fine	0.00	2.00	1.48	0.52			0.00	2.00
DNF	Coarse	1.28	0.72	1.07	0.93	0.35	1.65	0.64	1.36
WF	Coarse	1.16	0.84	0.15	1.85	1.09	0.91	0.73	1.27
	Fine	0.33	1.67	1.26	0.74	0.75	1.25	1.45	0.55
WNF	Coarse	0.47	1.53	0.64	1.36	1.38	0.63	0.95	1.05
	Fine	1.00	1.00	0.89	1.11	0.09	1.91	0.00	2.00

Longitudinal Spalling — Base type

Zone	Subgrade Type	8"						11"					
		12'			14'			12'			14'		
		D	ND		D	ND		D	ND		D	ND	
		PATB	DGAB	LCB	PATB	DGAB	LCB	PATB	DGAB	LCB	PATB	DGAB	LCB
DF	Coarse	0.00	2.79	0.21	0.00	3.00	0.00	0.00	0.00	3.00			
	Fine				1.93	0.00	1.07				0.00	0.64	2.36
DNF	Coarse	1.42	0.28	1.30	1.10	1.46	0.44	0.20	0.07	2.73	0.57	1.71	0.71
WF	Coarse	1.31	1.27	0.42	0.13	2.05	0.82	1.12	0.80	1.08	0.67	0.72	1.61
	Fine	0.26	0.46	2.28	1.35	0.07	1.58	0.69	1.00	1.31	1.69	0.09	1.22
WNF	Coarse	0.40	2.29	0.31	0.57	1.99	0.43	1.57	0.66	0.77	0.94	1.69	0.37
	Fine	1.25	1.66	0.09	0.86	0.85	1.28	0.07	1.90	1.04	0.00	3.00	0.00

Note: Shaded cells indicate that the magnitudes of distresses at that level of the factors are zero. In such a case, the relative performance values cannot be defined.

Table A- 41 Overall factor comparison for area of map cracking at the network level

Area of Map cracking — PCC thickness

Zone	Subgrade Type	ND								D			
		DGAB				LCB				PATB			
		12'		14'		12'		14'		12'		14'	
		8"	11"	8"	11"	8"	11"	8"	11"	8"	11"	8"	11"
DF	Coarse	2.00	0.00	1.54	0.46	1.47	0.53	1.82	0.18			2.00	0.00
	Fine			0.00	2.00	0.00	2.00					0.84	1.16
DNF	Coarse	1.81	0.19	0.75	1.25	0.98	1.02	0.84	1.16	1.40	0.60	0.46	1.54
WF	Coarse	0.06	1.94	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00
	Fine												
WNF	Coarse												
	Fine	2.00	0.00			2.00	0.00						

Area of Map cracking — Drainage type

Zone	Subgrade Type	8"				11"			
		12'		14'		12'		14'	
		D	ND	D	ND	D	ND	D	ND
DF	Coarse	0.00	2.00	0.28	1.72	0.00	2.00	0.00	2.00
	Fine			2.00	0.00			0.81	1.19
DNF	Coarse	0.62	1.38	0.60	1.40	0.68	1.32	0.99	1.01
WF	Coarse	0.00	2.00			0.70	1.30	0.49	1.51
	Fine								
WNF	Coarse								
	Fine	0.00	2.00						

Area of Map cracking — Base type

Zone	Subgrade Type	8"						11"					
		12'			14'			12'			14'		
		D	ND		D	ND		D	ND		D	ND	
		PATB	DGAB	LCB	PATB	DGAB	LCB	PATB	DGAB	LCB	PATB	DGAB	LCB
DF	Coarse	0.00	0.04	2.96	0.22	0.18	2.59	0.00	0.00	3.00	0.00	0.52	2.48
	Fine				3.00	0.00	0.00				0.49	2.51	0.00
DNF	Coarse	0.55	1.36	1.09	0.53	1.11	1.35	0.47	0.28	2.25	0.98	1.01	1.01
WF	Coarse	0.00	3.00	0.00				0.63	1.12	1.25	0.42	1.16	1.43
	Fine												
WNF	Coarse												
	Fine	0.00	1.85	1.15									

Table A- 42 Overall factor comparison for number of map cracks at the network level

Number of Map cracks — PCC thickness

Zone	Subgrade Type	ND								D			
		DGAB				LCB				PATB			
		12'		14'		12'		14'		12'		14'	
		8"	11"	8"	11"	8"	11"	8"	11"	8"	11"	8"	11"
DF	Coarse	2.00	0.00	1.64	0.36	1.28	0.72	0.59	1.41			2.00	0.00
	Fine			0.00	2.00	0.00	2.00					0.57	1.43
DNF	Coarse	1.59	0.41	0.94	1.06	0.71	1.29	1.03	0.97	1.73	0.27	1.09	0.91
WF	Coarse	1.31	0.69	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00
	Fine												
WNF	Coarse												
	Fine	2.00	0.00			2.00	0.00						

Number of Map cracks — Drainage type

Zone	Subgrade Type	8"				11"			
		12'		14'		12'		14'	
		D	ND	D	ND	D	ND	D	ND
DF	Coarse	0.00	2.00	1.16	0.84	0.00	2.00	0.00	2.00
	Fine			2.00	0.00			0.91	1.09
DNF	Coarse	1.31	0.69	1.10	0.90	0.59	1.41	1.00	1.00
WF	Coarse	0.00	2.00			0.94	1.06	0.80	1.20
	Fine								
WNF	Coarse								
	Fine	0.00	2.00						

Number of Map cracks — Base type

Zone	Subgrade Type	8"						11"					
		12'			14'			12'			14'		
		D	ND		D	ND		D	ND		D	ND	
		PATB	DGAB	LCB	PATB	DGAB	LCB	PATB	DGAB	LCB	PATB	DGAB	LCB
DF	Coarse	0.00	0.15	2.85	1.22	1.00	0.78	0.00	0.00	3.00	0.00	0.32	2.68
	Fine				3.00	0.00	0.00				0.58	2.42	0.00
DNF	Coarse	1.47	0.85	0.69	1.14	0.85	1.01	0.41	0.39	2.20	1.00	1.00	1.00
WF	Coarse	0.00	3.00	0.00				0.92	0.92	1.17	0.75	1.13	1.13
	Fine												
WNF	Coarse												
	Fine	0.00	0.50	2.50									

Note: Shaded cells indicate that the magnitudes of distresses at that level of the factors are zero. In such a case, the relative performance values cannot be defined.

Table A- 43 Overall factor comparison for number of corner breaks at the network level

Zone	Subgrade Type	Number of corner breaks																															
		PCC thickness												Drainage type								Base type											
		ND								D				8"				11"				8"						11"					
		DGAB				LCB				PATB				12'		14'		12'		14'		12'			14'			12'			14'		
		12'		14'		12'		14'		12'		14'		D	ND	D	ND	D	ND	D	ND	D	ND		D	ND		D	ND		D	ND	
		8"	11"	8"	11"	8"	11"	8"	11"	8"	11"	8"	11"									PATB	DGAB	LCB	PATB	DGAB	LCB	PATB	DGAB	LCB	PATB	DGAB	LCB
DF	Coarse					2.00	0.00							0.00	2.00							0.00	0.00	3.00									
	Fine							0.00	2.00											0.00	2.00										0.00	0.00	3.00
DNF	Coarse									0.00	2.00							2.00	0.00									3.00	0.00	0.00			
WF	Coarse																																
	Fine					2.00	0.00	2.00	0.00					0.00	2.00	0.00	2.00					0.00	0.00	3.00	0.00	0.00	3.00						
WNF	Coarse			2.00	0.00			0.00	2.00			0.00	2.00			0.00	2.00			1.47	0.53				0.00	3.00	0.00				1.74	0.00	1.26
	Fine	0.00	2.00			2.00	0.00			0.00	2.00	2.00	0.00	0.00	2.00	2.00	0.00	1.60	0.40			0.00	0.00	3.00	3.00	0.00	0.00	2.00	1.00	0.00			

Table A- 44 Overall factor comparison for length of longitudinal cracking at the network level

Zone	Subgrade Type	Total length of longitudnal cracking																															
		PCC thickness												Drainage type								Base type											
		ND								D				8"				11"				8"						11"					
		DGAB				LCB				PATB				12'		14'		12'		14'		12'			14'			12'			14'		
		12'		14'		12'		14'		12'		14'		D	ND	D	ND	D	ND	D	ND	D	ND		D	ND		D	ND		D	ND	
		8"	11"	8"	11"	8"	11"	8"	11"	8"	11"	8"	11"									PATB	DGAB	LCB	PATB	DGAB	LCB	PATB	DGAB	LCB	PATB	DGAB	LCB
DF	Coarse	2.00	0.00			2.00	0.00	2.00	0.00					0.00	2.00	0.00	2.00					0.00	0.83	2.17	0.00	0.00	3.00						
	Fine			0.30	1.70	0.00	2.00	1.59	0.41			1.29	0.71	2.00	0.00	0.43	1.57			0.19	1.81				0.38	1.04	1.58				0.10	2.72	0.19
DNF	Coarse			2.00	0.00	1.74	0.26	1.99	0.01	2.00	0.00	1.89	0.11	0.56	1.44	0.35	1.65	0.00	2.00	1.63	0.37	0.49	0.00	2.51	0.28	1.09	1.63	0.00	0.00	3.00	2.07	0.00	0.93
WF	Coarse					2.00	0.00	0.00	2.00	2.00	0.00			1.10	0.90					0.00	2.00	0.96	0.00	2.04							0.00	0.00	3.00
	Fine	1.97	0.03	1.88	0.12	2.00	0.00	2.00	0.00	2.00	0.00	0.00	2.00	0.33	1.67	0.00	2.00	0.00	2.00	1.98	0.02	0.27	1.55	1.17	0.00	0.11	2.89	0.00	3.00	0.00	2.95	0.05	0.00
WNF	Coarse			2.00	0.00	2.00	0.00	2.00	0.00					0.00	2.00	0.00	2.00	0.00	2.00			0.00	0.00	3.00	0.00	1.71	1.29	0.00	0.00	3.00			
	Fine	2.00	0.00	2.00	0.00	2.00	0.00					2.00	0.00	0.00	2.00	1.61	0.39					0.00	0.23	2.77	2.03	0.97	0.00						

Note: Shaded cells indicate that the magnitudes of distresses at that level of the factors are zero. In such a case, the relative performance values cannot be defined.

Table A- 45 Overall factor comparison for number of transverse joint sealant damages at the network level

Number of transverse joint sealant damages — PCC thickness

Zone	Subgrade Type	ND								D			
		DGAB				LCB				PATB			
		12'		14'		12'		14'		12'		14'	
		8"	11"	8"	11"	8"	11"	8"	11"	8"	11"	8"	11"
DF	Coarse	1.00	1.00	0.99	1.01	1.00	1.00	0.90	1.10	1.00	1.00	0.99	1.01
	Fine			0.99	1.01	1.01	0.99	1.00	1.00			1.01	0.99
DNF	Coarse	1.00	1.00	1.03	0.97	1.03	0.97	1.03	0.97	1.00	1.00	1.01	0.99
WF	Coarse	1.08	0.92	1.00	1.00	1.18	0.82	1.00	1.00	1.04	0.96	1.03	0.97
	Fine	1.01	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
WNF	Coarse	1.00	1.00	1.01	0.99	1.00	1.00	1.00	1.00	0.99	1.01	0.98	1.02
	Fine	1.00	1.00	1.00	1.00	0.99	1.01	1.00	1.00	0.99	1.01	1.00	1.00

Number of transverse joint sealant damages — Drainage type

Zone	Subgrade Type	8"				11"			
		12'		14'		12'		14'	
		D	ND	D	ND	D	ND	D	ND
DF	Coarse	1.00	1.00	1.05	0.95	1.00	1.00	1.01	0.99
	Fine	0.99	1.01	1.00	1.00			1.00	1.00
DNF	Coarse	0.97	1.03	1.01	0.99	0.98	1.02	1.03	0.97
WF	Coarse	0.92	1.08	1.03	0.97	1.00	1.00	1.00	1.00
	Fine	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
WNF	Coarse	1.00	1.00	0.99	1.01	1.01	0.99	1.01	0.99
	Fine	1.00	1.00	1.00	1.00	1.01	0.99	1.00	1.00

Number of transverse joint sealant damages — Base type

Zone	Subgrade Type	8"						11"					
		12'			14'			12'			14'		
		D	ND		D	ND		D	ND		D	ND	
		PATB	DGAB	LCB	PATB	DGAB	LCB	PATB	DGAB	LCB	PATB	DGAB	LCB
DF	Coarse	1.00	1.00	1.00	1.07	1.07	0.87	1.00	1.00	1.00	1.01	1.00	0.99
	Fine				1.00	1.01	0.99				0.99	1.02	0.99
DNF	Coarse	0.97	1.02	1.02	1.02	0.99	0.99	0.98	1.04	0.98	1.04	0.98	0.98
WF	Coarse	0.88	0.96	1.16	1.04	0.98	0.98	1.00	1.00	1.00	1.00	1.00	1.00
	Fine	0.99	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
WNF	Coarse	1.00	1.00	1.00	0.99	1.02	0.99	1.02	0.99	0.99	1.02	0.99	0.99
	Fine	1.00	1.00	1.00	1.00	1.00	1.00	1.01	0.98	1.01	1.00	1.00	1.00

Table A- 46 Overall factor comparison for number of transverse spalls at the network level

Number of transverse spalls — PCC thickness

Zone	Subgrade Type	ND								D			
		DGAB				LCB				PATB			
		12'		14'		12'		14'		12'		14'	
		8"	11"	8"	11"	8"	11"	8"	11"	8"	11"	8"	11"
DF	Coarse	2.00	0.00			0.69	1.31	0.00	2.00			0.00	2.00
	Fine			0.00	2.00	0.99	1.01	1.71	0.29			2.00	0.00
DNF	Coarse	1.41	0.59	2.00	0.00	0.69	1.31	1.88	0.12	1.22	0.78	0.74	1.26
WF	Coarse	2.00	0.00	1.50	0.50	2.00	0.00	1.15	0.85	1.75	0.25	0.73	1.27
	Fine	1.75	0.25	1.38	0.62	0.62	1.38	2.00	0.00	0.66	1.34	1.56	0.44
WNF	Coarse			0.00	2.00	1.83	0.17	0.62	1.38	2.00	0.00	0.44	1.56
	Fine	0.47	1.53			2.00	0.00	2.00	0.00	0.00	2.00	2.00	0.00

Number of transverse spalls — Drainage type

Zone	Subgrade Type	8"				11"			
		12'		14'		12'		14'	
		D	ND	D	ND	D	ND	D	ND
DF	Coarse	0.00	2.00			0.00	2.00	1.83	0.17
	Fine	0.90	1.10	1.30	0.70			0.00	2.00
DNF	Coarse	0.83	1.17	0.79	1.21	0.60	1.40	1.93	0.07
WF	Coarse	0.75	1.25	0.26	1.74	2.00	0.00	0.67	1.33
	Fine	0.58	1.42	1.07	0.93	0.61	1.39	1.40	0.60
WNF	Coarse	0.31	1.69	0.62	1.38	0.00	2.00	0.78	1.22
	Fine	0.00	2.00	1.53	0.47	0.87	1.13		

Number of transverse spalls — Base type

Zone	Subgrade Type	8"						11"					
		12'			14'			12'			14'		
		D	ND		D	ND		D	ND		D	ND	
		PATB	DGAB	LCB	PATB	DGAB	LCB	PATB	DGAB	LCB	PATB	DGAB	LCB
DF	Coarse	0.00	1.35	1.65				0.00	0.00	3.00	2.38	0.00	0.62
	Fine				1.62	0.00	1.38				0.00	2.26	0.74
DNF	Coarse	0.79	0.57	1.64	0.74	0.83	1.43	0.39	0.18	2.43	2.80	0.00	0.20
WF	Coarse	0.66	0.90	1.43	0.21	1.51	1.27	3.00	0.00	0.00	0.61	0.83	1.56
	Fine	0.49	0.55	1.96	1.08	0.56	1.36	0.54	0.04	2.42	1.63	1.37	0.00
WNF	Coarse	0.25	0.00	2.75	0.55	0.00	2.45	0.00	0.00	3.00	0.72	0.21	2.07
	Fine	0.00	1.81	1.19	1.85	0.00	1.15	0.83	2.17	0.00			

Note: Shaded cells indicate that the magnitudes of distresses at that level of the factors are zero. In such a case, the relative performance values cannot be defined.

Table A- 47 Overall factor comparison for number of scaling occurrences at the network level

Zone	Subgrade Type	Number of scaling occurrences																															
		PCC thickness												Drainage type								Base type											
		ND								D				8"				11"				8"						11"					
		DGAB				LCB				PATB				12'		14'		12'		14'		12'			14'			12'			14'		
		12'		14'		12'		14'		12'		14'		D	ND	D	ND	D	ND	D	ND	D	ND		D	ND		D	ND		D	ND	
		8"	11"	8"	11"	8"	11"	8"	11"	8"	11"	8"	11"									PATB	DGAB	LCB	PATB	DGAB	LCB	PATB	DGAB	LCB	PATB	DGAB	LCB
DF	Coarse					1.82	0.18			0.00	2.00			0.00	2.00			1.98	0.02			0.00	0.00	3.00				2.96	0.00	0.04			
	Fine					0.00	2.00	0.55	1.45			0.39	1.61	2.00	0.00	1.76	0.24			1.82	0.18				2.47	0.00	0.53				2.64	0.00	0.36
DNF	Coarse			2.00	0.00							2.00	0.00			1.80	0.20								2.45	0.55	0.00						
WF	Coarse			2.00	0.00			2.00	0.00			2.00	0.00			0.41	1.59								0.32	0.72	1.97						
	Fine																																
WNF	Coarse																																
	Fine	2.00	0.00			2.00	0.00	0.00	2.00	2.00	0.00	2.00	0.00	1.25	0.75	2.00	0.00			0.00	2.00	1.07	0.27	1.66	3.00	0.00	0.00				0.00	0.00	3.00

Table A- 48 Overall factor comparison for area of scaling at the network level

Zone	Subgrade Type	Area of scaling																															
		PCC thickness												Drainage type								Base type											
		ND								D				8"				11"				8"						11"					
		DGAB				LCB				PATB				12'		14'		12'		14'		12'			14'			12'			14'		
		12'		14'		12'		14'		12'		14'		D	ND	D	ND	D	ND	D	ND	D	ND		D	ND		D	ND		D	ND	
		8"	11"	8"	11"	8"	11"	8"	11"	8"	11"	8"	11"									PATB	DGAB	LCB	PATB	DGAB	LCB	PATB	DGAB	LCB	PATB	DGAB	LCB
DF	Coarse					0.26	1.74			0.00	2.00			0.00	2.00			0.78	1.22			0.00	0.00	3.00				0.94	0.00	2.06			
	Fine					0.00	2.00	0.26	1.74			0.08	1.92	2.00	0.00	0.61	1.39			1.15	0.85				0.64	0.00	2.36				1.47	0.00	1.53
DNF	Coarse			2.00	0.00							2.00	0.00			1.85	0.15								2.58	0.42	0.00						
WF	Coarse			2.00	0.00			2.00	0.00			2.00	0.00			1.85	0.15								2.54	0.10	0.35						
	Fine																																
WNF	Coarse																																
	Fine	2.00	0.00			2.00	0.00	0.00	2.00	2.00	0.00	2.00	0.00	1.56	0.44	2.00	0.00			0.00	2.00	1.57	0.13	1.31	3.00	0.00	0.00				0.00	0.00	3.00

Note: Shaded cells indicate that the magnitudes of distresses at that level of the factors are zero. In such a case, the relative performance values cannot be defined.

Table A- 49 State level comparisons for longitudinal joint sealant damage

LONGITUDINAL JOINT SEALANT DAMAGE													
ZONE	SUBGRADE	STATE ID	DRAINAGE		BASE TYPE			PCC THICKNESS		FLEXURAL STRENGTH		LANE WIDTH	
			D	ND	DGAB	LCB	PATB	8"	11"	550 psi	900 psi	12'	14'
WF	C	10	0.72	1.28	0.98	0.94	1.08	1.02	0.98	1.04	0.96	1.06	0.94
	F	19											
	F	20	0.71	1.29	1.33	0.60	1.07	1.28	0.72	1.37	0.63	0.93	1.07
	F	26	0.58	1.42	0.97	1.16	0.88	1.07	0.93	1.06	0.94	0.99	1.01
	F	38											
	F	39	0.56	1.44	0.60	1.56	0.84	1.26	0.74	1.16	0.84	0.67	1.33
WNF	C	5	0.59	1.41	0.86	1.26	0.88	0.81	1.19	0.82	1.18	0.69	1.31
	F	37	0.57	1.43	1.09	1.07	0.85	0.97	1.03	0.90	1.10	0.80	1.20
DF	F+C	8	0.69	1.31	0.37	1.59	1.04	1.11	0.89	1.00	1.00	1.07	0.93
	F+C	32	0.02	1.98	0.48	2.48	0.05	1.25	0.75	0.11	1.89	0.69	1.31
	C	53	0.72	1.28	1.50	0.42	1.08	1.04	0.96	0.92	1.08	1.14	0.86
DNF	C	4	0.33	1.67	1.28	1.23	0.49	1.14	0.86	0.87	1.13	1.82	0.18
	C	6	0.00	2.00	0.00	3.00	0.00	0.00	2.00	0.00	2.00	2.00	0.00

Table A- 50 State level comparisons for longitudinal spalling

LONGITUDINAL SPALLING													
ZONE	SUBGRADE	STATE ID	DRAINAGE		BASE TYPE			PCC THICKNESS		FLEXURAL STRENGTH		LANE WIDTH	
			D	ND	DGAB	LCB	PATB	8"	11"	550 psi	900 psi	12'	14'
WF	C	10	0.51	1.49	1.31	0.93	0.76	1.12	0.88	0.82	1.18	0.99	1.01
	F	19	0.00	2.00	0.00	3.00	0.00	1.55	0.45	0.45	1.55	2.00	0.00
	F	20	0.64	1.36	1.20	0.84	0.96	1.08	0.92	1.10	0.90	1.22	0.78
	F	26	0.05	1.95	2.93	0.00	0.07	2.00	0.00	0.05	1.95	1.95	0.05
	F	38	0.73	1.27	0.02	1.89	1.09	1.26	0.74	0.99	1.01	1.16	0.84
	F	39	0.00	2.00	1.02	1.98	0.00	1.32	0.68	0.00	2.00	0.68	1.32
WNF	C	5	0.64	1.36	1.52	0.51	0.97	0.89	1.11	1.00	1.00	1.46	0.54
	F	37	0.52	1.48	1.75	0.47	0.78	1.26	0.74	1.22	0.78	1.73	0.27
DF	F+C	8	1.06	0.94	0.12	1.29	1.58	1.58	0.42	1.88	0.12	0.51	1.49
	F+C	32	0.74	1.26	0.72	0.97	1.31	1.21	0.79	0.57	1.43	1.26	0.74
	C	53	0.00	2.00	3.00	0.00	0.00	2.00	0.00	0.00	2.00	0.00	2.00
DNF	C	4	0.41	1.59	0.38	2.01	0.61	0.81	1.19	1.55	0.45	1.60	0.40
	C	6	0.43	1.57	1.65	0.70	0.65	0.21	1.79	1.36	0.64	0.42	1.58

Table A- 51 State level comparisons for length of longitudinal cracks

LENGTH OF LONGITUDINAL CRACKS													
ZONE	SUBGRADE	STATE ID	DRAINAGE		BASE TYPE			PCC THICKNESS		FLEXURAL STRENGTH		LANE WIDTH	
			D	ND	DGAB	LCB	PATB	8"	11"	550 psi	900 psi	12'	14'
WF	C	10	0.06	1.94	0.00	2.91	0.09	0.19	1.81	2.00	0.00	0.19	1.81
	F	19	1.51	0.49	0.74	0.00	2.26	1.17	0.83	0.49	1.51	0.67	1.33
	F	20	0.00	2.00	2.16	0.84	0.00	2.00	0.00	1.60	0.40	1.60	0.40
	F	26	0.00	2.00	0.88	2.12	0.00	2.00	0.00	0.21	1.79	1.79	0.21
	F	38	0.20	1.80	0.05	2.65	0.31	1.78	0.22	1.52	0.48	0.28	1.72
	F	39	0.00	2.00	0.00	3.00	0.00	2.00	0.00	0.00	2.00	0.00	2.00
WNF	C	5	0.00	2.00	1.11	1.89	0.00	2.00	0.00	1.30	0.70	0.70	1.30
	F	37	0.13	1.87	0.30	2.50	0.20	2.00	0.00	1.80	0.20	1.80	0.20
DF	F+C	8	0.15	1.85	0.00	2.77	0.23	2.00	0.00	1.95	0.05	0.05	1.95
	F+C	32	0.06	1.94	1.30	1.59	0.11	1.55	0.45	0.99	1.01	0.75	1.25
	C	53	0.00	2.00	0.00	3.00	0.00	2.00	0.00	0.00	2.00	0.00	2.00
DNF	C	4	0.22	1.78	0.86	1.81	0.34	1.98	0.02	1.58	0.42	0.41	1.59
	C	6	0.00	2.00	0.00	3.00	0.00	0.04	1.96	0.04	1.96	2.00	0.00

Table A- 52 State level comparisons for number of transverse joint sealant damages

NUMBER OF TRANSVERSE JOINT SEALANT DAMAGES													
ZONE	SUBGRADE	STATE ID	DRAINAGE		BASE TYPE			PCC THICKNESS		FLEXURAL STRENGTH		LANE WIDTH	
			D	ND	DGAB	LCB	PATB	8"	11"	550 psi	900 psi	12'	14'
WF	C	10	0.65	1.35	0.98	1.04	0.98	1.06	0.94	1.05	0.95	1.05	0.95
	F	19	0.67	1.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	F	20	0.67	1.33	1.00	0.99	1.00	1.00	1.00	1.01	0.99	1.00	1.00
	F	26	0.66	1.34	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	F	38	0.67	1.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	F	39	0.67	1.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
WNF	C	5	0.67	1.33	1.00	0.99	1.01	1.00	1.00	1.00	1.00	1.00	1.00
	F	37	0.67	1.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.01	0.99
DF	F+C	8	0.66	1.34	1.01	1.00	1.00	1.00	1.00	0.99	1.01	1.00	1.00
	F+C	32	0.55	1.45	1.00	1.00	1.01	1.00	1.00	1.08	0.92	0.90	1.10
	C	53	0.68	1.32	1.02	0.97	1.02	0.98	1.02	1.02	0.98	1.02	0.98
DNF	C	4	0.67	1.33	1.01	0.99	1.00	1.02	0.98	1.01	0.99	0.99	1.01
	C	6	0.67	1.33	1.00	1.00	1.00	0.99	1.01	1.01	0.99	0.99	1.01

Table A- 53 State level comparisons number of transverse spalls

NUMBER OF TRANSVERSE SPALLS													
ZONE	SUBGRADE	STATE ID	DRAINAGE		BASE TYPE			PCC THICKNESS		FLEXURAL STRENGTH		LANE WIDTH	
			D	ND	DGAB	LCB	PATB	8"	11"	550 psi	900 psi	12'	14'
WF	C	10	0.30	1.70	1.17	1.38	0.45	1.41	0.59	1.03	0.97	0.47	1.53
	F	19	0.67	1.33	0.42	1.57	1.01	1.37	0.63	1.65	0.35	0.28	1.72
	F	20	0.84	1.16	0.08	1.65	1.27	1.25	0.75	0.76	1.24	1.51	0.49
	F	26	0.18	1.82	0.31	2.43	0.26	1.00	1.00	1.19	0.81	1.81	0.19
	F	38	0.60	1.40	1.33	0.77	0.90	1.57	0.43	0.74	1.26	0.83	1.17
	F	39											
WNF	C	5	0.38	1.62	0.11	2.32	0.57	0.87	1.13	0.45	1.55	0.49	1.51
	F	37	0.66	1.34	1.43	0.58	1.00	0.99	1.01	0.37	1.63	1.38	0.62
DF	F+C	8	0.66	1.34	0.43	1.57	1.00	1.18	0.82	0.86	1.14	1.49	0.51
	F+C	32	0.61	1.39	0.66	1.23	1.12	1.28	0.72	0.89	1.11	1.24	0.76
	C	53	0.00	2.00	0.00	3.00	0.00	0.00	2.00	2.00	0.00	0.00	2.00
DNF	C	4	0.67	1.33	0.49	1.50	1.01	1.22	0.78	1.31	0.69	0.77	1.23
	C	6	0.86	1.14	1.29	0.43	1.29	0.29	1.71	0.86	1.14	1.43	0.57

Table A-54 Summary of influence of the design and construction features on performance and response for SPS-2 sites

State ID	Zone	Design and Construction	Performance	Response	Comments
AZ (4)	DNF	• Mat defects and coarse mix in DGAB. Insufficient filter fabric around PATB mat. • No significant deviations in the thicknesses.	• 8" sections showed more cracking and faulting. • No pumping occurrences • DGAB sections have highest faulting	• Less variability in the midslab deflections was observed for most of the sections. Deflections for the 8" and 11" slabs are close to each other. • SDs for the LCB sections is relatively higher. • All sections showed VP, with LCB sections showing relatively higher potential for voids.	• Only 8" LCB sections showed transverse cracking. Construction problems and low structural capacity could be the causes of cracking. • Since the section is in DNF, no pumping was observed. • Since no pumping was observed, faulting could be due to the malfunctioning of the dowel bars. • VP in all sections is because of a positive thermal gradient. It is also accompanied by a high D-ratio. • Effect of lane width is inconclusive.
AR (5)	WNF	• No significant deviations	• 8" sections showed more cracking. • High severity cracking was observed in 5-0218.Quicker progression in severity levels was also observed. • Pumping was observed in the LCB sections. • DGAB sections have higher faulting than PATB sections.	• 8" sections and DGAB sections had greater variability in deflections than the 11" sections. • LCB sections have the least LTE. • SDs for J4 and J5 are however close and not too high. • LCB sections showed higher VP.	• Sections with 12' had higher transverse cracking than the 14' sections. • Pumping might be aggravated due to the joint sealant damages. • Non-drainable sections showed higher faulting than drainable sections. • DGAB sections showed variability in the midslab deflections, which could be due to the low stiffness. • High SDs on J4 and low SDs on J5 may indicate problems on the approach side of the joint. • VP in all sections is because of a positive thermal gradient. It is also accompanied by a high D-ratio

Table A-54 (cont'd).

State ID	Zone	Design and Construction	Performance	Response	Comments
CA (6)	DNF	• Cracks in LCB due to shrinkage	• Transverse Cracks prominent in the LCB sections. • High intensity of Transverse Cracks in the 8" sections. • No pumping occurrences	• J1 Deflection Variability in cracked sections only. • SDs are least for LCB sections and highest for PATB sections. • 8" DGAB sections showed VP.	• Construction problems in LCB caused Transverse cracks. • Since the section is in DNF, no pumping was observed. • Midslab cracking caused J1 deflection variability. • Low stiffness of DGAB could have resulted in VP.
CO (8)	DF	• Pumping and rise in level of GW table	• 8-0218 showed Transverse Cracks. • 8" PATB sections had higher faulting	• 8" sections showed J1 deflection data variability • 8-0217 showed high variability • SDs is high at the PATB joints. • VP observed in DGAB sections	• Only 8" sections with 12' lanes showed Transverse Cracks. • PATB faulting could be due to the pumping observed during construction. • 8" sections and positive thermal gradient resulted in J1 deflection data variability. • Positive thermal gradient, high D-ratio and high LTEs accompanied VP.
DE(10)	WF	• Serious shrinkage cracking and spalling	• 10-0205 showed Transverse Cracks • Pumping only in LCB • DGAB and LCB had higher faulting with 8" slabs showing higher faulting than 11" sections.	• DGAB sections and 10-0205 showed J1 data variability. • SDs is high at the PATB joints.	• Only 8" sections with 12' lanes showed Transverse Cracks. • Low stiffness of the DGAB sections could have caused deflection data variability. • Variability in 10-0205 could be due to transverse cracking.

Table A-54 (cont'd).

State ID	Zone	Design and Construction	Performance	Response	Comments
IA(19)	WF	• 19-0217 was constructed 0.3 in thinner.	• Transverse Cracks and pumping in LCB sections only. • Faulting was higher in the non-drainable sections.	• 8" sections showed more variability. • LTEs are low in the PATB sections and SDs are high in the DGAB sections. • VP only in the 8" DGAB sections.	• Effect of lane width is inconclusive. • Pumping might be aggravated due to the longitudinal cracking and joint sealant damages. • Sections that did not crack did not meet the target design ESALs (according to AASHTO '98 analysis) • 19-0217 showed high variability in J1 data because of under-construction of the PCC slab. • High positive thermal gradient could have resulted in J1 data variability in section 0221.
KS(20)	WF	• Excess PATB was placed and removed.	• 8" sections showed Transverse Cracks. • 0201 and 0206 showed pumping.	• 0201,0202,0207,0209 and 0211 showed variability in J1 data. • DGAB and LCB sections have the least LTE values. • VP observed in the 8" and 12' sections, in both the DGAB, LCB and PATB sections.	• High positive thermal gradient, transverse cracking, under construction of the sections could have caused deflection data variability. • High SDs at J4 indicate problems at the approach side of the joint. • High LTE, high D-ratio and negative thermal gradient accompanied VP.

Table A-54 (cont'd).

State ID	Zone	Design and Construction	Performance	Response	Comments
MI(26)	WF	• Transverse shrinkage cracks in the LCB. • Extra amount of water entered the pavement structure since this section is located on super elevation, which drains toward the outside shoulder.	• 0213,0214,0215 and 0218 showed Transverse Cracks. • LCB sections had higher pumping occurrences than DGAB sections. • DGAB sections had higher faulting than other sections.	• 11" sections had lower deflections than 8" sections. • Less variation in the deflection data was observed for 11" sections. • High SDs and low LTEs were observed. • DGAB sections showed a higher potential for voids than other sections.	• 11" thick and 14' wide sections did not show Transverse Cracks. • 0218 showed Transverse Cracks because of LCB shrinkage cracks during construction. • Pumping in 26-0218 was accentuated due to the extra amount of water entering the pavement structure since the section is located on a super elevation, which drains towards the outside shoulder. • Effect of dowel diameter on faulting is not explicit as thicker sections have 1.5" dowel bars. • All 11" sections and 8" PATB sections showed less variation in the deflection data over time. • Variation in the deflection data in sections 0213,0214 and 0218 indicate low structural capacity, which is supported by the presence of transverse cracking. • Variation in the deflection data in section 0217 is caused by thermal curling of the slab as the deflection test was done under a positive thermal gradient.

Table A-54 (cont'd).

State ID	Zone	Design and Construction	Performance	Response	Comments
NV(32)	DF	• 0205 and 0212 had severe shrinkage cracking • Block cracking in 0208 • Target strengths and w/c ratios lowered • 0201 and 0209 had high variations in deflection	• Extensive cracking in all sections. • High number of cracks in the non-drainable sections. • 8" sections showed greater faulting than the 11" sections.	• 0201,0202 and 0210 have shown variability in the midslab deflection data. • Joints in the LCB sections have the least LTE while those in the PATB sections have the highest LTE. • 12' DGAB and LCB sections showed VP.	• Severe problems encountered during construction resulted in transverse cracks on the surface and midslab deflection data variability. • Sections with an 8" PCC and a non-drainable base showed more Transverse Cracks and faulting. • Good load transfer and low VP were observed in the non-drainable sections.
NC(37)	WNF	• Heavy rains cause problems for sections 0204 and 0207. • 1" dowel bars were used instead of 1.25" dowel bars. • Embankment at 0210 had a slope failure, which may cause failure in the shoulder and driving lane. • DGAB at 0201 was not compacted and hence it may lead to settlement.	• Transverse Cracks occurred in all base types. • Transverse Cracks predominant in sections with an 8" PCC and a 12' lane width. • High faulting in the non-drainable sections.	• 0201,0202,0205 and 0210 showed midslab deflection data variability. • Low LTEs and high SDs in the LCB joints. • VP observed only in 0201.	• Transverse Cracks in 0210 might be due to the slope failure. • Low structural capacity and low lane width (12') could have resulted in Transverse Cracks. • High faulting may be due to non-provision of drainage and use of 1" dowel bars instead of 1.25" dowel bars. • Transverse cracks in 0201,0205 and 0210 could be due to Transverse cracks in these sections. • High positive thermal gradient during the time of FWD testing could have resulted in variability in the deflection data. • Positive thermal gradient and reasonably high LTEs accompanied VP.

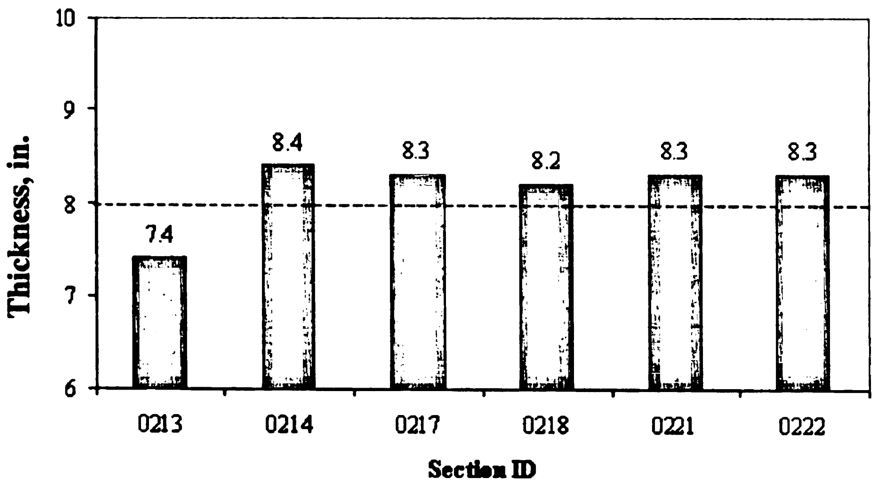
Table A-54 (cont'd).

State ID	Zone	Design and Construction	Performance	Response	Comments
ND(38)	WF	• Reflection cracks appeared in 0217. • Improper placement of the PATB layer resulted in loss of shape.	• Transverse cracks observed only in 0217. • 8" LCB sections showed pumping. • High faulting in the PATB sections.	• 0213,0214,0217 and 0221 showed variability in the midslab deflection data. • Low LTEs and high SDs in the LCB joints. • VP observed in some sections.	• Cracks that appeared during construction manifested as Transverse cracks in 0217. • Pumping could have been aggravated by longitudinal cracks. • High faulting in the PATB sections could be due to the improper placement of the PATB layer because of which it lost shape. • LCB joints are performing worse than the others. • High D-ratio and positive thermal gradient accompanied VP.
OH(39)	WF	• No problems were encountered	• Cracking was more in the DGAB sections. • 8" sections with 12' lane width exhibited higher cracking.	• 0201,0202,0205 and 0209 have shown midslab and sensor 7 deflection data variability. • High SDs and low LTEs at the DGAB joints. • Only 12' DGAB sections showed VP.	• 8" sections with 12' lane width showed Transverse cracks. • Transverse cracks in 0202 and 0205 together with a high positive thermal gradient could be the cause of variability in the deflection data in these sections. • High D-ratio accompanied VP in all these sections.

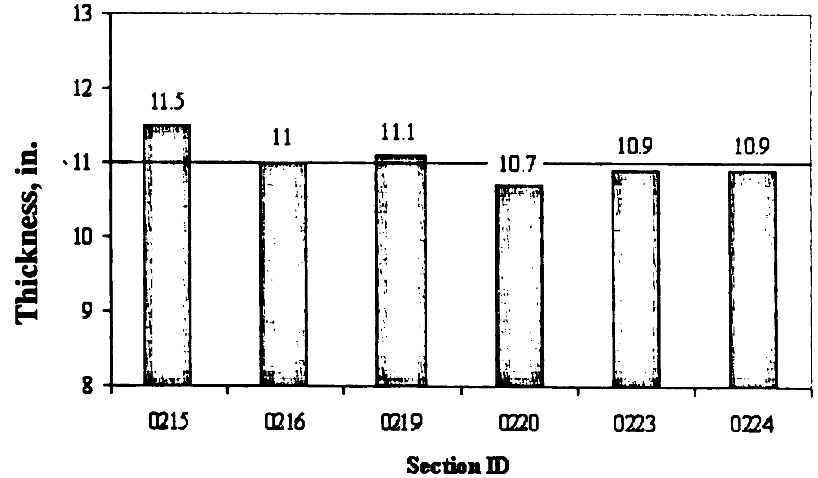
Table A-54 (cont'd).

State ID	Zone	Design and Construction	Performance	Response	Comments
WA(53)	WF	• Traffic during construction caused bleeding to surface. • Surface voids appeared due to the mix being unconsolidated. • Shrinkage cracks in 0206.	• 8" sections showed Transverse cracks. • Higher faulting in the LCB and PATB sections.	• 0201,0202,0206,0209 and 0210 showed variability in the J1 data. • PATB joints have the least LTE. • High SDs in the DGAB joints. • VP observed in the 8" sections in all the three base types.	• Counter intuitively, faulting in the LCB and PATB sections. • Transverse cracks (as a result of shrinkage cracks during construction) could have resulted in the deflection data variability. • Positive thermal gradient and reasonably high D-ratio accompanied VP in all the three base types.
WI(55)	WF	• No problems during construction	• Faulting was observed mostly in the 8" sections.	• Excessively high deflections in 0222. • VP observed in the 12-ft LCB sections and 8" PATB sections.	• High positive thermal gradient of 11.6 deg C/in. at the time of FWD testing could be the reasons for excessively high deflections in 0222. • High D-ratios and positive thermal gradients accompanied VP in all the sections.

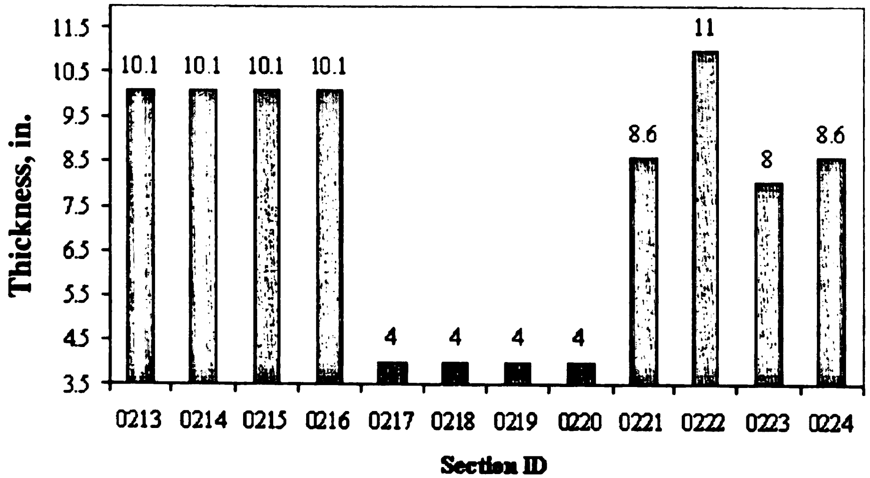
Appendix B
Figures



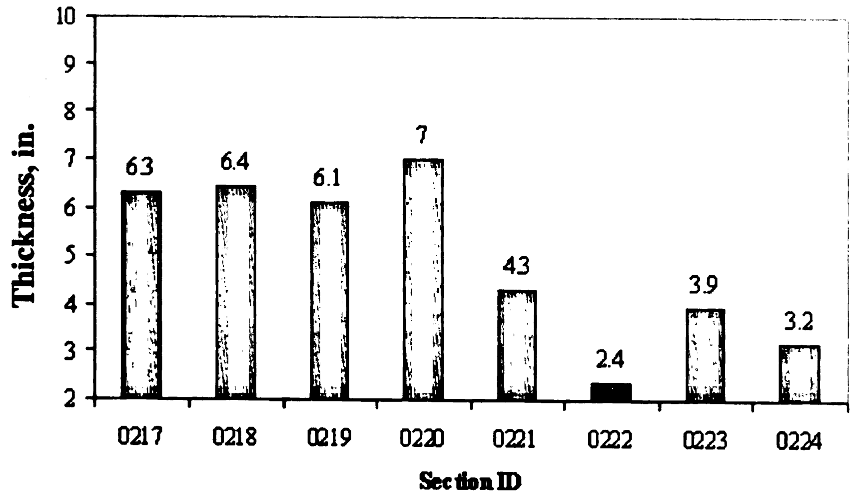
PCC thickness variability in the 8" sections



PCC thickness variability in the 11" sections

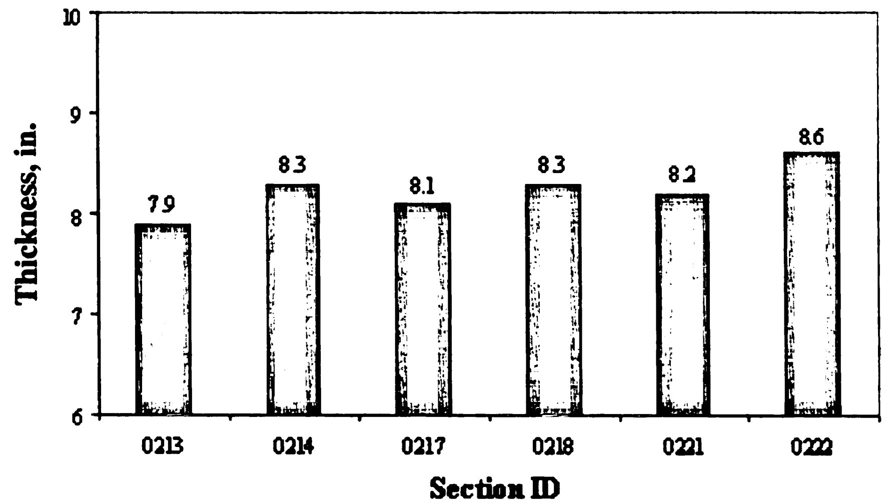


DGAB thickness variability

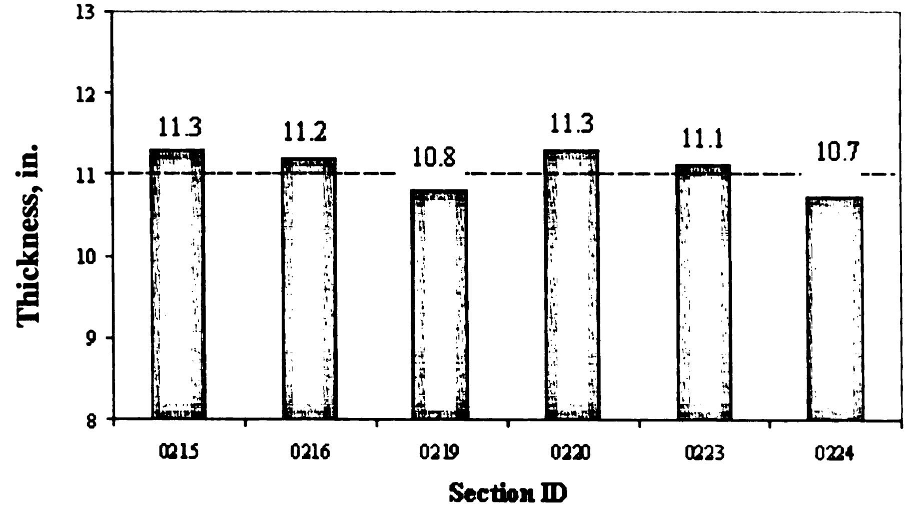


PATB thickness variability

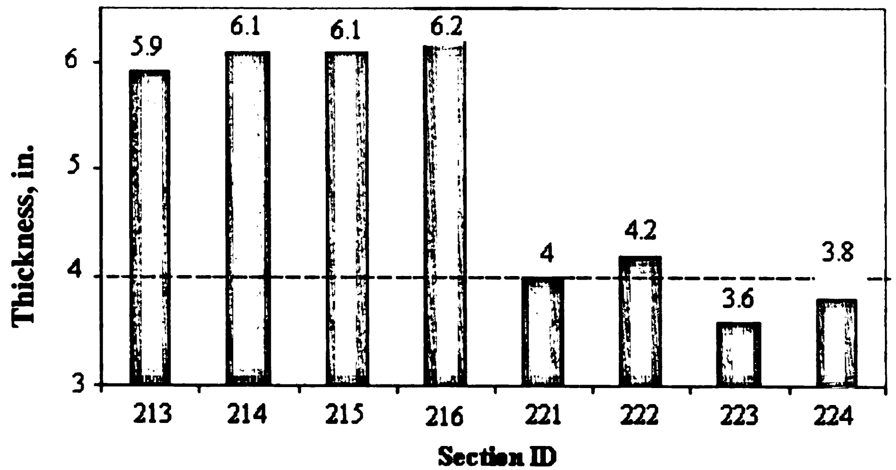
Figure B- 1 Thickness variability plots in AR (5)



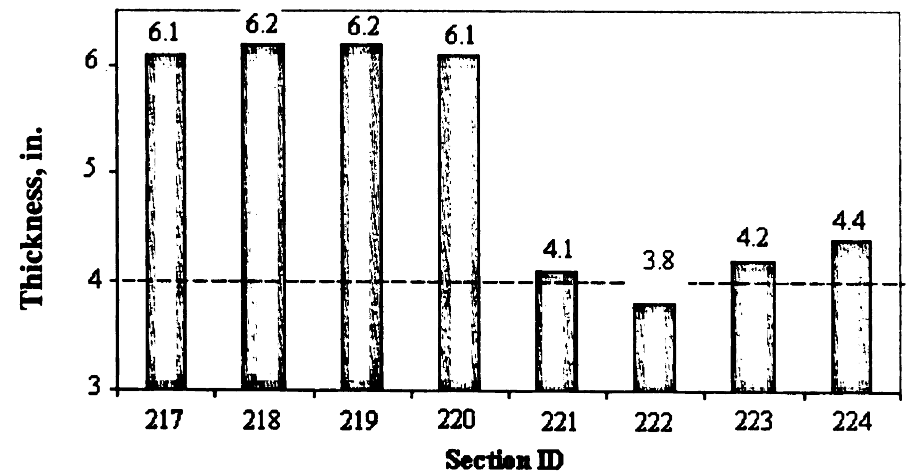
PCC thickness variability in the 8" sections



PCC thickness variability in the 11" sections

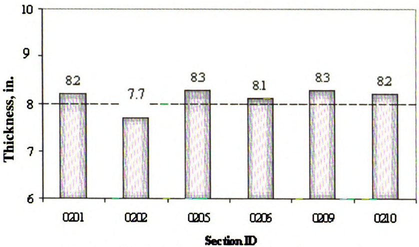


DGAB thickness variability

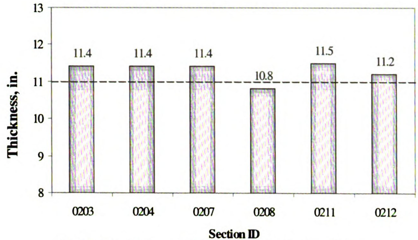


LCB and PATB thickness variability

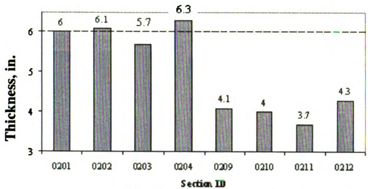
Figure B-2 Thickness variability in AZ (4)



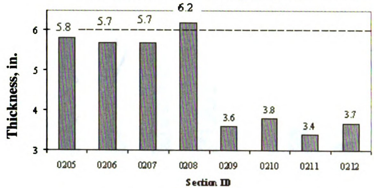
PCC thickness variability in the 8" sections



PCC thickness variability in the 11" sections

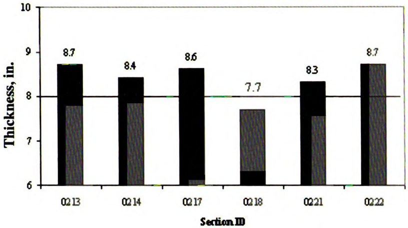


DGAB thickness variability

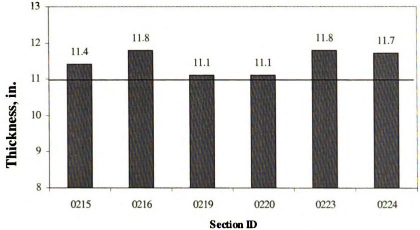


LCB and PATB thickness variability

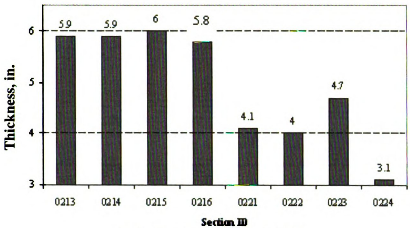
Figure B-3 Thickness variability in CA (6)



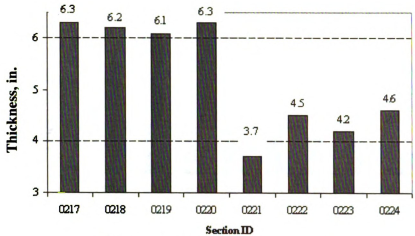
PCC thickness variability in the 8" sections



PCC thickness variability in the 11" sections

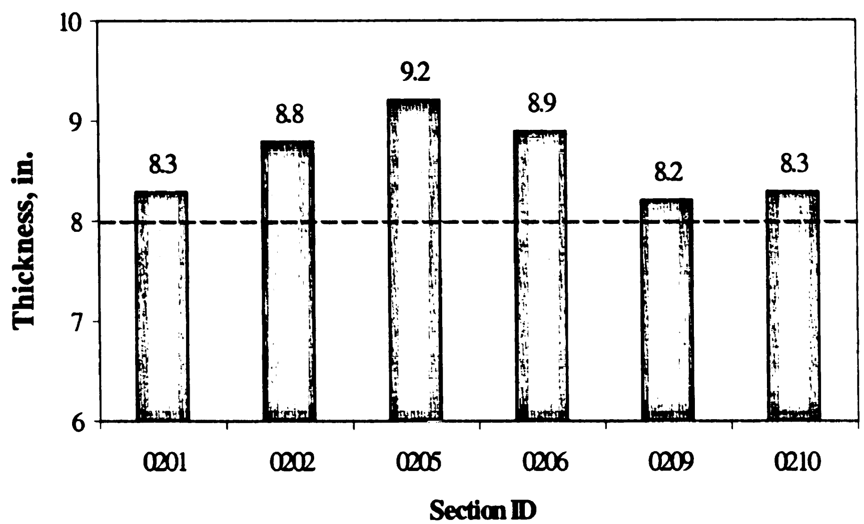


DGAB thickness variability

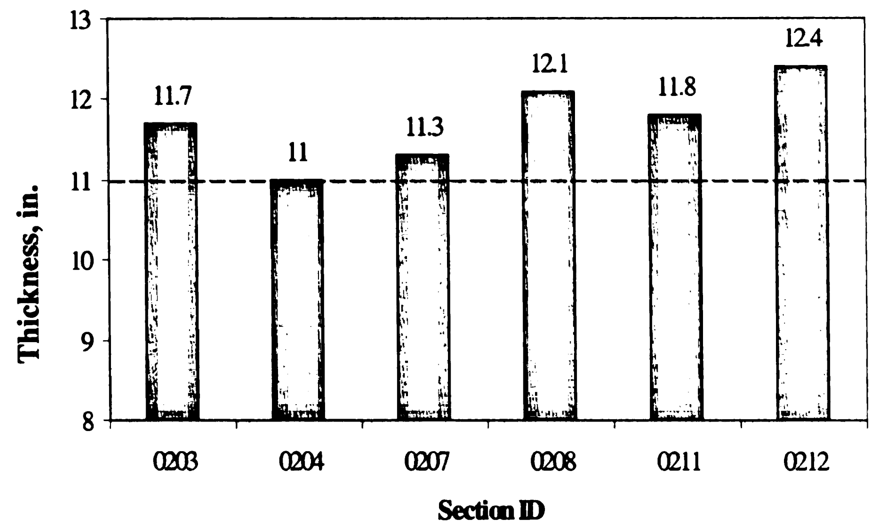


LCB and PATB thickness variability

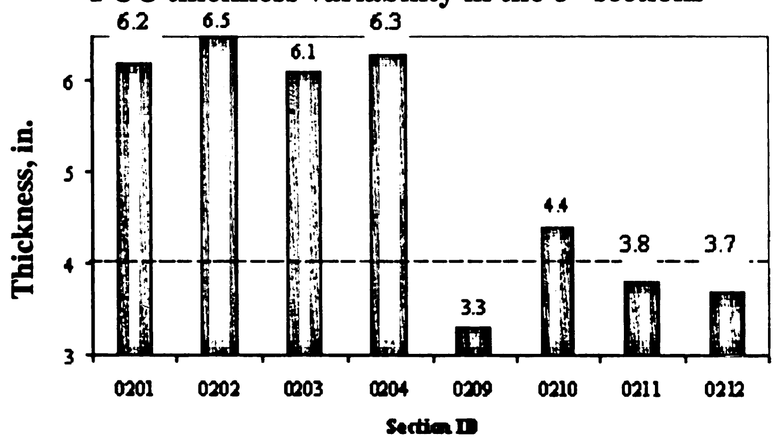
Figure B-4 Thickness variability in CO (8)



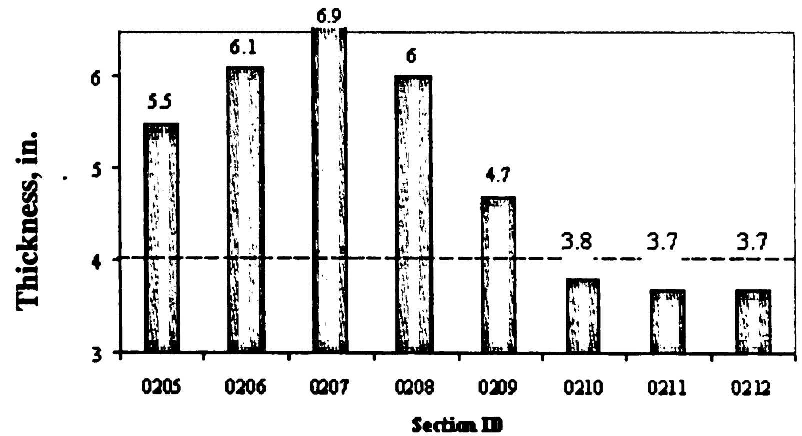
PCC thickness variability in the 8" sections



PCC thickness variability in the 11" sections

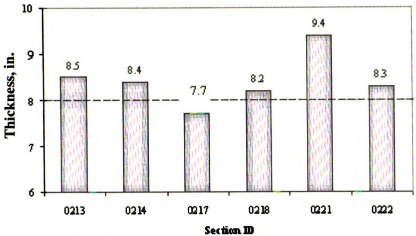


DGAB thickness variability

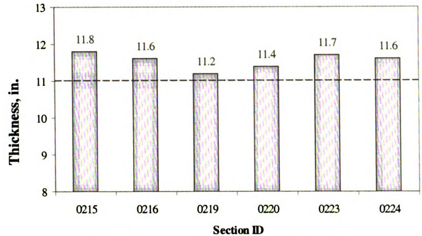


LCB and PATB thickness variability

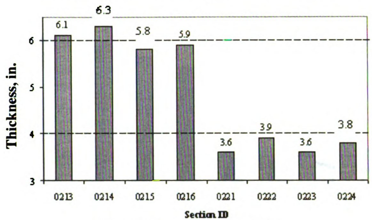
Figure B-5 Thickness variability in DE (10)



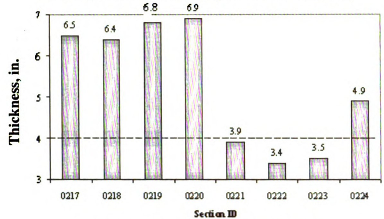
PCC thickness variability in the 8" sections



PCC thickness variability in the 11" sections

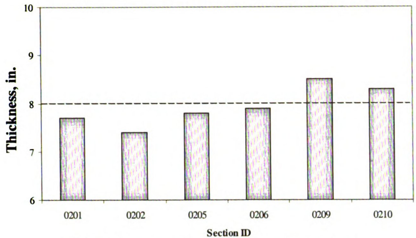


DGAB thickness variability

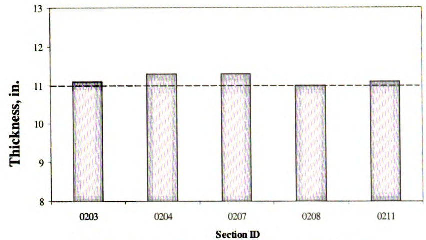


LCB and PATB thickness variability

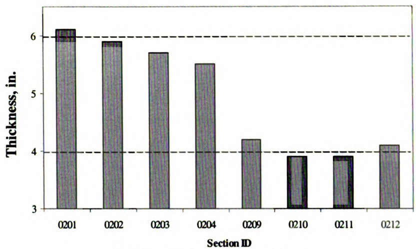
Figure B-6 Thickness variability in IA (19)



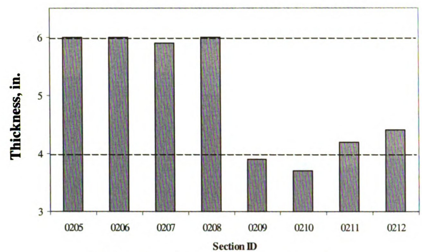
PCC thickness variability in the 8" sections



PCC thickness variability in the 11" sections

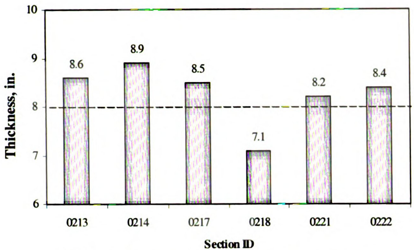


DGAB thickness variability

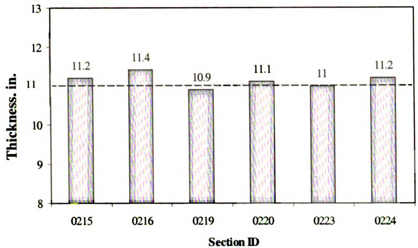


LCB and PATB thickness variability

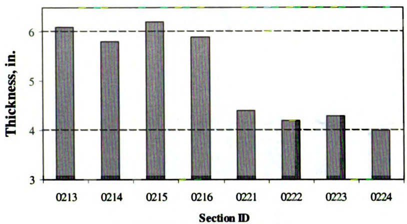
Figure B-7 Thickness variability in KS (20)



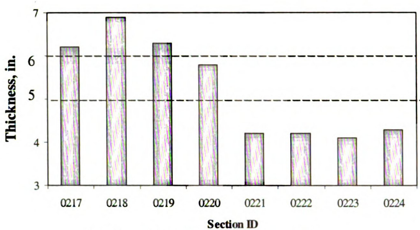
PCC thickness variability in the 8" sections



PCC thickness variability in the 11" sections

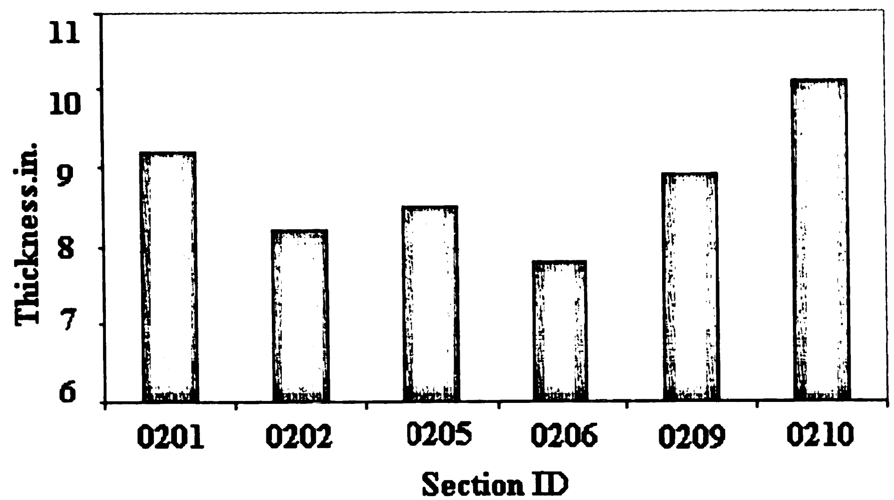


DGAB thickness variability

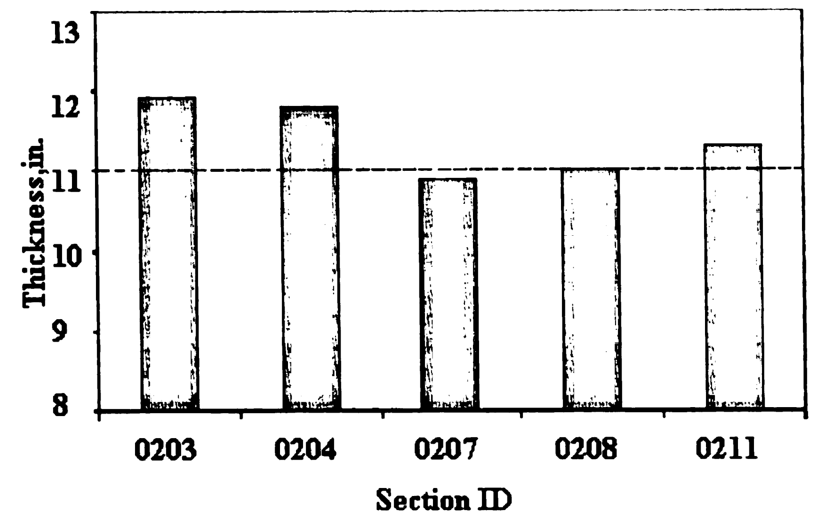


LCB and PATB thickness variability

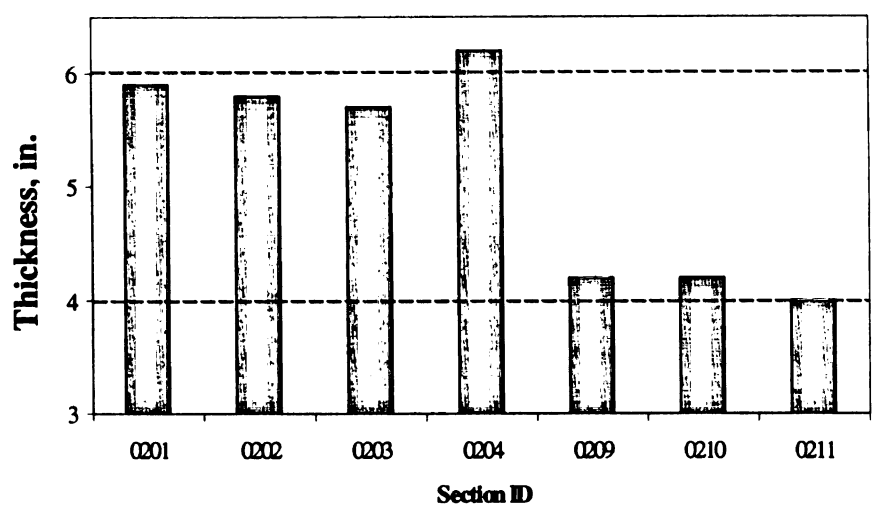
Figure B-8 Thickness variability in MI (26)



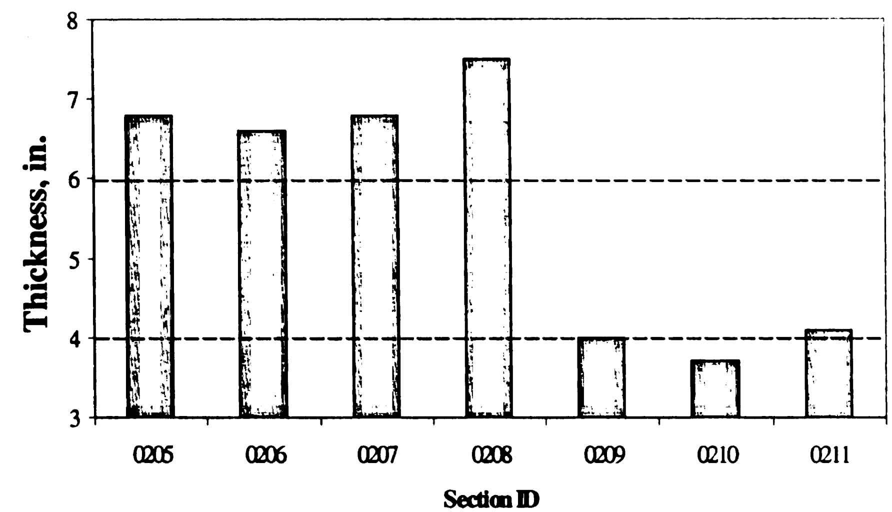
PCC thickness variability in the 8" sections



PCC thickness variability in the 11" sections

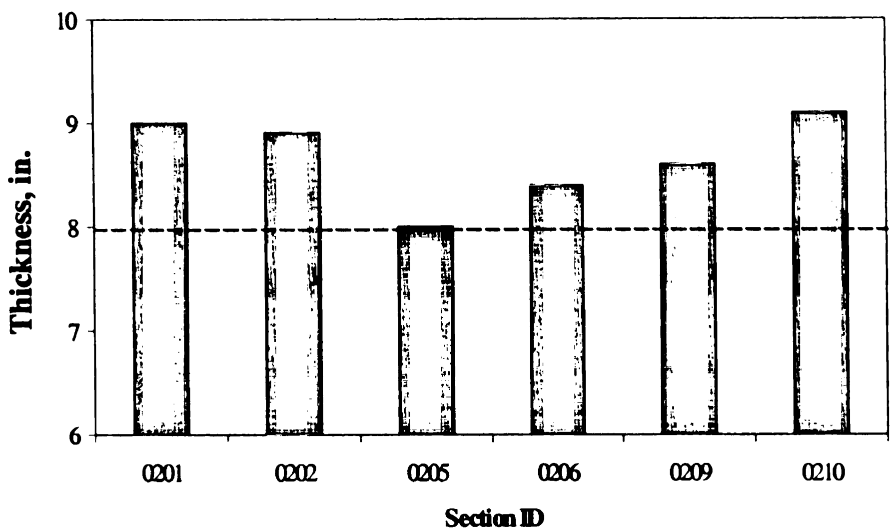


DGAB thickness variability

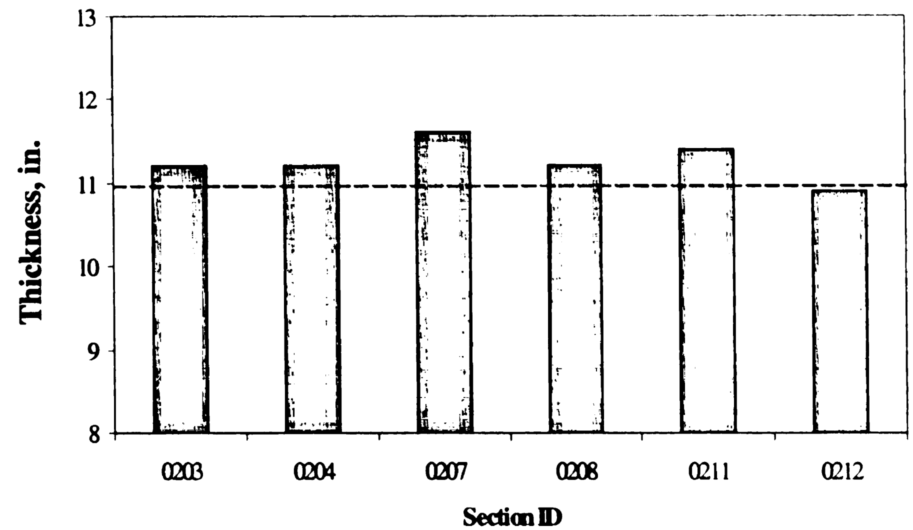


LCB and PATB thickness variability

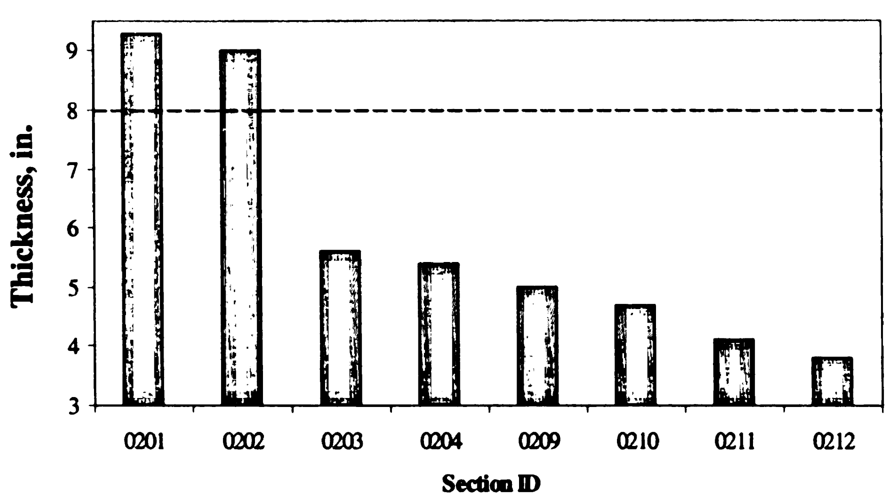
Figure B-9 Thickness variability in NV (32)



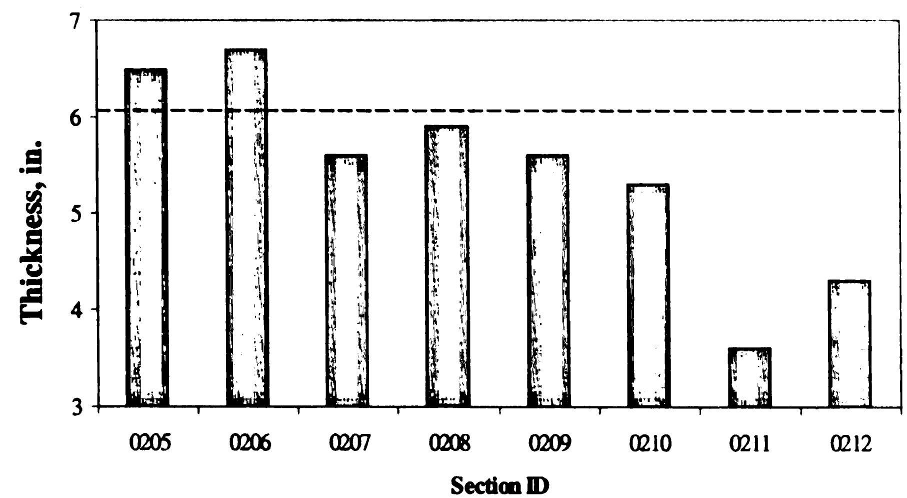
PCC thickness variability in the 8" sections



PCC thickness variability in the 11" sections

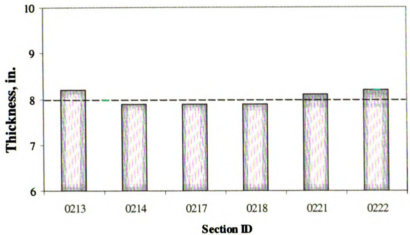


DGAB thickness variability

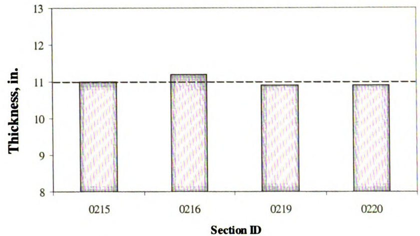


LCB and PATB thickness variability

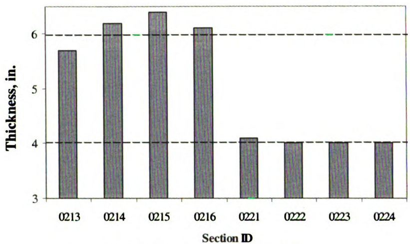
Figure B-10 Thickness variability in NC (37)



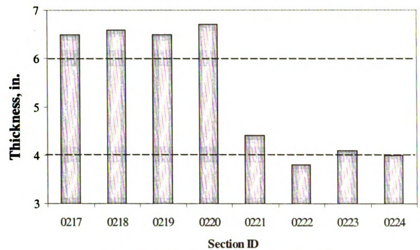
PCC thickness variability in the 8" sections



PCC thickness variability in the 11" sections

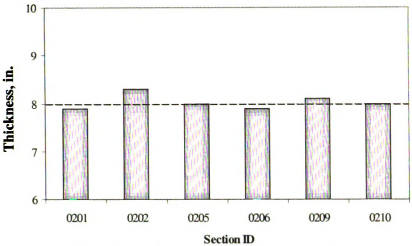


DGAB thickness variability

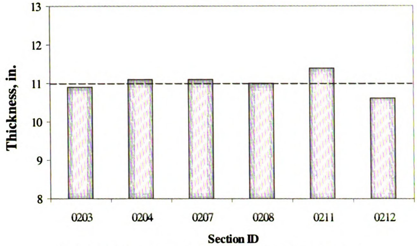


LCB and PATB thickness variability

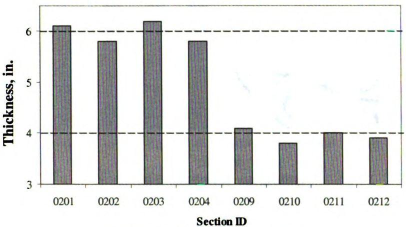
Figure B-11 Thickness variability in ND (38)



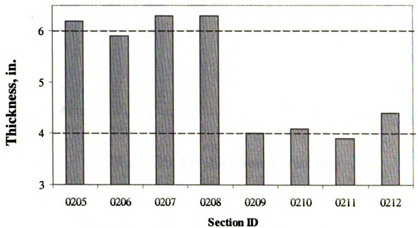
PCC thickness variability in the 8" sections



PCC thickness variability in the 11" sections

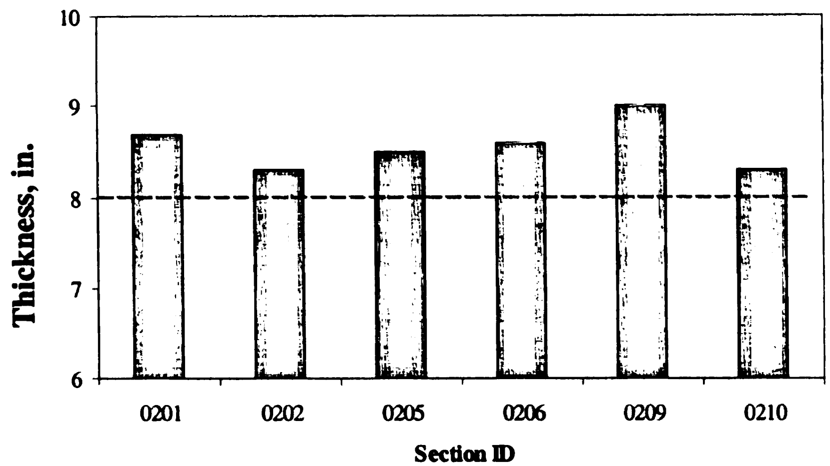


DGAB thickness variability

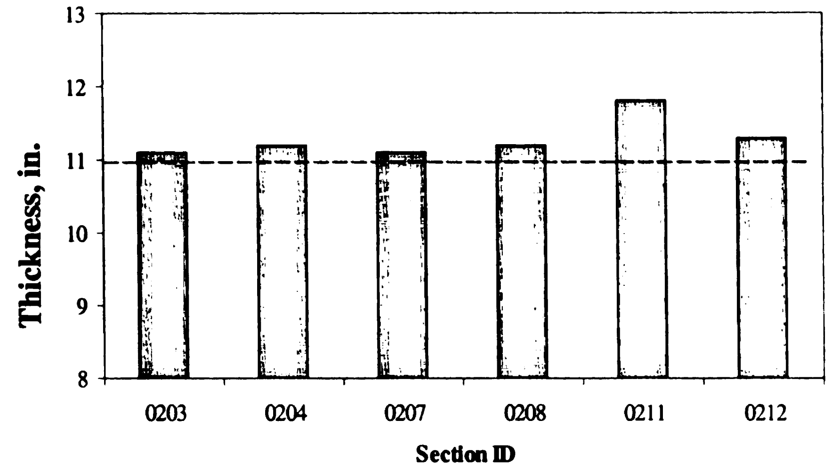


LCB and PATB thickness variability

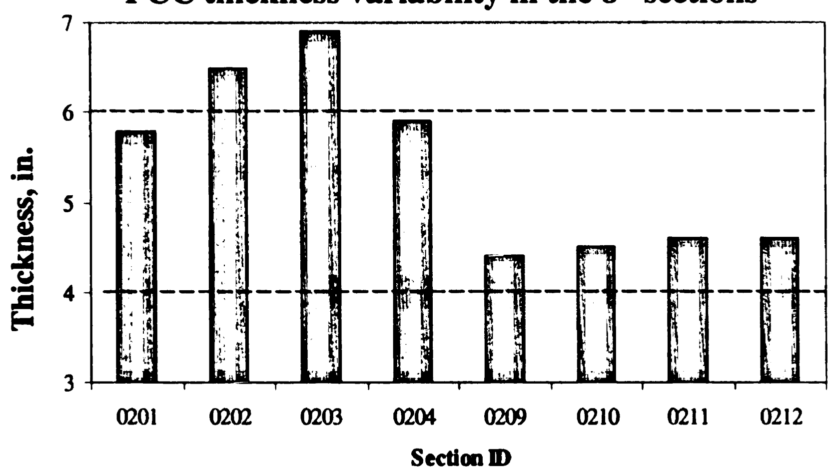
Figure B-12 Thickness variability in OH (39)



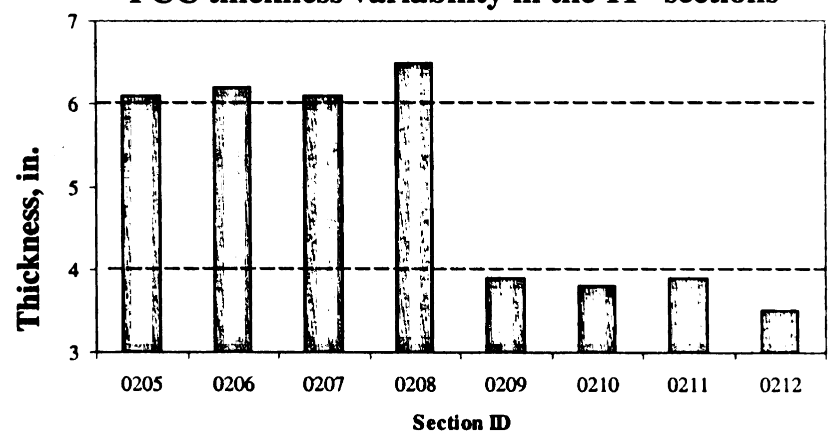
PCC thickness variability in the 8" sections



PCC thickness variability in the 11" sections



DGAB thickness variability



LCB and PATB thickness variability

Figure B-13 Thickness variability in WA (53)

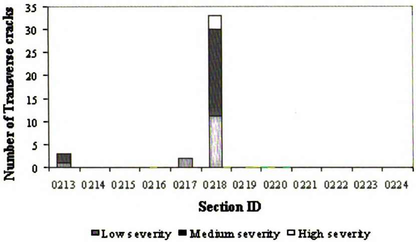


Figure B-14 Transverse cracks with time for AR (5)

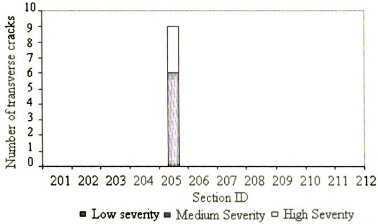


Figure B-15 Transverse cracks with time for DE (10)

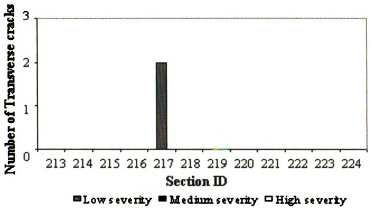


Figure B-16 Transverse cracks with time for IA (19)

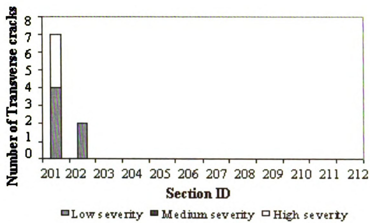


Figure B-17 Transverse cracks with time for KS (20)

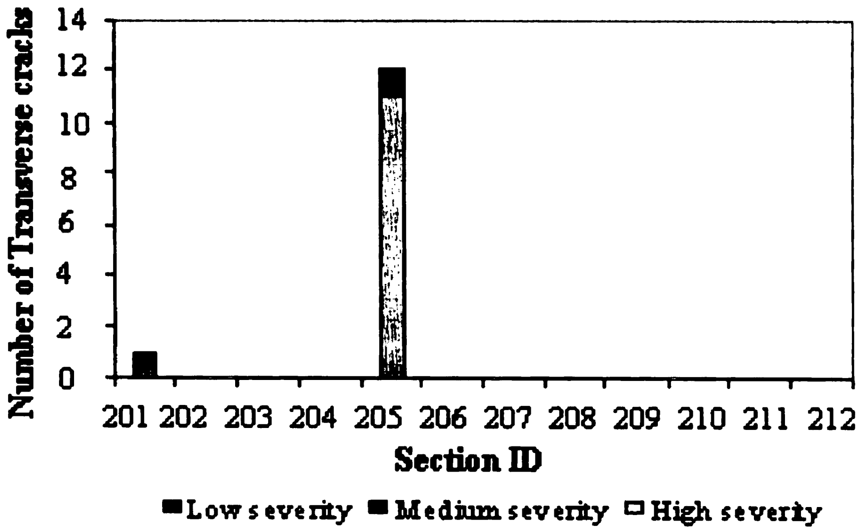


Figure B-18 Transverse cracks with time for NC (37)

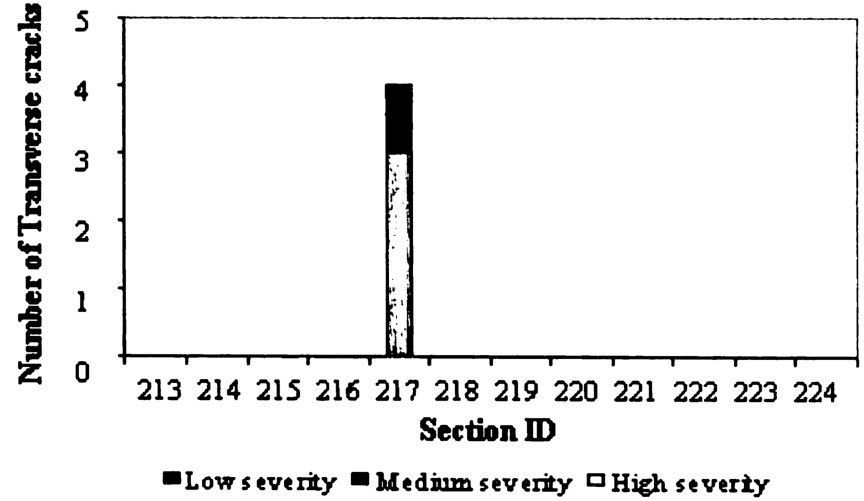


Figure B-19 Transverse cracks with time for ND (38)

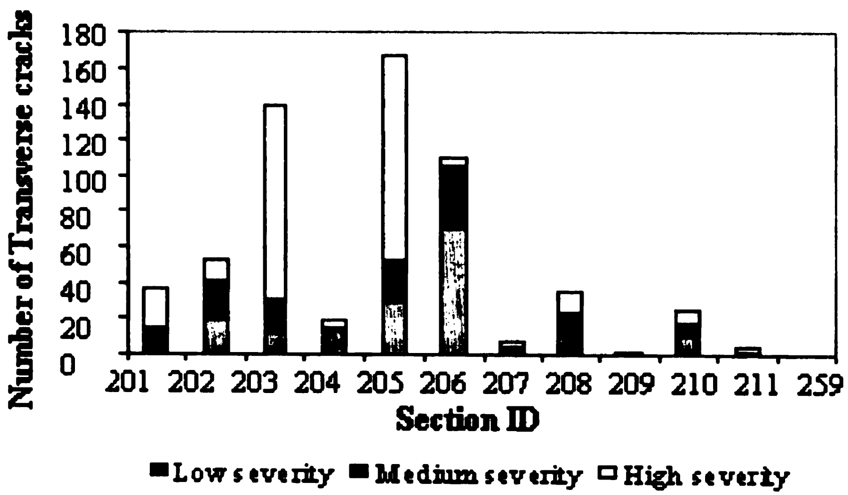


Figure B-20 Transverse cracks with time for NV (32)

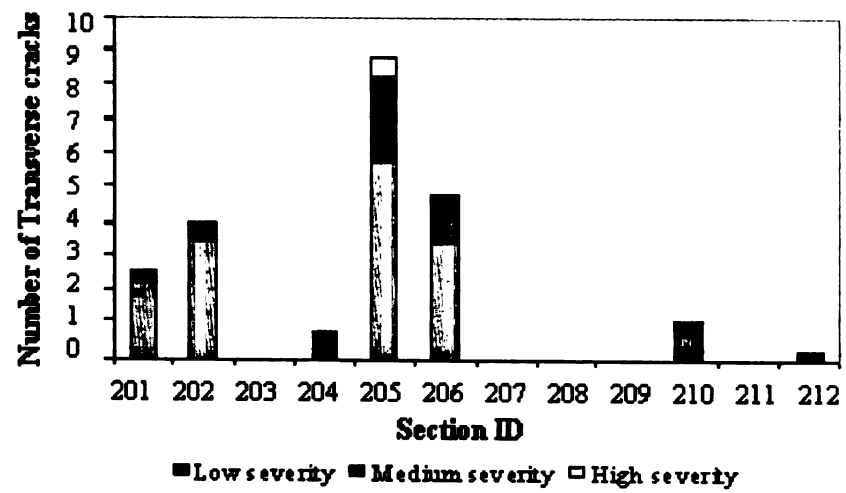


Figure B-21 Transverse cracks with time for OH (39)

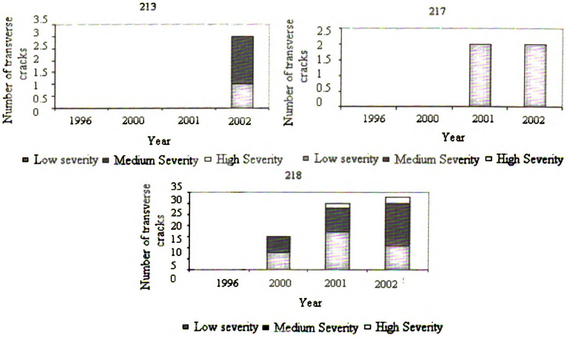


Figure B-22 Progression of transverse cracks in AR (5)

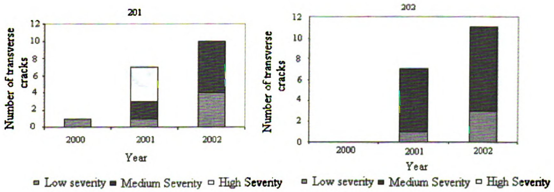


Figure B-23 Progression of transverse cracks in CA (6)

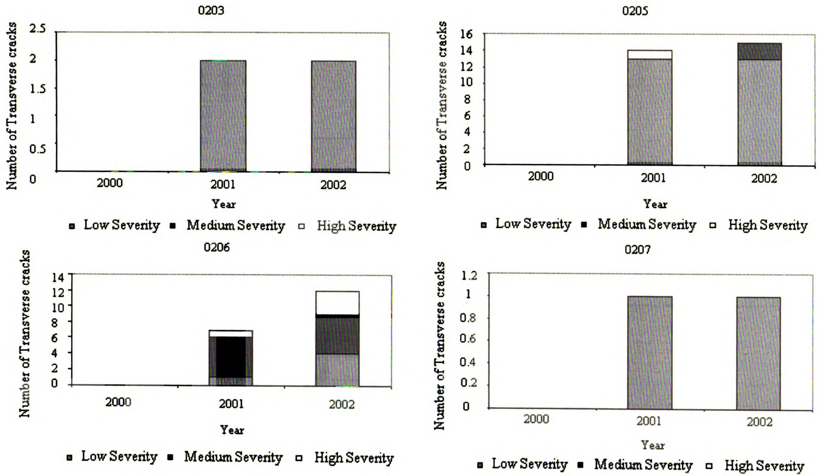


Figure B- 24 Progression of transverse cracks in CA (6) (contd.)

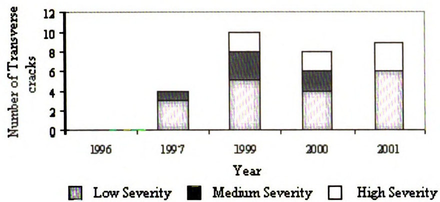


Figure B- 25 Progression of transverse cracks in DE (10)

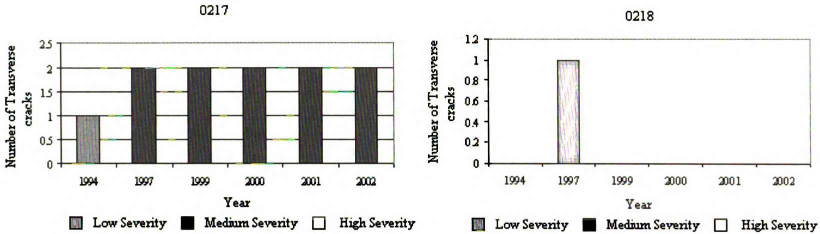


Figure B- 26 Progression of Transverse cracks in IA (19)

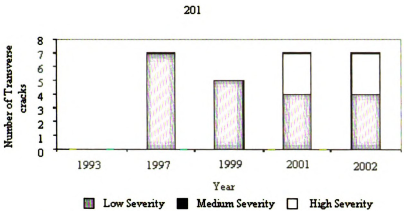


Figure B- 27 Progression of transverse cracks in KS (20)

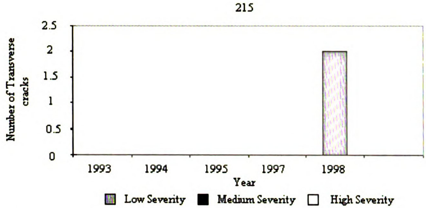


Figure B- 28 Progression of Transverse cracks in MI (26)

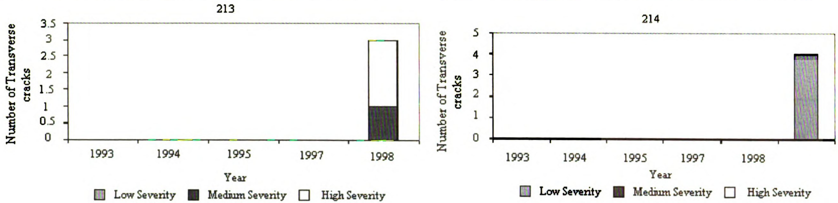


Figure B- 29 Progression of Transverse cracks in MI (26) (contd.)

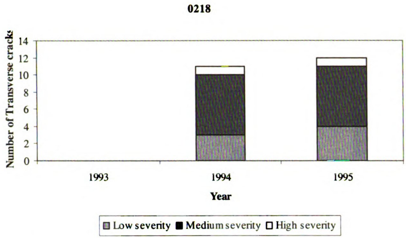


Figure B- 30 Progression of Transverse cracks in MI (26) (Contd.)

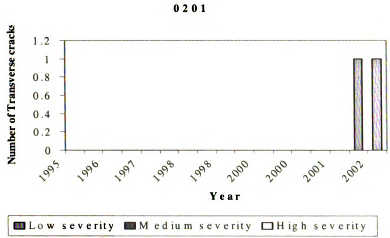


Figure B- 31 Progression of Transverse cracks in NC (37)

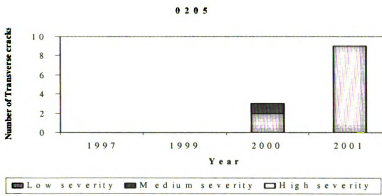


Figure B- 32 Progression of Transverse cracks in NC (37) (contd.)

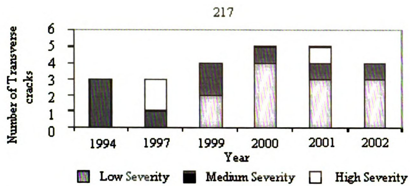


Figure B- 33 Progression of Transverse cracks in ND (38)

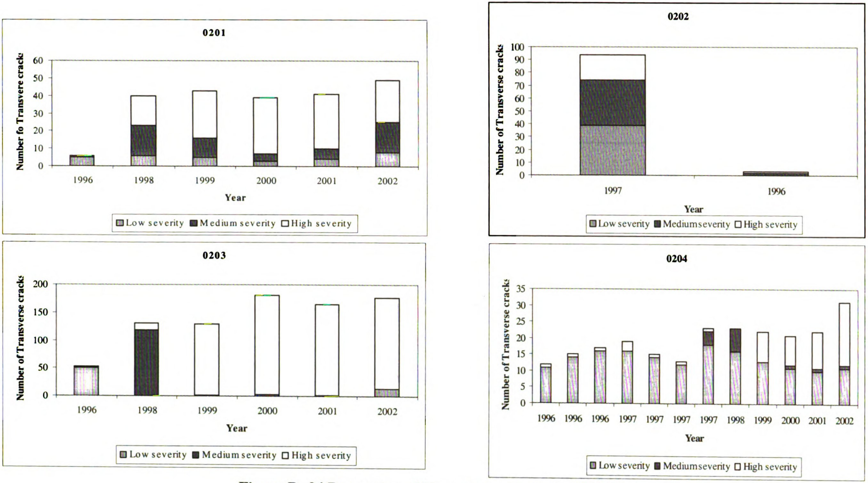


Figure B- 34 Progession of Transverse cracks in NV (32)

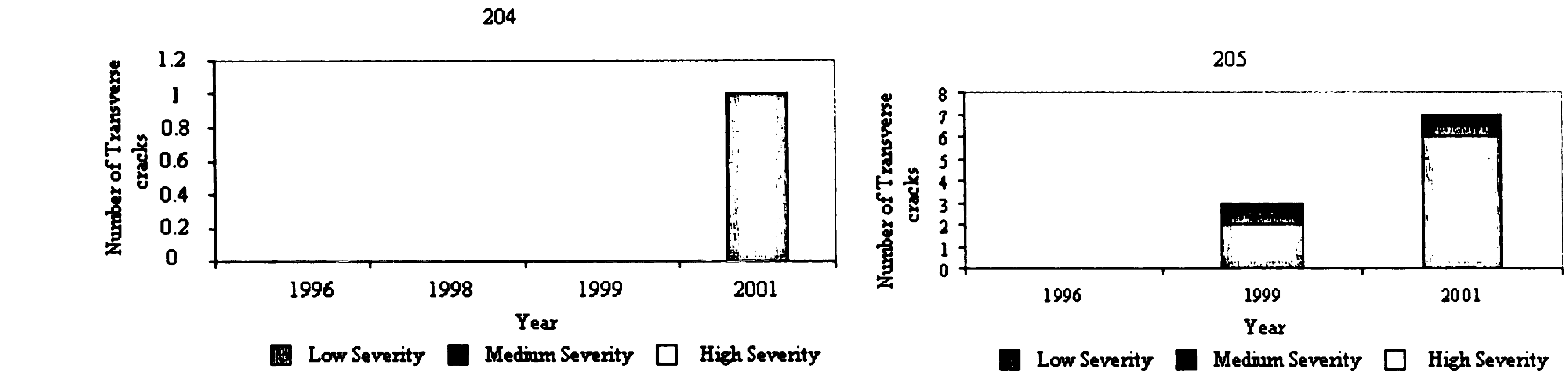


Figure B- 35 Progression of Transverse cracks in OH (39)

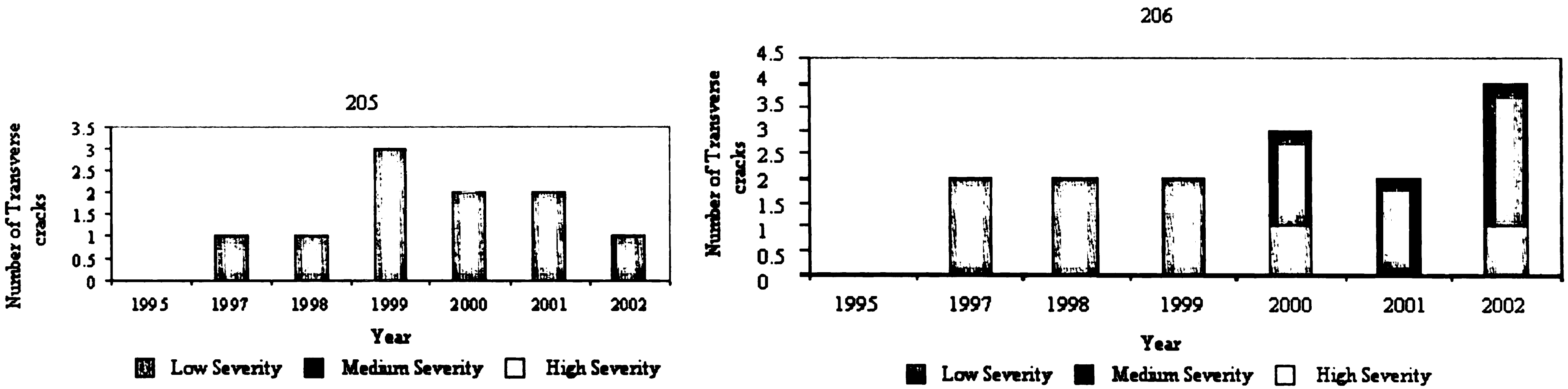


Figure B- 36 Progression of Transverse cracks in WA (53)

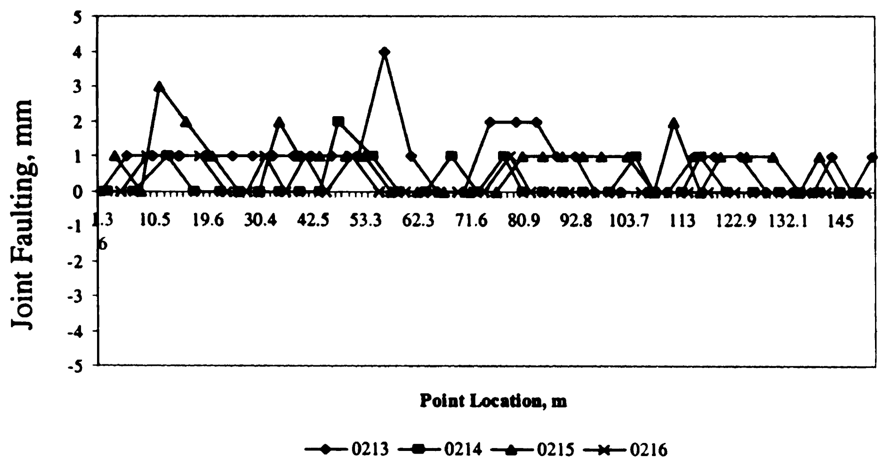


Figure B- 37 Joint faulting in DGAB sections - AR (5)

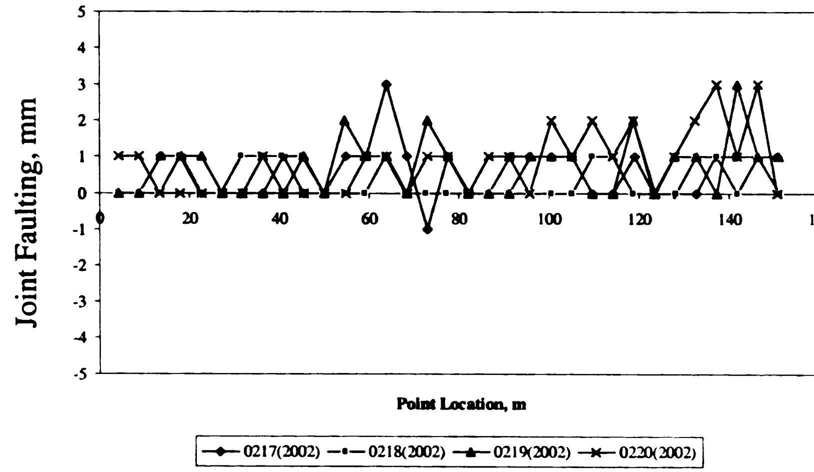


Figure B- 38 Joint faulting in LCB sections - AR (5)

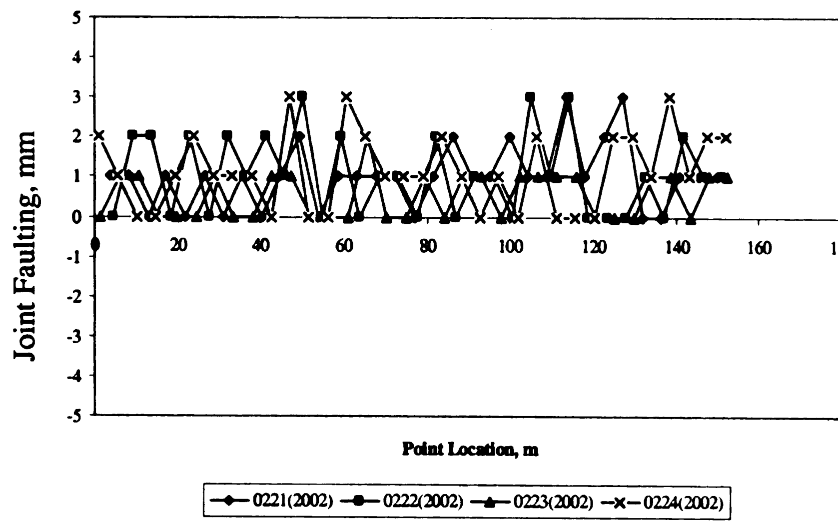


Figure B- 39 Joint faulting in PATB sections - AR (5)

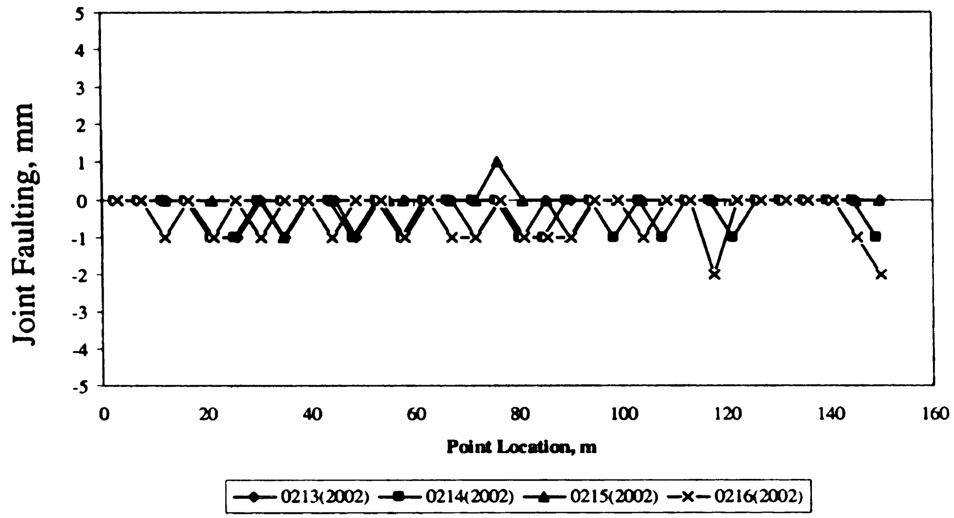


Figure B- 40 Joint faulting in DGAB sections - AZ (4)

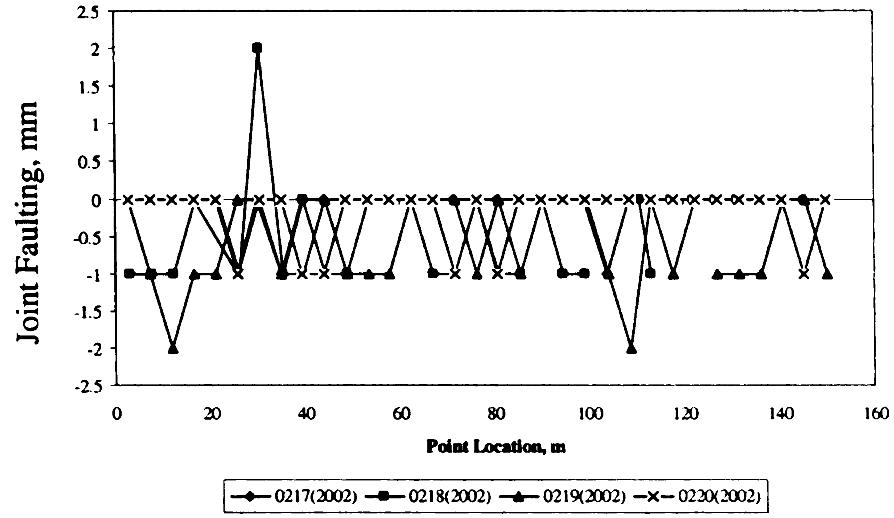


Figure B- 41 Joint faulting in LCB sections - AZ (4)

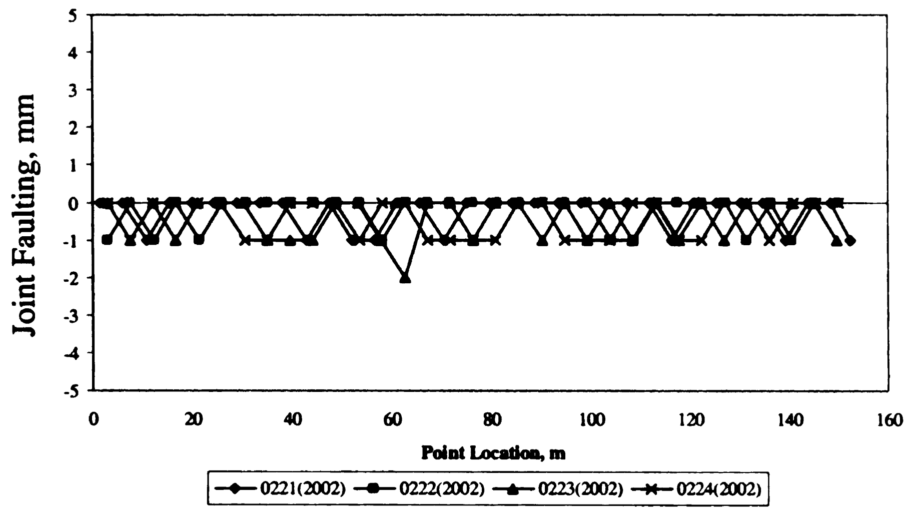


Figure B- 42 Joint faulting in PATB sections - AZ (4)

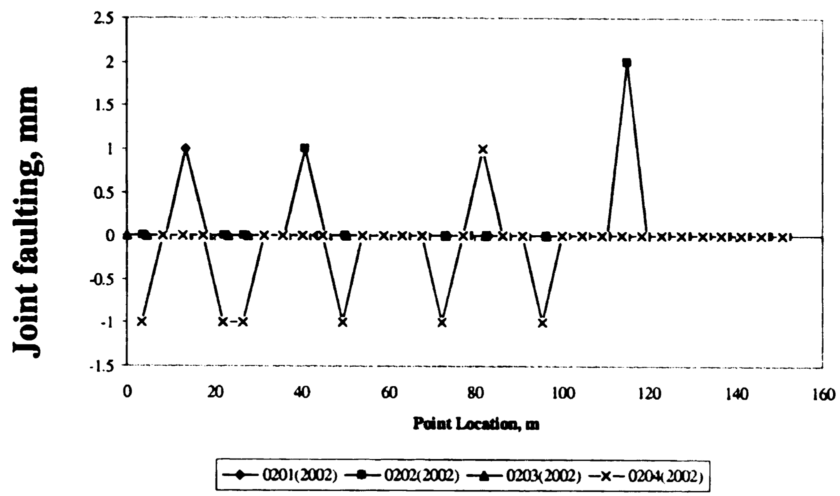


Figure B- 43 Joint faulting in DGAB sections - CA (6)

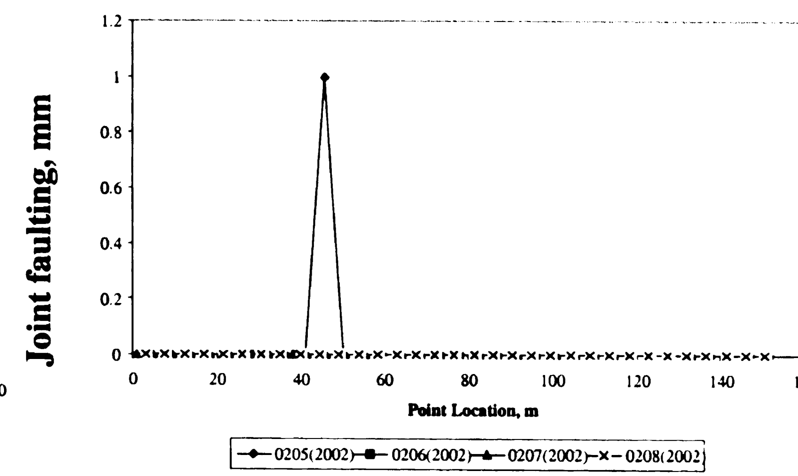


Figure B- 44 Joint faulting in LCB sections - CA (6)

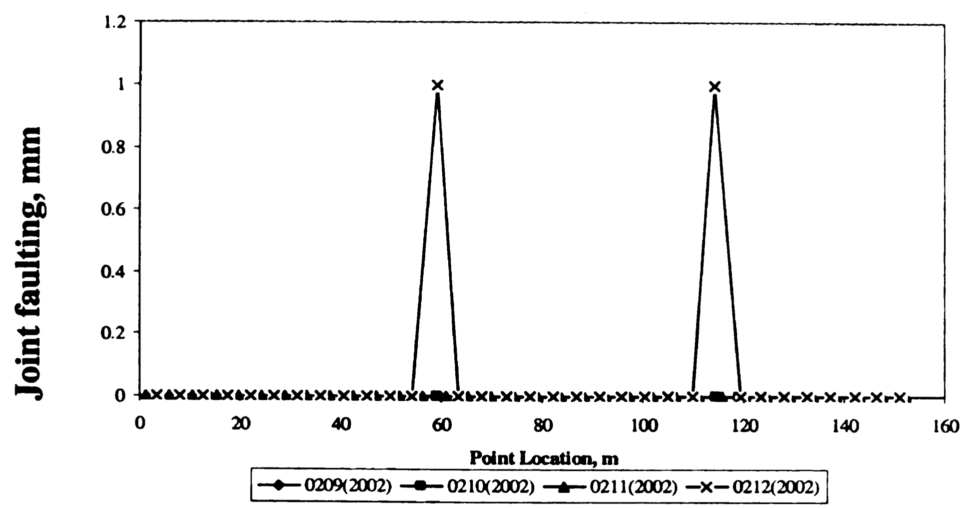


Figure B- 45 Joint faulting in PATB sections - CA (6)

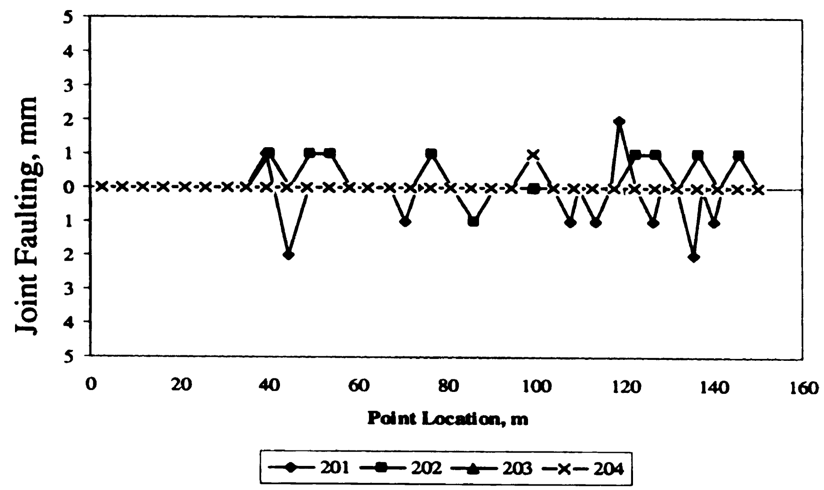


Figure B- 46 Joint faulting in DGAB sections - DE (10)

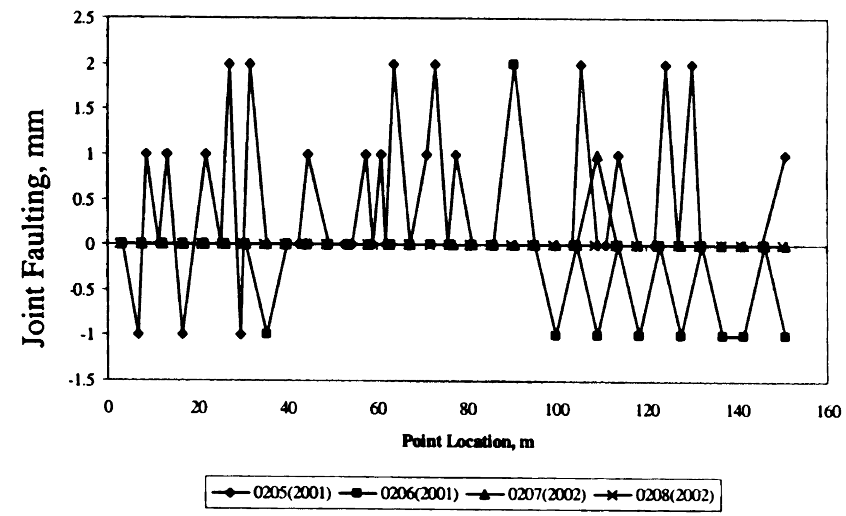


Figure B- 47 Joint faulting in LCB sections – DE (10)

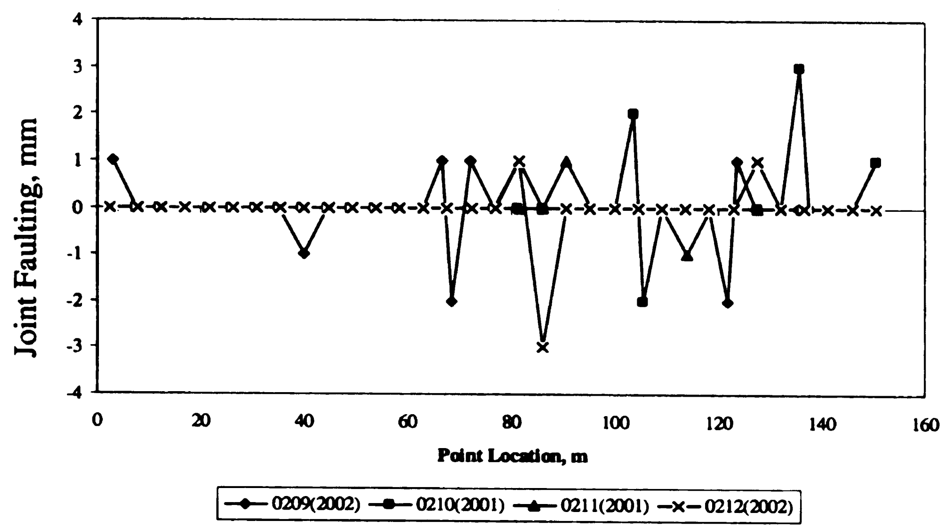


Figure B- 48 Joint faulting in PATB sections - DE (10)

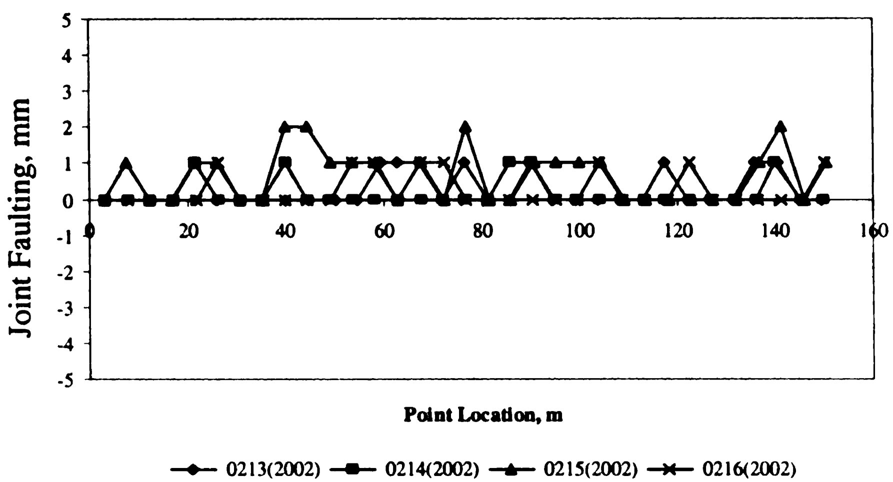


Figure B- 49 Joint faulting in DGAB sections - IA (19)

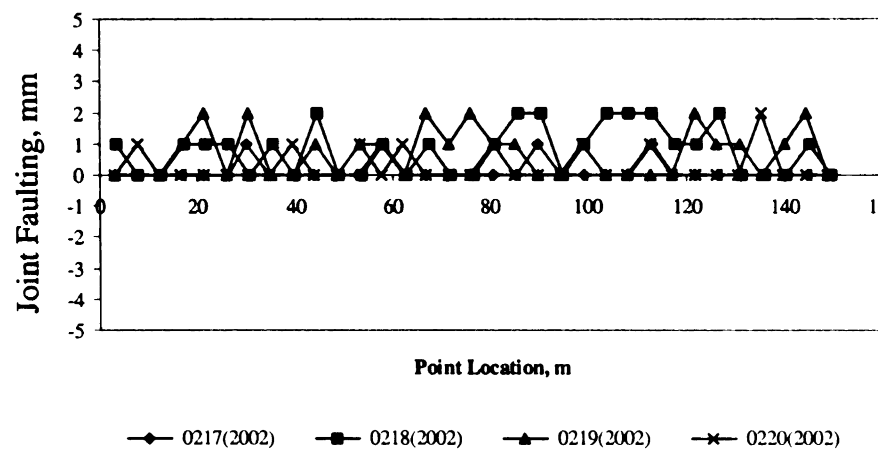


Figure B- 50 Joint faulting in LCB sections – IA (19)

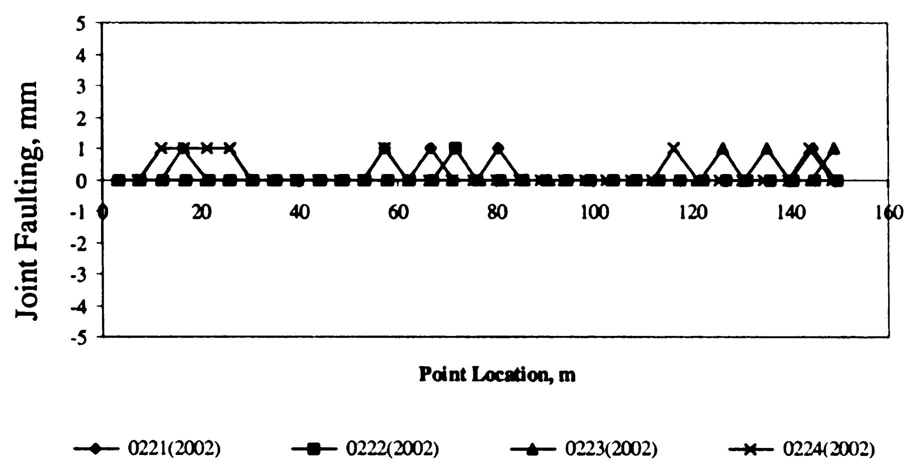


Figure B- 51 Joint faulting in PATB sections – IA (19)

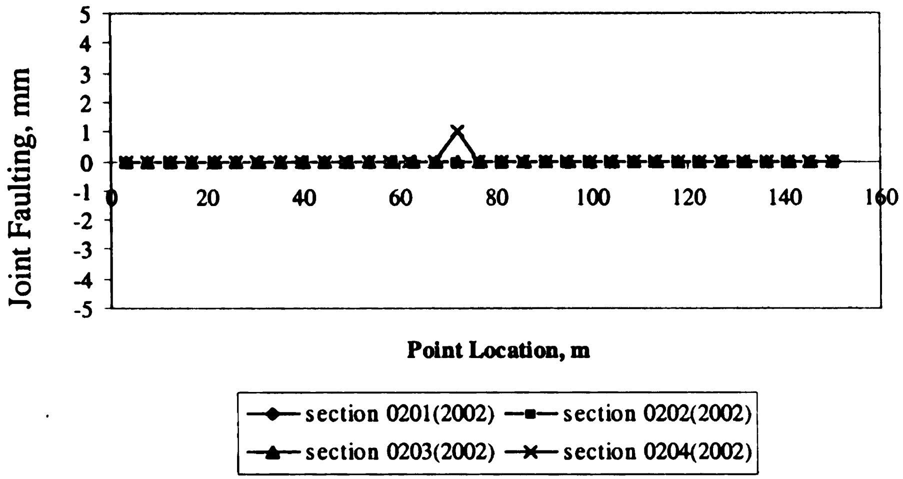


Figure B- 52 Joint Faulting in DGAB sections in WA (53)

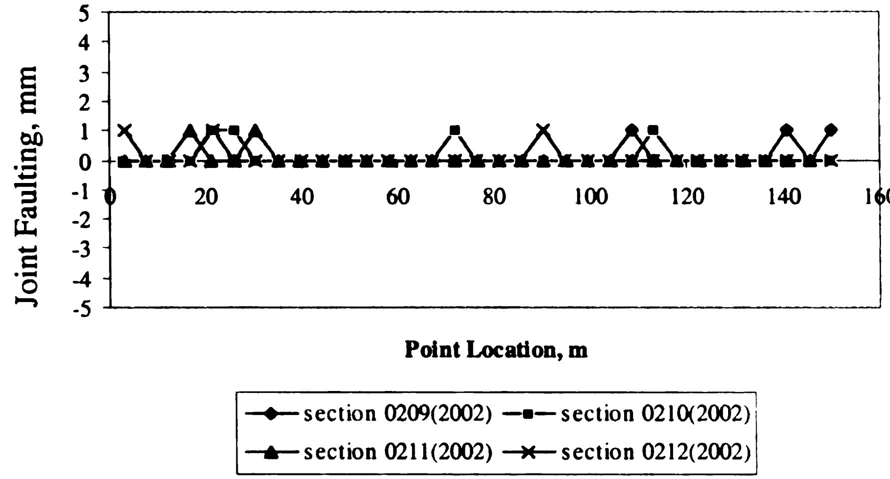


Figure B- 53 Joint Faulting in LCB sections in WA (53)

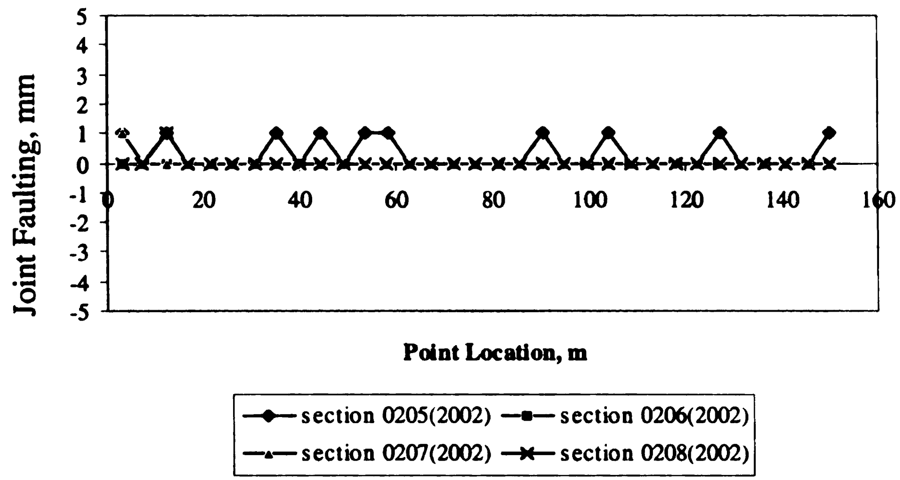


Figure B- 54 Joint Faulting in PATB sections in WA (53)

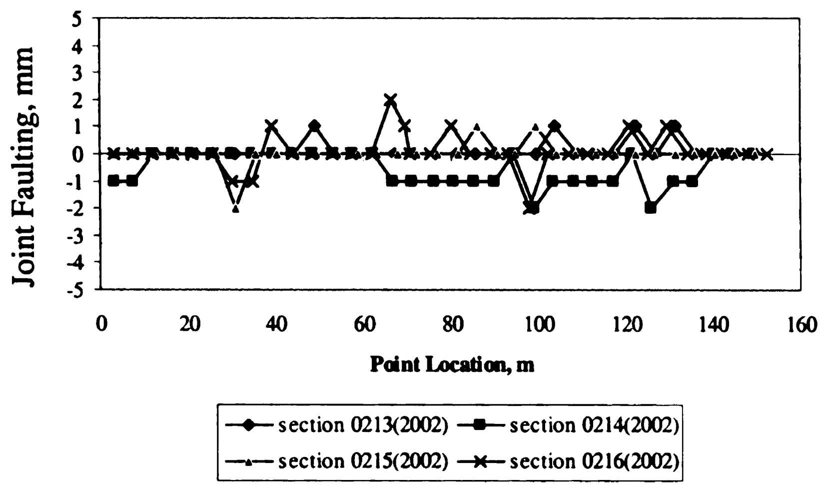


Figure B- 55 Joint faulting in DGAB sections in WI (55)

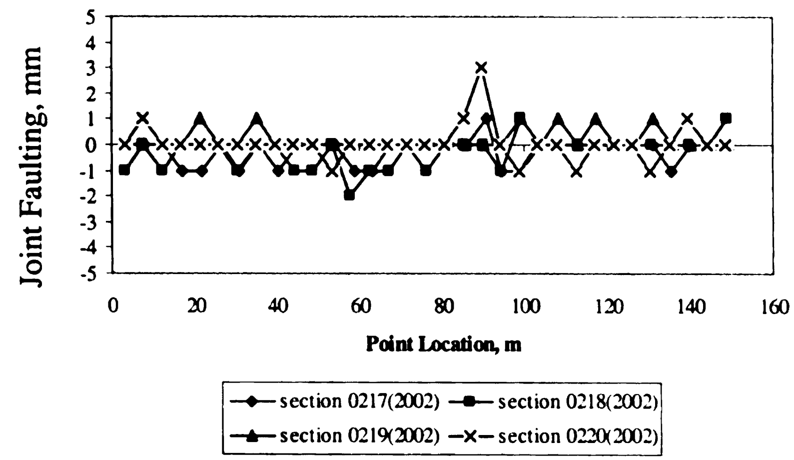


Figure B- 56 Joint Faulting in LCB sections in WI (55)

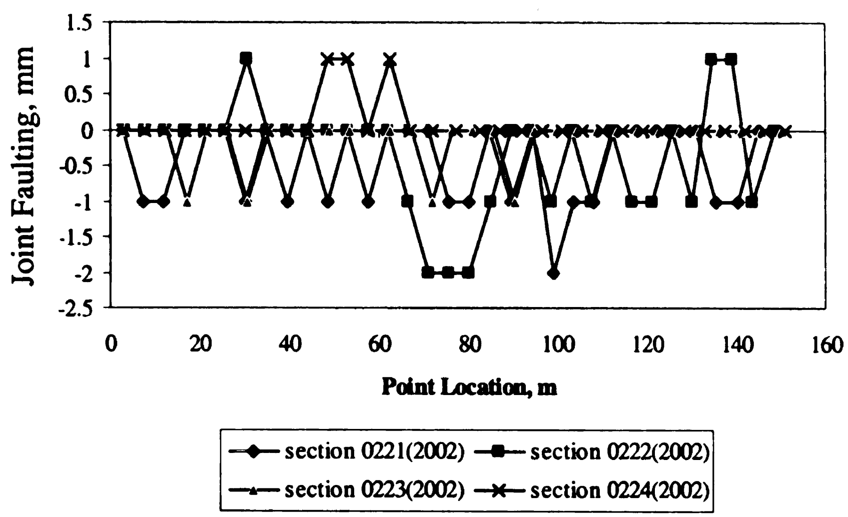


Figure B- 57 Joint Faulting in PATB sections in WI (55)

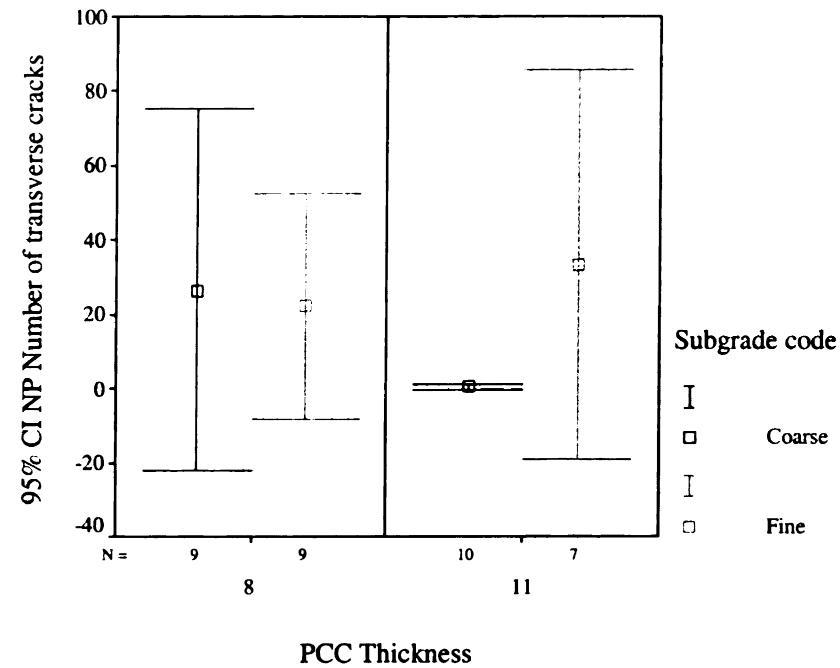


Figure B-58 Hypothesis testing for PCC thickness on Transverse cracks by Subgrade Type (DF)

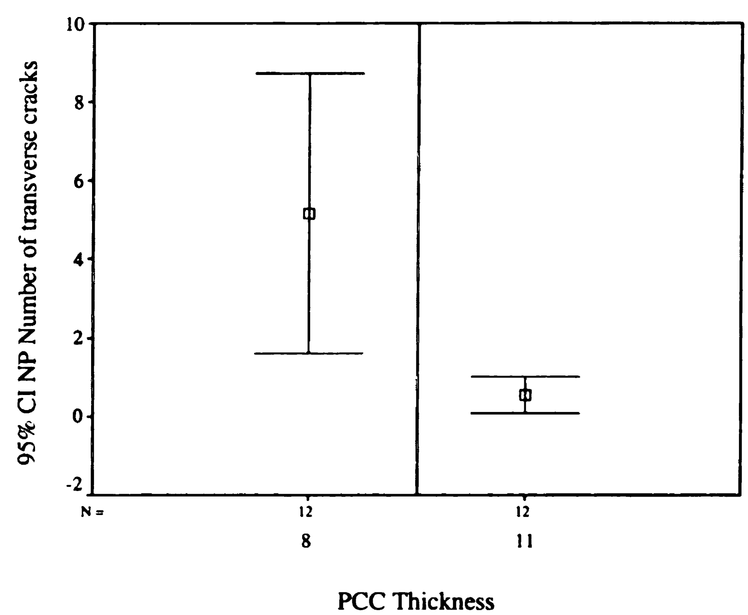


Figure B-59 Hypothesis testing for PCC thickness on Transverse cracks by Subgrade Type (DNF)

(Note: All sections on DNF zone are constructed on a coarse subgrade)

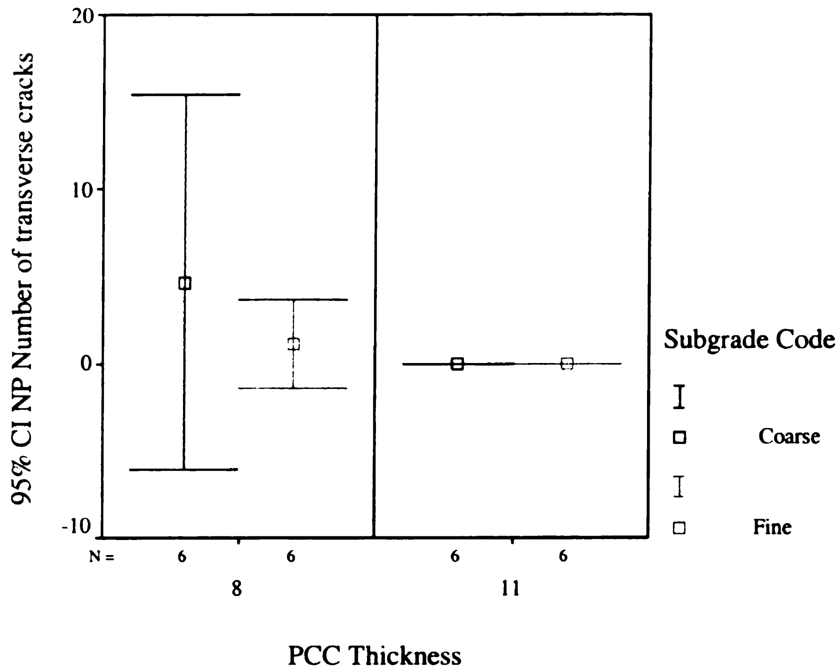


Figure B-60 Hypothesis testing for PCC thickness on Transverse cracks by Subgrade Type (WNF)

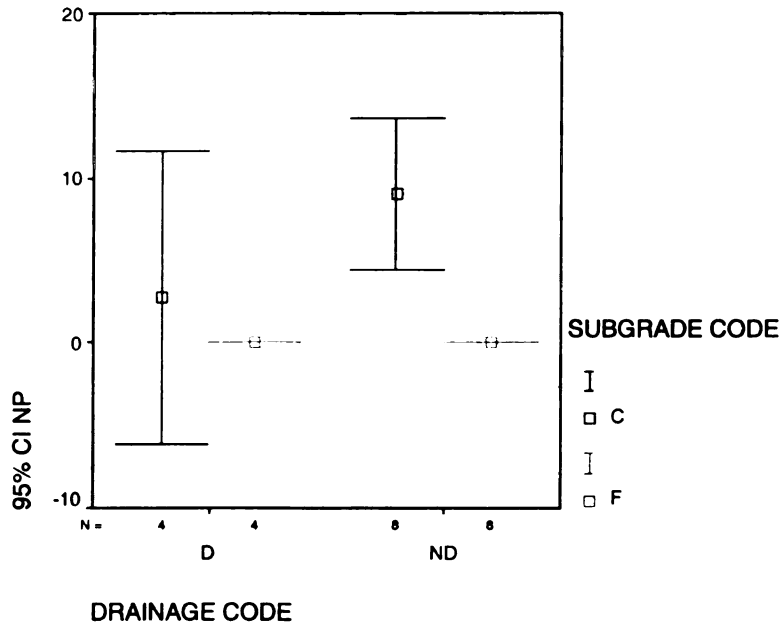


Figure B-61 Hypothesis testing for drainage condition on pumping by Subgrade type (WNF)

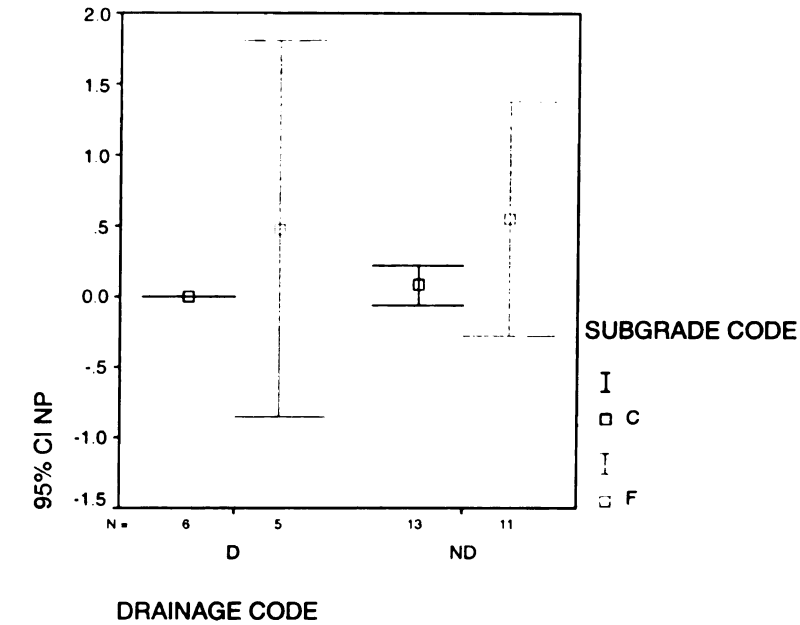


Figure B-62 Hypothesis testing for drainage condition on pumping by Subgrade type (DF)

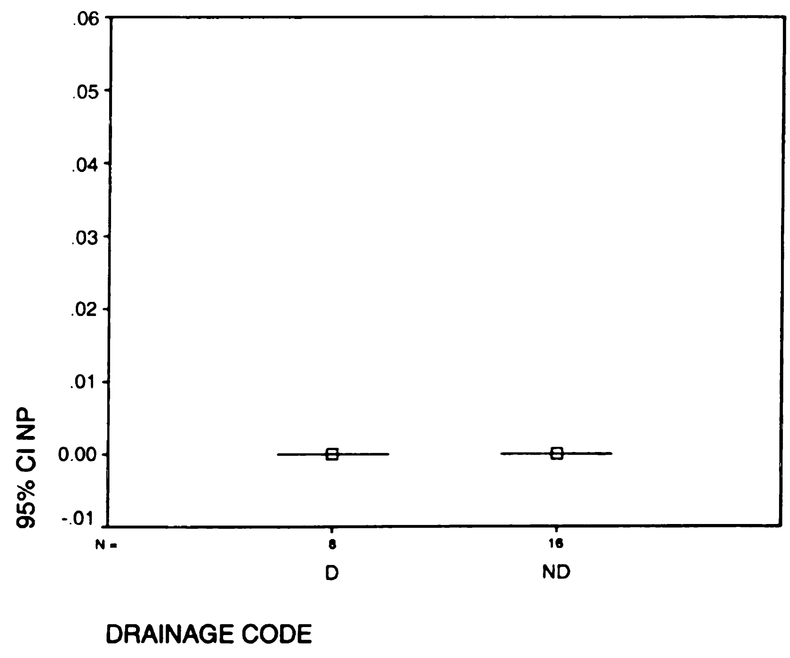


Figure B-63 Hypothesis testing for drainage condition on pumping by Subgrade type (DNF)

(Note: All sections in DNF zone are constructed on a coarse subgrade)

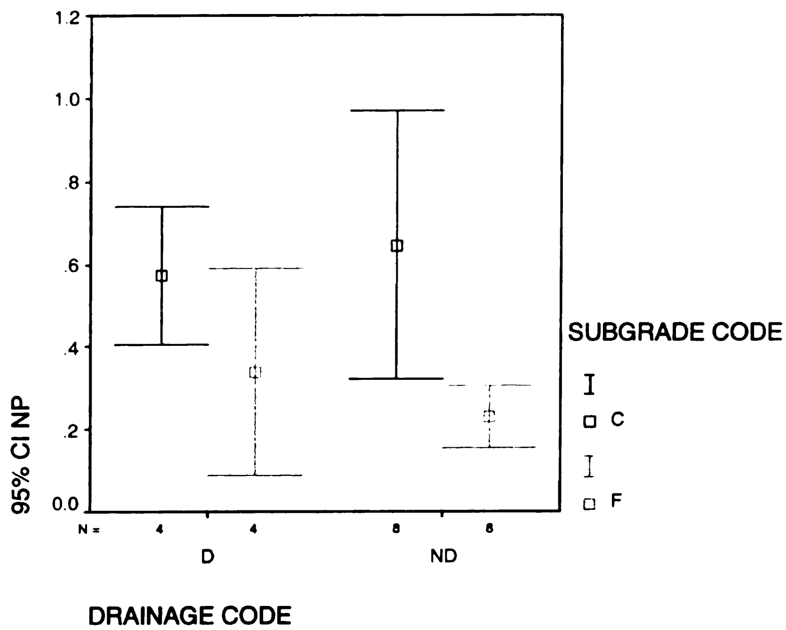


Figure B- 64 Hypothesis testing for drainage condition on faulting by Subgrade type (WNF)

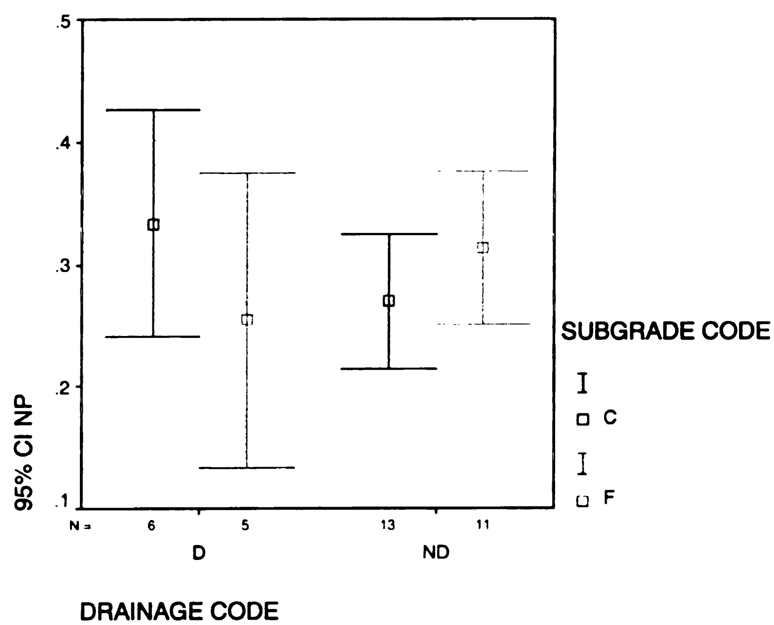


Figure B- 65 Hypothesis testing for drainage condition on faulting by Subgrade type (DF)

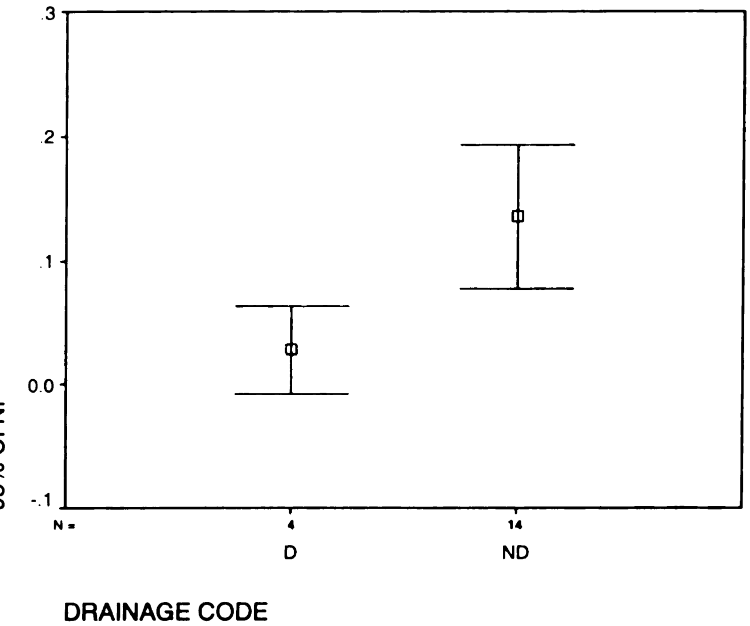
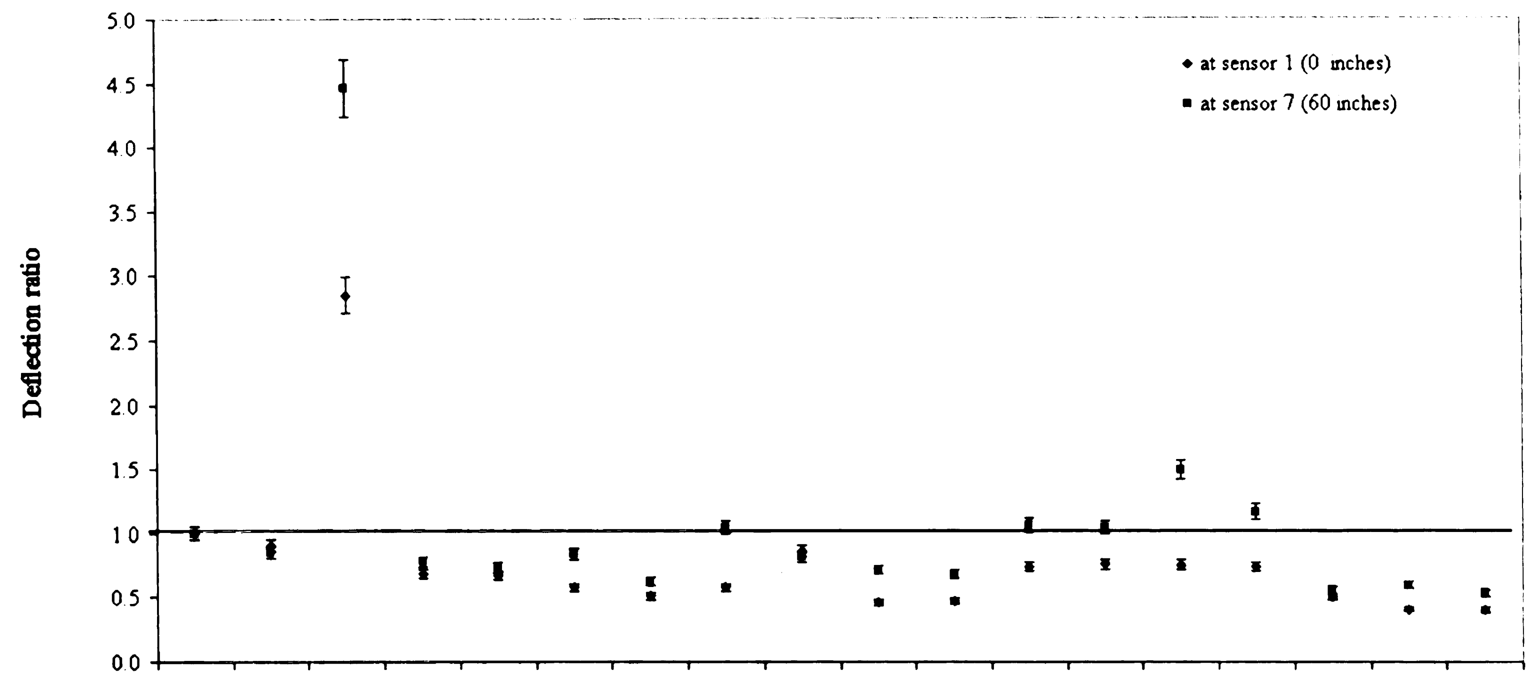


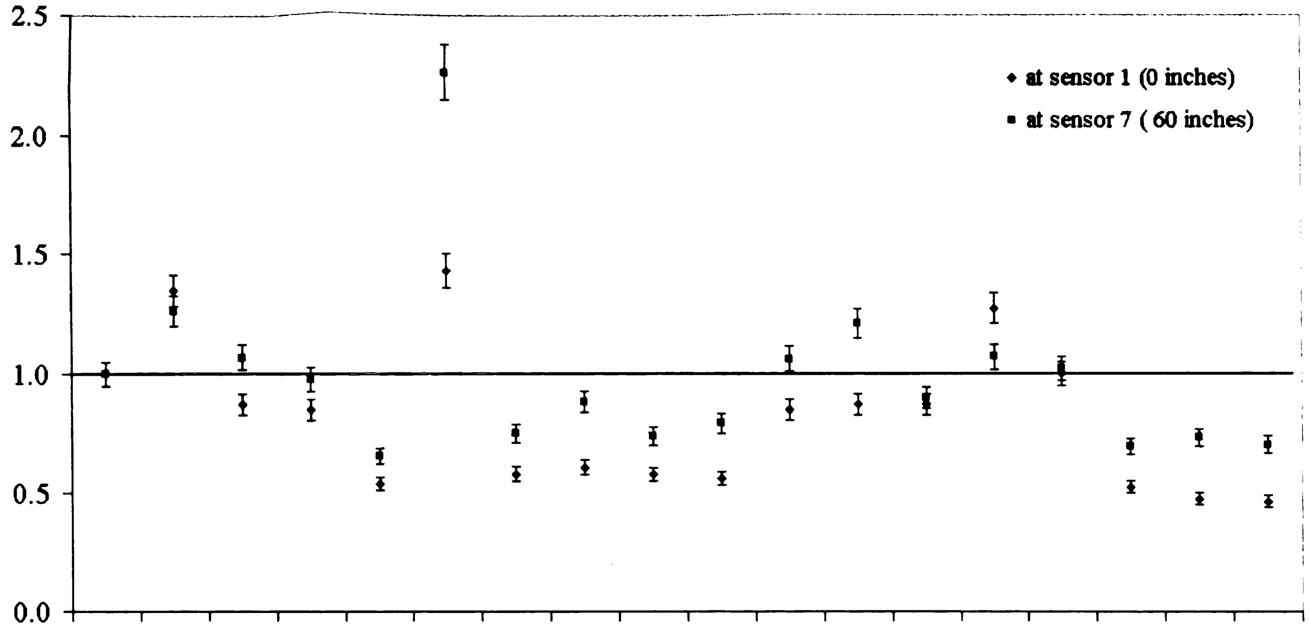
Figure B- 66 Hypothesis testing for drainage condition on faulting by Subgrade type (DNF)

(Note: All sections in the DNF zone are constructed on a coarse subgrade)



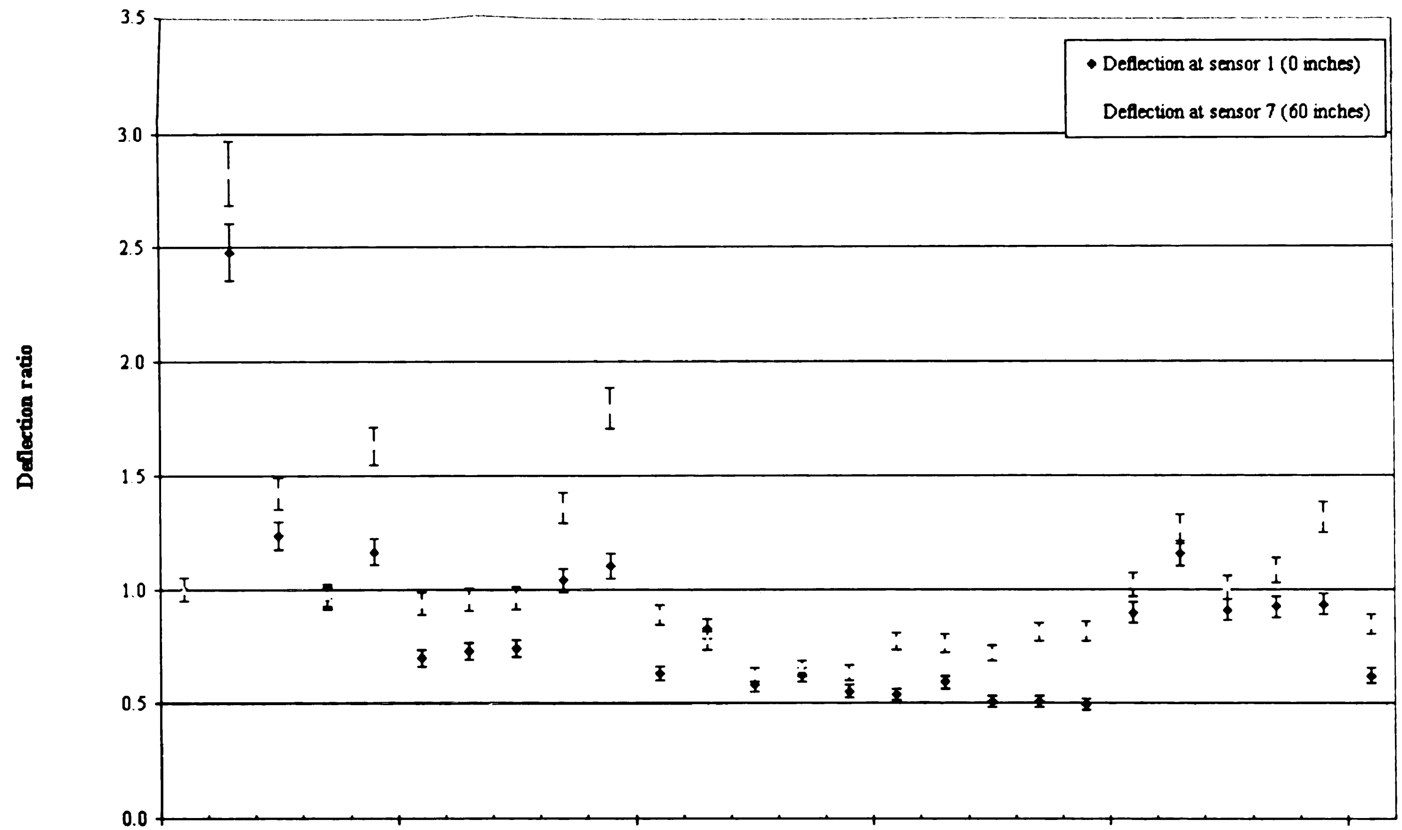
Section ID	0214	0214	0214	0215	0215	0215	0218	0218	0218	0219	0219	0219	0222	0222	0222	0223	0223	0223
Flexural strength, psi	900	900	900	550	550	550	900	900	900	550	550	550	900	900	900	550	550	550
Age of pavement , years	1996	1999	2001	1996	1999	2001	1996	1999	2001	1996	1999	2001	1996	1999	2001	1996	1999	2001
Surface temp, deg C	14.8	23.6	49.9	23.4	30.2	33.2	12.7	22.8	33.1	9.2	16	48.5	9.3	34.5	31.7	22.9	38.3	31.5
Temp at the middepth , deg C	12.7	21.3	44	21.2	23.9	33.4	13	20.7	32.6	9.6	15.8	39.7	9.4	30.7	31.5	19.8	30.5	31.7
Temp at the bottom , deg C	12.3	21.3	37.3	18.4	22.8	33.8	12.8	19.5	33.6	10.4	15.6	41	9.6	26.2	32.1	18.7	26	33.4
Temp gradient	0.016	0.015	0.082	0.033	0.048	-0	-0	0.022	-0	-0.01	0.003	0.049	-0	0.054	-0	0.027	0.08	-0.01

Figure B-67 Deflections for the 12-ft sections in AR (5)



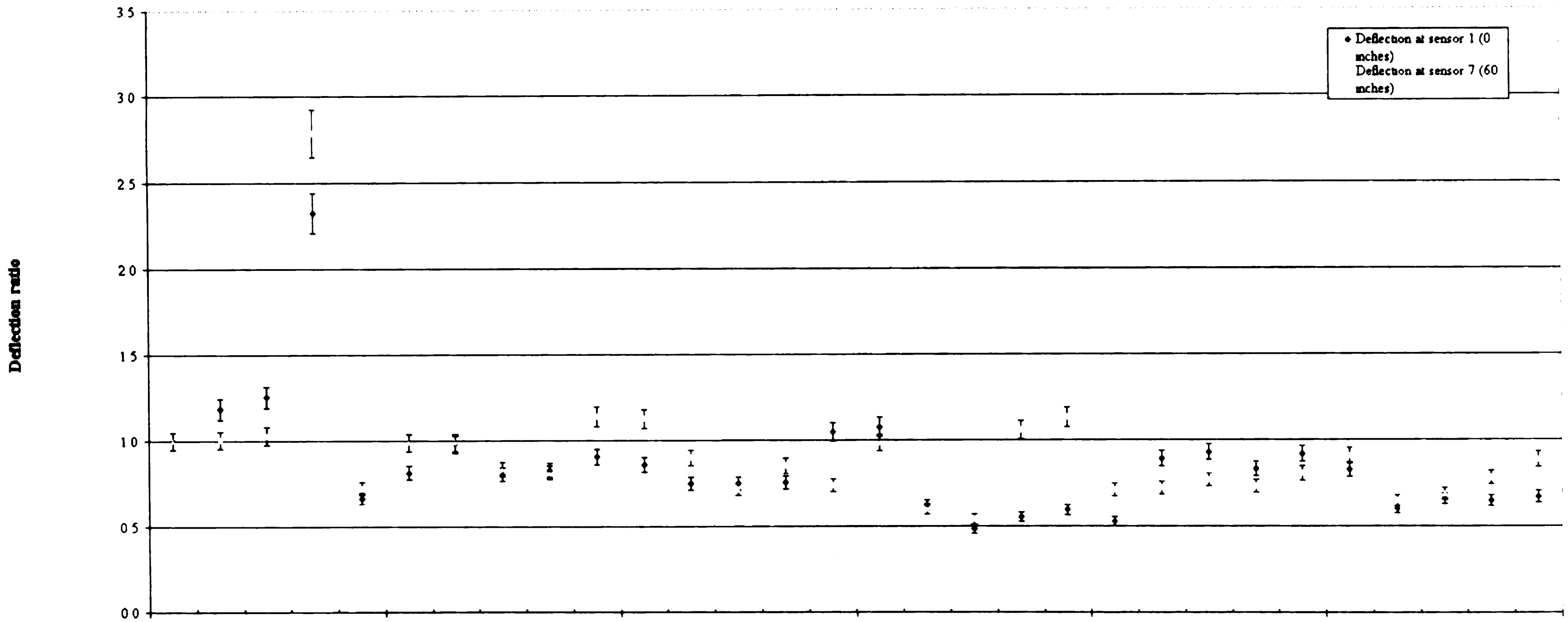
Section ID	0213			0216			0217			0220			0221			0224		
Age of pavement , years	1	4	6	1	4	6	1	4	6	1	4	6	1	4	6	1	4	6
Surface temp , °C	13.7	25.9	36.9	20.5	27.4	40.1	9.4	26.7	30.5	11.8	36.7	48.5	13.1	23.4	45.6	14.7	24.5	30.2
Temp at middepth , ° C	13.5	21.3	35	18.2	24.9	38.7	10.2	23	30	10.8	25	42.8	12.3	19.7	41.4	12.8	24.2	30.5
Temp at the bottom of the slab, ° C	13.7	20.4	36.2	15.1	23.8	34.3	10.3	21.9	30.5	10.3	23.3	43.3	12.6	19.1	42	12.6	24.6	31
Temp gradient,	0.00	0.04	0.00	0.04	0.02	0.04	-0.01	0.03	0.00	0.01	0.09	0.03	0.00	0.03	0.02	0.01	0.00	-0.01

Figure B- 68 Deflections for the 14-ft sections in AR (5)



Section ID			0213					0216					0217					0220					0221			0224
Flexural Strength, psi	550	550	550	550	550	900	900	900	900	900	550	550	550	550	550	900	900	900	900	900	550	550	550	550	550	900
Age of pavement, years	0	1	4	5	8	0	1	4	5	8	0	1	4	5	8	0	1	4	5	8	0	1	4	5	8	0
Surface Temp, deg C	16	27	30	17	18	17	29	29	26	17	12	29	30	23	17	18	32	27	17	18	12	29	20	23	23	7.1
Temp at the middepth, deg C	14	22	26	14	14	12	23	26	17	13	12	24	23	17	13	12	26	24	13	13	11	24	18	20	17	7.7
Temp at the bottom, deg C	13	20	24	13	13	11	21	24	15	13	12	21	21	16	13	11	22	24	14	13	12	21	19	15	15	9.4
Temp gradient	0.02	0.05	0.04	0.03	0.03	0.04	0.05	0.03	0.07	0.03	0.00	0.05	0.06	0.05	0.03	0.05	0.06	0.02	0.02	0.03	0.00	0.05	0.01	0.05	0.05	-0.02

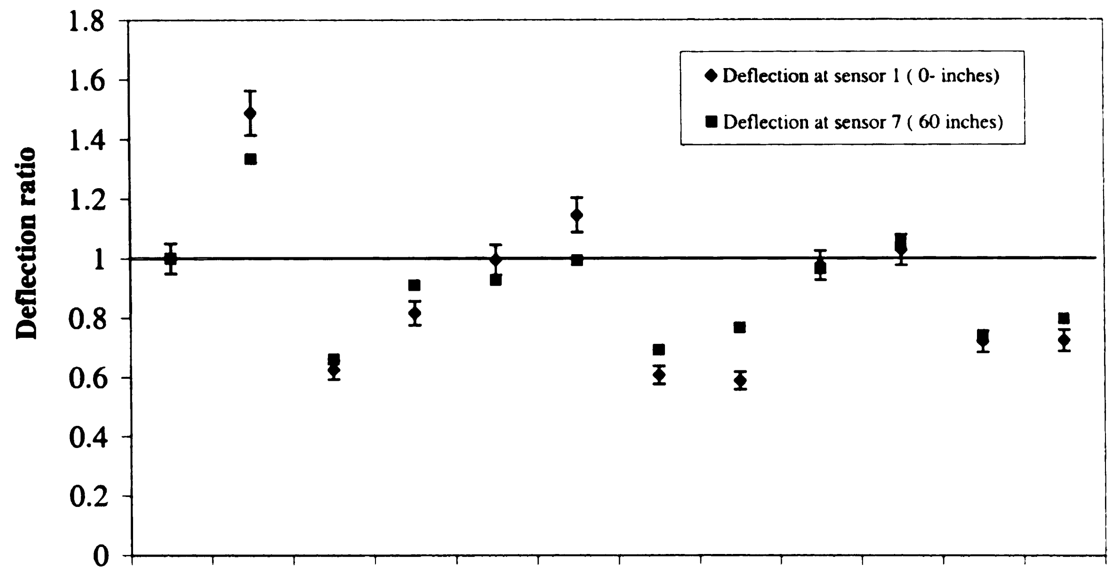
Figure B-69 Deflections for the 14-ft sections in AZ (4)



Section ID	0214			0215		0215					0218				
Flexural Strength, psi		900			550			550					900		
Age of pavement, years	4	5	8	1	2	3	4	5	8	9	0	1	4	5	8
Surface Temp, deg C	32.2	17.7	27.0	29.1	34.9	17.9	29.3	24.1	18.7	31.9	5.1	25.1	22.4	27.1	27.1
Temp at the middepth, deg C	27.5	14.9	21.4	25.6	31.0	16.5	25.5	18.3	14.8	26.6	6.3	21.0	21.4	17.9	20.7
Temp at the bottom, deg C	25.9	13.6	18.7	25.3	29.5	17.4	25.1	15.5	14.3	25.3	7.5	20.2	21.6	15.4	18.9
Temp Gradient	0.04	0.03	0.05	0.03	0.03	0	0.03	0.06	0.03	0.04	-0.02	0.03	0.01	0.08	0.05

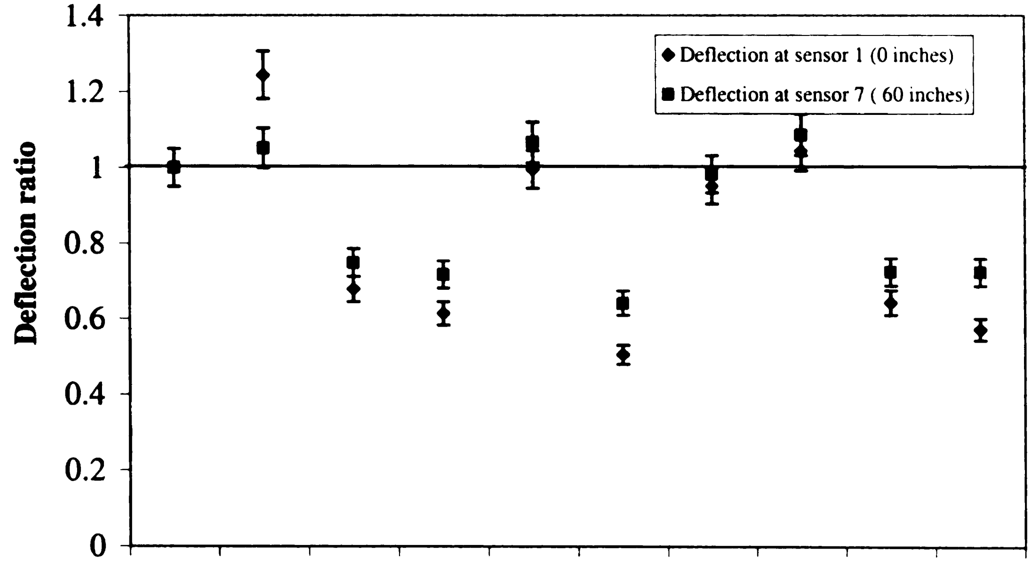
Section ID	0219					0222					0223			
Flexural Strength, psi			550					900				550		
Age of pavement, years	0	1	4	5	8	0	1	4	5	8	1	4	5	8
Surface Temp, deg C	11.9	19.1	19.4	14.1	24.6	18.9	30.8	28.1	24.5	21.3	23.6	29.2	12.8	14.3
Temp at the middepth, deg C	12.4	17.4	18.7	11.8	18.6	14.8	29.3	23.9	20.0	16.3	18.7	23.9	10.4	11.4
Temp at the bottom, deg C	13.1	18.2	21.4	13.3	16.0	12.3	27.2	22.5	15.8	14.8	19.0	22.4	11.1	12.0
Temp Gradient	-0.01	0.01	-0.01	0.01	0.06	0.04	0.02	0.04	0.06	0.04	0.03	0.04	0.01	0.02

Figure B-70 Deflections for the 12-ft sections in AZ (4)



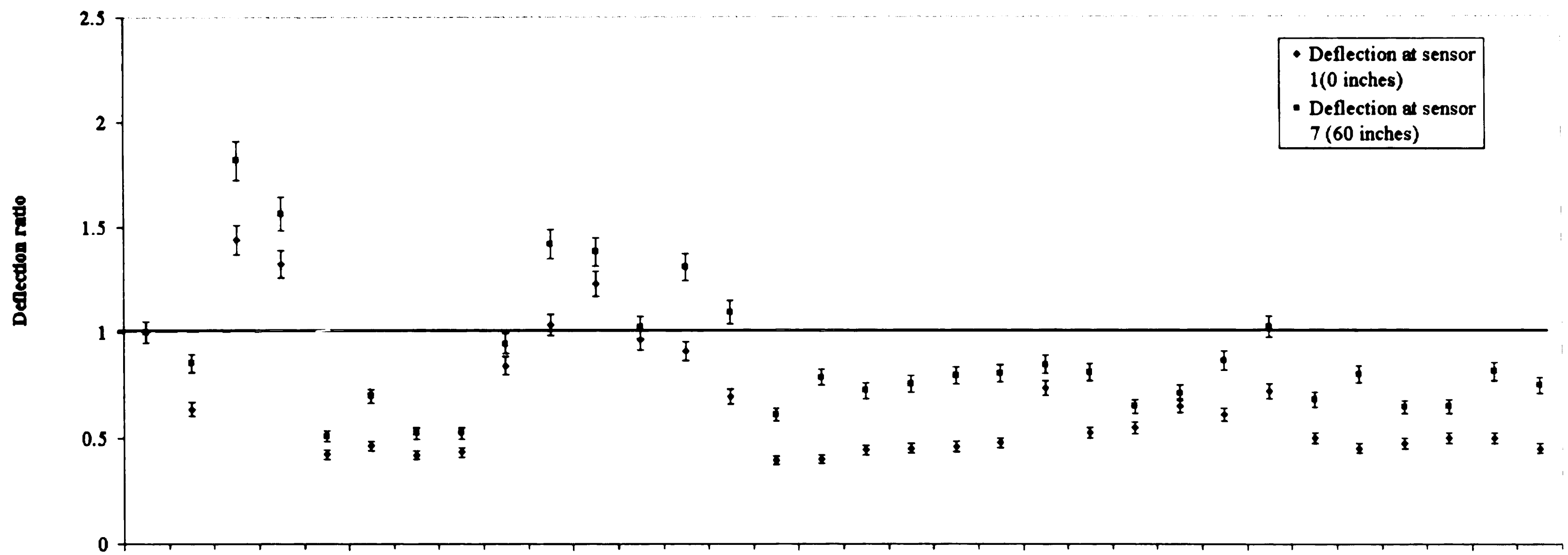
Section ID	0202		0203		0206		0207		0210		0211	
Year of pavement testing	0	2	0	2	0	2	0	2	0	2	0	2
Surface Temp , deg C	26.08	25.38	25.9	21.85	36.76	23.78	35.07	20.98	26.08	23.21	37.4	20.2
Temp at the middepth, deg C	24.35	23.68	25.11	18.52	34.68	21	31.36	17.93	23.99	20.6	33	16.3
Temp at the bottom, deg C	24.6	21.9	25.69	17.05	31.51	19.44	27.92	17.17	24.59	19.09	29.7	15.7
Temp gradient	0.01	0.023	0.001	0.031	0.034	0.028	0.047	0.025	0.01	0.027	0.05	0.03

Figure B-71 Deflections for the 14-ft sections in CA (6)



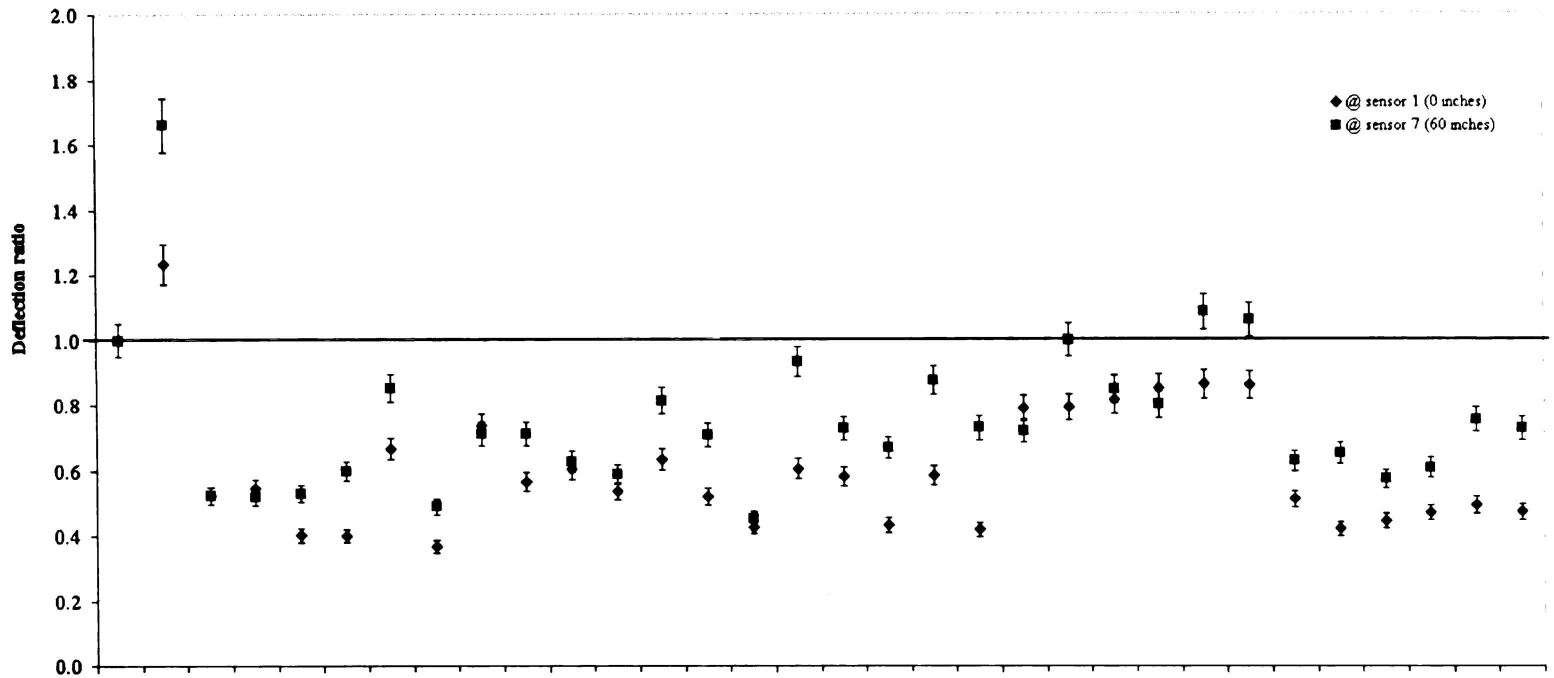
Section ID	0201		0204	0205		0208	0209		0212	
Year of pavement testing	0	2	0	0	2	0	0	2	0	2
Surface Temp, deg C	27.1	15.7	35.3	31.5	18.5	31.5	27.1	14.9	35.0	21.4
Temp at the mid depth, deg C	30.2	15.0	30.0	32.2	17.3	31.2	30.2	14.4	29.8	17.1
Temp at the bottom, deg C	31.6	14.8	26.4	31.3	16.1	29.1	31.6	14.4	26.3	15.8
Temp gradient	-0.03	0.01	0.06	0.00	0.02	0.02	-0.03	0.00	0.06	0.04

Figure B-72 Deflections for the 12-ft sections in CA (6)



Section ID	0213				0216				0217						0220						0221						0224					
Flexural Strength, psi	550	550	550	550	900	900	900	900	550	550	550	550	550	550	900	900	900	900	900	900	550	550	550	550	550	550	900	900	900	900	900	900
Age of pavement, years	1	3	5	6	1	3	5	6	1	3	5	6	8	9	1	3	5	6	8	9	1	3	5	6	8	9	1	3	5	6	8	9
Surface Temp, °C	22	29	-0.8	28	8.7	21	2.6	31	23	26	35	28	43	42	14	33	40	28	39	38	22	29	42	28	38	38	18	20	35	41	38	50
Temp at the mid-depth, °C	15	23	-3.2	26	3.7	16	-1.1	26	20	20	31	31	36	36	6.7	25	36	27	31	32	16	22	35	27	34	32	14	16	27	31	31	41
Temp at the bottom,° C	10	19	-3.9	26	3.9	12	-3.6	26	15	18	28	28	31	33	5.3	20	31	28	29	31	12	18	32	26	32	31	11	16	26	30	30	37
Temp gradient	0.08	0.07	0.02	0.01	0.03	0.06	0.04	0.03	0.05	0.05	0.04	0.00	0.08	0.06	0.05	0.09	0.05	0.00	0.07	0.05	0.07	0.07	0.07	0.01	0.04	0.04	0.05	0.03	0.06	0.07	0.05	0.08

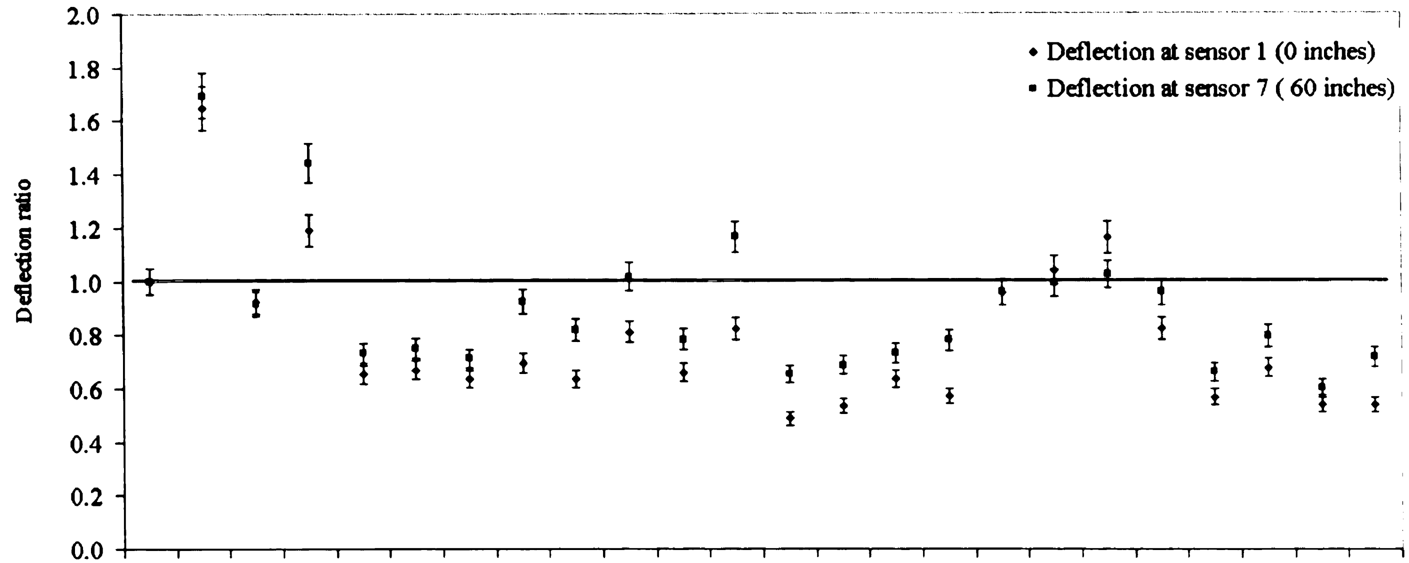
Figure B-73 Deflections for the 14- ft sections in CO (8)



Section ID	0214				0215				0218					
Age of pavement, years	1	3	5	6	1	3	5	6	1	3	5	6	8	9
Surface temp, °C	21	18	6	39	11	24	0	27	19	34	6	39	31	35
Temp at slab middepth, °C	18	15	3	35	7	17	-2	26	11	26	3	34	27	32
Temp at slab bottom, °C	15	15	0	31	8	15	-3	26	9	21	1	30	26	30
Temp gradient	0.04	0.02	0.03	0.05	0.02	0.06	0.01	0.01	0.07	0.09	0.03	0.06	0.03	0.03

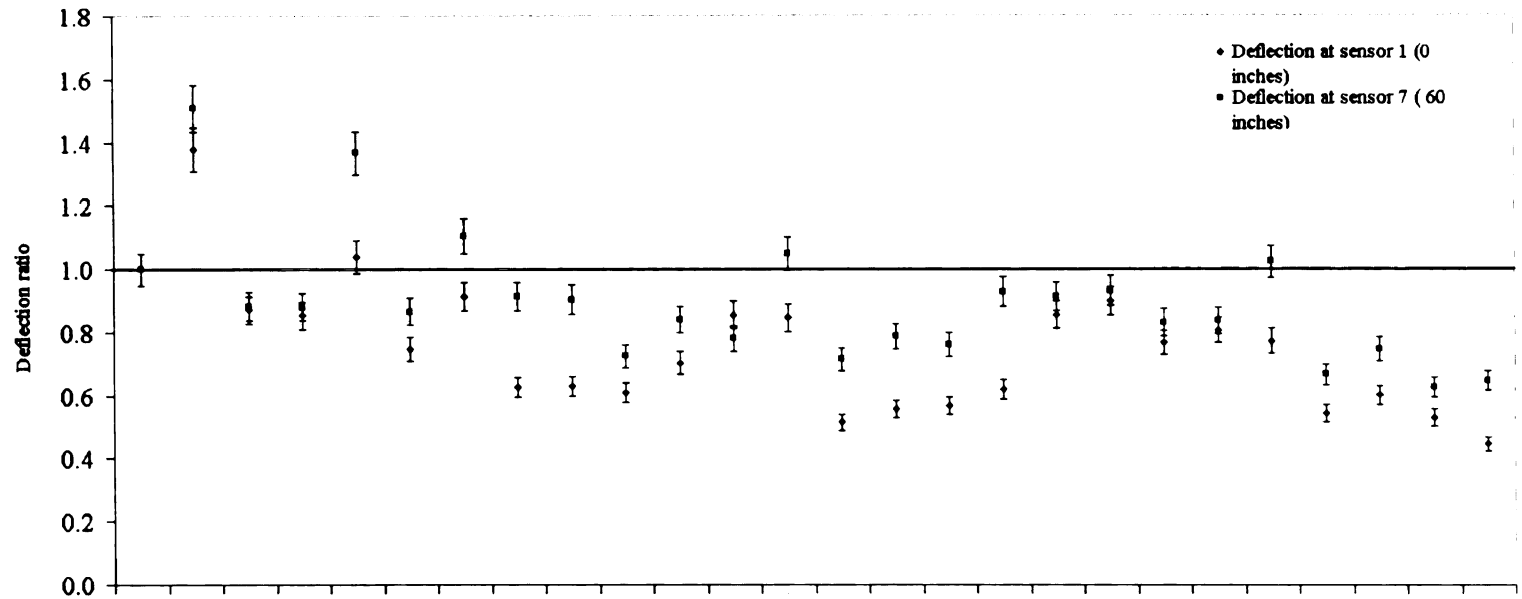
Section ID	0219						0222						0223					
Age of pavement, years	1	3	5	6	8	9	1	3	5	6	8	9	1	3	5	6	8	9
Surface temp, °C	25	15	26	28	32	47	14	10	26	41	31	52	14	17	36	39	41	34
Temp at slab middepth, °C	14	15	25	25	26	36	10	7	25	35	26	40	9	13	28	36	31	31
Temp at slab bottom, °C	9	16	25	26	26	32	7	7	24	32	26	36	7	10	26	32	28	31
Temp gradient	0.10	0.00	0.00	0.01	0.04	0.10	0.04	0.02	0.01	0.06	0.03	0.10	0.04	0.04	0.06	0.05	0.09	0.02

Figure B- 74 Deflections for the 12-ft sections in CO (8)



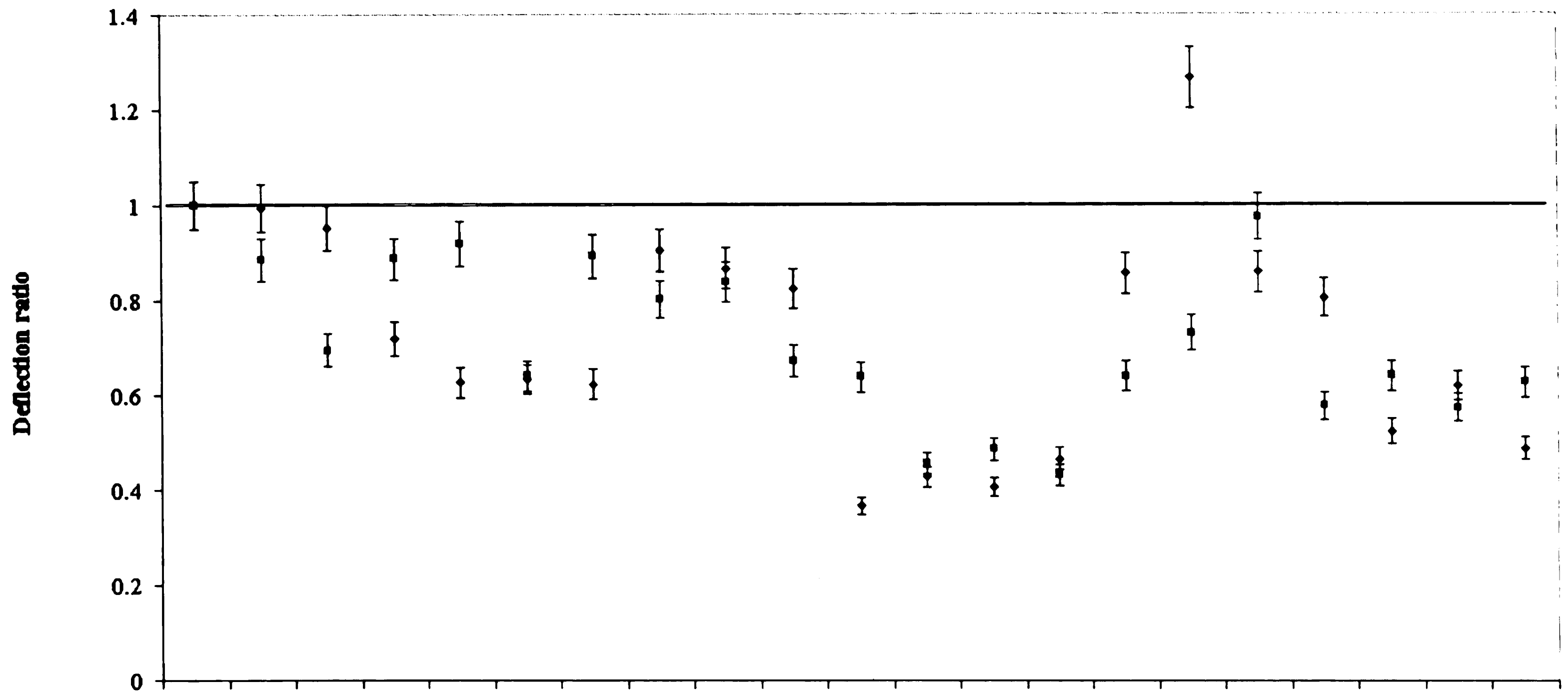
Section ID	0202				0203				0206				0207				0210				0211			
Flexural Strength, psi	900	900	900	900	550	550	550	550	900	900	900	900	550	550	550	550	900	900	900	900	550	550	550	550
Age of pavement, years	0	1	3	5	0	1	3	5	0	1	3	5	0	1	3	5	0	1	3	5	0	1	3	5
Surface Temp, deg C	16	42	27	20	16	34	24.1	24	16	41	29	22	18	35	33	21	14	33	41	16	15.3	43	26	19
Temp at the mid-depth, deg C	16	37	26	20	17	31	24.7	21	16	36	28	19	17	31	29	16	14	30	35	13	15.9	35	25	16
Temp at the bottom, deg C	16	33	26	20	17	30	25.7	23	16	33	28	16	17	30	28	15	14	27	30	12	16.1	31	25	16
Temp gradient	0.00	0.06	0.00	0.00	0.00	0.03	-0.01	0.01	0.00	0.05	0.01	0.04	0.01	0.03	0.03	0.04	0.00	0.04	0.08	0.03	-0.01	0.08	0.01	0.02

Figure B-75 Deflections in 14- ft sections in DE (10)



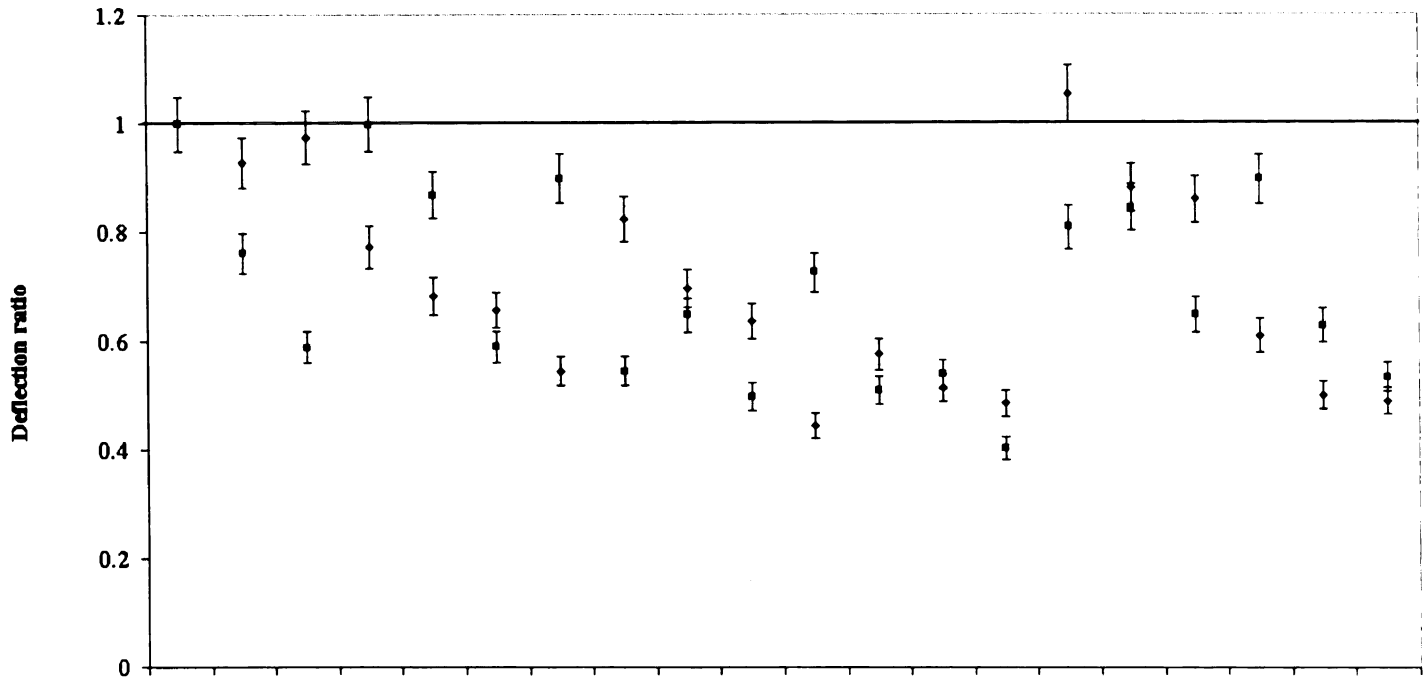
Section ID	0201	0201	0201	0201	0201	0204	0204	0204	0204	0205	0205	0205	0205	0208	0208	0208	0208	0209	0209	0209	0209	0209	0212	0212	0212	0212
Flexural Strength, psi	550	550	550	550	550	900	900	900	900	550	550	550	550	900	900	900	900	550	550	550	550	550	900	900	900	900
Age of pavement, years	0	1	2	3	5	0	1	3	5	0	1	3	5	0	1	3	5	0	1	2	3	5	0	1	3	5
Surface Temp, deg C	21.9	44.4	13.9	22	20.4	31.7	40.7	26.6	9.87	18.2	36.1	23.8	20.2	28.5	33.6	28.5	13.8	16.2	34.8	10.1	28.3	19.2	21.1	44	34.8	18
Temp at the mid-depth, deg C	20.2	41.5	12.1	23.2	20.5	23.5	36.6	26.9	9.03	19	33.3	23.6	16.4	26.5	29.3	24.8	11.2	14.8	31.3	8.8	26.5	19.7	23.7	34.7	28.3	18.5
Temp at the bottom, deg C	18	37	11.1	23.4	20.8	20.9	32.5	27.7	9.8	18.8	31.8	23.8	14.1	23.2	28.8	24.8	10.4	14.5	29.6	8.83	25.5	19.6	22.9	31.1	28.1	18.5
Temp gradient	0.03	0.05	0.02	-0.01	0.00	0.07	0.05	-0.01	0.00	0.00	0.03	0.00	0.04	0.03	0.03	0.02	0.02	0.01	0.03	0.01	0.02	0.00	-0.01	0.08	0.04	0.00

Figure B-76 Deflections in 12- ft sections in DE (10)



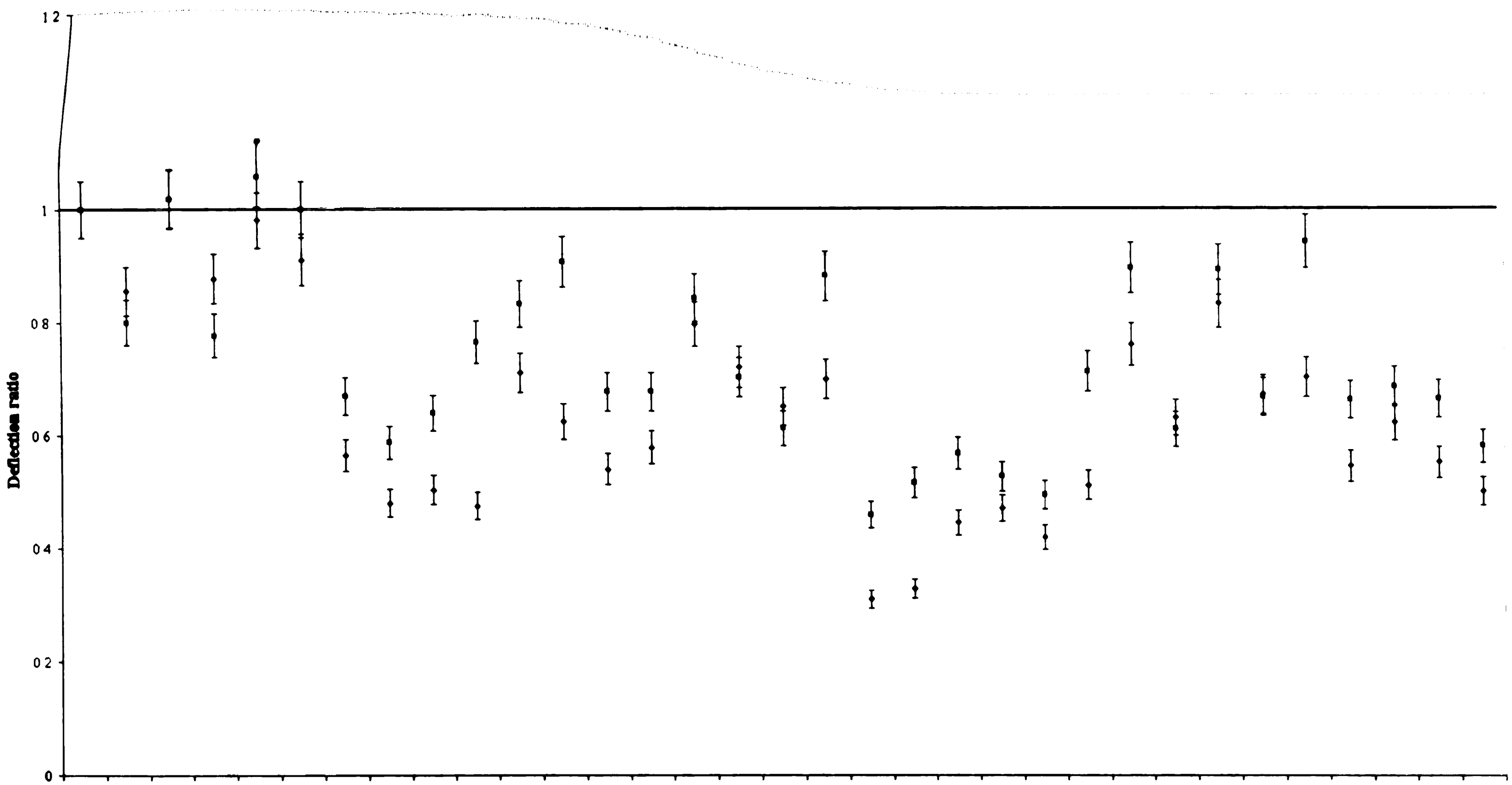
Section ID	0213	0213	0213	0216	0216	0216	0217	0217	0217	0217	0220	0220	0220	0220	0221	0221	0221	0221	0224	0224	0224
Flexural strength,psi	550	550	550	900	900	900	550	550	550	550	900	900	900	900	550	550	550	550	900	900	900
Age, years	0	5	7	0	5	7	0	3	5	7	0	3	5	7	0	3	5	7	0	5	7
Surface Temp, °C	11.9	13.6	10.8	21.2	17.1	23.8	18.9	28	16.1	12.1	22.1	29.2	13.9	22.3	12.8	30.1	14	12.6	12.7	23.3	12.2
Temp at the middepth, °C	12.1	14.2	9.02	19.7	17.5	15.6	18.1	20.6	9.61	10.8	18.6	27.1	12.6	17.2	11.2	24.5	14.2	13.6	13	18.9	14.6
Temp at the bottom, °C	13	14.6	10.1	18	18	14.3	17.5	16.5	9.09	11.1	17.7	27.4	12.7	16.1	11.6	21.4	14.3	14.1	14.6	18.6	16.3
Temp gradient	-0.01	-0.01	0.00	0.02	-0.01	0.06	0.01	0.08	0.05	0.01	0.03	0.01	0.01	0.04	0.01	0.06	0.00	-0.01	-0.01	0.03	-0.03

Figure B-77 Deflections in 14- ft sections in IA (19)



Section ID	0214	0214	0214	0215	0215	0215	0218	0218	0218	0218	0219	0219	0219	0219	0222	0222	0222	0223	0223	0223
Flexural strength,psi	900	900	900	550	550	550	900	900	900	900	550	550	550	550	900	900	900	550	550	550
Age, years	0	5	7	0	5	7	0	3	5	7	0	3	5	7	0	5	7	0	5	7
Surface Temp, °C	20.5	15.2	19.7	23.7	21.2	11.8	18.5	30.7	13.7	17.3	17.3	37.2	16.7	16.9	23.2	14.7	19.9	24.9	15.1	20
Temp at the middepth, °C	17.2	14.9	12.7	17	20.5	11.9	18.2	26.5	12.4	16	17	29.4	13.3	14.8	18.7	15.2	17.1	20.1	15.3	16.3
Temp at the bottom, °C	15.7	14.7	11.6	15.6	20.2	14.4	17.9	26	12.2	15.9	17.2	26.8	12.5	15	16.6	14.8	15.2	17	18.3	15.2
Temp gradient	0.03	0.00	0.05	0.05	0.01	-0.02	0.00	0.03	0.01	0.01	0.00	0.07	0.03	0.01	0.04	0.00	0.03	0.05	-0.02	0.03

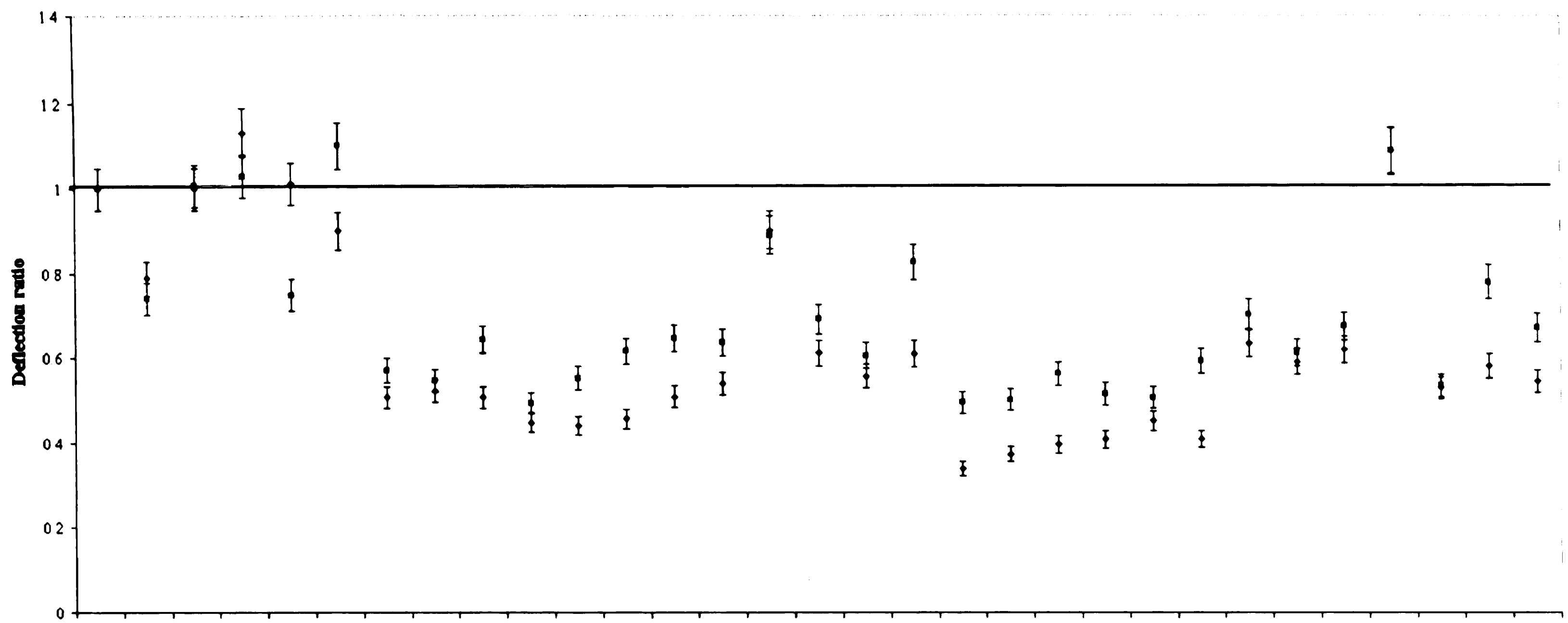
Figure B-78 Deflections in 12- ft sections in IA (19)



Section ID	0201	0201	0201	0201	0201	0204	0204	0204	0204	0204	0204	0205	0205	0205	0205	0205
Flexural strength, psi	550	550	550	550	550	900	900	900	900	900	900	550	550	550	550	550
Age of pavement, years	0	1	5	7	9	0	1	3	5	7	9	0	1	3	7	9
Surface Temp, deg C	15.2	12.1	21.2	15.2	28.9	18.9	10.3	33	18.9	8.2	43.1	21.3	6.2	29.7	11	31.2
Temp at the mid depth, deg C	12.8	10.5	20.5	10.4	28.4	16.9	8.2	31.5	18.8	7.08	33.4	17.3	6.98	31.8	10.4	30.3
Temp at the bottom, deg C	11.9	9.52	20.1	9.78	29	15.5	7.85	31.7	20	8.33	30.5	15.3	7.72	31.8	10.6	30
Temp gradient	0.02	0.02	0.01	0.04	-0	0.02	0.02	0.01	-0	-0	0.08	0.04	-0	-0	0	0.01

Section ID	0208	0208	0208	0208	0208	0208	0209	0209	0209	0209	0209	0212	0212	0212	0212	0212	0212
Flexural strength, psi	900	900	900	900	900	900	550	550	550	550	550	900	900	900	900	900	900
Age of pavement, years	0	1	3	5	7	9	0	1	3	5	9	0	1	3	5	7	9
Surface Temp, deg C	19	11.7	36.5	31.9	17.9	39.1	17.2	5.95	43.9	22.9	31.4	23.3	27.2	45.1	37	12	27.3
Temp at the mid depth, deg C	16.2	7.7	30.3	26.5	15.9	32	17	6.28	37.5	22.1	29.7	17.8	14.8	35.2	30.3	13.1	26.8
Temp at the bottom, deg C	15.7	6.71	29	23.7	15.3	28.6	16.5	6.8	34.2	21.9	29.2	16.1	13.5	33.5	26.4	12.9	27.7
Temp gradient	0.02	0.03	0.05	0.05	0.02	0.07	0	-0	0.06	0.01	0.01	0.05	0.09	0.08	0.07	-0	-0

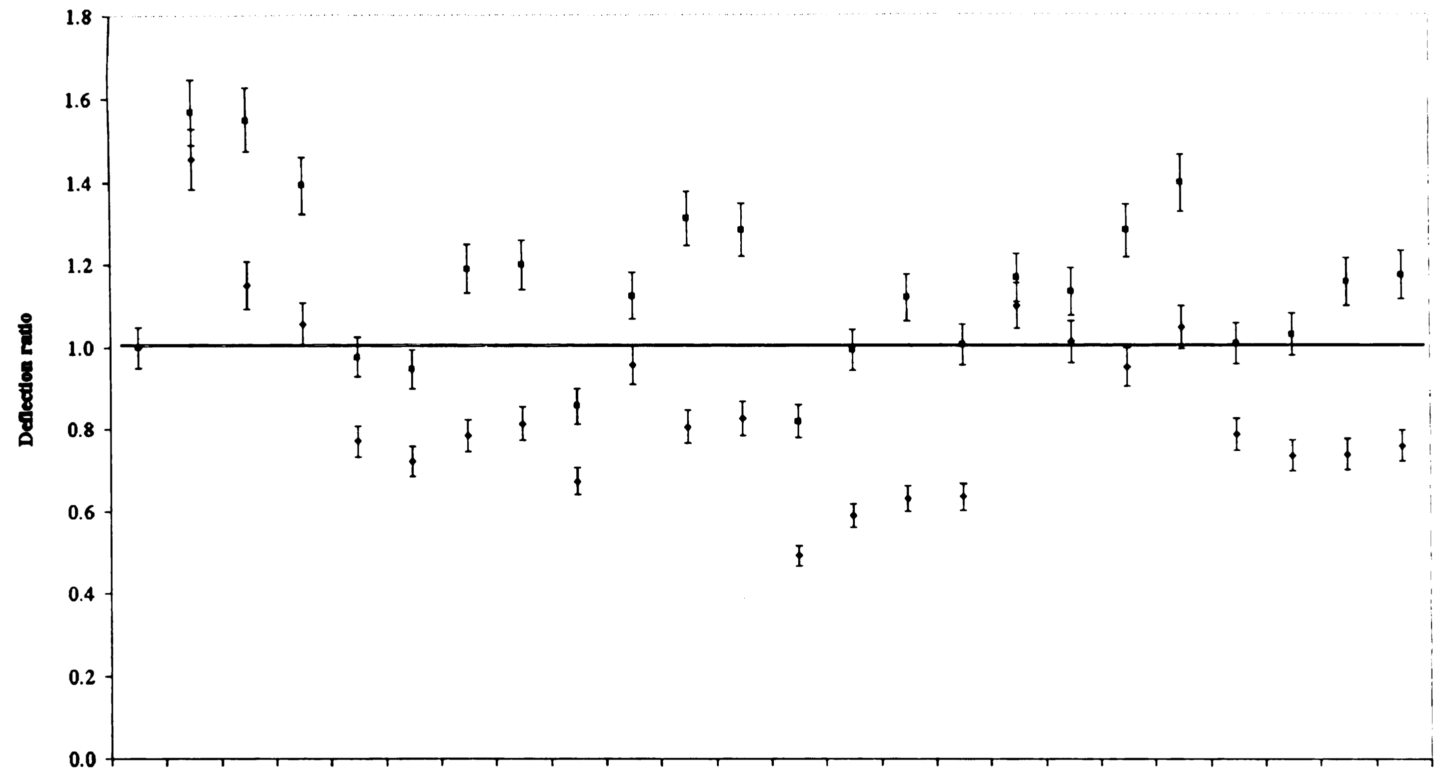
Figure B- 79 Deflections in 12- ft sections in KS (20)



Section ID	0202	0202	0202	0202	0203	0203	0203	0203	0203	0206	0206	0206	0206	0207	0207
Flexural strength, psi	900	900	900	900	550	550	550	550	550	900	900	900	900	550	550
Age of pavement, years	1	5	7	9	0	1	3	5	9	1	5	7	9	0	1
Surface Temp, deg C	10.3	26.4	16.4	39.6	12.3	11.7	28.9	18.5	32.2	11.5	21.1	14.7	28.5	13.6	11.2
Temp at the mid depth, deg C	9.73	22.4	13.1	33.8	10.3	8.79	30.1	16.7	29.4	10.7	19.6	13.6	28.9	13	9.12
Temp at the bottom , deg C	9.86	21.1	10.4	31.9	10.5	7.39	30.6	17.3	29.3	10.3	19.1	13.3	29.8	12.9	8.54
Temp gradient	0	0.03	0.04	0.05	0.01	0.03	-0	0.01	0.02	0.01	0.01	0.01	-0	0	0.02

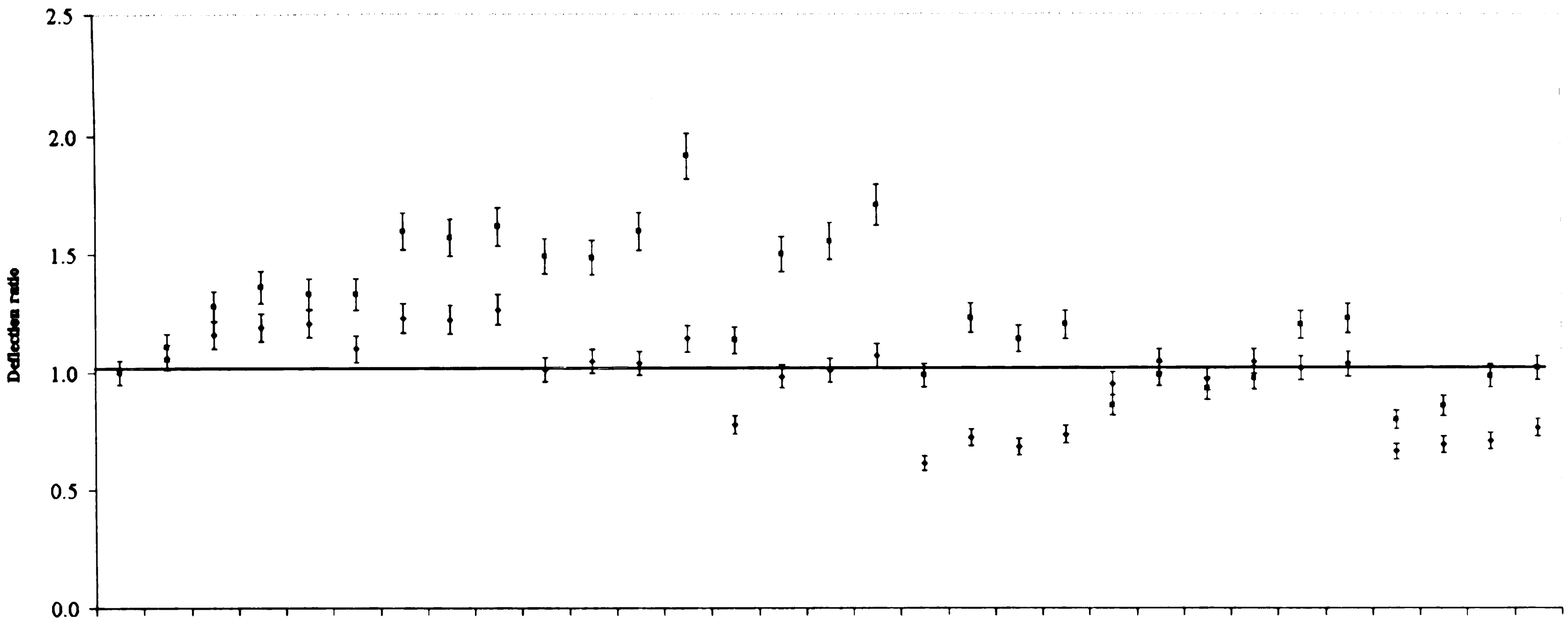
Section ID	0207	0207	0207	0207	0210	0210	0210	0210	0210	0210	0211	0211	0211	0211	0211	0211
Flexural strength, psi	550	550	550	550	900	900	900	900	900	900	550	550	550	550	550	550
Age of pavement, years	3	5	7	9	0	1	3	5	7	9	0	1	3	5	7	9
Surface Temp, deg C	25.6	20.1	17.6	28.8	19.5	10.4	33	36.3	6.39	33.9	14.6	7.78	31.7	21.7	13	36.5
Temp at the mid depth, deg C	25.6	20.4	13.8	26.9	17.6	9.5	31.1	29.2	6.2	30.6	14.9	8.34	31.3	16.9	13.1	28.7
Temp at the bottom , deg C	27	19.9	12.8	27.9	16.4	9	30.5	24	7.43	30.2	15.6	9.04	32	16.7	13.5	27
Temp gradient	-0	0	0.03	0.01	0.02	0.01	0.02	0.08	-0	0.02	-0	-0	-0	0.03	-0	0.06

Figure B- 80 Deflections in 14- ft sections in KS (20)



Section ID	0202	0202	0202	0202	0203	0203	0203	0203	0206	0206	0206	0206	0207	0207	0207	0207	0210	0210	0210	0210	0211	0211	0211	0211
Flexural Strength, psi	900	900	900	900	550	550	550	550	900	900	900	900	550	550	550	550	900	900	900	900	550	550	550	550
Pavement age, years	1994	1996	1999	2001	1994	1996	1999	2001	1994	1996	1999	2001	1994	1996	1999	2001	1994	1996	1999	2001	1994	1996	1999	2001
Surface Temp, deg C	23.6	28.3	14.4	24.1	33.4	14.2	15.3	32.5	25.7	22.9	11.1	31.3	22.4	19.6	12.3	27.7	31.7	27.9	13	33.5	20.9	14.5	18.9	35.9
Temp at the middepth, deg C	21.4	26.3	13.5	23	27.2	16.6	12.7	26.7	22.9	24.8	8.89	25.2	19.4	17.9	8.19	21.5	26.4	24.7	12	29.6	20	15.7	15.4	27.9
Temp at the bottom, deg C	20.5	24	13.2	22	24	17.8	12.1	23	21.5	23.7	9.28	22.5	19.9	18.3	8.16	20.3	23	23.4	11.3	25.2	20.6	16.7	13.9	26.2
Temp gradient	0.02	0.03	0.01	0.01	0.06	-0	0.02	0.06	0.03	-0	0.01	0.06	0.02	0.01	0.03	0.05	0.06	0.03	0.01	0.05	0	-0	0.03	0.06

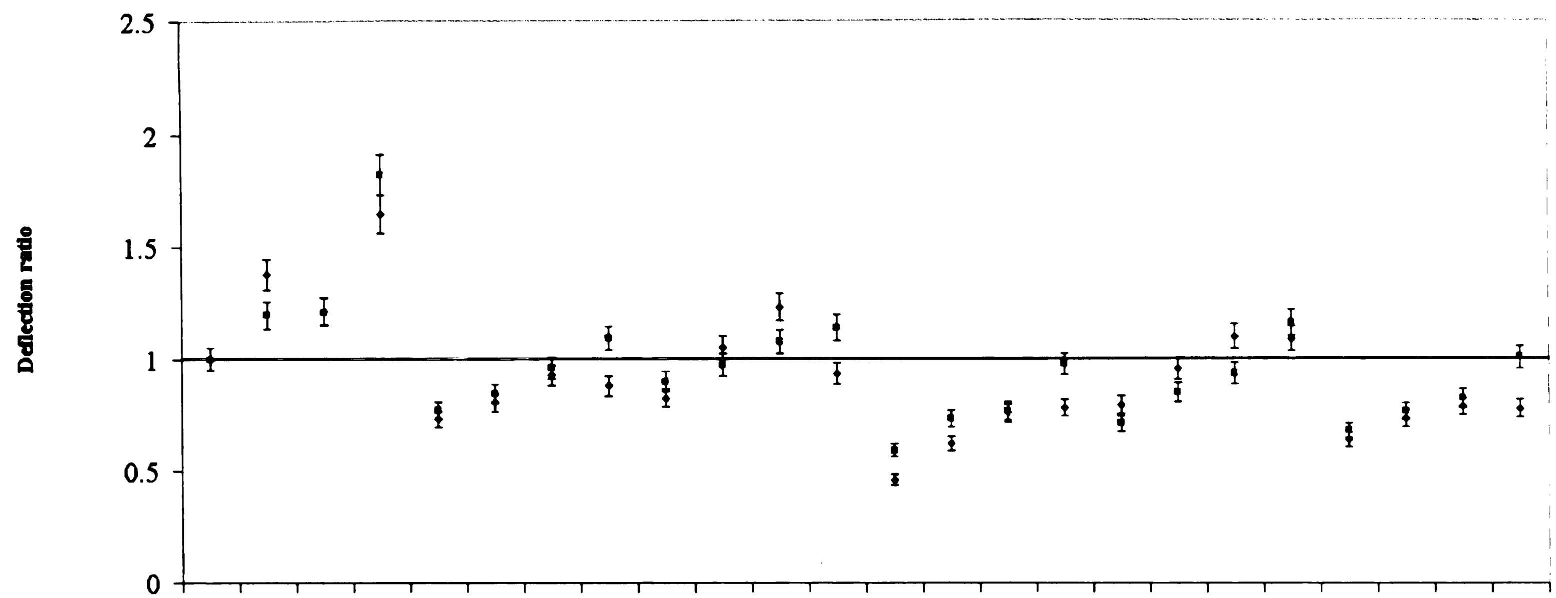
Figure B- 81 Deflections in 14- ft sections in NC (37)



Section ID	0201	0201	0201	0201	0201	0201	0201	0201	0201	0204	0204	0204	0204	0205	0205
Flexural Strength, psi	550	550	550	550	550	550	550	550	550	900	900	900	900	550	550
Pavement age, years	1994	1995	1996	1997	1998	1999	2000	2001	2002	1994	1996	1999	2001	1994	1996
Surface Temp, deg C	21.3	27.2	25	18.6	28.9	25.5	21.8	26.6	23.9	20.1	24.7	18.9	21.8	26	18.4
Temp at the middepth, deg C	19.7	22.6	22	13.2	24.8	19.8	17.7	21.6	19.7	21.1	19.6	15.1	19.9	22	21
Temp at the bottom, deg C	19.6	21.4	20.9	12.2	23.2	18.5	16.6	19.7	18.1	22.2	18.4	12.5	21.3	19.6	21.6
Temp gradient	0.01	0.04	0.03	0.04	0.04	0.05	0.03	0.04	0.04	-0	0.04	0.04	0	0.04	-0

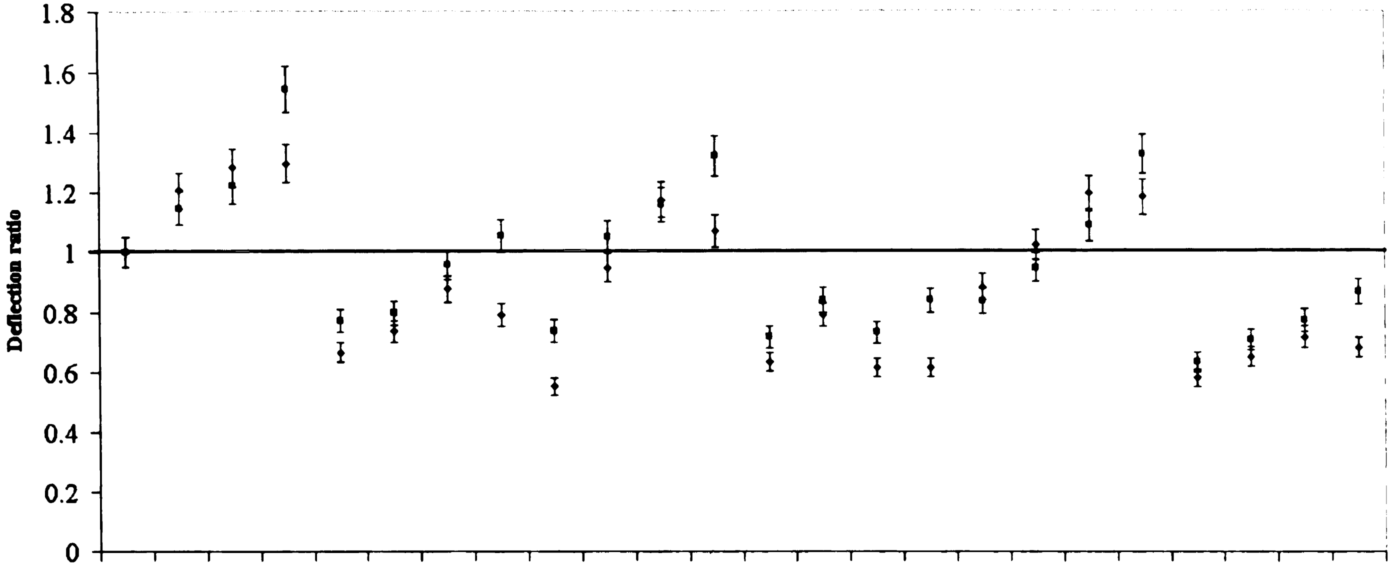
Section ID	0205	0205	0208	0208	0208	0208	0209	0209	0209	0209	0209	0209	0212	0212	0212	0212
Flexural Strength, psi	550	550	900	900	900	900	550	550	550	550	550	550	900	900	900	900
Pavement age, years	1999	2001	1994	1996	1999	2001	1994	1995	1996	1998	1999	2001	1994	1996	1999	2001
Surface Temp, deg C	24.8	23.8	23.1	17.9	20.5	32.5	21.6	27.7	27.7	33.9	25.8	36.5	20.8	20.8	21.1	36.3
Temp at the middepth, deg C	17.4	19.8	19	19.9	15.4	30.7	18.4	24.4	21.4	35.1	21.6	32	17.8	20.1	16.5	27.6
Temp at the bottom, deg C	15.2	19.7	17.8	20.1	13.3	26.8	17.4	20.8	19.5	34.3	18.4	29.5	17.6	19.6	14	23.2
Temp gradient	0.06	0.03	0.03	-0	0.05	0.04	0.03	0.05	0.05	-0	0.05	0.05	0.02	0.01	0.05	0.09

Figure B- 82 Deflections in 12- ft sections in NC (37)



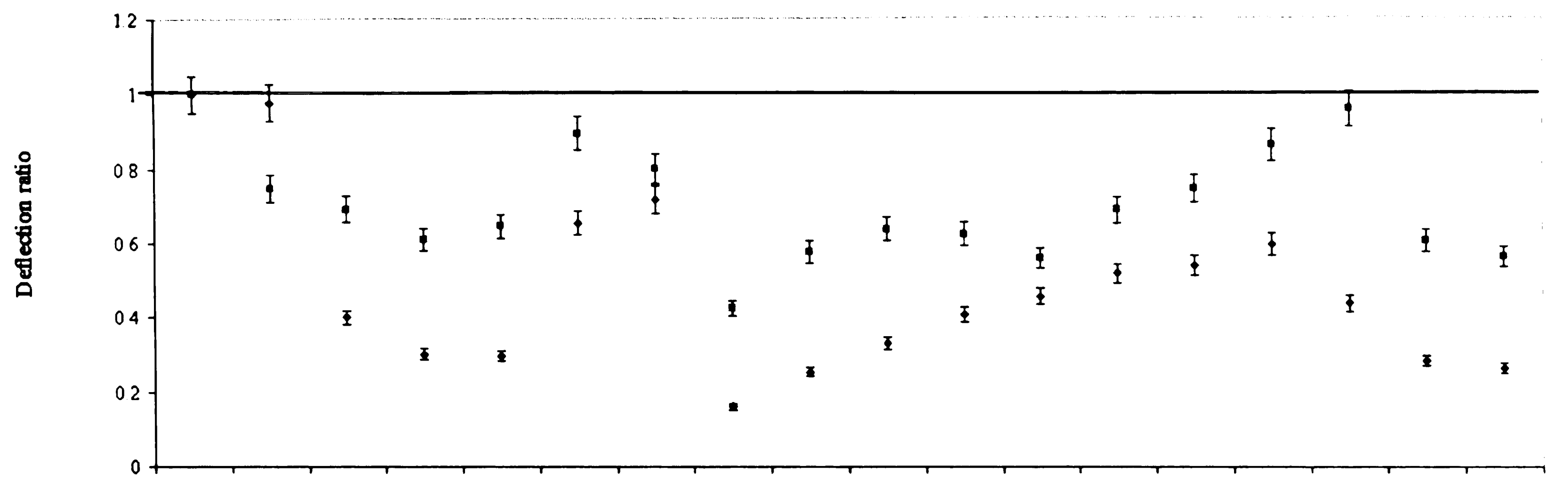
Section ID	0214	0214	0214	0214	0215	0215	0215	0215	0218	0218	0218	0218	0219	0219	0219	0219	0222	0222	0222	0222	0223	0223	0223	0223
Flexural Strength, psi	900	900	900	900	550	550	550	550	900	900	900	900	550	550	550	550	900	900	900	900	550	550	550	550
Age of pavement, years	1994	1995	1999	2001	1994	1995	1999	2001	1994	1995	1999	2001	1994	1995	1999	2001	1994	1995	1999	2001	1994	1995	1999	2001
Surface Temp, deg C	4.13	28.3	26.7	38.1	8.1	11.7	35.4	23.4	7.6	29.2	33.2	22.2	6.57	19.6	35.4	35.9	4.43	12.7	22.6	25.3	4.45	27.4	33.6	26
Temp at the mid-depth, deg C	4.37	24.9	22.2	32.9	7	13.6	26.7	22.9	6.1	24	30.2	23.3	6.4	19	26.4	27.1	5.13	14	21.3	24.1	4.45	22	26.8	25.1
Temp at the bottom, deg C	5.07	21.1	22.3	29.9	6.77	17.9	22.2	24.5	5.67	22	26.7	25.2	6.43	20.2	22.4	24.8	5.57	13.9	21.3	24.5	4.85	20.3	22.6	25.7
Temp gradient	-0.01	0.05	0.03	0.05	0.01	-0.04	0.09	-0.01	0.01	0.05	0.04	-0.02	0.00	0.00	0.08	0.07	-0.01	-0.01	0.01	0.01	0.00	0.05	0.07	0.00

Figure B- 83 Deflections in 12- ft sections in ND (38)



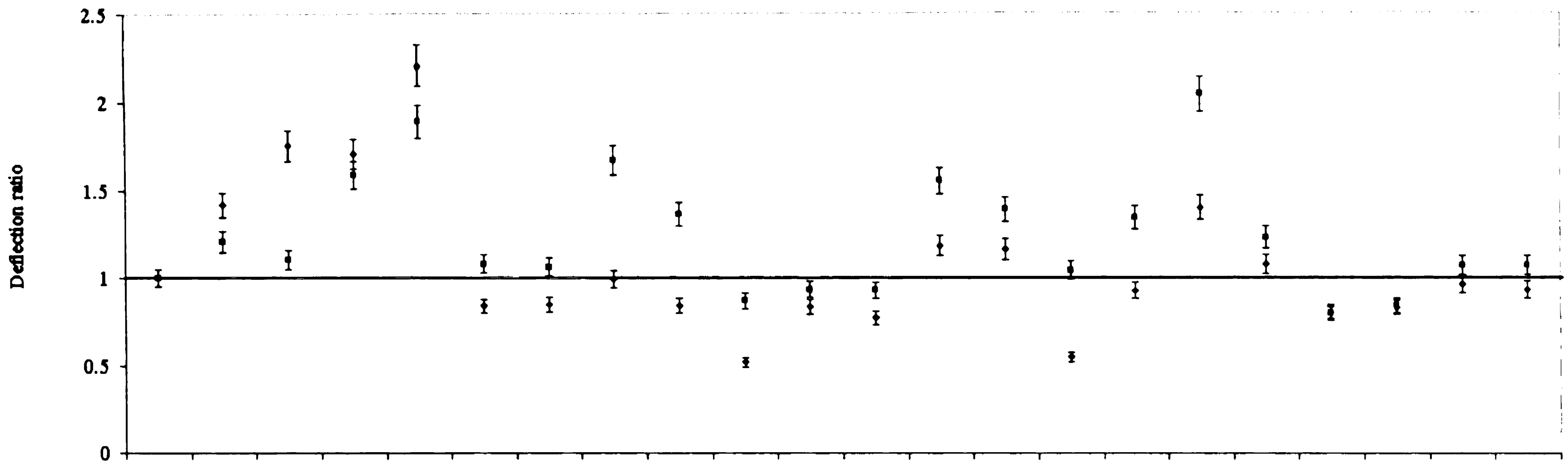
Section ID	0213	0213	0213	0213	0216	0216	0216	0216	0217	0217	0217	0217	0220	0220	0220	0220	0221	0221	0221	0221	0224	0224	0224	0224
Flexural Strength, psi	550	550	550	550	900	900	900	900	550	550	550	550	900	900	900	900	550	550	550	550	900	900	900	900
Age of pavement, years	1994	1995	1999	2001	1994	1995	1999	2001	1994	1995	1999	2001	1994	1995	1999	2001	1994	1995	1999	2001	1994	1995	1999	2001
Surface Temp, deg C	3.44	28.8	28.6	20.3	5.7	23.9	36.3	34.6	4.65	19	31.3	24.9	4.22	34.6	27.3	22.2	6.96	22.7	35.2	37.4	10.9	31.1	36.9	29.7
Temp at the mid-depth, deg C	3.9	22.9	24.2	22.3	6	19.5	29.7	26.5	3.27	18.3	27.2	23.1	3.52	27.3	20.8	23.9	5.68	18.1	28.4	31.2	7.38	24.2	28.1	26.4
Temp at the bottom, deg C	4.74	20.4	23	24	6.73	18.7	25.2	24.9	3.43	18.8	24.4	23.3	5.64	23.6	20.7	25	4.94	19	24.8	28.2	6.32	20.6	23.7	25.8
Temp gradient	-0.01	0.05	0.04	-0.02	-0.01	0.03	0.07	0.06	0.01	0.00	0.05	0.01	-0.01	0.07	0.04	-0.02	0.01	0.02	0.07	0.06	0.03	0.07	0.09	0.03

Figure B- 84 Deflections in 14- ft sections in ND (38)



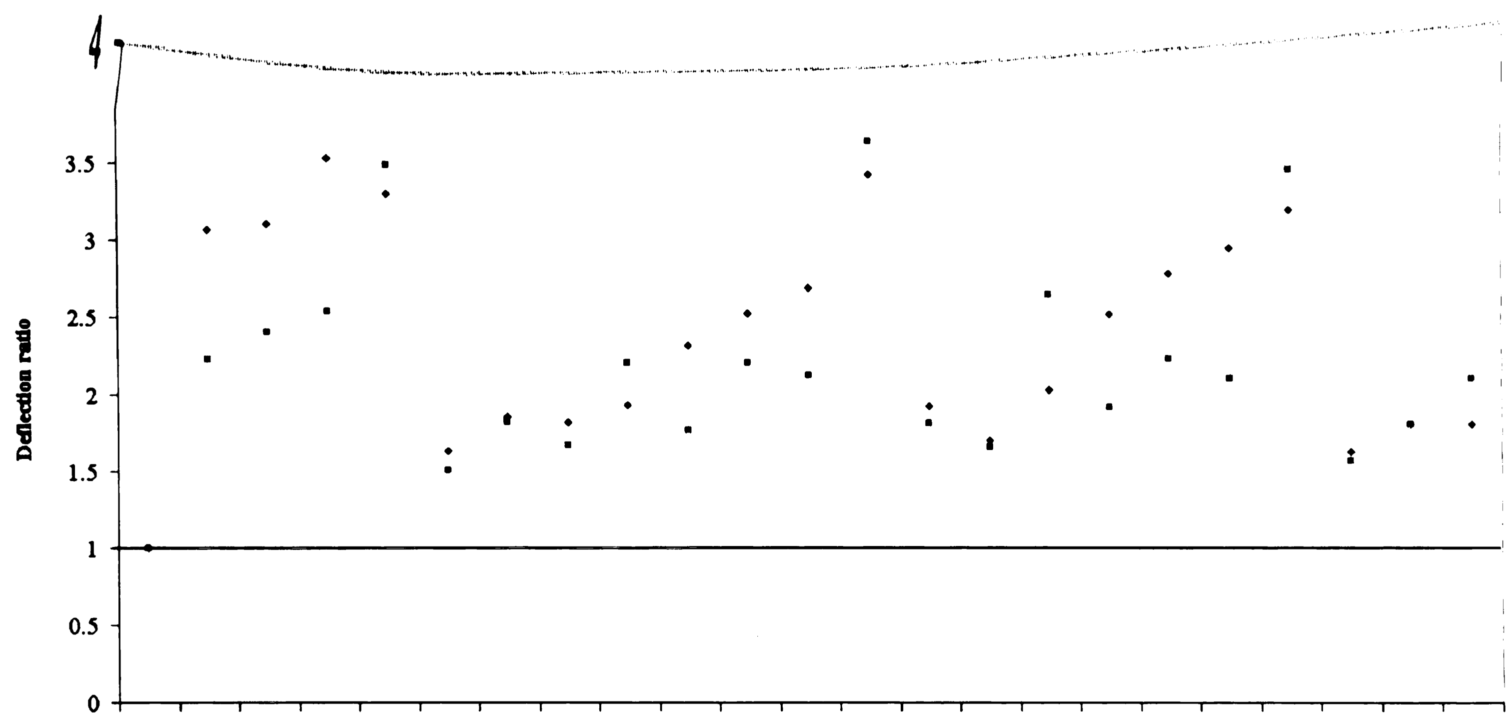
Section ID	0202	0202	0203	0203	0203	0206	0206	0207	0207	0207	0210	0210	0210	0210	0210	0211	0211	0211
Flexural Strength, psi	900	900	550	550	550	900	900	550	550	550	900	900	900	900	900	550	550	550
Age of pavement, years	1996	1997	1996	2000	2002	1996	1997	1996	2000	2002	1996	1997	1998	2000	2002	1996	2000	2002
Surface Temp, deg C	16.48	30.12	19.2	35	44.05	11.33	28.48	11.71	35.44	32.14	16.15	18.38	10	32.5	41.18	16.65	38.55	33.03
Temp at the mid-depth, deg C	11.7	26.92	13.16	28.88	32.9	8.962	25.52	7.1	30.89	27.23	13.68	18.53	3.643	28.5	32.2	10.26	33.09	27.68
Temp at the bottom, deg C	9.713	24.44	10.68	27	29.28	8.575	24.12	6.663	28.22	27.7	12.4	19.38	2.014	26.5	29.04	6.7	30	27.44
Temp gradient	0.044	0.037	0.056	0.052	0.097	0.018	0.028	0.033	0.047	0.029	0.025	-0.01	0.052	0.039	0.079	0.065	0.056	0.037

Figure B- 85 Deflections in 14- ft sections in NV (32)



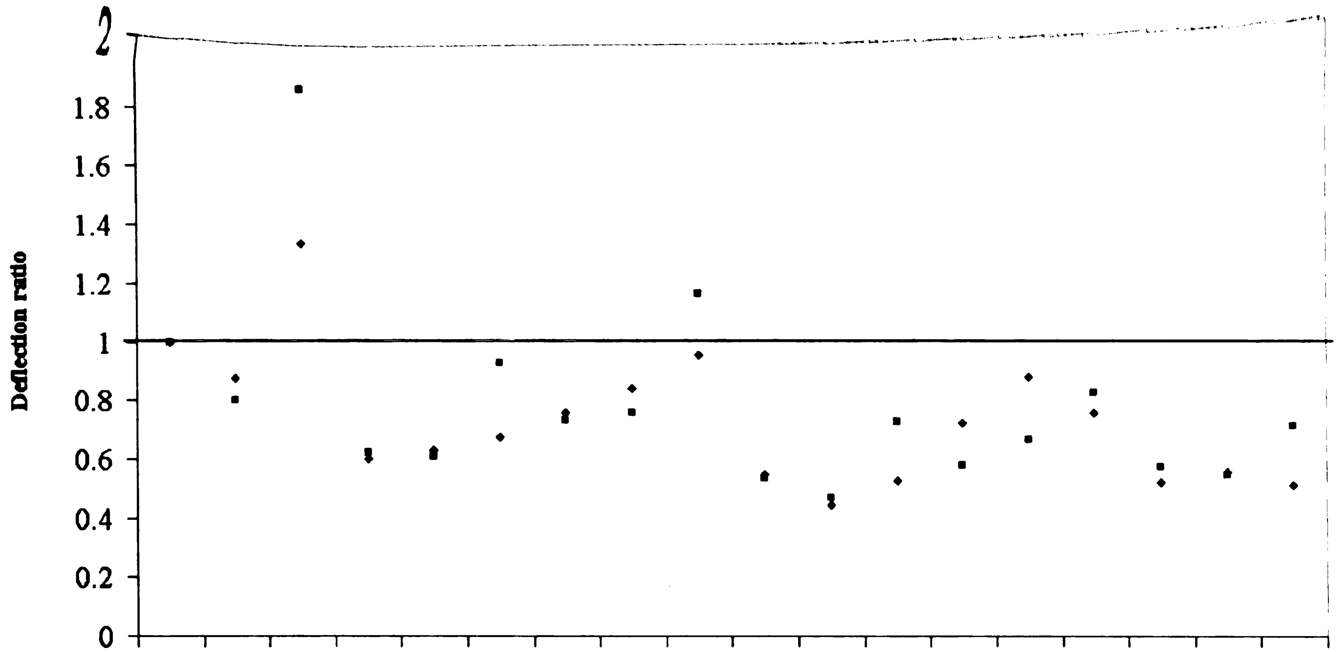
Section ID	0201	0201	0201	0201	0201	0204	0204	0204	0204	0205	0205	0205	0205	0205	0208	0208	0208	0209	0209	0209	0209	0209
Flexural Strength, psi	550	550	550	550	550	900	900	900	900	550	550	550	550	550	900	900	900	550	550	550	550	550
Age of pavement, years	1996	1997	1998	2000	2002	1996	1997	2000	2002	1996	1997	1998	2000	2002	1996	2000	2002	1996	1997	1998	2000	2002
Surface Temp, deg C	13.1	31	3.557	34.29	32.8	13.53	19.22	39.83	31.5	10.6	33.15	10	35	41.77	10.48	36.6	45.12	9.217	20.8	8.02	33.5	40.57
Temp at the mid-depth, deg C	10.68	30.78	1.171	30	26.2	9.487	14.39	34.83	26.78	7.925	31.9	5.95	28.67	32.88	8.825	31.2	34.25	5.167	17.36	5.56	30.67	32.9
Temp at the bottom, deg C	9.375	28.63	0.157	26.71	25.24	8.907	13.73	30.67	27.87	6.925	29.7	3.833	26.5	28.75	9.05	28.8	29.35	3.533	15.46	3.04	28.83	29
Temp gradient	0.024	0.016	0.022	0.049	0.049	0.03	0.036	0.06	0.024	0.024	0.023	0.04	0.056	0.085	0.009	0.051	0.103	0.037	0.035	0.033	0.031	0.076

Figure B- 86 Deflections in 12- ft sections in NV (32)



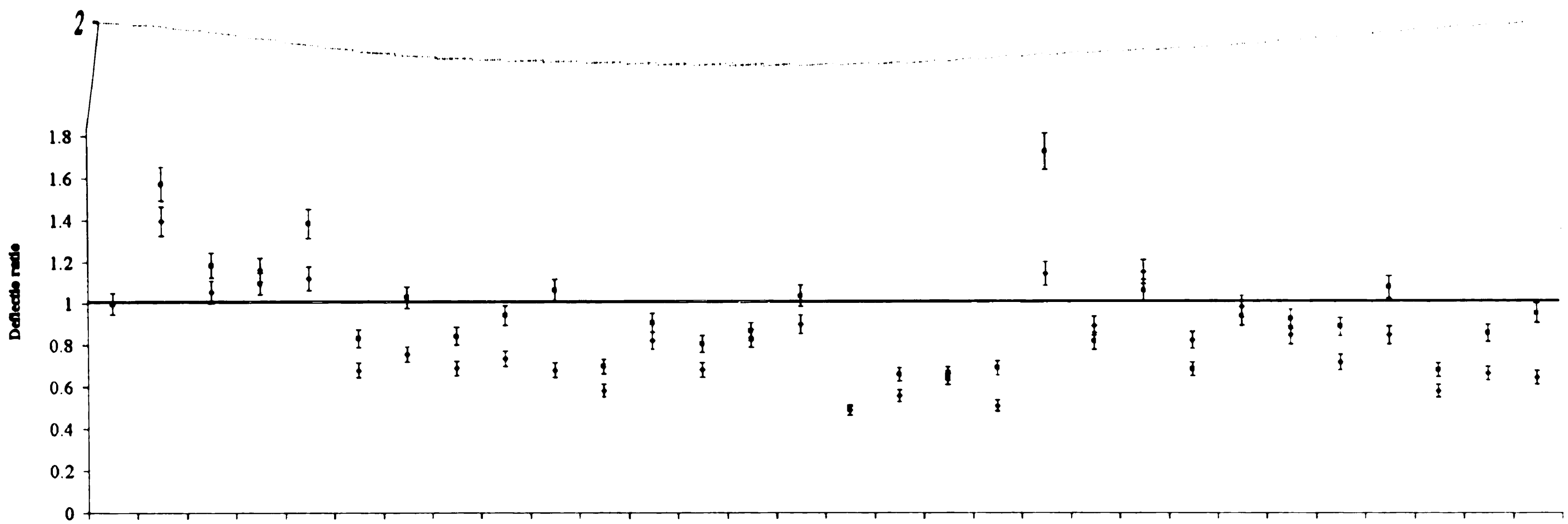
Section ID	0201	0201	0201	0201	0201	0204	0204	0204	0204	0205	0205	0205	0205	0208	0208	0208	0209	0209	0209	0209	0212	0212	0212
Flexural Strength, psi	550	550	550	550	550	900	900	900	900	550	550	550	550	900	900	900	550	550	550	550	900	900	900
Age of pavement, years	1995	1996	1997	1999	2001	1996	1998	1999	2001	1996	1997	1999	2001	1997	1999	2001	1996	1997	1999	2001	1996	1999	2001
Surface Temp, deg C	#N/A	4.73	25.4	32.9	14.5	17.1	25.3	22.3	20.1	9.15	25.5	29	26.2	14.4	23.9	30	5.85	25.5	30.7	24	5.13	36.1	22.1
Temp at the mid-depth, deg C	#N/A	5	26.5	26.7	10.3	16.2	20.7	18.2	13.6	8.05	25.9	23	20.5	13.6	22.6	24.8	5.43	25.6	28.9	14.9	4.15	30.7	17.6
Temp at the bottom, deg C	#N/A	5.43	26.7	23.6	9.73	15.6	19.3	17.2	10.5	7.2	26.9	23.3	15.6	12.5	22.1	20.2	5.43	25.2	28	12	3.73	27.2	13.3
Temp gradient	#N/A	-0	-0.01	0.06	0.03	0.01	0.04	0.03	0.06	0.01	-0.01	0.04	0.07	0.01	0.01	0.06	0	0	0.02	0.08	0.01	0.06	0.06

Figure B- 87 Deflections in 12- ft sections in OH (39)



Section ID	0202	0202	0202	0203	0203	0203	0206	0206	0206	0207	0207	0207	0210	0210	0210	0211	0211	0211
Flexural Strength, psi	900	900	900	550	550	550	900	900	900	550	550	550	900	900	900	550	550	550
Age of pavement, years	1996	1999	2001	1997	1999	2001	1996	1999	2001	1997	1999	2001	1996	1999	2001	1997	1999	2001
Surface Temp, deg C	8.54	36.8	22.7	11.7	33.7	26.9	8	30.6	18.7	14.9	21.5	20.9	6.68	33.9	12.9	9.32	31.7	19.4
Temp at the mid-depth, deg C	7.76	31.7	15.8	10.6	30.5	20.7	6.24	24.8	18.6	13.4	22.2	21.3	6.26	27.3	8.86	8.42	25.3	16.9
Temp at the bottom, deg C	6.7	28.1	12.1	9.86	27.9	17.8	5.68	24.7	16.8	11.7	23.7	19.1	6.34	23.2	7.96	7.9	22.2	16.8
Temp gradient	0.01	0.06	0.07	0.01	0.04	0.06	0.02	0.04	0.01	0.02	-0.01	0.01	0	0.07	0.03	0.01	0.06	0.02

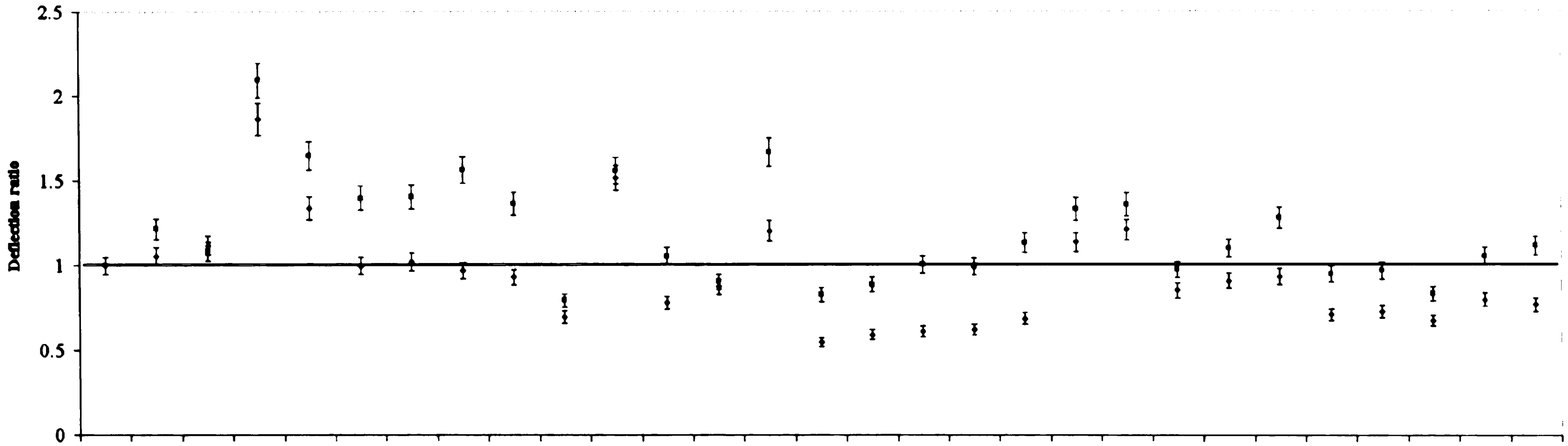
Figure B- 88 Deflections in 14- ft sections in OH (39)



Section ID	0201	0201	0201	0201	0201	0204	0204	0204	0204	0204	0205	0205	0205	0205	0205
Flexural Strength, psi	550	550	550	550	550	900	900	900	900	900	550	550	550	550	550
Age of pavement, years	1995	1997	1998	1999	2001	1995	1997	1998	1999	2001	1995	1997	1998	1999	2001
Surface Temp, deg C	13.15	24.76	14.8	9.433	25.37	10.9	18.83	25.3	20.23	25.11	13.3	29.54	24.8	18.3	35.28
Temp at the mid-depth, deg C	11.25	17.94	13.33	9.267	23.96	10	15.88	18.8	14.57	23.87	11.95	23.82	18.9	13.23	29.32
Temp at the bottom, deg C	10.58	16.14	14.13	10.67	25	9.95	16.18	16.37	13.57	24.3	11.2	19.06	16.3	11.5	25.83
Temp gradient	0.017	0.056	0.004	-0.01	0.002	0.006	0.017	0.058	0.044	0.005	0.014	0.068	0.056	0.044	0.062

Section ID	0208	0208	0208	0208	0208	0209	0209	0209	0209	0209	0212	0212	0212	0212	0212
Flexural Strength, psi	900	900	900	900	900	550	550	550	550	550	900	900	900	900	900
Age of pavement, years	1995	1997	1998	1999	2001	1995	1997	1998	1999	2001	1995	1997	1998	1999	2001
Surface Temp, deg C	10.45	18.82	30.17	14.48	41.67	14.9	26.36	12.57	9.267	17.7	13.23	34.92	19.53	15.93	24.05
Temp at the mid-depth, deg C	9.675	18.24	22.63	14.48	32.79	12.7	20.66	11.7	9.833	19.17	11.93	22.76	14.4	12.83	22.38
Temp at the bottom, deg C	9.625	19	17.47	16.63	26.74	11.8	17.72	12.97	11.37	21.7	11.05	20.44	15.03	12.8	23.38
Temp gradient	0.005	-0	0.083	-0.01	0.098	0.02	0.056	-0	-0.01	-0.03	0.014	0.095	0.029	0.02	0.004

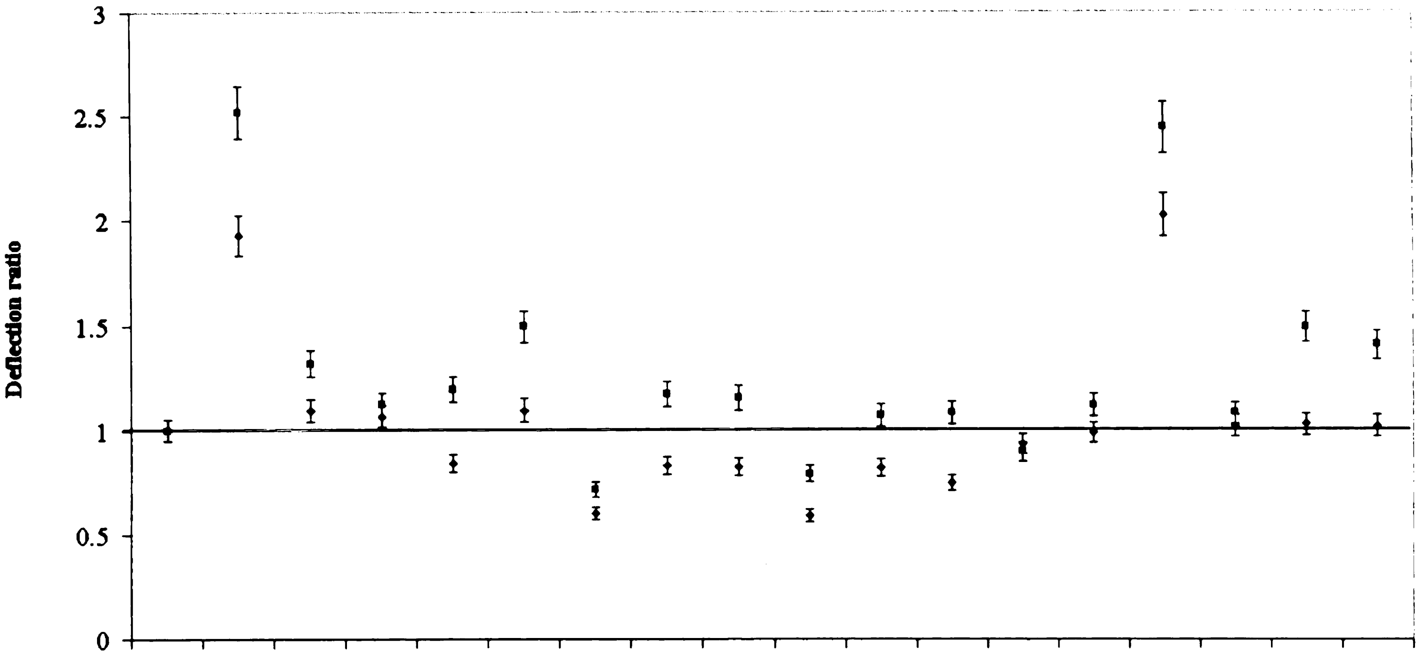
Figure B- 89 Deflections in 12- ft sections in WA (53)



Section ID	0202	0202	0202	0202	0202	0203	0203	0203	0203	0206	0206	0206	0206	0206	0207
Flexural Strength, psi	900	900	900	900	900	550	550	550	550	900	900	900	900	900	550
Age of pavement, years	1995	1997	1998	1999	2001	1995	1997	1998	1999	1995	1997	1998	1999	2001	1995
Surface Temp, deg C	10.04	19.19	32.3	23.63	36.73	15.4	30.29	20.31	11.1	8.52	29.93	16.06	22.5	23.89	12.32
Temp at the mid-depth, deg C	9.18	16.9	25.1	17.23	31.74	13.42	24.35	18.27	11.08	7.16	23.49	15.36	18.02	24.04	9.64
Temp at the bottom, deg C	9.04	17.06	20.97	15	26.97	11.74	20.36	19.43	12.88	7.58	19.83	16.02	16.88	25.51	9.34
Temp gradient	0.007	0.014	0.074	0.056	0.064	0.024	0.065	0.006	-0.01	0.006	0.066	3E-04	0.037	-0.01	0.019

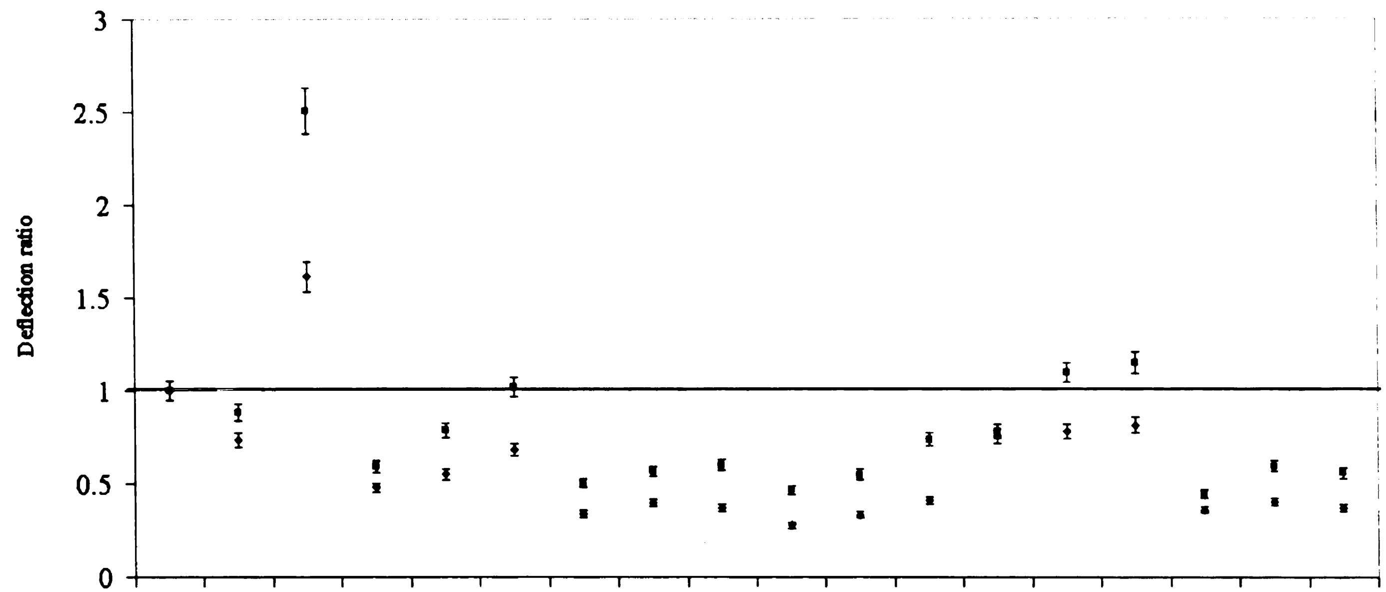
Section ID	0207	0207	0207	0207	0210	0210	0210	0210	0210	0211	0211	0211	0211	0211
Flexural Strength, psi	550	550	550	550	900	900	900	900	900	550	550	550	550	550
Age of pavement, years	1997	1998	1999	2001	1995	1997	1998	1999	2001	1995	1997	1998	1999	2001
Surface Temp, deg C	18.61	21.74	16.46	36.26	11.66	29.27	20.78	10.83	22.64	11.16	17.74	27.18	23.43	31.6
Temp at the mid-depth, deg C	18.43	18.98	13.68	28.02	10.3	23.56	18.28	9.575	23.84	10.16	16.57	22.22	15.08	26.84
Temp at the bottom, deg C	19.21	17.9	14.62	26.51	9.76	20.56	18.8	11.2	25.7	9.96	18.33	19.96	12.93	26.23
Temp gradient	-0	0.025	0.012	0.064	0.012	0.057	0.013	-0	-0.02	0.008	-0	0.047	0.069	0.035

Figure B- 90 Deflections in 14- ft sections in WA (53)



Section ID	0214	0214	0214	0215	0215	0215	0218	0218	0218	0219	0219	0219	0222	0222	0222	0223	0223	0223
Flexural Strength, psi	900	900	900	550	550	550	900	900	900	550	550	550	900	900	900	550	550	550
Age of pavement, years	1998	2000	2002	1998	2000	2002	1998	2000	2002	1998	2000	2002	1998	2000	2002	1998	2000	2002
Surface Temp, deg C	18.03	28.92	17.9	30.55	19.76	13.6	29.85	29.82	26.4	28.8	19.62	15.12	15.58	20.16	30.25	29.66	31.71	27.2
ıp at the mid-depth, deg C	16.25	24.42	16.83	23.48	18.22	8.94	24.4	28.98	21.48	21.08	19.64	15.76	12.75	19.2	23.23	29.9	22.98	20.06
'emp at the bottom, deg C	16.3	21.74	17.15	20.17	18.98	8.5	22.12	27.04	19.12	16.05	20.38	16.76	12.13	19.32	18.7	27.9	17.88	13.46
Temp gradient	0.011	0.047	0.005	0.068	0.005	0.033	0.051	0.018	0.048	0.083	-0	-0.01	0.023	0.005	0.075	0.012	0.09	0.09

Figure B- 91 Deflections in 12- ft sections in WI (55)



Section ID	0213	0213	0213	0216	0216	0217	0217	0217	0217	0220	0220	0220	0221	0221	0221	0224	0224	0224
Flexural Strength, psi	550	550	550	900	900	550	550	550	550	900	900	900	550	550	550	900	900	900
Age of pavement, years	1998	2000	2002	1998	2000	2002	1998	2000	2002	1998	2000	2002	1998	2000	2002	1998	2000	2002
Surface Temp, deg C	28.98	23.78	36.83	21.39	26.65	28.11	20.8	25.2	26.4	18.88	19.84	36.9	25.5	30.33	19.93	19.18	25.47	20.4
Temp at the mid-depth, deg C	24.66	23.28	31.03	16.69	23.58	19.64	17.41	22.81	22.63	14.44	19.69	28.37	23.63	25.47	13.86	16.88	25.57	13.41
Temp at the bottom, deg C	19.32	22.55	24.99	15.76	19.3	15.55	14.93	21.34	20.77	13.5	20.29	20.89	21.85	22.39	11.59	20.82	23.97	12.24
Temp gradient	0.063	0.008	0.077	0.037	0.048	0.082	0.038	0.025	0.037	0.035	-0	0.105	0.024	0.052	0.055	-0.01	0.01	0.053

Figure B- 92 Deflections in 14- ft sections in WI (55)

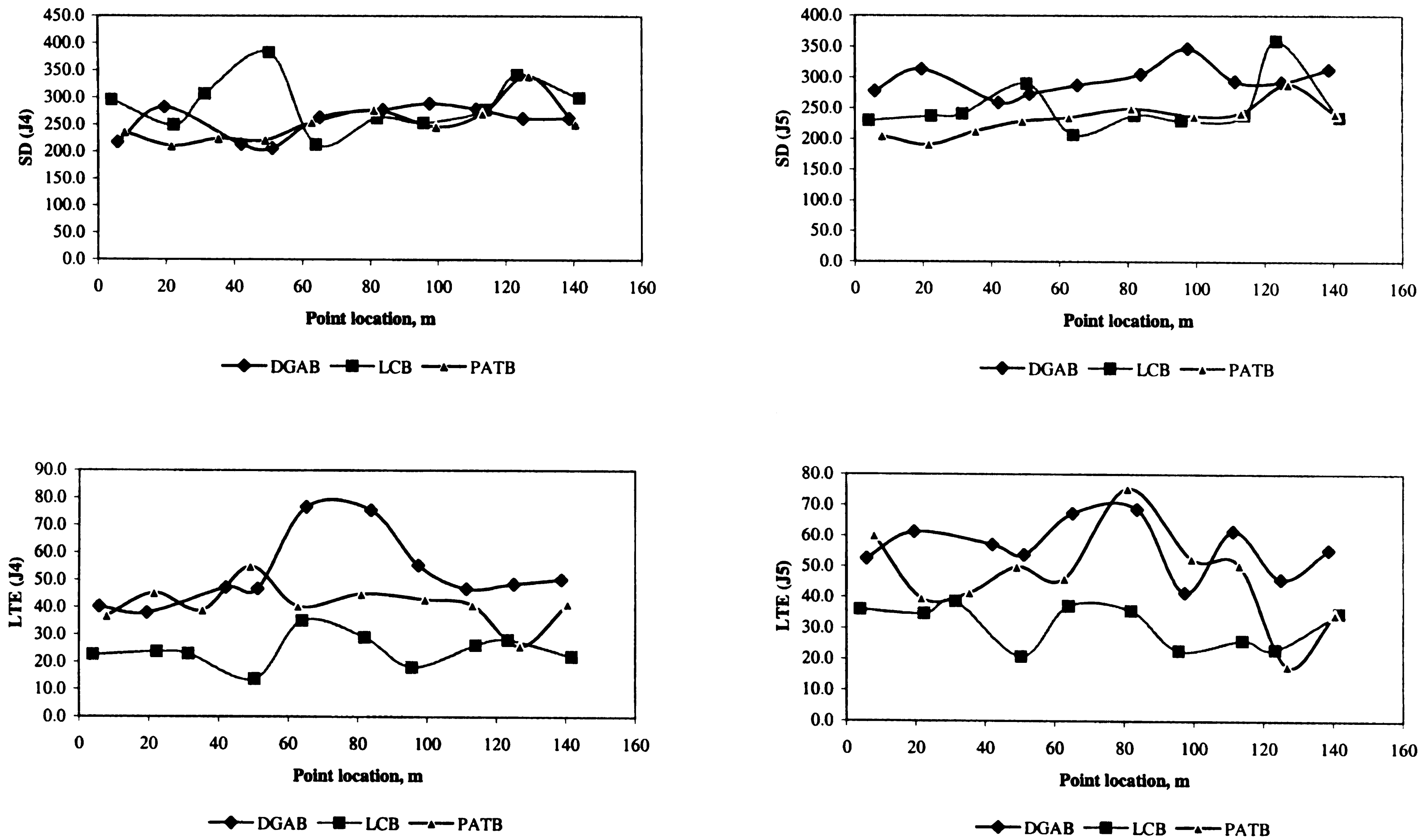


Figure B- 93 Effect of base type on performance –AR (5)

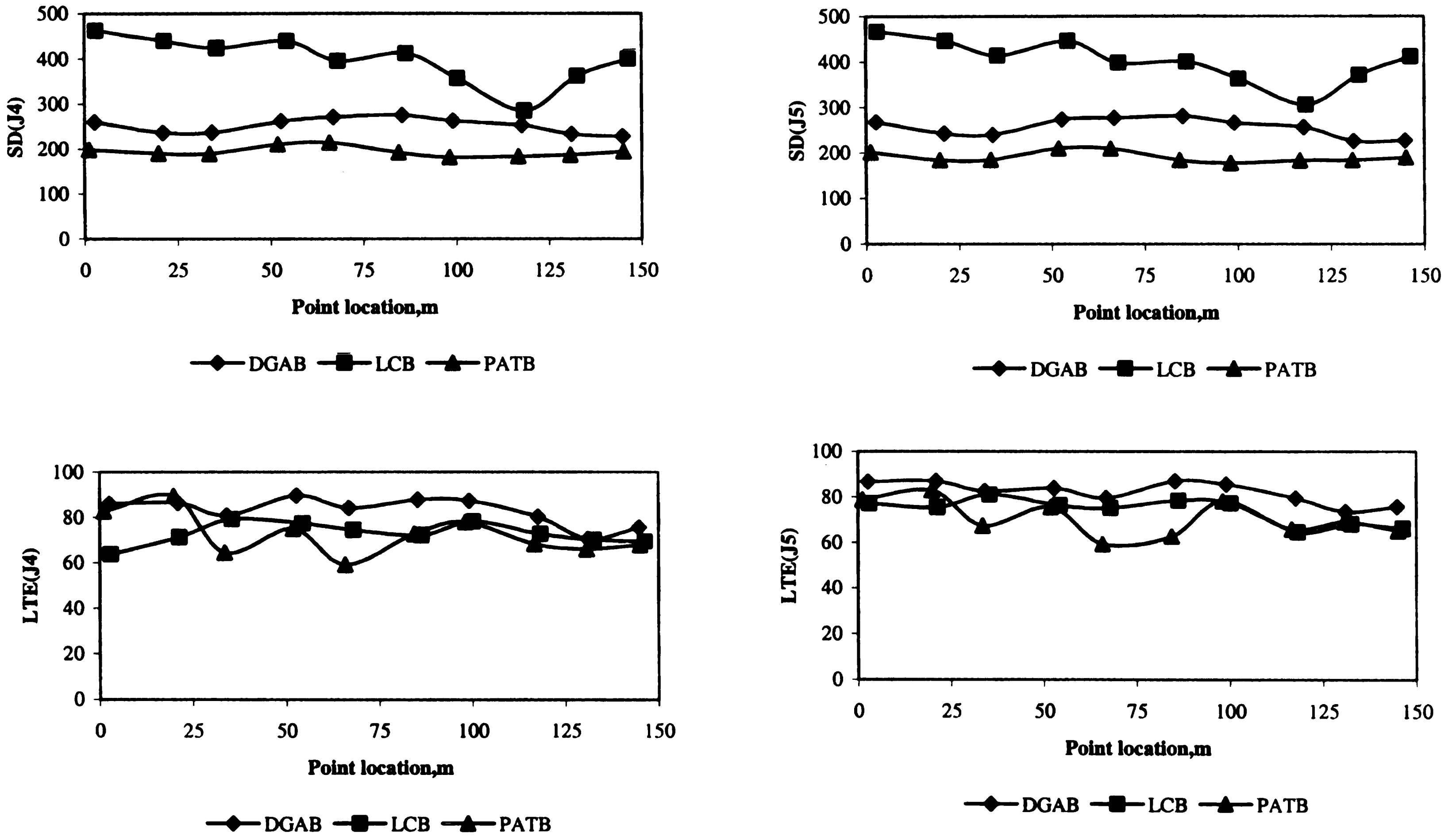


Figure B- 94 Effect of base type on performance –AZ (4)

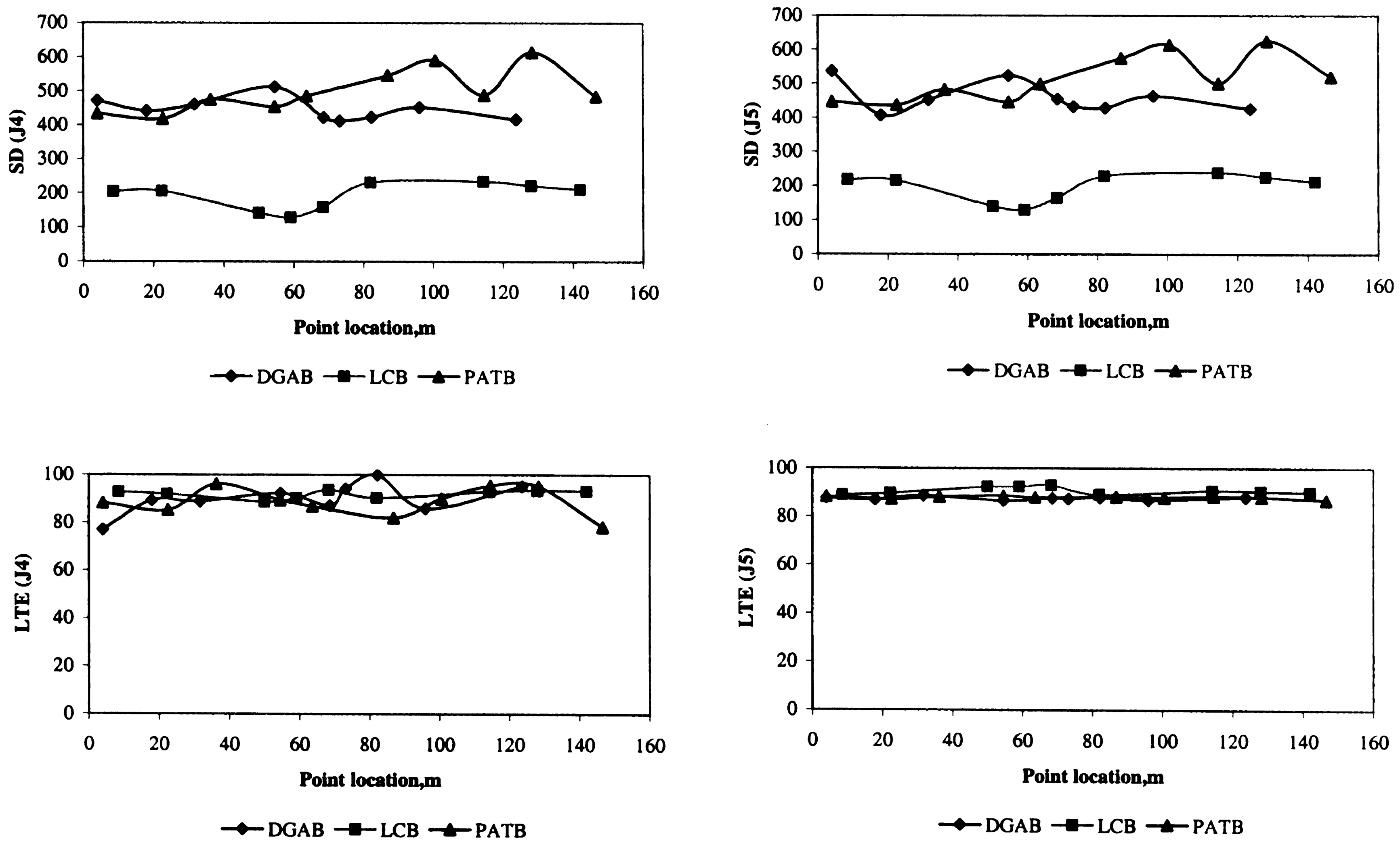


Figure B- 95 Effect of base type on performance –CA (6)

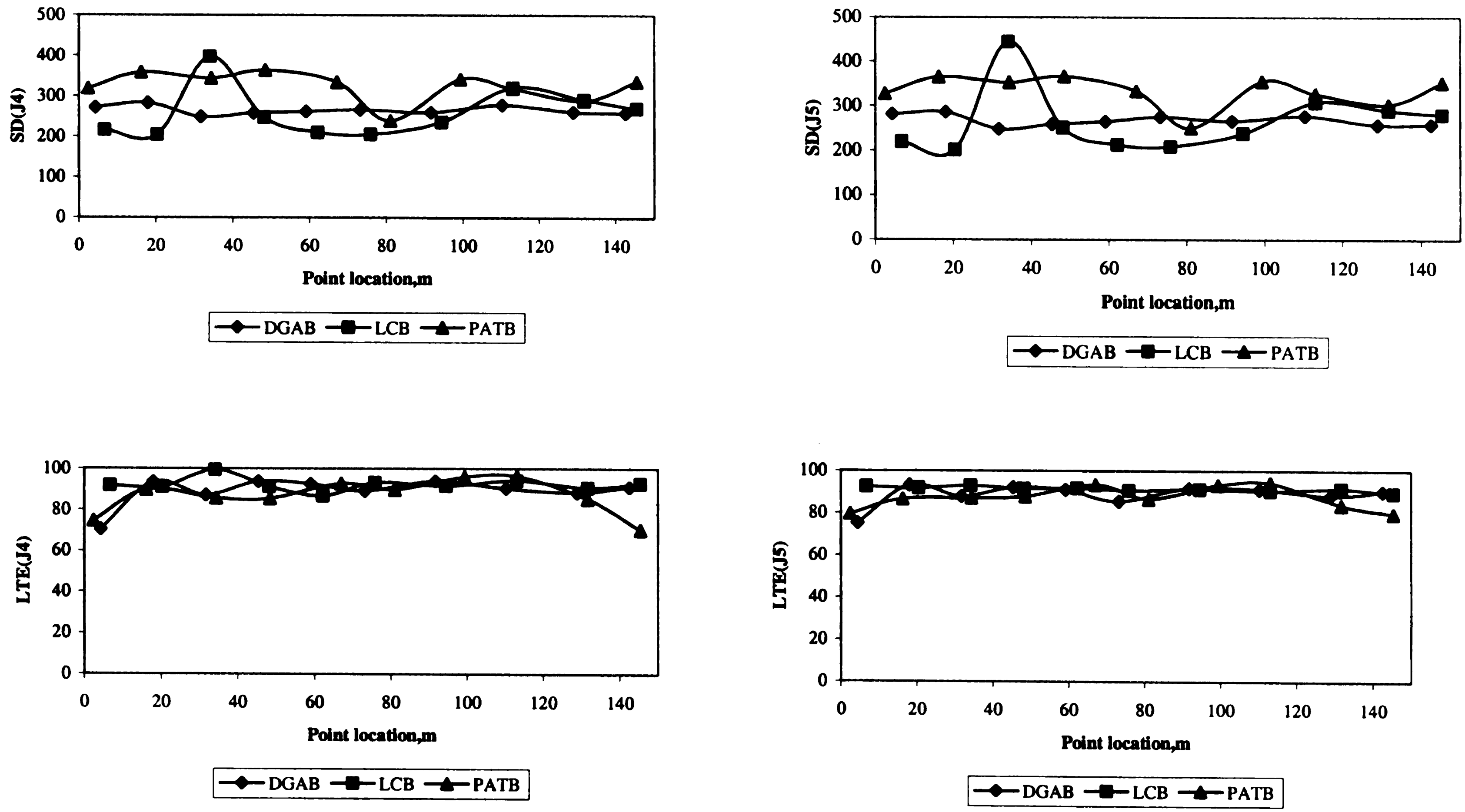


Figure B- 96 Effect of base type on performance – CO (8)

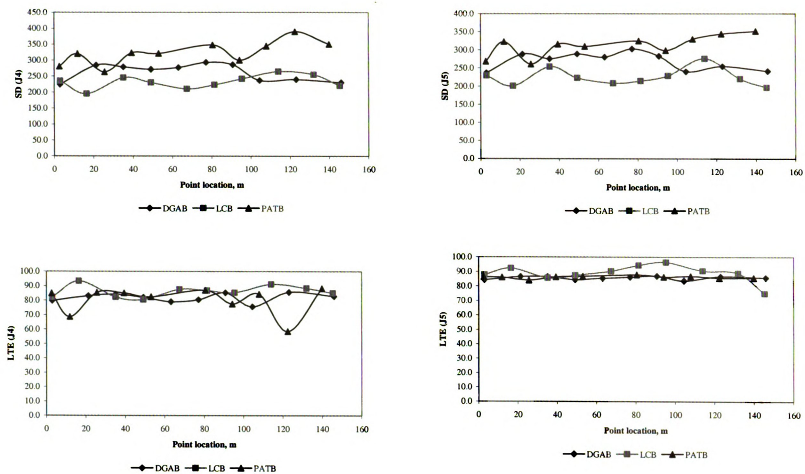


Figure B- 97 Effect of base type on performance – DE (10)

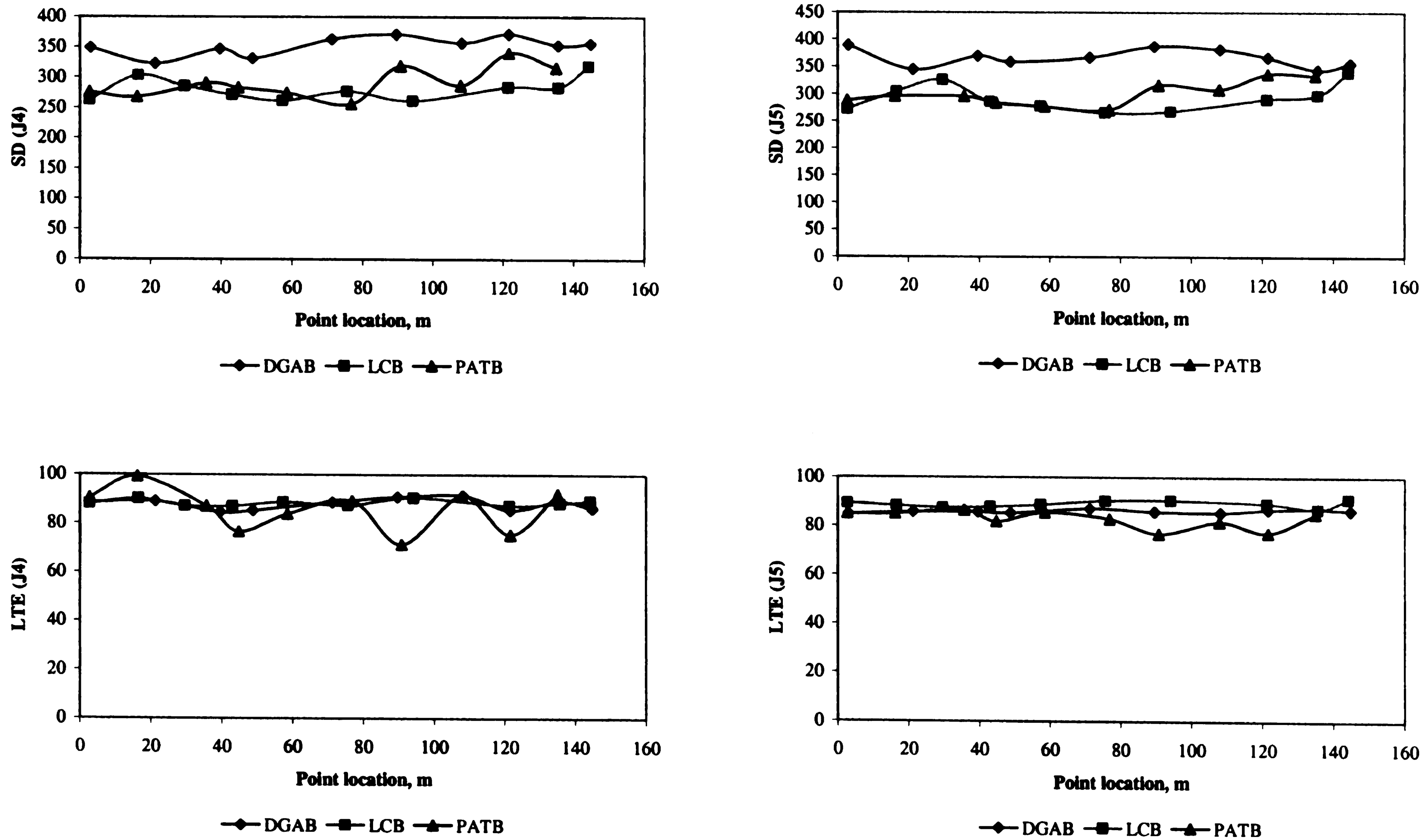


Figure B- 98 Effect of base type on performance –IA (19)

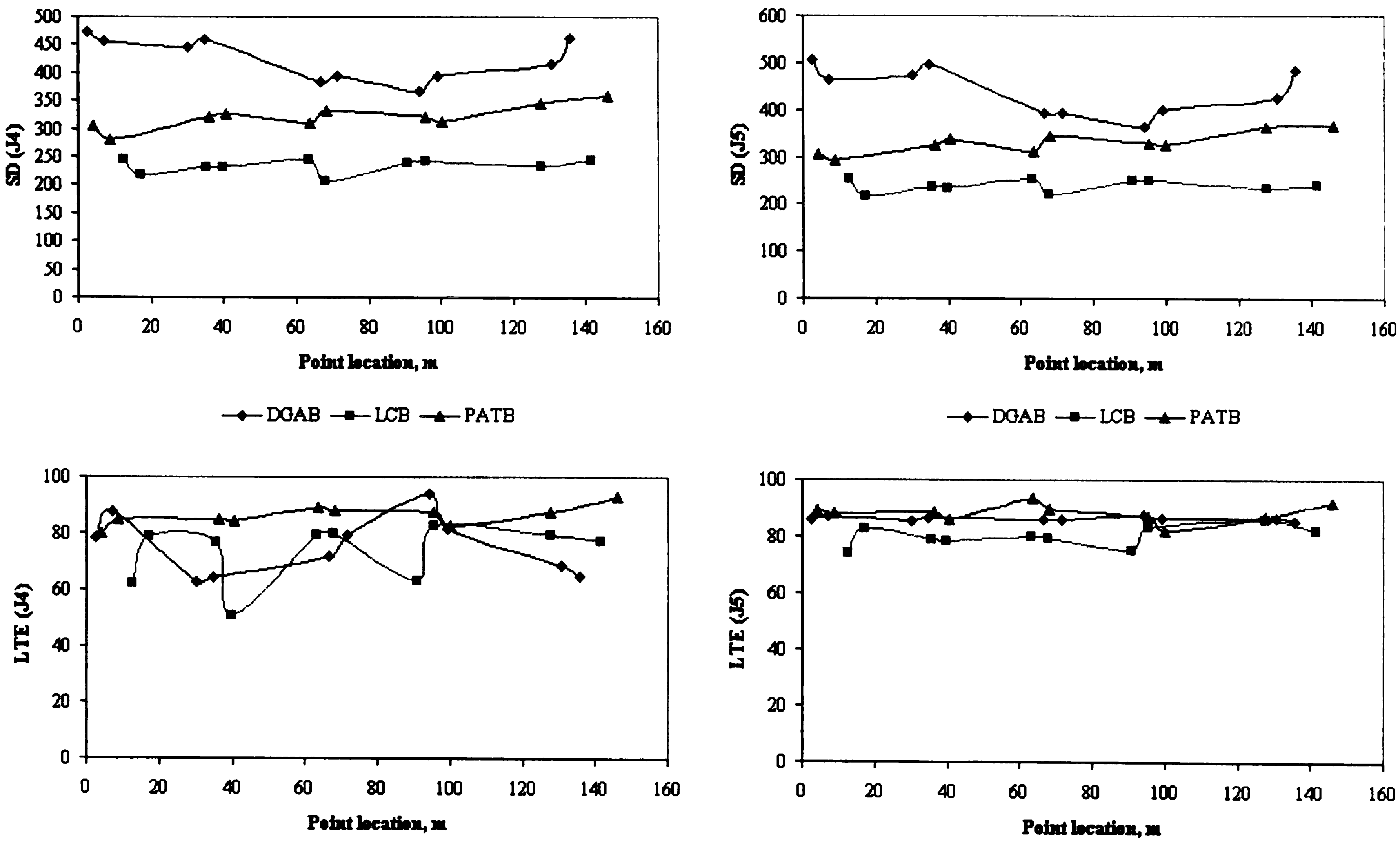


Figure B- 99 Effect of base type on performance –KS (20)

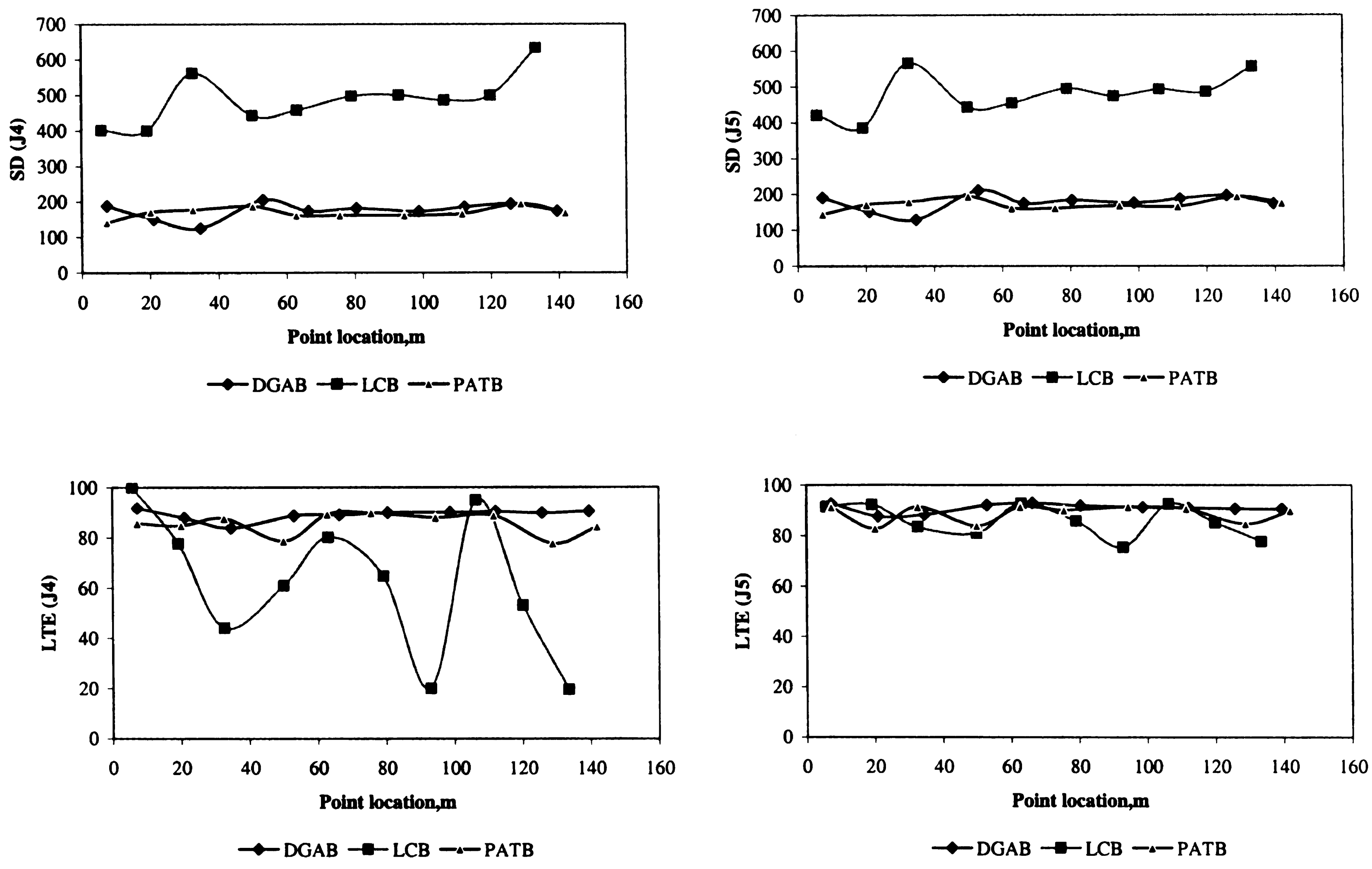


Figure B- 100 Effect of base type on performance –NC (37)

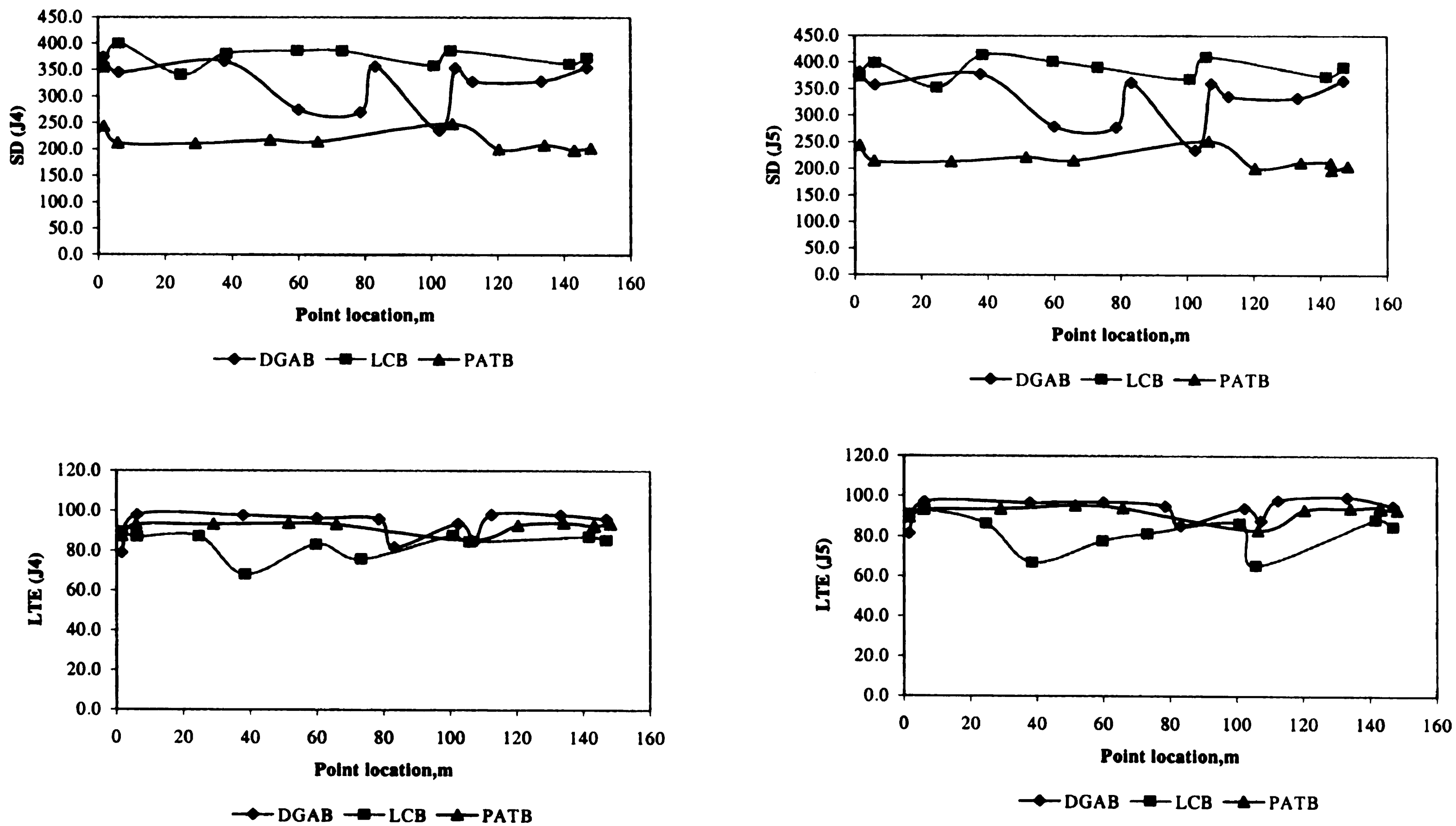


Figure B- 101 Effect of base type on performance -ND (38)

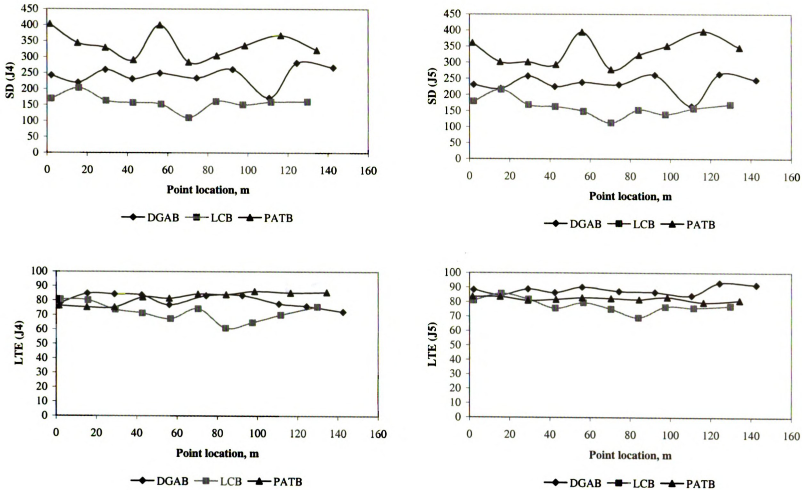


Figure B- 102 Effect of base type on performance –NV (32)

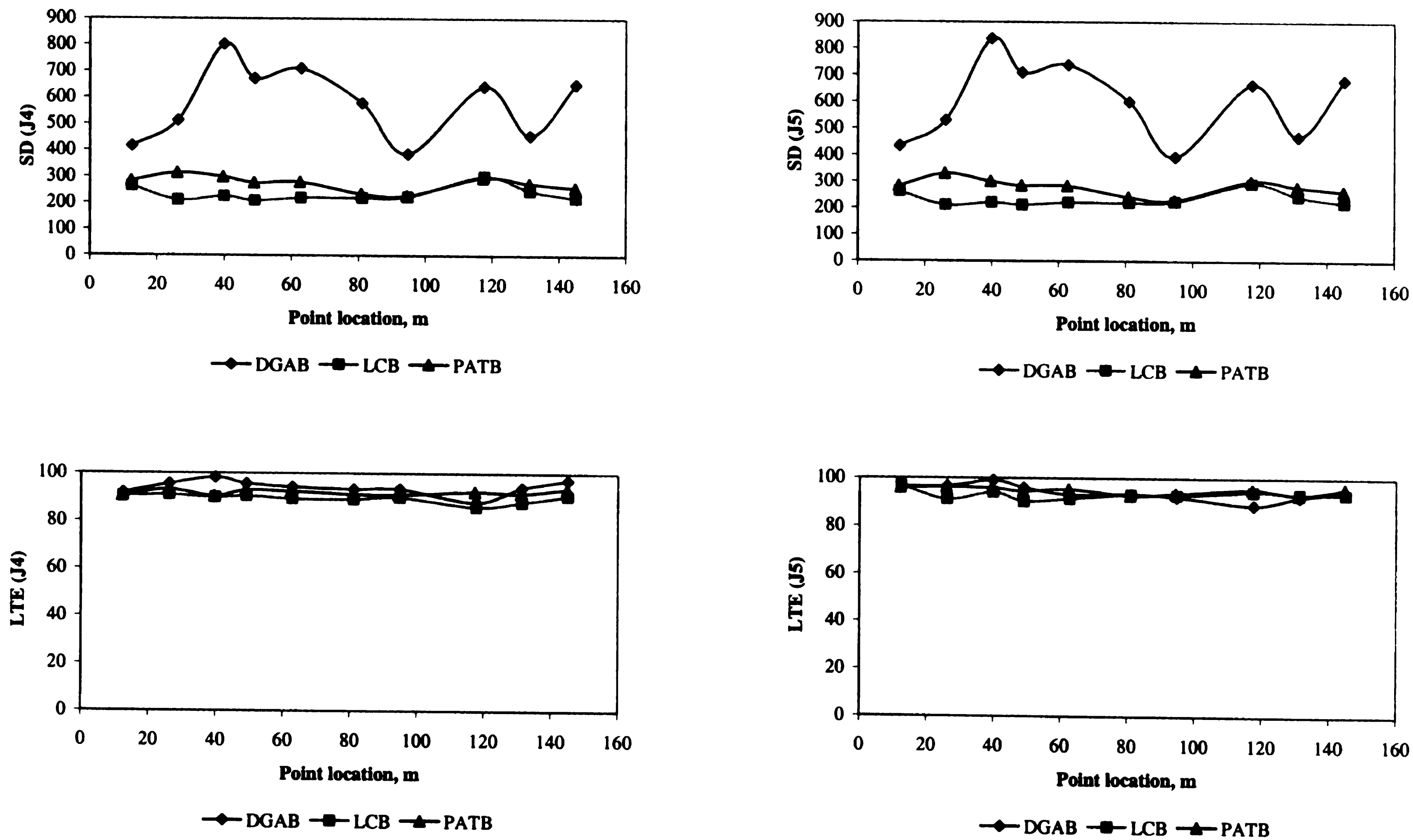


Figure B- 103 Effect of base type on performance – OH (39)

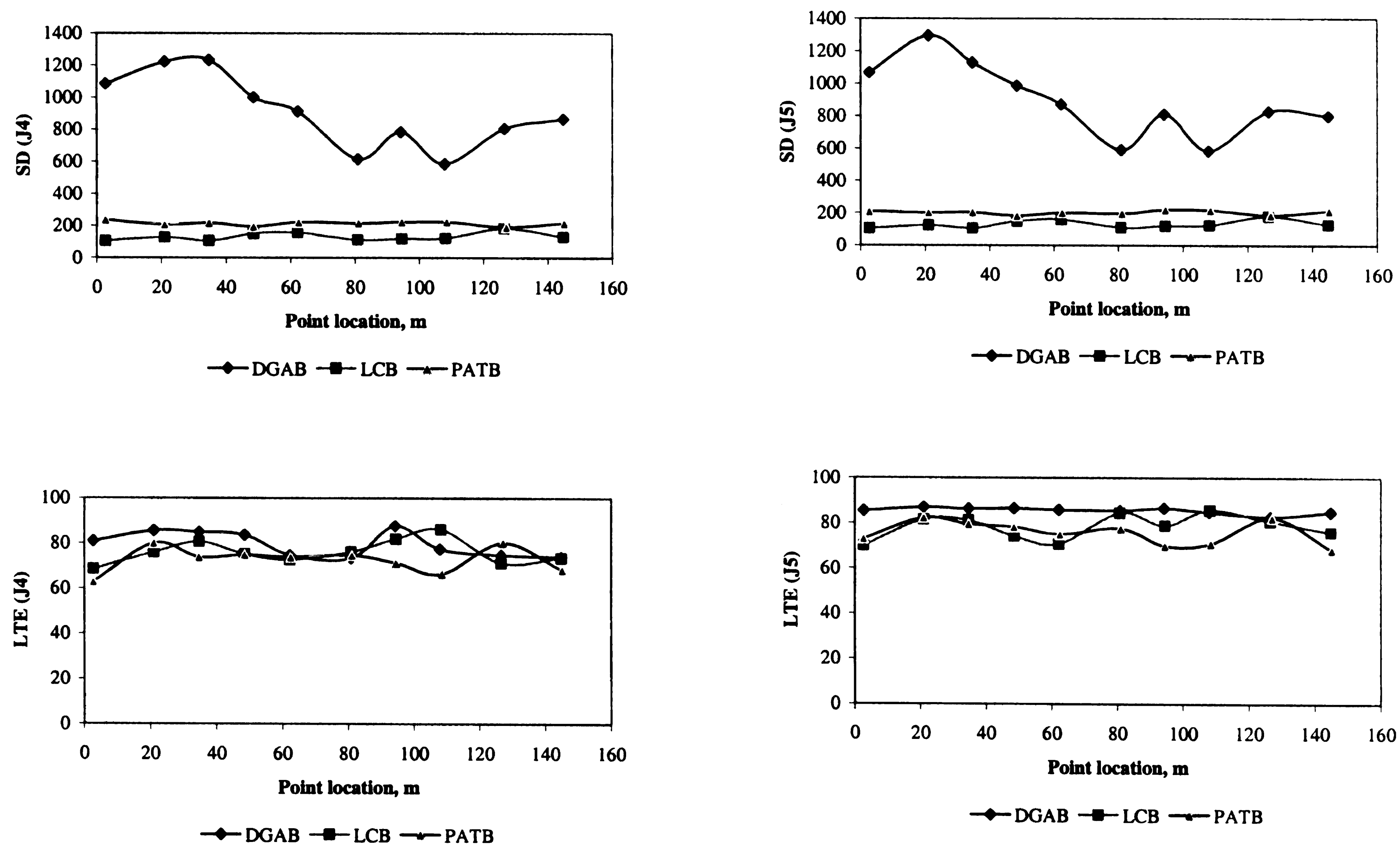


Figure B- 104 Effect of base type on performance –WA (53)

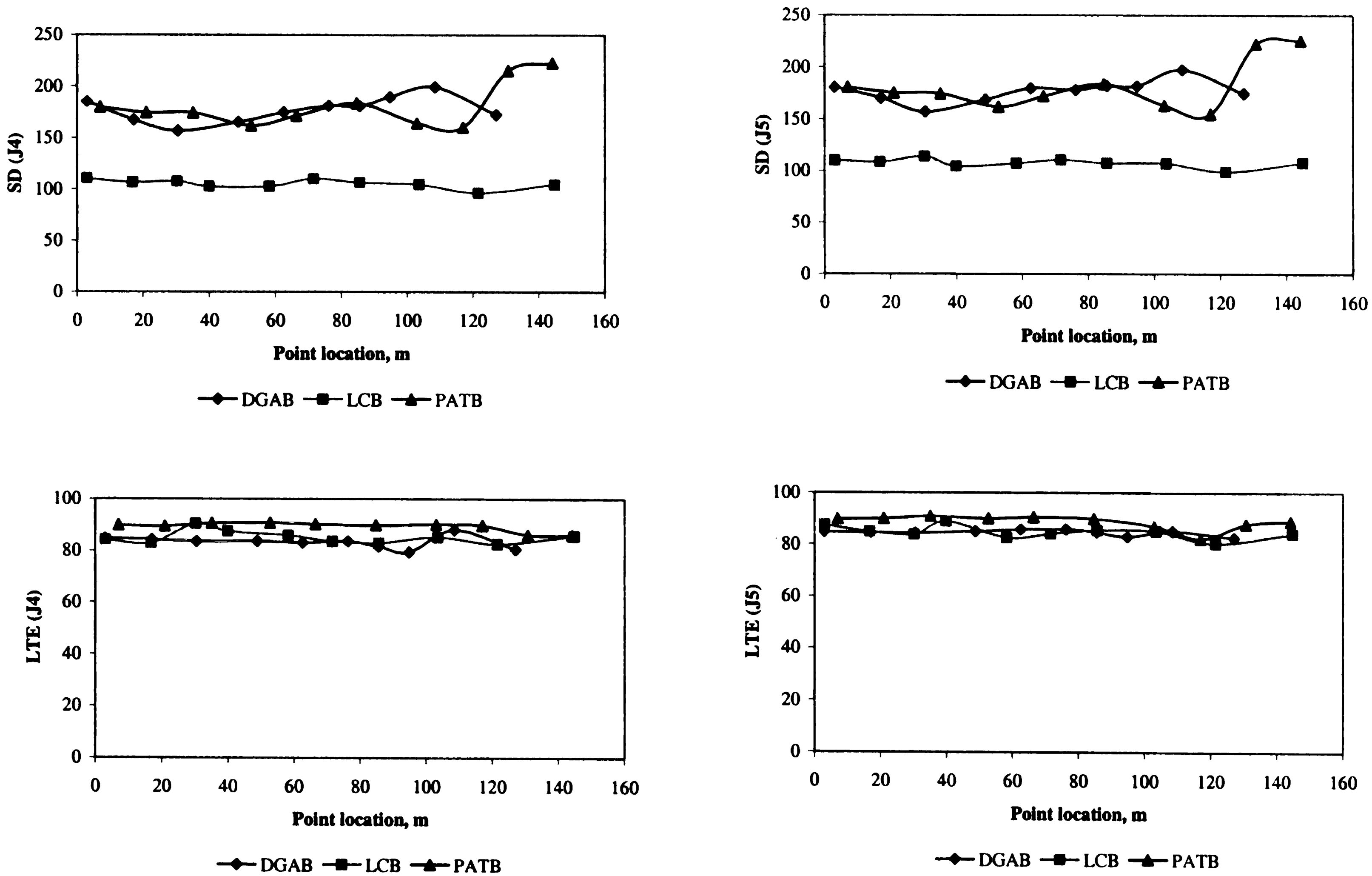


Figure B- 105 Effect of base type on performance –WI (55)

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