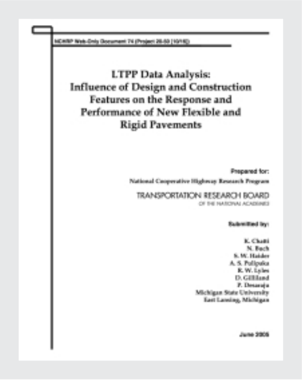

# LTPP Data Analysis: Influence of Design and Construction Features on the Response and Performance of New Flexible and Rigid Pavements

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## AUTHORS

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# LTPP Data Analysis: Influence of Design and Construction Features on the Response and Performance of New Flexible and Rigid Pavements

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**Submitted by:**

K. Chatti
N. Buch
S. W. Haider
A. S. Pulipaka
R. W. Lyles
D. Gilliland
P. Desaraju
Michigan State University
East Lansing, Michigan

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# CONTENTS

# ABBREVIATIONS

AASHTO—American Association of State Highway and Transportation Officials
AC—Asphalt Concrete
AGG—Aggregate bases, identical to dense graded aggregate base
ANOVA—Analysis of Variance
ATB—Asphalt Treated Base
AVC—Automated Vehicle Classification
AWS—Automated Weather Stations
BDI—Base Damage Index
BLR—Binary Logistic Regression
CTE—Coefficient of Thermal Expansion
DGAB—Dense Graded Aggregate Base, identical to aggregate base
DLR—Dynamic Load Response
D—Section with in-pavement drainage
FHWA—Federal Highway Administration
FWD—Falling Weight Deflectometer
GPS—General Pavement Studies
HMAC—Hot-Mix Asphalt Concrete
HMA—Hot-Mix Asphalt
IMS—Information Management System
IRI—International Roughness Index
JPCP—Jointed Plain Concrete Pavement
KESAL—Equivalent Single Axle Load in Thousands
LCB—Lean Concrete Base
LC-NWP—Longitudinal Cracking not in the Wheel Path
LC-WP—Longitudinal Cracking in the Wheel Path
LDA—Linear Discriminant Analysis
LTPP—Long-Term Pavement Performance
NCHRP—National Cooperative Highway Research Program
ND— Section with no in-pavement drainage
NIMS—National Information Management System
PATB—Permeable Asphalt Treated Base mixtures
PCC—Portland Cement Concrete
PI—Performance Index
SCI—Surface Curvature Index
SHRP—Strategic Highway Research Program
SPS—Special Pavement Studies
VWS—Virtual Weather Stations
WIM—Weigh-in-Motion

SPS-1, SPS-2 and SPS-8 Project Name Abbreviations
AL—Alabama
AR—Arkansas
AZ—Arizona
CA—California
CO—Calorodo
DE—Delaware
FL—Florida
IA—Iowa
KS—Kansas
LA—Louisiana
MI—Michigan
MO—Missouri
MS—Mississippi
MT—Montana
NC—North Carolina
ND—North Dakota
NE—Nebraska
NJ —New Jersey
NM—New Mexico
NV—Nevada
NY—New York
OH—Ohio
OK—Oklahoma
SD—South Dakota
TX—Texas
UT—Utah
VA—Virginia
WA—Washington
WI—Wisconsin

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Karim Chatti, Associate Professor of Civil and Environmental Engineering, was the Principal Investigator. Neeraj Buch, Associate Professor of Civil and Environmental Engineering, was the Co-Principal Investigator. They were assisted by Syed Waqar Haider, Aswani S. Pulipaka, Graduate Research Assistants, and Praveen Desaraju, former Graduate Research Assistant, now Staff Engineer at Applied Research Associates Inc.

Richard W. Lyles, Professor of Civil and Environmental Engineering, and Dennis Gilliland, Professor of Statistics and Probability, assisted in the data analyses aspects.

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# ABSTRACT

This report documents and presents the results of a study on the relative influence of design and construction features on the response and performance of new flexible and rigid pavements, included in SPS-1 and SPS-2 experiments. The SPS-1 experiment is designed to investigate the effects of HMA layer thickness, base type, base thickness, and drainage on flexible pavement performance, while the SPS-2 experiment is aimed at studying the effect of PCC slab thickness, base type, PCC flexural strength, drainage, and lane width on rigid pavement performance. The effects of environmental factors, in absence of heavy traffic, were also studied based on data from the SPS-8 experiment. Various statistical methods were employed for analyses of the LTPP NIMS data (Release 17 of DataPave) for the experiments.

In summary, base type seems to be the most critical design factor in achieving various levels of pavement performance for both flexible and rigid pavements, especially when provided with in-pavement drainage. The other design factors are also important, though not at the same level as base type. Subgrade soil type and climate also have considerable effects on the influence of the design factors.

Although, most of the findings from this study support the existing understanding of pavement performance, the methodology in this study provides a systematic outline of the interactions between design and site factors as well as new insights on various design options.

# EXECUTIVE SUMMARY

This report for the project “LTPP Data Analysis: Influence of Design and Construction Features on the Response and Performance of New Flexible and Rigid Pavements” [NCHRP 20-50 (10/16)] contains the background information, experiment status, data availability, results from analyses, and the conclusions for Specific Pavement Study-1 (SPS-1), Specific Pavement Study-2 (SPS-2) and Specific Pavement Study-8 (SPS-8) experiments of the long term pavement performance (LTPP) program.

This research was conducted to evaluate the relative influence of structural and site factors on the performance of new flexible and rigid pavements, based on LTPP NIMS data (Release 17 of DataPave) for SPS-1 and SPS-2 experiments. The effects of environmental factors, in absence of heavy traffic, were also studied based on the LTPP NIMS data for the SPS-8 experiment. The SPS-1 experiment was designed to investigate the effects of hot-mix asphalt (HMA) layer thickness, base type, base thickness, and drainage on flexible pavement performance, while the SPS-2 experiment is aimed at studying the effects of Portland cement concrete (PCC) slab thickness, base type, PCC flexural strength, drainage, and lane width on jointed plain concrete pavement (JPCP) performance.

In this report, a detailed description of the experiment designs and their current status are presented. A summary of data availability, extent, and occurrence of distresses in the test sections within each of the experiments are also included. A brief description of each analyses method and a synopsis of the salient findings from all the analysis are also presented. A summary of findings from a comprehensive evaluation of all the experiments, based on “mid-term” performance trends, is followed by a discussion on the limitations of the findings from this research and recommendations for future data collection and research.

Only two sites each are located in Dry Freeze (DF) and Dry No Freeze (DNF) zones for the SPS-1 experiment. A total of three sites are located in DF zone while two sites are located in DNF zone for the SPS-2 experiment. In light of this, the research team chose not to draw conclusions on the effects of these climates based on analyses of test sections located in these zones. However, the data from test sections in these climates were used for analyzing the effects of design factors.

Although most of the findings support the existing understanding of pavement performance, the results from this study provide a systematic outline of the interactions between design and site factors, as well as new insights on various design options. In addition, the analysis methodology outlined in this research will be useful for future data analysis. A detailed discussion of the effects of the experimental factors on pavement performance and response can be found in the concluding portion of the report (Chapter 8). A brief summary of the main findings regarding pavement performance from this study follows.

**Effects of Design and Site Factors on Pavement Performance— SPS-1 Experiment**

One of the main purposes behind the SPS-1 experiment is to investigate the interaction effects of key design and site factors on pavement performance. For this the test sections were constructed in various site conditions (soil-climate combinations). The "mid-term" assessment of the performance of the test sections in the SPS-1 experiment has thus highlighted some of these effects.

*Fatigue performance*

All the experimental factors were found to be affecting fatigue cracking, though not at the same level. Of the design factors in the experiment, base type has the greatest influence on the fatigue performance of flexible pavements, especially when built with in-pavement drainage. Pavements with ATB have shown the best performance. The interaction effects among design factors and between design and site factors are presented below.

- Among un-drained pavements, on average, an increase in HMA surface thickness from 4-inch (102 mm) to 7-inch (178 mm) has a slightly higher effect on fatigue cracking for pavements with DGAB than for pavements with ATB. However, this effect is not statistically significant.
- On the whole, pavements with "thin" 4-inch (102 mm) HMA surface layer have shown more fatigue cracking than those with "thick" 7-inch (178 mm) HMA surface layer. This main effect of HMA surface thickness is more significant for sections built on coarse-grained soils.
- Among pavements built on fine-grained soils, the effect of drainage is seen only in those sections with DGAB; i.e., those with drainage have less fatigue cracking than those without

drainage. For drained pavements built on fine-grained soils, those with 8-inch (203 mm) base have more cracking than those with 12-inch (305 mm) and 16-inch (406 mm) base. Hence, for pavements built on fine-grained soils, drainage improves the fatigue performance, especially if built with thicker bases.

- The main effect of HMA thickness, discussed above, is mainly seen among sections located in WNF zone. This may be an indication that an increase of HMA thickness from 4-inch (102 mm) to 7-inch (178 mm) is not sufficient in resisting fatigue cracking for pavements in WF zone as compared to WNF zone.
- Among sections located in the WF zone, those with DGAB have shown the highest amount of cracking while those with ATB have the least cracking. In addition, those with 16-inch (406 mm) drained base have the least amount of fatigue cracking. This suggests that among pavements located in WF zone, "thick" 16-inch (406 mm) treated bases with drainage are less prone to cracking. The effects of HMA thickness and base thickness discussed above imply that, among sections located in WF zone, an increase in base thickness to 16-inch (with drainage) has a greater impact than an increase in HMA thickness from 4-inch (102 mm) to 7-inch (178 mm), suggesting that using a thicker base with drainage helps in reducing frost effects.

*Structural rutting performance*

The extent of structural rutting among the test sections in the SPS-1 experiment is 6.5 mm, on average, with a standard deviation of 2.4 mm. Their average age is about 7 years with a range between 4.5 and 10 years. The amount of rutting for the majority of these sections is within the normal range at this point in time. Therefore, the results at this point may only show initial trends. The interaction effects between design and site factors are presented below.

- Among the pavements built on coarse-grained soils, those with 7-inch (178 mm) HMA surface have shown slightly less rutting than those with 4-inch (102 mm) HMA surface. However, this effect is not operationally significant at this point. This effect suggests that for sections built on fine-grained soils an increase in HMA thickness from 4-inch (102 mm) to 7-inch (178 mm) may not be sufficient in reducing the amount of rutting.

- Among pavements built on fine-grained soils, a marginal positive effect of drainage is seen in sections with ATB.
- Among drained pavements located in WF zone, those with DGAB have shown more rutting than those with ATB. Also, among sections located in WF zone and built with ATB, those with drainage have shown significantly less rutting than those without drainage. This implies that, among pavements located in WF zone, those with ATB and drainage perform better than those with other combinations of base type and drainage.
- Among un-drained sections located in WNF zone, those with 12-inch (305 mm) base have less rutting than those with 8-inch (203 mm) base. For sections built on DGAB and located in WNF zone, those with drainage have shown slightly less rutting than those without drainage. This effect was found to be marginally significant. These early trends imply that the importance of drainage among pavements with DGAB is considerable in improving rut performance among sections located in WNF zone. On the other hand an increase in base thickness from 8-inch (203 mm) to 12-inch (305 mm) improves rut performance for un-drained sections, irrespective of base type.

### *Roughness (IRI)*

All the experimental factors were found to be affecting roughness, though not at the same level. Of the design factors in the experiment, base type has the greatest influence on the change in roughness of flexible pavements, especially when built on fine-grained soils. Pavements with ATB have shown the best performance, while DGAB has contributed to the worst performance. The interaction effects among design factors and between design and site factors are presented below.

- Among pavements built on fine-grained soils, an increase in HMA thickness from 4-inch (102 mm) to 7-inch (178 mm) has a significant positive effect on change in roughness (ΔIRI). Also for un-drained pavements, those with ATB have significantly lower ΔIRI than those with DGAB. Finally the effect of drainage is significant only for sections with DGAB. These effects suggest that, for pavements built on fine-grained soils, higher HMA thickness and/or treated base will help inhibit the increase in roughness. Also, drainage appears to be more effective in preventing an increase in roughness for sections with DGAB, especially among those located in WF zone.

- For un-drained pavements built on coarse-grained soils, an increase in base thickness from 8-inch (203 mm) to 12-inch (305 mm) causes slightly lower ΔIRI.

*Transverse cracking*

Transverse cracking seems to be associated with wet-freeze climate. Pavements located in WF zone have shown significantly more transverse cracking than those located in WNF zone. This confirms that transverse cracking occurs mainly in freezing environment. The interaction effects between design and site factors are presented below.

- Among drained pavements built on coarse-grained soils, those with ATB performed better than those with DGAB.
- Among pavements with DGAB and built on fine-grained soils, those with drainage have shown significantly less transverse cracking than those without drainage.

*Longitudinal cracking-WP*

On the whole, longitudinal cracking-WP seems to be more prevalent in WF climate, especially when built on fine-grained soils. Base type including drainage are the most critical design factors; pavements with ATB have shown the best performance. The interaction effects between design and site factors are presented below.

- On average pavements in WF zone have shown higher levels of longitudinal cracking-WP than those in WNF, especially among pavements built on fine-grained subgrade. This effect was found to be only marginally significant.
- Among pavements built on fine-grained soils, those built with DGAB have shown more longitudinal cracking-WP, and those built with ATB have shown the least amount of cracking. Also, drainage has a significant effect on longitudinal cracking, and this effect is more pronounced in pavements built with DGAB. This trend implies that if a pavement on fine-grained subgrade is constructed with a DGAB base, better performance (in terms of

longitudinal cracking-WP) can be achieved by providing drainage. These effects are seen in both WF and WNF zones.

*Longitudinal cracking-NWP*

The initial trends indicate that longitudinal cracking-NWP is caused by "freeze" climate (frost effects), and that pavements without drainage may be more prone to it. In general, more longitudinal cracking-NWP was observed among sections located in "freeze" climate compared to those in "no-freeze" climate. It was also found that, the effect of drainage is more pronounced (with marginal statistical significance) among pavements located in "freeze" climate. However, this effect is not of practical significance.

In summary, based on the analysis of the SPS-1 data, base type seems to be the most critical design factor for fatigue cracking, roughness (IRI) and longitudinal cracking (wheel-path). This is not to say that the effect of HMA surface thickness is not significant. In fact, the effect of base type should be interpreted in light of the fact that an asphalt-treated base (ATB) effectively means thicker HMA layer. Drainage when combined with base type also plays an important role in improving flexible pavement performance, especially in terms of fatigue and longitudinal cracking. Base thickness has secondary effects on performance, especially in the case of roughness and rutting.

Subgrade soil type seems to be playing an important role in flexible pavement performance. In general, pavements built on fine-grained soils have shown the worst performance, especially in the case of roughness. Also, climate is a critical factor in determining flexible pavement performance. Longitudinal cracking and transverse cracking appear to be affected by climate. Longitudinal cracking (wheel-path) and transverse cracking seem to be associated with Wet Freeze environment, while longitudinal cracking (non wheel-path) seems to be dominant in "freeze" climate.

### Effects of Design and Site Factors on Pavement Performance— SPS-2 Experiment

A majority of SPS-2 sections are showing "low" occurrence and extent of distresses at this point in time. From an engineering viewpoint it can be said that the sections are exhibiting "good" performance. Thus the results presented in this report at this point are an indication of initial trends at best. It should be noted that the effects presented herein are statistically significant unless mentioned otherwise.

*Transverse cracking*

The PCC slab thickness and base type have significant influence on the occurrence of transverse cracking. Pavement sections built on PATB (with drainage) have the least occurrence of transverse cracking while sections built on LCB have exhibited highest occurrence of cracking. Considerable amount of cracking in LCB layer, which probably caused reflection cracking in the PCC slab, can be attributed to shrinkage cracking as per the construction reports. The effects of the experimental factors are summarized below:

- The occurrence of transverse cracking among pavements with 8-inch (203 mm) PCC slab is higher than pavements built with 11-inch (279 mm) PCC slab.
- The occurrence of transverse cracking among pavement sections constructed on LCB is higher than pavement sections built on PATB-over-DGAB or with DGAB. Pavements sections constructed on PATB-over-DGAB have shown the "best" performance (least occurrence of cracking).
- Sections without drainage (sections with DGAB) have a slightly higher likelihood of cracking than sections with drainage (sections with PATB-over-DGAB).
- On average, among sections built with LCB, those with 8-inch (203 mm) PCC slab have higher occurrence of cracking than those with 11-inch (279 mm) PCC slab. It is important to interpret these results in light of the construction issues, i.e. shrinkage cracking in LCB.
- Pavements built on fine-grained soils have slightly higher chances for the occurrence of transverse cracking than those built on coarse-grained soils. The effect is marginally significant

*Longitudinal Cracking*

The PCC slab thickness and base type have the greatest influence on the occurrence of longitudinal cracking on rigid pavements. Pavements constructed on PATB have least occurrence of longitudinal cracking while those with LCB have the highest occurrence of cracking. The effects of the experimental factors are summarized below:

- The occurrence of longitudinal cracking among pavements with 8-inch (203 mm) PCC slab thickness is higher than among those with 11-inch (279 mm) PCC slab thickness.
- The occurrence of longitudinal cracking among pavements constructed with LCB is higher than among those with PATB-over-DGAB or with DGAB. Pavements with PATB-over-DGAB have shown the "best" performance (least occurrence of cracking).
- On average, among sections built with LCB, those with 8-inch (203 mm) PCC slab have higher occurrence of cracking than those with 11-inch (279 mm) PCC slab. It is important to interpret these results in light of the construction issues i.e. shrinkage cracking in LCB.

*Faulting*

A majority of SPS-2 sections are exhibiting "good" performance with respect to joint faulting, at this point in time. About 33% of the sections have less than 20% of the joints with faulting more than 1.0 mm, and 5% of the sections have more than 20% of the joints that are faulted more than 1.0 mm. Therefore, the results at this point may only indicate the initial trends/observations. It would thus be premature to draw any conclusions on the influence of design and site features on joint faulting.

*Roughness*

The results suggest that the change in roughness can be inhibited by constructing pavements with PATB-over-DGAB, as compared to sections with DGAB or LCB, especially in the case of pavements built on fine-grained soils. In addition, PCC slab thickness also plays an important role in increase of roughness. The effects of the experimental factors are explained below:

- Pavements constructed with PATB have shown lower change in IRI (ΔIRI) compared to those with DGAB or LCB, while pavements with DGAB have the highest change in roughness.

- Among pavements constructed with standard lane width [12’ (3.7 m) wide lane], sections with DGAB have shown slightly higher ΔIRI than those with LCB or PATB. The effect is marginally significant.
- Among pavements built on fine-grained soils, those with 8-inch (203 mm) PCC slab have higher ΔIRI than those with 11-inch (279 mm) PCC slab. This effect is more prominent among sections located in WF zone.
- A positive effect of drainage is more noticeable among sections located in WF zone and built on fine-grained soils.

In summary, based on the findings from analysis of the SPS-2 data, base type and PCC slab thickness appear to be the most critical design factors in explaining cracking (transverse and longitudinal) and roughness (IRI). DGAB and drainage, when combined also play an important role in improving rigid pavement performance, especially in terms of cracking (transverse and longitudinal) and roughness. The effects of PCC flexural strength and lane width on pavement performance are inconclusive, at this point in time. However, sections with widened lane have shown lesser faulting occurrences than those with standard lane. The site conditions (climate and subgrade soil type) seem to be having marginal effects on cracking (transverse and longitudinal) and roughness.

### Effects of Environment on Pavement Performance—SPS-8 Experiment

The SPS-8 pavements have “low” occurrence and extent of distresses, at this point. Most of the pavements in the experiment are performing at comparable levels. No formal statistical methods could be employed due to this. Therefore the observations presented here are just based on average performance of the distressed pavements. The observations need to be considered as initial trends, in light of these limitations.

*Flexible Pavements*: On average, pavements in WF zone have more fatigue cracking, longitudinal cracking (non wheel-path), and roughness than pavements in other climates. Also, in general, pavements constructed on “active” (frost susceptible or expansive) subgrade soils have more longitudinal cracking (non wheel-path), transverse cracking, and fatigue cracking than pavements on “non-active” soils.

Pavements located in “wet” climate, on average, have higher change in IRI than those in “dry” climate. Furthermore, pavements located in WF zone and those built on active soils have the higher changes in IRI.

*Rigid Pavements*: Longitudinal spalling, on average, was more prevalent in sections located in “wet” climate. Spalling was not observed in any of the pavements located in the dry-freeze (DF) zone and in any of the pavements constructed on coarse-grained subgrade soil. Transverse cracking was not observed in any of the pavements constructed with thicker PCC slabs and in any of the pavements constructed on coarse-grained subgrade soils.

The results of this research should be useful for highway agencies and pavement engineers in assessing the relative importance of design and site factors for pavement design. As the results are based on data from controlled field experiments these are expected to be helpful in evaluating the existing design methods, and developing improved design options.

# CHAPTER 1 - INTRODUCTION

## 1.1 INTRODUCTION

The Long Term Pavement Performance (LTPP) Specific Pavement Studies (SPS) 1 and 2 are the experiments designed to provide information on the relative merits of different design features in newly constructed pavements for achieving different levels of performance under heavy traffic. Typical features include HMA surface layer and PCC slab thickness, base type and thickness, drainage (presence or absence thereof), PCC flexural strength, etc. In addition to this, instrumented sections were included in the SPS monitoring sites located in Ohio (SPS-1 and SPS-2) and North Carolina (SPS-2). The effects of environment in the absence of heavy traffic are studied through the SPS-8 experiment.

For specific site conditions (e.g., traffic level, climatic conditions, and subgrade type), the response and performance of flexible and rigid pavements will depend not only on pavement layer thicknesses and material properties, but also on other design and construction features (e.g., presence of in-pavement drainage, base type and thickness, etc.). Recent research based on limited analyses has documented the effects of these features on pavement response (as measured by deflection and strain) and performance (as measured by type and extent of distress or smoothness) using very limited data.

The data available from the LTPP studies, including instrumented SPS-1 and -2 test sections in Ohio and North Carolina, are expected to provide the information needed for a more rigorous analysis to enhance understanding of the effects of these features on pavement response and performance and to develop well-supported conclusions regarding their influence. There is therefore a need to determine the effects of design and construction features on pavement performance and response, and to establish their relative importance.

This research should provide guidance for assessing the relative importance of design and construction features for different pavement types, preliminary information on the relationship between pavement response and performance, and recommendations for improving data collection activities. The methodology that was employed for this research could be applicable for any in-service pavement data and thus the methodology presented here will help pavement engineers perform more appropriate statistical analyses and obtain more meaningful results.

## 1.2 PROJECT 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 to achieving different levels of performance. Also, it is expected that the research will provide information on the apparent relationship between pavement response and performance. The research is limited to new (i.e., non-rehabilitated) flexible and rigid pavements. The research is based on the data available from the LTPP experiments SPS-1 (strategic study of structural factors for flexible pavements), SPS-2 (strategic study of structural factors for rigid pavements) and SPS-8 (a study of environmental factors in absence of heavy loads). The analysis is limited to using the data available in the LTPP National Information Management System (NIMS) database classified as "Level E" (DataPave) and data available from LTPP instrumented test sections.

## 1.3 SCOPE OF STUDY

The scope of the study included the review and analysis of LTPP data (DataPave) pertaining to the SPS-1, SPS-2 and SPS-8 experiments. All relevant data for these experiments were obtained and reviewed from Release 17.0 (January 2004) of the NIMS database. After the data were obtained, a relational database was prepared for analyses of the study. Based on the availability of the data and the extent (and occurrence) of distresses, appropriate analyses (site-level and overall analyses) were conducted to fulfill the objectives of the study. At the site-level analysis each site was considered separately and the consistency of the effects across the sites was studied. The overall analyses were conducted, using the wealth of data from all the experiment sections in order to draw broad conclusions. Attempts were also made to verify apparent relationships between response (Falling Weight Deflectometer data and Dynamic Load Response data) and performance of the test sections in the SPS-1 and SPS-2 experiments. Based on all analyses (site-level and overall), the effects of design and construction features on pavement performance and response were studied. Finally, recommendations for future research and data collection are given.

## 1.4 REPORT ORGANIZATION

The report is divided into eight chapters including this introductory chapter. A description of the experiment designs and the current status of SPS-1, SPS-2 and SPS-8 experiments are presented in Chapter 2. A summary of data availability and extent/ occurrence of distresses are presented for the three experiments in Chapter 3. Based on the extent/occurrence of distresses, different methods of analysis were employed. A brief description of each of these analytical methods is given in Chapter 4. Chapters 5, 6 and 7 are summaries of results from all analyses conducted on SPS-1, SPS-2 and SPS-8 data, respectively. A synopsis of the salient findings from all the analyses, for each experiment, is presented in Chapter 8. Finally, based on the experience with LTPP data gained from this research, recommendations for future data collection and research are presented in Chapter 8.

# CHAPTER 2 - DESCRIPTION OF SPS 1, 2 AND 8 EXPERIMENTS

## 2.1 INTRODUCTION

This chapter includes description of Specific Pavement Studies (SPS) experiments 1, 2 and 8, in terms of their respective goals, experimental designs, and associated factors (design and construction). A separate section is included for the Dynamic Load Response (DLR) experiment, which constitutes a subset of the SPS-1 and -2 experiments.

## 2.2 STRATEGIC STUDY OF STRUCTURAL FACTORS FOR FLEXIBLE PAVEMENTS—SPS-1

The SPS-1 experiment is focused on the strategic study of structural factors for flexible pavements, and was intended to study the effect of specific design and construction features on pavement response and performance. As the test sections in the experiment are monitored since inception, the experiment provides an opportunity to determine the relative influence of the key pavement design and construction elements that affect pavement performance.

### 2.2.1 Experiment Design

The fractional factorial design for the SPS-1 experiment is shown in Table 2-1 . The overall experiment consists of 192 factor level combinations, which consist of 8 site-related (subgrade soil and climate) and 24 pavement structure combinations. The experiment design requires that “48 test sections representing all structural factor and subgrade type combinations in the experiment are to be constructed in each of the climatic zones, with 24 test sections to be constructed on fine-grained soil and 24 test sections to be constructed on coarse-grained soil”[1].

The SPS-1 experiment examines the effects of both site and structural factors. The site factors include: climatic region, subgrade soil (fine- and coarse-grained), and traffic rate (as a covariate) on pavement sections incorporating different levels of structural factors. The structural factors include:

- drainage (presence or lack of it),
- asphalt concrete (AC) surface thickness – 102 mm (4-inch) and 178 mm (7-inch),
- base type – dense-graded untreated aggregate base (DGAB), dense-graded asphalt-treated base (ATB) and a combination of both,

- base thickness – 203 mm (8-inch) and 305 mm (12-inch) for un-drained sections; and 203 mm (8-inch), 305 mm (12-inch) and 406 mm (16-inch) for drained sections.

The study design stipulates a traffic load level in excess of 100,000 Equivalent Single Axle Loads (ESALs) per year for the study lane [2].

According to the experiment design, twelve test sections were constructed at a given project location (site). Each section is represented by either XX-0101 to XX-0112 or XX-0113 to XX-0124, where XX denotes the state ID. Six sections have a target HMA surface thickness of 4-inch (102 mm) and the remaining six have a target HMA surface thickness of 7-inch (178 mm). Out of 12 sections, 5 have 203 mm (8-inch) base layer, 5 have a 305 mm (12-inch) base layer and the remaining 2 have a 406 mm (16-inch) base layer. Also 2 test sections have dense-graded aggregate base (DGAB), 2 sections have asphalt treated base (ATB), 2 sections have a combination of ATB/DGAB, 3 sections have permeable asphalt treated base (PATB) over DGAB, and 3 sections have ATB over PATB. In-pavement drainage is provided only for sections with PATB as the base.

Table 2-1 SPS-1 Experiment Design Matrix

| Pavement Structure | | | | Climatic Zones, Subgrade | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Drainage | Base Type | Base Thickness (mm) | HMA Thickness (mm) | WET | | | | | | | | DRY | | | | | | | |
| | | | | 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 | 203 | 102 | | 113 | | 113 | | 113 | | 113 | | 113 | | 113 | | 113 | | 113 |
| | | | 178 | 101 | | 101 | | 101 | | 101 | | 101 | | 101 | | 101 | | 101 | |
| | | 305 | 102 | 102 | | 102 | | 102 | | 102 | | 102 | | 102 | | 102 | | 102 | |
| | | | 178 | | 114 | | 114 | | 114 | | 114 | | 114 | | 114 | | 114 | | 114 |
| | ATB | 203 | 102 | 103 | | 103 | | 103 | | 103 | | 103 | | 103 | | 103 | | 103 | |
| | | | 178 | | 115 | | 115 | | 115 | | 115 | | 115 | | 115 | | 115 | | 115 |
| | | 305 | 102 | | 116 | | 116 | | 116 | | 116 | | 116 | | 116 | | 116 | | 116 |
| | | | 178 | 104 | | 104 | | 104 | | 104 | | 104 | | 104 | | 104 | | 104 | |
| | ATB/4" DGAB | 203 | 102 | 105 | | 105 | | 105 | | 105 | | 105 | | 105 | | 105 | | 105 | |
| | | | 178 | | 117 | | 117 | | 117 | | 117 | | 117 | | 117 | | 117 | | 117 |
| | | 305 | 102 | | 118 | | 118 | | 118 | | 118 | | 118 | | 118 | | 118 | | 118 |
| | | | 178 | 106 | | 106 | | 106 | | 106 | | 106 | | 106 | | 106 | | 106 | |
| Yes | PATB/DGAB | 203 | 102 | 107 | | 107 | | 107 | | 107 | | 107 | | 107 | | 107 | | 107 | |
| | | | 178 | | 119 | | 119 | | 119 | | 119 | | 119 | | 119 | | 119 | | 119 |
| | | 305 | 102 | | 120 | | 120 | | 120 | | 120 | | 120 | | 120 | | 120 | | 120 |
| | | | 178 | 108 | | 108 | | 108 | | 108 | | 108 | | 108 | | 108 | | 108 | |
| | | 406 | 102 | | 121 | | 121 | | 121 | | 121 | | 121 | | 121 | | 121 | | 121 |
| | | | 178 | 109 | | 109 | | 109 | | 109 | | 109 | | 109 | | 109 | | 109 | |
| | ATB/PATB | 203 | 102 | | 122 | | 122 | | 122 | | 122 | | 122 | | 122 | | 122 | | 122 |
| | | | 178 | 110 | | 110 | | 110 | | 110 | | 110 | | 110 | | 110 | | 110 | |
| | | 305 | 102 | 111 | | 111 | | 111 | | 111 | | 111 | | 111 | | 111 | | 111 | |
| | | | 178 | | 123 | | 123 | | 123 | | 123 | | 123 | | 123 | | 123 | | 123 |
| | | 406 | 102 | 112 | | 112 | | 112 | | 112 | | 112 | | 112 | | 112 | | 112 | |
| | | | 178 | | 124 | | 124 | | 124 | | 124 | | 124 | | 124 | | 124 | | 124 |

### 2.2.2 Current Status of the Experiment (Release 17 of DataPave)

The SPS-1 experiment includes eighteen sites with twelve sections each, with a total of 216 sections located at all four LTPP climatic regions. The Wet-Freeze (WF) and the Wet-No-Freeze (WNF) zones contain the majority of the sections. This is in line with the common wisdom that WF and WNF conditions critically affect flexible pavement performance.

The geographical distribution of sites within the SPS-1 experiment is presented in Figure 2-1 . The full factorial design for SPS-1 experiment design requires that a total of thirty-six similar designs be replicated across eight (8) soil-climate combinations. The thirty-six designs were reduced to twenty-four designs in each soil-climate combination making the experiment design a fractional factorial. However, it was considered that the construction of twenty-four test sections at each site would require a greater effort on the part of the participating agencies [1]. Therefore, to reduce the cost of construction the experiment was developed so that only 50% of the possible combinations of factors (i.e. 12 test sections) will be built at each site. The experiment, designed in a factorial manner to enhance implementation practicality, permits the construction of twelve test sections (0101 through 0112 or 0113 through 0124) at one site with the complementary twelve test sections to be constructed at another site within the same climatic region on a similar subgrade type [2].

The LTPP NIMS data (DataPave 3.0) shows that the site populations within the SPS-1 experiment design are not equally distributed. This deviation is partly because of the cutoff values of precipitation and freeze index used for categorizing the “wet/dry” and “freeze/non-freeze” climates. The current status of the factorial design, along with the current distribution of sites in each climatic zone, is shown in Table 2-2 . As these deviations are expected to seriously affect the results of the analysis (the experimental design is unbalanced), this issue will be further discussed in Chapter 3 under design versus actual construction. It can also be seen from Table 2-2 , that there is no replication available for sites in DF zone for different subgrade types. Therefore, the subgrade effects in DF zone cannot be estimated. Similarly, the results may be seriously hampered due to the small number of sites in Dry zones. A discussion on the current status of the experiment for each can be found in Appendix A1.

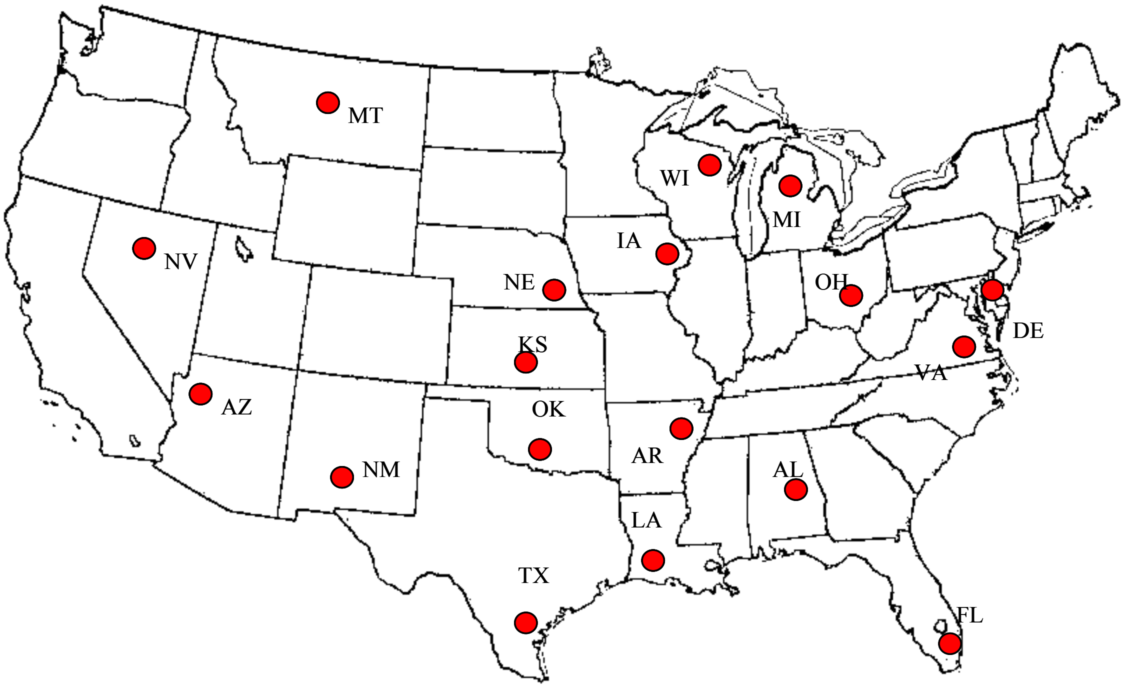


Figure 2-1 Geographical location of SPS-1 sites

Table 2-2 SPS-1 site factorial — From DataPave 3.0

| Subgrade Type | Designs | Wet[a] | | Dry[b] | | Total |
|---|---|---|---|---|---|---|
| | | **Freeze[c]** | **Non-Freeze[d]** | **Freeze** | **Non-Freeze** | |
| **Fine** | 0101-0112 | IA (19)<br>OH (39)<br>KS (20) | AL (1) | - | NM (35) | 9 |
| | 0113-0124 | MI (26)<br>NE (31) | LA (22)<br>VA (51) | - | - | |
| **Coarse** | 0101-0112 | AR (5)<br>DE (10) | FL (12) | NV (32) | - | 9 |
| | 0113-0124 | WI (55) | OK (40)<br>TX (48) | MT (30) | AZ (4) | |
| Total | | 8 | 6 | 2 | 2 | 18 |

Note:

a. Wet Regions — Average Annual Rainfall > 20 inches (508 mm)
b. Dry Regions — Average Annual Rainfall < 20 inches (508 mm)
c. Freeze Regions — Average Annual Freezing Index > 83.3 °C-day (150 °F-day)
d. Non-Freeze Regions — Average Annual Freezing Index < 83.3 °C-day (150 °F-day)

### 2.2.3 Construction Guidelines for SPS-1 Experiment

The study of the SPS-1 experiment has specific objectives; mainly the experiment was designed to study the influence of design and construction features on the response and performance of new flexible pavements. Therefore the focus of the experiment is on the main factors (HMA and base thicknesses, base type and presence or absence of drainage). The designs were repeated across 18 states in order to study the effect of different climates and subgrade soils. To study the specific objectives of the SPS-1 experiment, it is essential to control for other sources of variability, which can mask the effects of the main factors. These factors may include differences in construction quality, material properties and traffic levels across sites. Therefore, each SPS-1 project had to meet certain construction criteria. To approach uniformity across projects, there were limitations on the methods and materials used in construction, as well as requirements for testing and continued monitoring. These guidelines are outlined below.

#### Construction Requirements

Construction requirements were provided in the "Construction Guidelines" section of the *SHRP-LTPP Specific Pavement Studies: Five-Year Report[2, 3]*. The overall length of each section was required to be 183 m (600 ft) with 152.4 m (500 ft) for monitoring and 15.25 m (50 ft) on each side for material sampling. The distance between each of these sections had to be long enough to allow sufficient space (transition) for changes in materials and thicknesses during construction. The suggested length for these transitions was 30.5 m (100 ft).

#### Subgrade Requirements

The finished subgrade elevations could not vary from the design by more than 12 mm (0.5-inch). This could be determined using rod and level readings taken on the lane edge, outer wheel path, mid lane, inner wheel path and inside lane edge at 15 m (50 ft) intervals throughout the length of the project. Surface irregularities could not exceed 6 mm (0.5-inch) between two points in any direction in a 3.05 m (15 ft) interval. Modifiers may be used to provide a stable working platform for construction but not to increase subgrade strength.

**Base Layers**

Two types of bases are included in each SPS-1 project — drained and un-drained. The drained bases include a permeable asphalt treated base with edge drains. The un-drained bases consist of dense graded materials. Two types of dense graded bases were specified for the sections without drainage. The un-drained bases were used in sections 101-106 and 113-118 and were defined as dense graded aggregate base (DGAB), asphalt treated base (ATB), or a combination of these two materials. The drained base was used in sections 107-112 and 119-124 with a combination with DGAB and ATB base types. The requirements for each base type are as follows:

*Dense graded aggregate base (DGAB)*

- Minimum 50% retained on the No. 4 sieve.
- Top-size aggregate was specified as 38 mm (1.5-inch).
- Less than 60% passing the No. 30 sieve and less than 10% passing the No. 200 sieve.
- Liquid limit less than 25 and plasticity index less than 4 for fraction passing No. 40 sieve.
- In L. A. Abrasion Test, the loss must not exceed 50% at 500 revolutions.
- The compacted lift thickness must not exceed 200 mm (8 inches).
- The DGAB must be compacted to at least 95% of maximum density.
- In-place density of DGAB should be determined prior to the application of an asphalt prime coat.
- The base surface must be primed with low-viscosity asphalt and allowed to cure prior to placement of the asphalt concrete surface.
- The finished DGAB elevations should not vary from design by more than 12 mm (0.5 inches).

*Asphalt treated base (ATB)*

- The aggregate used in the ATB layer must meet the same requirements as the aggregate for DGAB layer.
- Asphalt emulsions should not be used in ATB.
- Experimental modifiers were allowed only in the supplemental sections.
- No recycled HMA was allowed in ATB.

- For the Hveem mix design procedure, the following requirements were required for the ATB:

| | |
|---|---|
| Swell | 0.7 mm |
| Stabilometer Value | 35 min |
| Moisture Vapor Susceptibility | 25 |
| Design Air Voids | 3 to 5 percent |

- For the Marshal mix design procedure, the following requirements were required for the ATB:

| | |
|---|---|
| Compaction blows | 50 |
| Flow | 3 to 5 mm |
| Stability | 4.4 KN |
| Design Air Voids | 3 to 5 percent |

- The maximum compacted lift thickness for the ATB layer should be limited to a maximum of 200 and 100 mm (8- and 4-inch) for the first and subsequent lifts, respectively.
- The minimum compaction requirement was 90% of the maximum theoretical specific gravity for the first lift and 92% for subsequent lifts.
- The finished surface of the ATB base should not vary from the design more than 12 mm, as measured using rod and levels.
- The base layer thickness should not vary from design by more than 6 mm (0.25-inch).

*Permeable asphalt treated base (PATB)*

The drained base was used in sections 107-112 and 119-124 with a combination of DGAB and ATB base types. Each of these sections included a PATB layer with edge drains to permit water to drain out of the pavement structure. The requirements for the PATB layer were as follows:

- An asphalt emulsion was not allowed as binder for PATB base layer.
- The gradation for the PATB layer should be within the following ranges:

| **Sieve No.** | **% Passing** |
|---|---|
| 38 mm (1.5 inch) | 100 % |
| 25 mm (1 inch) | 95 – 100 % |
| 13 mm (0.5 inch) | 25 – 60 % |
| No. 4 | 0 – 10 % |
| No. 8 | 0 – 5 % |
| No. 200 | 0 – 2 % |

- More than 90% of the aggregate has at least one crushed face.
- No recycled HMA should be used in PATB.
- Compaction should be performed by using static wheel roller applying 0.5 to 1.0 ton of force per foot of roller width.
- No portion of the PATB should be day-lighted.

### HMA Layer

The HMA surface layers were required to meet the following minimum requirements.

- For the Hveem mix design procedure, the following requirements were required for the HMA mix:

| | |
|---|---|
| Swell (maximum) | 0.7 mm |
| Stabilometer Value (minimum) | 37 min |
| Air Voids | 3 - 5% |

- For the Marshal mix design procedure, the following requirements were required for the HMA mix:

| | |
|---|---|
| Compaction blows | 75 |
| Flow | 2 to 4 mm |
| Stability | 8 KN |

- No recycled materials were permitted in HMA mixtures.
- The aggregates should have a minimum of 60% retained on the No. 4 sieve with at least two fractured faces, and a minimum sand equivalent of 45.
- The asphalt grade and characteristics should be selected based on normal agency practice.
- The use of modifiers should be discouraged in the main sections.
- Lift thickness could not exceed 102 mm (4-inch) and compacted thickness of any single layer had to be at least 51 mm (2-inch).
- Longitudinal joints should be staggered between successive lifts to avoid vertical joints.
- All transverse joints should be placed outside the main sections.
- The thickness of the HMA layer (surface and binder) should be within 6 mm (0.25-inch) of the thickness specified by the experiment design.
- The as-constructed finished surface should have a profile index of less than 158 mm per km (10 inches per mile) as measured by the California-type profile-graph.

### Shoulders

- The shoulders placed on these projects should have a minimum width of 1.2 m (4-ft) and have the full pavement structure across their width.
- If possible, the shoulders should be paved full-width with the surface course to eliminate longitudinal joints. If not, then the shoulders should be paved such that the longitudinal joint is at least 205 mm (12-inch) outside the travel lane.

### Drainage Materials

Filter fabric (or geo-textile) was required on sections that included a PATB layer. This was specified to prevent the clogging of the PATB layer due to migration of fine material from the subgrade. The filter fabrics used should meet the American Association of State Highway and Transportation Officials-American Building Contractors-American Road and Transportation Builders Association (AASHTO-ABC-ARTBA) Task Force 25 recommendations, which include the following requirements for the geo-textiles:

- In order to separate the base layer from the subgrade non-woven and woven geo-textile materials that conform to Class A requirements should be used.
- The geo-textile material conforming to Class B requirements could be used in the edge drains.
- Geo-textiles should be overlapped a minimum of 610 mm (2 ft) at all longitudinal and transverse geo-textile joints.
- Filter fabrics should be installed in accordance with the manufacturer's specifications.
- For the sections where the PATB layer was placed on DGAB, the filter fabrics should extend around each edge drain and wrap around the outer edge of the PATB layer.
- Exposure time of the geo-textile to elements between lay down and cover should be limited to a maximum of 3 days.

Edge drains were to be installed on sections containing a PATB layer to collect water draining from the permeable base. The requirements on these drains were as follows:

- Inside and outside edge drains should be constructed for crowned pavements.
- Edge drains should be at least 914 mm (3 ft) away from the edge of the travel lane.
- The PATB was recommended for backfill around the edge drains; however, other open graded materials could be used as backfill materials if approved.
- Collector pipes (slotted) should be at least 76 mm (3-inch) diameter.
- Outlet pipes (un-slotted) should be rigid plastic pipes with a minimum diameter of 76 mm (3-in).
- Drainage pipes should be sized for the expected discharge determined as part of design.
- Discharge outlet pipe should be placed at a maximum interval spacing of 76.2 m (250-ft).

### Material Sampling and Testing

Sampling and testing were required for each of the material used for the construction of sections. The material characterization is necessary to evaluate the differences between the as-constructed sections within a site and between different sites within the experiment. These measured parameters are used mostly in the design procedures as well as to assess important performance characteristics of the materials.

A general sampling and testing plan was created for use as a guideline[3]. These guidelines were then used to develop the sampling and testing plan specific to each site. These plans were created prior to the construction of each project and the location of each sample was predetermined. The following types of samples should be taken from each project:

- Bulk samples from the upper 305 mm (12-inch) of the subgrade.
- Thin-walled tube samples of the subgrade to a depth of 1.2 m (4 ft).
- Jar samples for subgrade.

- Bulk samples for the DGAB.
- Jar samples for the DGAB.
- Bulk samples for PATB.
- Bulk samples for ATB.
- Bulk samples for the asphalt mixes used in the surface and binder course.
- Bulk sample of asphalt mixes used in all mixes.
- Cored samples for bound bases and surface asphalt layers.

In addition to these samples, bulk samples were to be taken for the asphalt cement, aggregates and un-compacted HMA mixes. These samples were to be stored for long term. A series of auger probes should be performed in the shoulder of each test section up to a depth of 6 m. This allows for the determination of the stiff layer depth. Finally, as part of the construction activity, nuclear density and moisture testing should be conducted at the location of the bulk sampling areas for the subgrade and on the top of each layer in every test section. The type and number of tests per layer are given elsewhere [3].

### Monitoring Requirements

The monitoring of the sections at each site includes several types of data. These include distress surveys, deflection measurements, transverse profiles and longitudinal measurements. Each of these measurements has different frequency requirements, which can be revised over time.

#### *Distress Surveys*

A distress survey was to be performed on each section within 6 months of construction. A manual distress survey should be performed on the sections biennially, with the exception of “weak” sections (2, 5, 7 and 13 in SPS-1 projects where distress surveys should be more frequent). The survey could be postponed by a year if necessary.

#### *Deflection Surveys*

Deflection measurements should be collected using a falling weight deflectometer (FWD) from 1 to 3 months after the construction of the project. The deflection survey of these projects is to be completed biennially except of the “weak” sections (2, 5, 7 and 13 in SPS-1 projects where distress surveys should be more frequent). This testing also could be postponed up to 1 year if necessary.

### *Transverse Profile*

Transverse profile measurements should be taken at the same frequency and at the same time, as the distress surveys.

### *Longitudinal Profile*

Longitudinal profiles should be taken on the sections within 3 months after construction. These measurements can be postponed up to 3 additional months. The "weak" sections (2, 5, 7 and 13 in SPS-1 projects) should be monitored every 6 months but monitoring can be postponed up to 6 additional months. The other sections should be monitored biennially and can be postponed by 1 year if necessary.

## Traffic Data

Traffic data should be collected on each site. The current requirement states that weigh-in-motion (WIM) data should be continuously collected on all SPS-1 sections. Continuous data collection has been defined as the "use of a device that is intended to operate throughout the year and to which the SHA commits the resources necessary to both monitor the quality of the data being collected and to fix problems quickly upon determination of any fault" [2]. WIM devices are to be calibrated biannually. This level of data collection is necessary to assess accurate traffic loading measurements.

## Climatic Data

Each SPS-1 site was required to install an automatic weather station (AWS). The AWS should be located close enough to each of the sites to provide weather data that is representative of the climate on each site. The equipment installed at these locations should measure the following weather components:

- Rain
- Humidity
- Wind speed
- Temperature

All the data collected should be stored by a data-logger. The data should be downloaded from the data-logger at least every 6 months.

In addition to AWS used to collect weather data, weather data should also be obtained from the four or five closest National Oceanic and Atmospheric Association (NOAA) weather stations. The data should be averaged using the weighting procedure, with the weights based on the distance of the weather station from the particular site. The data collected from NOAA stations should include information about the temperatures, rainfall, wind and solar radiation levels.

## 2.3 STRATEGIC STUDY OF STRUCTURAL FACTORS FOR RIGID PAVEMENTS — SPS-2

The primary objective of the SPS-2 experiment is to determine the relative influence and long-term effectiveness of design features and site conditions on the performance of doweled jointed plain concrete pavement (JPCP) sections with and uniformly spaced transverse joints.

As the test sections in the experiment are monitored since inception, the experiment provides an opportunity to estimate, more precisely, the relative influence of the key pavement elements that affect pavement performance.

### 2.3.1 Experiment Design

The design factorial for the SPS-2 experiment is shown in Table 2-3. The overall experiment consists of 192 factor level combinations comprising of 8 site-related (subgrade soil type and climate, also referred to as site factors) combinations and 24 pavement structure combinations (design factors). The experiment was developed such that 12 sections should be built, with only half of the possible combinations of design factors, at each of the 16 sites. It was planned that “48 test sections representing all structural factor and subgrade type combinations in the experiment are to be constructed in each of the climatic zones, with 24 test sections to be constructed on fine-grained soil and 24 test sections to be constructed on coarse-grained soil” (see Table 2-3). Moreover, for each climatic zone and soil type combination, 12 sections are to be constructed at one site and the other 12 sections at the other site [4].

Table 2-3 SPS-2 Experiment Design Matrix

| Pavement Structure | | | | | Climatic Zones, Subgrade | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Drainage | Base Type | PCC | | Lane Width (m) | WET | | | | | | | | DRY | | | | | | | |
| | | Thickness (mm) | 14-day Flexural Strength (MPa) | | 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 | 203 | 3.8 | 3.7 | 201 | | 201 | | 201 | | 201 | | 201 | | 201 | | 201 | | 201 | |
| | | | | 4.3 | | 213 | | 213 | | 213 | | 213 | | 213 | | 213 | | 213 | | 213 |
| | | | 6.2 | 3.7 | | 214 | | 214 | | 214 | | 214 | | 214 | | 214 | | 214 | | 214 |
| | | | | 4.3 | 202 | | 202 | | 202 | | 202 | | 202 | | 202 | | 202 | | 202 | |
| | | 279 | 3.8 | 3.7 | | 215 | | 215 | | 215 | | 215 | | 215 | | 215 | | 215 | | 215 |
| | | | | 4.3 | 203 | | 203 | | 203 | | 203 | | 203 | | 203 | | 203 | | 203 | |
| | | | 6.2 | 3.7 | 204 | | 204 | | 204 | | 204 | | 204 | | 204 | | 204 | | 204 | |
| | | | | 4.3 | | 216 | | 216 | | 216 | | 216 | | 216 | | 216 | | 216 | | 216 |
| No | LCB | 203 | 3.8 | 3.7 | 205 | | 205 | | 205 | | 205 | | 205 | | 205 | | 205 | | 205 | |
| | | | | 4.3 | | 217 | | 217 | | 217 | | 217 | | 217 | | 217 | | 217 | | 217 |
| | | | 6.2 | 3.7 | | 218 | | 218 | | 218 | | 218 | | 218 | | 218 | | 218 | | 218 |
| | | | | 4.3 | 206 | | 206 | | 206 | | 206 | | 206 | | 206 | | 206 | | 206 | |
| | | 279 | 3.8 | 3.7 | | 219 | | 219 | | 219 | | 219 | | 219 | | 219 | | 219 | | 219 |
| | | | | 4.3 | 207 | | 207 | | 207 | | 207 | | 207 | | 207 | | 207 | | 207 | |
| | | | 6.2 | 3.7 | 208 | | 208 | | 208 | | 208 | | 208 | | 208 | | 208 | | 208 | |
| | | | | 4.3 | | 220 | | 220 | | 220 | | 220 | | 220 | | 220 | | 220 | | 220 |
| Yes | PATB | 203 | 3.8 | 3.7 | 209 | | 209 | | 209 | | 209 | | 209 | | 209 | | 209 | | 209 | |
| | | | | 4.3 | | 221 | | 221 | | 221 | | 221 | | 221 | | 221 | | 221 | | 221 |
| | | | 6.2 | 3.7 | | 222 | | 222 | | 222 | | 222 | | 222 | | 222 | | 222 | | 222 |
| | | | | 4.3 | 210 | | 210 | | 210 | | 210 | | 210 | | 210 | | 210 | | 210 | |
| | | 279 | 3.8 | 3.7 | | 223 | | 223 | | 223 | | 223 | | 223 | | 223 | | 223 | | 223 |
| | | | | 4.3 | 211 | | 211 | | 211 | | 211 | | 211 | | 211 | | 211 | | 211 | |
| | | | 6.2 | 3.7 | 212 | | 212 | | 212 | | 212 | | 212 | | 212 | | 212 | | 212 | |
| | | | | 4.3 | | 224 | | 224 | | 224 | | 224 | | 224 | | 224 | | 224 | | 224 |

The structural factors included in the experiment are:

- Drainage (presence or lack of drainage),
- Base type (DGAB, LCB, and PATB),
- PCC slab thickness (203 mm and 279 mm),
- PCC flexural strength (3.8 MPa and 6.2 MPa, at 14-day), and
- Lane Width (3.66 m and 4.27 m).

The site factors included in the experiment are:

- Subgrade soil type (fine-grained and coarse-grained, based on Unified system),
- Climate (Wet Freeze, Wet No Freeze, Dry Freeze and Dry No Freeze), and
- Traffic (considered as a covariate).

At each site, 6 sections have a target PCC slab thickness of 8-inch (203 mm) and the remaining 6 have a target PCC slab thickness of 11-inch (279 mm). The 76 mm difference between the lower and upper levels of PCC slab thickness was believed to be necessary to demonstrate the effect of PCC slab thickness and its interaction with other factors on performance [4]. The other factors with two levels (PCC flexural strength and lane width) have 6 test sections corresponding to each level. Also 4 test sections have dense-graded aggregate base (DGAB), 4 sections have lean concrete base (LCB), and the other 4 sections have permeable asphalt treated base (PATB) over DGAB. In-pavement drainage is provided only to the sections with PATB as the base.

Other features common to all SPS-2 sections are as follows [2]:

- The monitored part of a test section is 152.4 m (500 feet) long with a transition zone of at least 15.2 m (50 feet) on each side for material sampling and other destructive testing.
- A uniform joint spacing of 4.6 m (15 feet) is maintained for all test sections.
- All the sections with 203 mm (8-inch) as the target PCC slab thickness are built with dowel bars of 32 mm (1.25-inch) diameter. The sections with the target PCC slab thickness of 279 mm (11-inch) are built with dowel bars of 38 mm (1.5-inch) diameter. Also, all the dowels are 457 mm (18-inch) long and placed at slab mid-depth with a center-to-center spacing of 305 mm (1 ft).
- The HMA or PCC shoulders are not tied to the mainline pavement of the test sections.
- Longitudinal joints are tied using 762 mm (30-inch) long, No. 5 epoxy-coated deformed steel bars of grade 40 steel and spaced 762 mm (30-inch) center-to-center.
- All structural repairs are performed on the test sections before opening to traffic. In addition, all joint sealing is completed prior to opening to traffic.

Though a major factor, traffic is not addressed like other design factors, in that, only a lower limit was specified for traffic volume in terms of ESALs per year. A SPS-2 test site must have a minimum estimated traffic loading of 200,000 rigid ESAL per year in the design lane [2, 4]. Traffic will thus vary from site to site and will therefore be treated as a covariant in the study.

Based on the average annual precipitation and the average annual Freezing Index, the sites in the experiment have been categorized into different climatic zones using the thresholds defined by LTPP program.

In the experiment, the 12 sections at a given site are represented by either XX-0201 through XX-0212, or XX-0213 through XX-0224, where XX denotes the site code. The number 02 indicates the SPS experiment number and the last two digits represent the sequential numbering of the sections.

### 2.3.2 Current Status of the Experiment

A total of 14 sites with 167 test sections are in the experiment according to the latest data (from Release 17 of DataPave). The geographical distribution of the sites within the SPS-2 experiment is presented in Figure 2-2. The full factorial design for SPS-2 experiment design requires that a total of 48 similar designs be replicated across 8 soil-climate combinations. However, the 48 designs were reduced to 24 designs in each soil-climate combination making the experiment design a fractional factorial. Later, it was considered that the construction of 24 test sections at each site would require a greater effort on the part of the participating agencies [4]. Therefore, to reduce the cost of construction the experiment was developed so that only 50% of the possible combinations of factors (i.e. 12 test sections) will be built at each site. The experiment, designed in a factorial manner to enhance implementation practicality, permits the construction of 12 test sections (0201 through 0212 or 0213 through 0224) at one site with the complementary 12 test sections to be constructed at another site within the same climatic region and on a similar subgrade soil type [2].

The status of the design factorial is shown in Table 2-4. There are six cells within the table that are missing from the factorial, indicating a loss of 6/16 or 37.5% of the overall experiment population. Though the experiment was designed to have 4 sites in each climatic zone, there are only 2 sites each in Wet No Freeze and Dry No Freeze climatic zones, and 3 sites in the Dry Freeze climatic zone. The majority of sites (7 of 14) have been constructed in the Wet Freeze zone making the current SPS-2 design unbalanced.

The experiment design also called for half of the sites to be constructed on coarse-grained soils and the other half to be constructed on fine-grained soils. In addition to this, it was required that all the sections within a site be constructed on the same type of soil (coarse or fine). Of the 14 sites, 5 sites were constructed on coarse-grained subgrade soils (see Table 2-4). In 3 of the 4 climatic zones the number of sites constructed on fine-grained and coarse-grained soils is not the same. Moreover in AR (5), CO (8), CA (6) and NV (32), not all the sections within the site were constructed on the same type of soil. A discussion on the current status of the experiment at site-level can be found in Appendix B1.

Table 2-4 Status of the design factorial

| Subgrade Type | Designs | Wet | | Dry | | Total |
|---|---|---|---|---|---|---|
| | | **Freeze** | **Non Freeze** | **Freeze** | **Non Freeze** | |
| Fine-grained | 0201-0212 | KS (20)<br>OH (39) | NC (37) | WA (53)<br>NV (32)* | | 9 |
| | 0213-0224 | MI (26)<br>IA (19)<br>ND (38) | | CO (8)* | | |
| Coarse-grained | 0201-0212 | DE (10) | | | CA (6) | 5 |
| | 0213-0224 | WI (55) | AR (5)* | | AZ (4) | |
| Total | | 7 | 2 | 3 | 2 | 14 |

Note: * Two sections in NV and five sections in CO are coarse-grained while two sections in AR are fine-grained.

a. Wet Regions — Average Annual Rainfall > 20 inches (508 mm)
b. Dry Regions — Average Annual Rainfall < 20 inches (508 mm)
c. Freeze Regions — Average Annual Freezing Index > 83.3 °C-day (150 °F-day)
d. Non-Freeze Regions — Average Annual Freezing Index < 83.3 °C-day (150 °F-day)

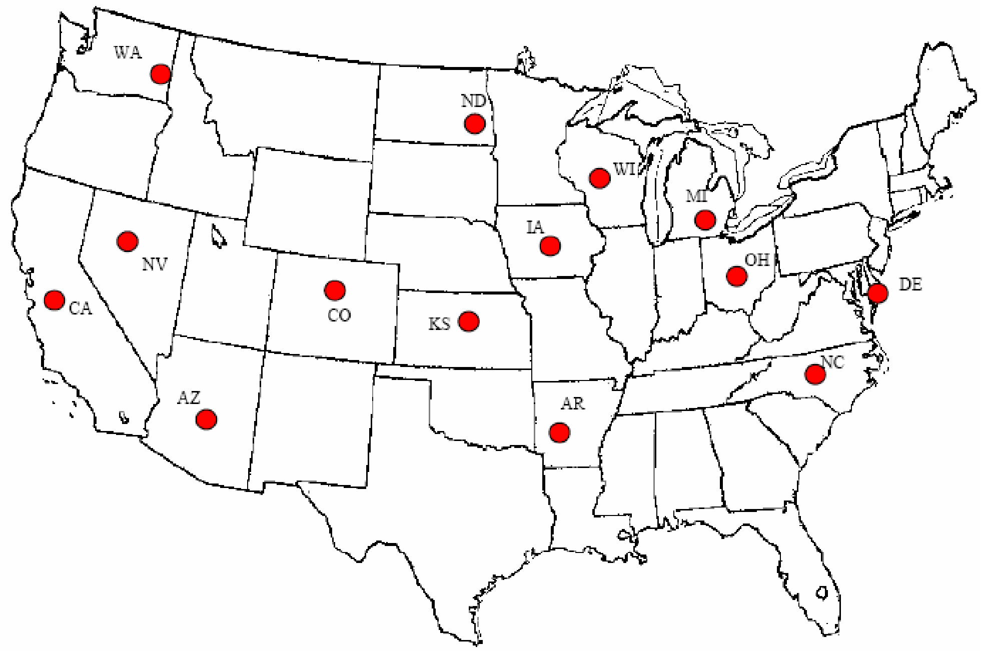


Figure 2-2 Geographical location of SPS-2 sites

### 2.3.3 Construction Guidelines for SPS-2 Experiment

The SPS-2 experiment requires construction of multiple test sections with similar details and/ or materials at several sites distributed throughout the country. Construction variability that may arise from this large project can potentially affect the results from analysis of the data. Therefore, construction uniformity at all sites was deemed important for the success of the experiment. In light of this, guidelines were developed to help participating highway agencies. The guidelines addressed those items that should be considered by the participating agencies to ensure adherence to the study requirements. Adherence to the criteria will ensure that any difference in performance between test sections constructed with similar experimental parameters at different locations is mainly due to difference in climatic conditions and traffic levels. The salient aspects of the guidelines have been summarized in the section below. Further details of the guidelines can be obtained from the relevant SHRP report [2].

### Subgrade Requirements

The requirements for preparation and compaction of the subgrade are the same as those for the SPS-1 experiment explained above.

### Base Layers

*Dense Graded Aggregate Base (DGAB)*

The requirements for DGAB are essentially the same as those described for the SPS-1 experiment. However, the lift thickness must be 102 and 152 mm for the test sections with and without PATB, respectively. Also the DGAB should be kept uniformly moist prior to the placement of PCC surface layer, using a procedure that will avoid formation of puddles of water.

*Lean Concrete Base (LCB)*

The general requirements for the LCB are as follows:

- A slump (Slip-form method of concrete placement) of 25 to 76 mm.
- Target compressive strength 3.5 MPa at 7 days of (maximum is 5.2 MPa).
- An air content of 4 to 9%.
- Portland Cement (Type I or II) and aggregates confirming with the AASHTO specifications M85 and M80, respectively,. The recommended aggregate size is AASHTO Size No. 57.
- The LCB shall be constructed such that it extends to the outside edge of the shoulders. When in reconstruction projects, LCB shall extend at least 914 mm outside the edge of the travel lanes.
- The LCB should be finished to a smooth surface without texturing.
- No traffic shall be allowed on LCB.

### *Permeable Asphalt Treated Base (PATB)*

The drained base structure in the SPS-2 is similar to that described for SPS-1 experiment above. The 102 mm thick PATB layer should be constructed over an equally thick DGAB layer. Filter fabric (or geotextile) should be used only in edge drains and transverse interceptor drains.

## Portland Cement Concrete

The guidelines stipulate that the concrete mix design be done according to the procedures and specifications followed by the participating agency. The slip-form method is recommended for concrete placement. The main requirements are as follows:

- Use Type I or II Portland cement (meeting requirements of AASHTO specifications M85). Fly ash of Class C or F can be used to replace up to 15% (by weight) of cement. Use of silica fume or additives to accelerate strength gain is prohibited.
- Crushed gravel or stone should be used as coarse aggregate and the aggregate should confirm to requirements in AASHTO specification M80. Fine aggregate should a fineness modulus between 2.3 and 3.1 and should meet the requirements of AASHTO specification M6.
- Flexural Strength: 3.8 or 6.2 MPa average, at 14 days, depending on the test section. For high strength concrete (6.2 MPa) the guidelines require the conduct of a well-planned laboratory testing of trial mixes.
- Slump: 25.4 to 63.5 mm.
- Air Content: 6.5 ± 1.5 % for freeze-thaw areas.
- The as-placed concrete thickness should be within 6.4 mm from the target value.

## Construction Operations

Specifications were also developed regarding the construction operations of the pavement. The salient features are:

- The slip-form machine should vibrate the concrete for the full depth and width of the concrete.
- All joints should be sawn with an initial saw cut of one-third the slab thickness and a second saw cut to provide a sealant reservoir of 9.5 mm width and 25.4 mm depth.
- Silicone sealant is to be used for sealing of joints.
- Liquid curing compound should be placed within 15 minutes after surface texturing but no later than 45 minutes after concrete placement.
- High pavement areas with a vertical deviation greater than 10.2 mm in 7.6 m should be removed by diamond grinding or multiple-saw devices as approved by the agency.

### Data Collection Requirements

To ensure uniform and consistent data collection, detailed procedures have been developed for the experiment. Most of the requirements are similar to the ones applicable to SPS-1. The requirements that are applicable to SPS-2 are briefly listed below.

1. *Inventory and construction data*: Includes items necessary to identify the test sections, describe geometric details, and material properties. Most of this data is obtained from the participating agency. Construction data pertains to the as-built thickness and properties of different layers.
2. *Materials and testing data*: This data is obtained from field sampling and laboratory testing. The data should help characterize pavement material properties that may influence performance.

   For SPS-2, testing is to be done on field samples obtained from PCC layer to determine compressive strength, split tensile strength, coefficient of thermal expansion, static modulus of elasticity, unit weight, core condition and thickness, air content of hardened concrete, and flexural strength. In addition to tests on field samples from the as-built pavement, properties of as-delivered PCC are determined from samples taken from ready-mix truck. For unbound granular base layer or PATB, tests are performed as in the case of SPS-1. For LCB, tests are performed to determine core condition and thickness, compressive strength and split tensile strength. For the subgrade, tests are performed in the same way as in SPS-1. Testing on samples obtained from LCB and PCC obtained from pavements at different ages is also done.
3. *Traffic data*: This data includes estimated, and monitored data. Continuous weigh-in-motion data is also required, as for SPS-1.
4. *Distress data*: Distress data to be collected are described in the SHRP Distress Identification Manual for Long-term Pavement Performance Studies [5].
5. There are 16 types of distresses for jointed plain concrete pavements. The frequency of collection of distress data, profile data and deflection data suggested by the LTPP guidelines is summarized at the end of this section.
6. *Profile data*: Profile measurements are made using profilometers conforming with the method laid out in the manual for profile measurements.

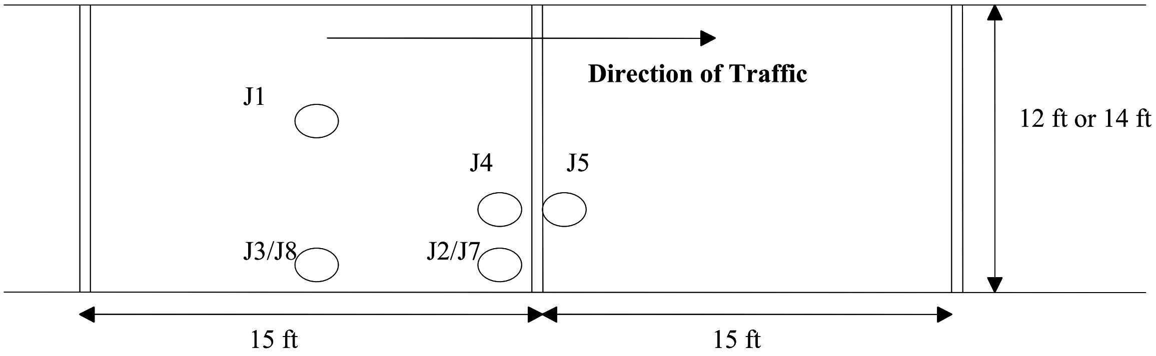


Figure 2-3 Deflection test locations on the pavement slabs

Table 2-5 Details of FWD testing locations and potential use of testing

| Lane No. | Location on slab | Type of test section | Potential use of the data |
|---|---|---|---|
| J1 | Midslab | Sections with 3.7 or 4.3 m lane width | Used with J3 to compute the D-ratio or the edge support factor<br>Used to analyze the response of the PCC layer |
| J2 | Corner | Sections with 3.7 m lane width | Used to estimate void potential |
| J3 | Midslab-Edge | Sections with 3.7 m lane width | Used with J1 to compute the D-ratio or the edge support factor |
| J4 | Wheelpath, Leave Slab | Sections with 3.7 or 4.3 m lane width | Used with J5 to compute LTE |
| J5 | Wheelpath, Approach slab | Sections with 3.7 or 4.3 m lane width | Used with J4 to compute LTE |
| J7 | Corner | Sections with 4.3 m lane width | Used to estimate void potential |
| J8 | Midslab-Edge | Sections with 4.3 m lane width | Used with J1 to compute the D-ratio or the edge support factor |

Table 2-6 Data Collection Frequency guidelines

| Data type | Post construction monitoring | Long-term Monitoring Frequency | |
|---|---|---|---|
| | | In effect before 10/1/99 | In effect after 10/1/99 |
| Longitudinal profile | <6 months is permitted | Biennially, but may be postponed up to one year | Annually |
| Deflection | <6 months is permitted | Biennially and responsive | Biennially and responsive |
| Manual distress | <3 months | Biennially, but may be postponed up to one year | Annually |

7. *Deflection data*: Deflection measurements are performed using Dynatest FWD. Figure 2-3 is a plan view showing locations of FWD testing. Table 2-5 is a summary of FWD testing locations and potential use of the data obtained from testing. ‘Lane No.’ is the number given to the location of testing and has been explained in the table.
8. *Climatic data*: The requirements are similar for SPS-2 and SPS-1. An Automated Weather Station (AWS) should be installed on every site if representative weather stations are not located in proximity to the test site. Maximum, minimum, and mean daily temperatures, daily precipitation, and daily snowfall are considered essential data that must be obtained for each site.
9. *Maintenance data*: Maintenance can be done for safety or other reasons, and information about this need to be collected.
10. *Rehabilitation data*: No rehabilitation activity should be performed on the SPS test sites. If rehabilitation is performed for any reason, the section will be considered no longer part of the experiment. However, data needs to be collected about the rehabilitation.

### Monitoring Requirements

Based on the LTPP directives a summary of data collection guidelines have been prepared and are presented in Table 2-6.

Monitoring of sections is to be continued until one of the following conditions is satisfied:” the LTPP program concludes, application of rehabilitation construction event, or test section goes out-of-study”.

## 2.4 SPS-8 EXPERIMENT

The SPS-8 experiment evaluates environmental effects in the absence of heavy traffic loads. The study examines the effect of climatic factors and subgrade type (frost-susceptible, expansive, fine, and coarse) on pavement sections incorporating different designs of flexible and rigid pavements, which are subjected to very limited traffic as measured by ESAL accumulation. Pavement structure includes two levels of structural design for each class of pavements. Flexible pavement sections consist of 102 mm (4-inch) and 178 mm (7-inch) HMA surfaces on 203 mm (8-inch) and 305 mm (12-inch) layers of DGAB, respectively. Rigid pavement test sections consist of 203 mm (8-inch) and 279 mm (11-inch) doweled JPCP slabs on 152 mm (6-inch) DGAB. The study design stipulates the traffic volume in the study lane be at least 100 vehicles per day but not more than 10,000 ESALs per year. The combination of study factors results in four possible section combinations, two flexible and two rigid. The flexible and rigid sections may be constructed at the same or at different sites. Table 2-7 shows the experiment design matrix for SPS-8.

For flexible pavements in SPS-8 experiment, the sections are identified as XX-0801 to XX-0806, while for rigid pavements they are identified as XX-0807 to XX-0812, where 'XX' is the state code and '08' stands for SPS-8 experiment. The sections with SHRP ID that ends with an odd number have target HMA thickness of 102 mm or PCC slab thickness of 203 mm, while the others have HMA thickness of 178 mm or PCC slab thickness of 279 mm thickness. In the section ID, an alphabet is introduced before the SHRP ID in case a second site is constructed in the same state.

### 2.4.1 Current Status of the SPS-8 Flexible Pavements

Table 2-8 shows the flexible pavement sites in the SPS-8 experiment. There are fifteen sites constructed for SPS-8 flexible pavement sections with the largest number of sites (7) located in the WF climatic zone. The details of test sections for flexible pavements according to SPS-8 experiment design are given in Table 2-9. In total, 32 flexible pavement sections have been constructed in the 15 sites. There are a limited number of test sections in the Dry zones with no pavements on fine subgrade in DF or active subgrade in DNF zones.

### 2.4.2 Construction Guidelines for SPS-8 Flexible Pavements

Construction guidelines were provided to ensure uniformity and consistency among the test sites. The requirements for preparation and compaction of the subgrade for flexible sections are the same as for the SPS-1 experiment. The construction guidelines stipulated the use of DGAB; the requirements for the materials and construction of the base layers are also the same as those of the SPS-1 experiment. Similarly, the guidelines for the materials and construction of asphalt layers are similar to the un-drained sections included in the SPS-1 experiment, which require DGAB.

Table 2-7 SPS-8 Experiment Design Matrix

| Pavement Type | AC/PCC Thickness | Base Thickness | WF | | | WNF | | | DF | | | DNF | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | A | F | C | A | F | C | A | F | C | A | F | C |
| Flexible | 4 | 8 | x | x | x | x | x | x | x | x | x | x | x | x |
| | 7 | 12 | x | x | x | x | x | x | x | x | x | x | x | x |
| Rigid | 8 | 6 | x | x | x | x | x | x | x | x | x | x | x | x |
| | 11 | 6 | x | x | x | x | x | x | x | x | x | x | x | x |

A: Active subgrade soil (either frost susceptible or swelling type relative to climatic zone)
F: Fine-grained subgrade soil
C: Coarse-grained subgrade soil

Table 2-8 Distribution of SPS-8 flexible pavements sites by subgrade type and climatic zone

| Subgrade Type | **Wet**[a] | | **Dry**[b] | | Total |
|---|---|---|---|---|---|
| | **Freeze**[c] | **Non-Freeze**[d] | **Freeze** | **Non-Freeze** | |
| **Fine** | AR (5)<br>MO (29)<br>NJ (34)<br>OH (39) | MS (28)<br>TX (48) | SD (46) | NM (35) | 8 |
| **Coarse** | NY (36)<br>WA (53)<br>WI (55) | NC (37) | MT (30)<br>UT (49) | CA (6) | 7 |
| Total | 7 | 3 | 3 | 2 | 15 |

Note:

a. Wet Regions — Average Annual Rainfall > 20 inches (508 mm)
b. Dry Regions — Average Annual Rainfall < 20 inches (508 mm)
c. Freeze Regions — Average Annual Freezing Index > 83.3 $^{o}$C-day (150 $^{o}$F-day)
d. Non-Freeze Regions — Average Annual Freezing Index < 83.3 oC-day (150 oF-day)

Table 2-9 Distribution of SPS-8 flexible pavements sections by design, subgrade type and climatic zone

| Pavement Structure | | | Moisture, Temperature and Subgrade Type | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pavement Type | Surface Thickness inches | DGAB Thickness inches | Wet | | | | | | | | | | | | Dry | | | | | | | | | | | |
| | | | Freeze | | | | | | No-Freeze | | | | | | Freeze | | | | | | No-Freeze | | | | | |
| | | | Active* | | Fine | | Coarse | | Active | | Fine | | Coarse | | Active | | Fine | | Coarse | | Active | | Fine | | Coarse | |
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| Flexible | 4 | 8 | 2 | | 2 | | 3 | | 1 | | 1 | | 2 | | 1 | | 0 | | 2 | | 0 | | 1 | | 1 | |
| | 7 | 12 | 3 | | 0 | | 4 | | 1 | | 2 | | 1 | | 2 | | 0 | | 1 | | 0 | | 1 | | 1 | |

Note: DGAB= Dense-graded aggregate base.
*Active soil can be either frost-susceptible or swelling (expansive) type. Each no. indicates presence of sections fulfilling the criteria of the cell

### 2.4.3 Current Status of SPS-8 Rigid Pavements

Table 2-10 shows the distribution of rigid pavement sections in the actual SPS-8 experiment, as per Release 17 of DataPave. While the minimum required number of rigid pavement sections to fulfill the proposed experiment criteria is 24, only 14 rigid pavement sections are currently in the experiment, spread over 6 states. There are 2 sites [Missouri (29) and Ohio (39)] in Wet Freeze zone, 2 sites [Arkansas (5) and Texas (48)] in Wet No Freeze zone, and 2 sites [Colorado (8) and Washington (53)] in Dry Freeze zone. There are no sites in the Dry No Freeze zone. An active subgrade can be coarse-grained or fine-grained. A section that is 'active' is not categorized under 'fine' or 'coarse' but is taken just as 'active'.

Table 2-10 Distribution of rigid pavement sections in the SPS-8 experiment

| Pavement Structure Factors | | Moisture, Temperature and subgrade soil type | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PCC slab thickness, mm | DGAB thickness, mm | Wet | | | | | | Dry | | | | | |
| | | Freeze | | | No Freeze | | | Freeze | | | No Freeze | | |
| | | Active | Fine | Coarse | Active | Fine | Coarse | Active | Fine | Coarse | Active | Fine | Coarse |
| 203 | 152 | X | X | | X | X | | | X | | | | X |
| 279 | | X | X | | X | X | | | X | | | | X |

Each 'X' indicates presence of one or more sections fulfilling the criteria of the cell

### 2.4.4 Construction Guidelines for SPS-8 Rigid Pavements

Each section is constructed as uniformly as is practical over a length of 183 m to allow 152 m for monitoring purposes and 15 m at each end for destructive testing. The guidelines also stipulate that an asphalt concrete, untied PCC, or bituminous surface-treated aggregate shoulder be constructed as part of the test section. The concrete used for the surface layer has to have a target average 14-day flexural strength of 3.8 MPa. Moreover, no subsurface drainage is to be provided to the pavements in the experiment. The other construction guidelines for the experiment are the same as for the SPS-2 experiment.

## 2.5 INSTRUMENTED SPS TEST SECTIONS

The Strategic Highway Research Program (SHRP) has included two projects with instrumented test sections as part of the SPS-1 and SPS-2 experiments. This subset of sections constitutes the Dynamic Load Response (DLR) experiment. The sections are located in Ohio and North Carolina. The Ohio test sections include both flexible and rigid pavements while the North Carolina test sections include only rigid pavements. The objective of this experiment is to support the development of mechanistic-empirical design procedures for flexible and rigid pavement systems.

More specifically, it can be used to investigate the relationship between pavement response and performance, and to validate pavement response and performance prediction models.

In addition to standard FWD, profile and distress measurements, pavement dynamic response parameters are being measured in these test sections including:

- Vertical deflections in the surface layer, base and subgrade;
- Horizontal strains in the pavement;
- Vertical pressure at layer interfaces; and
- Joint opening in PCC pavements.

The seasonal parameters being measured include:

- Temperature within the pavement layers including base and subgrade;
- Frost depth in base and subgrade;
- Soil suction in the subgrade;
- Water table elevation; and
- Moisture in the subgrade.

In addition to measurements within the pavement system, the loads being applied on the pavement are measured using weigh-in-motion (WIM) scales. Several series of controlled vehicle tests at different speeds and non-destructive load tests have been conducted to measure the pavement response.

### 2.5.1 SPS-1 Sections

The instrumented flexible pavement sections are located in the SPS-1 site Ohio (39). These sections were instrumented with strain gauges, pressure cells and linear variable differential transformers (LVDT) to conduct the controlled loading experiments.

The experiment targeted four core sections for the installation of sensors to monitor dynamic pavement response during controlled vehicle testing. These sections include 39-0102, 39-0104, 39-0108 and 39-0110. Tests were to be performed with a single axle and tandem axle dump truck. The rear axle on the single–axle truck was loaded to approximately 18 kips (40 kN) and 22 kips (49 kN) while the total load on the rear axles of the tandem-axle dump truck were 32 kips (142 kN) and 42 kips (187 kN), respectively. Both trucks ran over the instrumented sections at 50(30), 65(40) and 80(50) km/hr (mph) in the morning and in the afternoon.

*Experiment Setup*

The details of the instrumented flexible pavement sections are given in Table 2-11. Tests were conducted in the morning and in the afternoon to gather information on how temperature differences in the pavement layers affect response.

Table 2-12 shows the instrumentation details of all the strain gauges and LVDTs for each instrumented section. This information is taken from Report No. FHWA/OH-94/019 by Ohio University, as this data was not available in the DataPave Release 17.0.

Table 2-11 Details of instrumented sections for flexible pavements

| Section ID | HMA Thickness (inches) | Base Thickness (inches) / Base Type | Drainage | Comments |
|---|---|---|---|---|
| 39-102 | 4 | 12 DGAB | No | Strain gauges at 4” |
| 39-104 | 7 | 12 ATB | No | Strain gauges at 7” and 19” |
| 39-108 | 7 | 4 PATB<br>8 DGAB | Yes | Strain gauges at 7” |
| 39-110 | 7 | 4 ATB<br>4 PATB | Yes | Strain gauges at 7” and 11” |

Note: DGAB ─ Dense graded aggregate base, ATB ─ Asphalt treated base, PATB ─ Permeable asphalt treated base

Table 2-12 Instrumentation details for all the SPS-1 sections in Ohio

| **Section ID** | **Strain Gauge Designation** | **Location** | **LVDT Designation** |
|---|---|---|---|
| 39-102 | DYN7 ─ Transverse<br>DYN8 ─ Longitudinal<br>DYN9 ─ Transverse<br>DYN10 ─ Longitudinal<br>DYN11 ─ Transverse<br>DYN12 ─ Longitudinal | All strain gauges are installed at the bottom of AC, 4” deep from the surface | LVDT1 ─ Deep[1]<br>LVDT2 ─ Shallow[2]<br>LVDT3 ─ Shallow<br>LVDT4 ─ Deep |
| 39-104 | DYN10 ─ Transverse<br>DYN11 ─ Longitudinal<br>DYN12 ─ Transverse<br>DYN13 ─ Longitudinal<br>DYN14 ─ Transverse<br>DYN15 ─ Longitudinal | DYN10 to DYN15 are located at bottom of AC, 7” deep from the surface | LVDT1 ─ Deep<br>LVDT2 ─ Shallow<br>LVDT3 ─ Shallow<br>LVDT4 ─ Deep |
| | DYN16 ─ Longitudinal<br>DYN17 ─ Longitudinal<br>DYN18─ Longitudinal | These three strain gauges are installed at the bottom of ATB, at 19” deep from the surface | |
| 39-108 | DYN10 ─ Transverse<br>DYN11 ─ Longitudinal<br>DYN12 ─ Transverse<br>DYN13 ─ Longitudinal<br>DYN14 ─ Transverse<br>DYN15 ─ Longitudinal | All strain gauges are installed at the bottom of AC, 7” deep from the surface | LVDT1 ─ Deep<br>LVDT2 ─ Shallow<br>LVDT3 ─ Shallow<br>LVDT4 ─ Deep |
| 39-110 | DYN10 ─ Transverse<br>DYN11 ─ Longitudinal<br>DYN12 ─ Transverse<br>DYN13 ─ Longitudinal<br>DYN14 ─ Transverse<br>DYN15 ─ Longitudinal | DYN10 to DYN15 are located at bottom of AC, 7” deep from the surface | LVDT1 ─ Deep<br>LVDT2 ─ Shallow<br>LVDT3 ─ Shallow<br>LVDT4 ─ Deep |
| | DYN16 ─ Longitudinal<br>DYN17 ─ Longitudinal<br>DYN18─ Longitudinal | These three strain gauges are installed at the bottom of ATB, at 11” deep from the surface | |

[1] The deep referenced LVDT is anchored at 10 ft depth from the surface

[2] The shallow referenced LVDT is anchored at bottom of base layer for each section from the surface

Source: Report No. FHWA/OH-94/019

### 2.5.2 SPS-2 Sections

Two projects with instrumented test sections were included as a part of the SPS-2 experiment in Ohio and in North Carolina. Four sections (0201, 0205, 0208, and 0212) at each of the sites have been instrumented with strain gauges and LVDTs (Linear Variable Differential Transformers) for measurement of longitudinal strains and vertical deflections, respectively, of the PCC slab. Instrumentation was installed in 2 slabs in the transition zone of each section. The design features of the four sections are summarized in Table 2-13. A brief description of the DLR experiments in Ohio and North Carolina follows.

#### *Ohio DLR Sections*

The longitudinal strain in the PCC slab and the vertical deflection of the PCC slab are the structural response parameters that are measured in the experiment using embedded strain gauges and LVDTs, respectively. The details of the instrumentation setup are described below. Information about the set-up of the experiment has been obtained from reports “Development of an instrumentation plan for the Ohio SPS test pavement”, “Coordination of load response instrumentation of SHRP pavements- Ohio university” and “Continued Monitoring of Instrumented Pavement in Ohio” [6] apart from the data (Release 17 of DataPave).

*Setup of strain gauges*

In the Ohio sections, strain gauges were installed to measure longitudinal strain along the wheel path at 25.4 mm from the top and 25.4 mm from the bottom of the PCC slab. Figure 2-4 is the plan view showing the locations of strain gauges. The numbering used for strain gauges in the LTPP data has been used in this report**.** The spatial coordinates of the gauge locations are summarized in Table 2-14. Figure 2-5 is a sketch showing the locations of the strain gauges in cross-section.

*Setup of LVDTs*

LVDTs (Linear Variable Differential Transformers) were used to measure the vertical deflection of the PCC slab. Two types of LVDTs have been installed: shallow-reference and deep-reference. The shallow-reference LVDTs have their reference in the subgrade layer while the deep-reference LVDTs are founded in the roadbed soil. The LVDTs that are located at the edge of the slab have been anchored in the shoulder. Deep-reference LVDTs give ‘total’ deflections as they are referred to a depth where measurable deflections are not likely and shallow-reference LVDTs represent the difference in deflection between pavement surface and the depth of the anchor. The shallow-reference LVDTs are the ones that give deflections that are nearer (magnitude-wise) to deflections of the slab. The locations of the various LVDTs in the plan view, according to DataPave are shown in Figure 2-6.

*Test setup*

The testing procedure adopted for SPS-1 and SPS-2 sections is identical. Two types of trucks, a single-axle and a tandem-axle, were used to ‘load’ the sections. On each testing day, twelve runs were made by each of the trucks by varying speed and loading for different runs. The rear load of the single-axle truck was 80.3 kN or 98.1 kN, while the total load on the tandem-axle dump truck was 142.7 kN or 187.3 kN, respectively, for different runs. For the same rear axle load, the speeds of the truck varied between 50, 65 and 80 km/hr. The trucks were run such that the right rear tires either pass over or straddle the sensors.

Table 2-13 Design details of instrumented sections

| Section ID | PCC slab details | | Base Course details | Drainage |
|---|---|---|---|---|
| | Thickness, mm | Average 14-day flexural strength, MPa | | |
| 0201 | 203 | 3.8 | 152 mm DGAB | No |
| 0205 | 203 | 3.8 | 152 mm LCB | No |
| 0208 | 279 | 6.2 | 152 mm LCB | No |
| 0212 | 279 | 6.2 | 102 mm PATB over 102 mm DGAB | Yes |

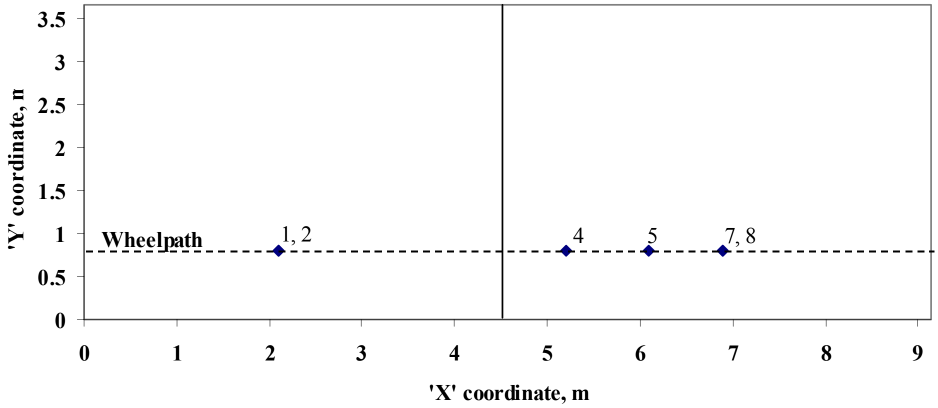


Figure 2-4 Plan view of locations of strain gauges

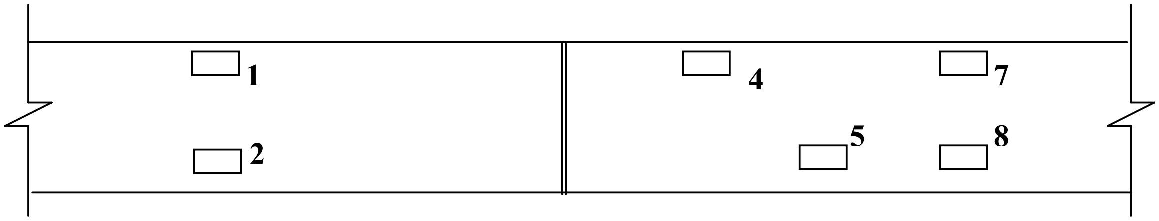


Figure 2-5 Slab cross-section at wheel path showing typical strain gauge locations

Table 2-14 Spatial locations of strain gauges in the PCC slabs

| Gauge ID | 'X'$^+$ coordinate, m | 'Y'$^+$ coordinate, m | 'Z'$^+$ coordinate, mm |
|---|---|---|---|
| DYN1 | 2.1 | 0.8 | 25.4 (from top) |
| DYN2 | 2.1 | 0.8 | 25.4 (from bottom) |
| DYN4 | 5.2 | 0.8 | 25.4 (from top) |
| DYN5 | 6.1 | 0.8 | 25.4 (from bottom) |
| DYN7 | 6.9 | 0.8 | 25.4 (from top) |
| DYN8* | 6.9 | 0.8 | 25.4 (from bottom) |

* In section 0208 the gauge is in the top one-inch of the PCC slab, $^+$ 'X' is the distance along the traffic from the entry slab corner; 'Y' is the distance from the longitudinal joint; and 'Z' is the depth-wise location

### North Carolina DLR

In addition to the embedded strain gauges and LVDTs, surface-mounted strain gauges were instrumented in the DLR test sections of North Carolina. The details of the instrumentation setup are as follows. Information about the set-up of the experiment has been obtained from “Pavement Instrumentation Program for SPS-2 Experiments Instrumentation Details” (April 1994), apart from the data (Release 17 of DataPave).

#### *Setup of strain gauges*

The embedded strain gauges were installed to measure longitudinal strains in the PCC slab. Three gauges at the mid-slab edge location and one gauge at the mid-slab wheel path location were installed in one slab of each of the instrumented sections (see Figure 2-7).

The surface-mounted gauges were installed at the slab surface at mid-slab edge (about 25.4 mm from edge) and mid-slab wheel path locations. Twelve surface-mounted gauges were installed in each instrumented section before testing and were later removed after the completion of the test. Figure 2-8 shows of the locations of surface-mounted gauges in plan view.

#### *Setup of LVDTs*

Two types of LVDTs have been installed in the NC DLR sections; one for the measurement of subgrade deflections and another for measurement of PCC slab deflections. The LVDTs installed for measuring deflections of PCC slab have been considered in this study. Figure 2-9 illustrates in plan the locations of the 8 LVDTs installed in these sections. The LVDTs were installed at corner, mid-slab edge and mid-slab wheel path locations of both the instrumented slab panels in each test section.

#### *Testing setup*

The testing procedure adopted for NC DLR experiment is similar to the one adopted for the OH DLR experiment. Two types of trucks, a single-axle and a tandem-axle, were used to ‘load’ the sections. On a typical testing day, the rear axle of each truck was loaded to a certain pre-determined level and the sections were tested with the trucks at various speeds. The single-axle truck was loaded with 79.1 kN or 89 kN. The tandem-axle truck was loaded with 142.4, 160.3, or 168.2 kN, respectively. For a particular load level, speeds varied between 48, 64 and 80 km/ hr. The trucks were run such that the right rear tires either pass over or straddle the sensors.

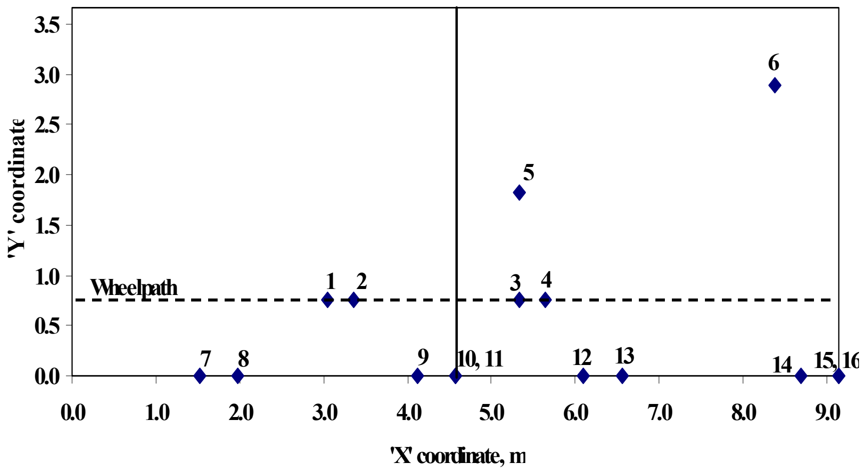


Figure 2-6 Location of LVDTs (plan-view, OH)

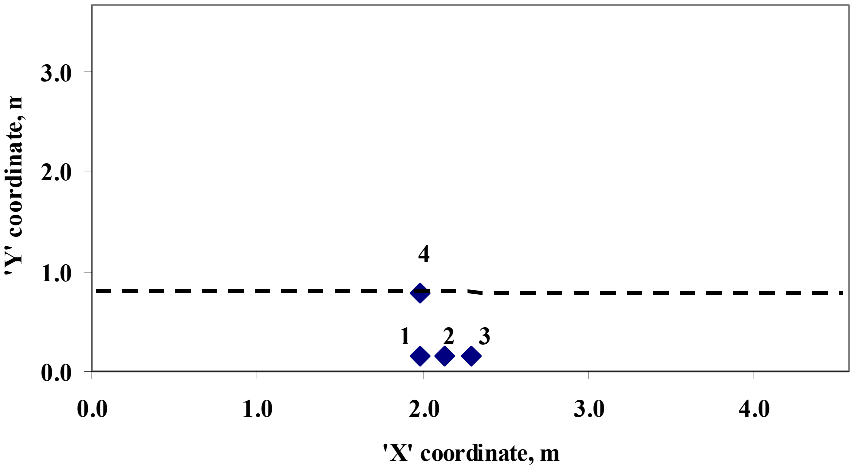


Figure 2-7 Strain gauge location (plan view, NC)

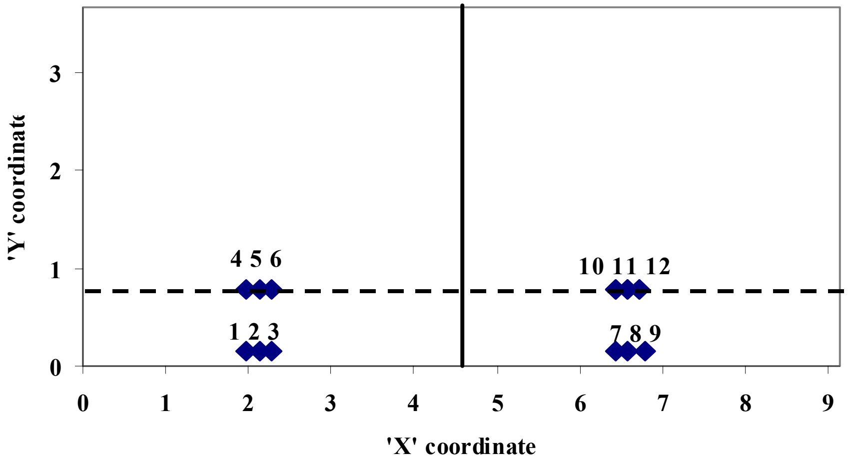


Figure 2-8 Location of surface-mounted strain gauges (NC)

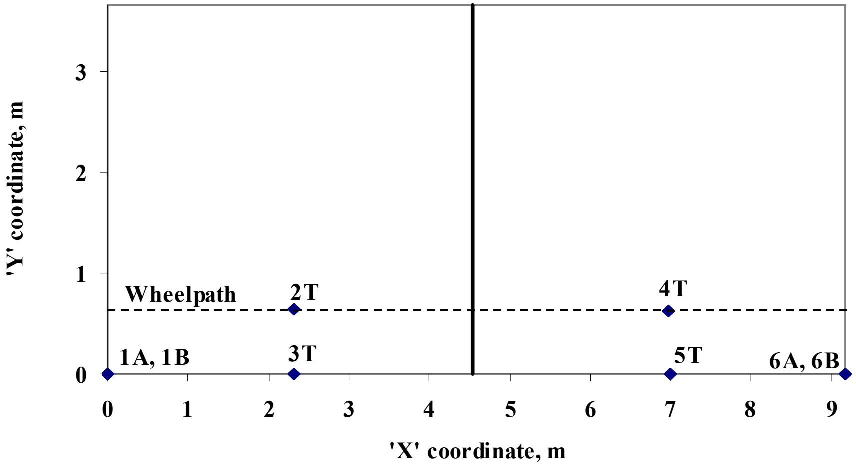


Figure 2-9 Location of LVDTs (plan view, NC)

# CHAPTER 3 - DATA AVAILABILITY AND EXTENT

## 3.1 INTRODUCTION

This chapter presents a summary on the available data and extent of various performance measures for SPS-1, SPS-2 and SPS-8 experiments. For this study DataPave (Release 17, January 2004) was the primary data source. However, data from previous releases and other sources were used only to supplement the level E data from Release 17. The construction information of each site was obtained from the construction reports. The essential data required for this study can be broadly classified into following categories:

- Site Information: site information, construction issues, climatic and traffic data.
- Material Data: Material type and properties for various bound and un-bound pavement layers.
- Pavement Structure: Layer type and thickness information and other design features such as lane width, shoulder type and dowel bar diameter etc.
- Monitoring Data: Longitudinal and transverse profiles, distress and deflections (FWD).
- Dynamic Load Response Data: Response data for instrumented sections.

## 3.2 IDENTIFICATION OF DATA ELEMENTS

The relevant variables contained in the SPS-1, SPS-2 and SPS-8 experiments can be divided into: (1) dependent variables, and (2) independent variables.

The dependent variables are those used to describe pavement response and performance. Measures of pavement response are those measures that do not cumulate with time. The bulk of pavement responses in these experiments are surface deflections from Falling Weight Deflectometer (FWD) testing. For flexible pavements, FWD testing is conducted in the wheel path and outside the wheel path. For rigid pavements, FWD testing is done at several locations on the PCC slab (see Figure 2-3). Other pavement responses collected in the SPS-1 and SPS-2 experiments include strain data and vertical deflections at various depths. These measurements are only available from the instrumented sections in the Dynamic Load Response (DLR) experiments.

Measures of pavement performance are those that cumulate with time (e.g., alligator cracking in flexible pavements). These are collected using both manual and automated surveys.

The independent variables are those that describe the 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 respective SPS experiments (e.g., base type). Whereas, the variables that have potential impacts on pavement response and performance but are not controlled in the experiment design were considered as exogenous variables. 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 zones in the matrix.

Table 3-1and Table 3-2 list the relevant independent and dependent variables identified for flexible (SPS-1 and SPS-8) and rigid (SPS-2 and SPS-8) pavements, respectively. After the identification of the relevant variables, a relational database was developed for this research. The development of database is briefly discussed next.

Table 3-1 Categorized list of variables for flexible pavements (SPS-1 and SPS-8)

| Factor | Factors |
|---|---|
| Environmental Factors | No. of days with Freezing Temperature<br>No. of days with temperature>32$^{o}$C<br>Annual No. of days with precipitation<br>Annual No. of days with high precipitation<br>Avg. Annual No. of FT cycles<br>**FI, Degrees-Days**<br>**Avg. Annual Precipitation**<br>**Environmental Zone**<br>Avg. Max Temperature, $^{o}$C, Avg. Min Temperature, $^{o}$C, Avg. Temperature Range, $^{o}$C |
| Asphalt Concrete Material Properties | AC Grade<br>**Target AC Thickness, mm**<br>***Thickness deviations, mm***<br>AC Back calculated Resilient Modulus<br>AC Indirect Tensile Strength after $M_R$ Test, kpa<br>AC Indirect Tensile Strength Prior to $M_R$ Test, kpa<br>AC Instantaneous Resilient Modulus at 5, 25 and 40 $^{o}$C, MPa<br>AC Total Resilient Modulus at 5, 25 and 40 $^{o}$C, MPa<br>Bulk Specific Gravity of AC Mix<br>Water absorption for AC mix aggregate<br>AV%<br>AC%<br>AC mix gradation (all sieves)<br>AC viscosity at 60 $^{o}$C |
| Aggregate Base Material Properties | **Target base thickness, mm**<br>***Thickness deviations, mm***<br>**Type of base (GB, TB, PATB)**<br>Granular base Compaction (Max. density and OMC)<br>Base back calculated resilient modulus<br>Avg. Lab based granular base resilient modulus<br>Base gradation (all sieves)<br>Atterberg Limits (LL, PL, PI) |
| Subgrade Material Properties | **Subgrade soil type**<br>Subgrade Compaction (Max. density and OMC)<br>Subgrade back calculated resilient modulus<br>$K_1$ ,$K_2$ and $K_5$ parameters from the resilient modulus testing for subgrade<br>Avg. Lab based granular base resilient modulus<br>Subgrade gradation (all sieves)<br>Atterberg Limits (LL, PL, PI)<br>Embankment heights (cut or fill) |
| Traffic/Age | Cumulative Annual Traffic in KESALs<br>***Average Annual Traffic in KESALs***<br>***Age, Years*** |
| Performance | **Alligator Cracking (fatigue)**<br>**Transverse Cracking**<br>**Longitudinal Cracking in WP and NWP**<br>Bleeding<br>Raveling<br>**Roughness (IRI)**<br>**Rutting** |
| Response | **Deflections**<br>**Various Deflection Basin Parameters**<br>**Strains (DLR)** |

Note: The variables in bold are the potential main factors (independent variables) and performance/response (dependent variables). The variables in italics were considered as exogenous factors.

Table 3-2 Categorized list of variables for rigid pavements (SPS-2 and SPS-8)

| Factor | Factors |
|---|---|
| Environmental Factors | No. of days with Freezing Temperature<br>No. of days with temperature>32°C<br>Annual No. of days with precipitation<br>Annual No. of days with high precipitation<br>Avg. Annual No. of FT cycles<br>**FI, Degrees-Days**<br>**Avg. Annual Precipitation**<br>**Environmental Zone**<br>Avg. Max Temperature, °C, Avg. Min Temperature, °C, Avg. Temperature Range, °C |
| Concrete Material Properties | **Target PCC Thicknesses, mm**<br>***Thickness deviations, mm***<br>**PCC Flexure Strength, psi**<br>**PCC Compressive Strength, psi**<br>PCC Splitting Tensile Strength, psi<br>PCC Mix gradation (all sieves) |
| Aggregate Base Material Properties | **Target base thickness, mm**<br>***Thickness deviations, mm***<br>**Type of base (GB, TB, PATB)**<br>Granular base Compaction (Max. density and OMC)<br>Base back calculated resilient modulus<br>Base gradation (all sieves)<br>Atterberg Limits (LL, PL, PI) |
| Subgrade Material Properties | **Subgrade soil type**<br>Subgrade Compaction (Max. density and OMC)<br>Subgrade back calculated resilient modulus<br>Subgrade gradation (all sieves)<br>Atterberg Limits (LL, PL, PI)<br>Embankment heights (cut or fill) |
| Traffic/Age | Cumulative Annual Traffic in KESALs<br>*Average Annual Traffic in KESALs*<br>*Age, Years* |
| Performance | Map Cracking<br>**Transverse Cracking**<br>**Longitudinal Cracking in WP and NWP**<br>Longitudinal Spalling<br>Transverse Spalling<br>Pumping<br>**Faulting**<br>**Roughness (IRI)**<br>Rutting |
| Response | **Deflections**<br>**Various Deflection Basin Parameters**<br>**Strains (DLR)** |

Note: The variables in bold are the potential main factors (independent variables) and performance/response (dependent variables). The variables in italics were considered as exogenous factors.

The data used in this study are “Level E” data from the NIMS database (Release 17.0) for SPS-1, SPS-2 and SPS-8 experiments. All data were extracted from the Release 17.0 CD. The DLR data contained in the DataPave 3.0 database is insufficient and/or inadequate for the analysis.

The flowchart describing the process of data extraction from the DataPave Release 17.0 is shown in Figure 3-1. The database has been set up such that the linkage between different data elements is preserved. This was done using ACCESS$^{TM}$, EXCEL$^{TM}$ and SPSS$^{TM}$ software. This relational database allows for describing the data in different ways by combining various factors according to the specific objective of the particular analysis at hand. Tables and figures produced and presented in the data availability section for all experiment designs are example outcomes of this data structure.

For cases where multiple data values were available for a data element, the values were averaged to obtain a best estimate. For example, IRI values were averaged over several runs for each section and for a particular date. Deflection measurements were averaged for several load levels for a particular test date.

To complement/cross-check the inventory data available in Release 17.0, construction reports for all sections within the SPS-1, -2 and -8 experiments were obtained.

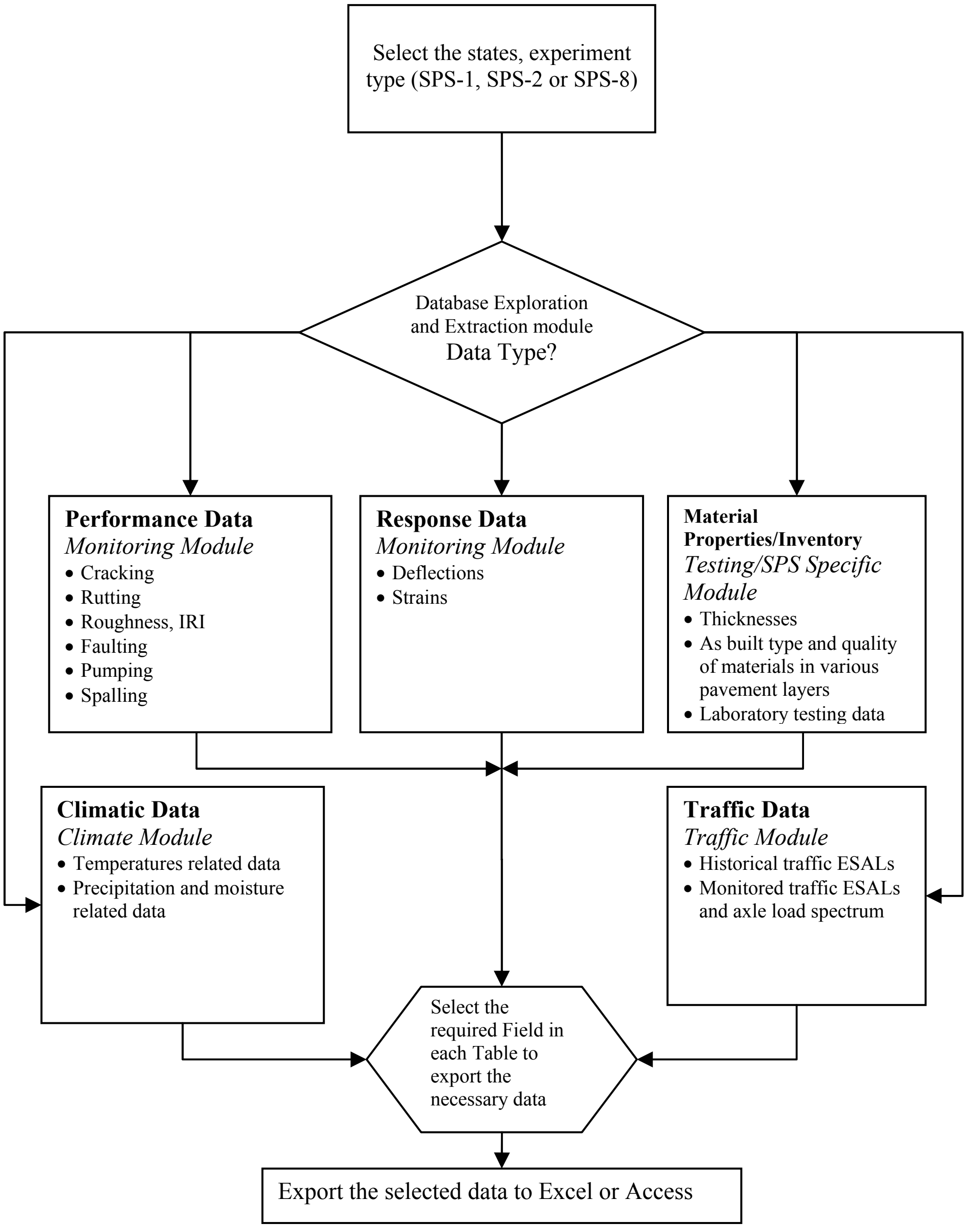


Figure 3-1 Data Extraction Process Flow Chart

The construction reports were reviewed for the purpose of obtaining additional detailed information on construction and design features. They also include problems encountered during construction of the SPS pavement sections. Some of these problems have been highlighted in this Chapter. The reports were useful in confirming/disproving conflicting information as well as identifying and explaining some anomalies in the performance.

After extraction of all relevant data elements and building the analysis database, the data were reviewed to determine:

- the availability of main (design and construction) factors and exogenous (confounding) factors in the identified data element tables,
- the availability and extent of response and performance data,
- the variability of response and performance measures, and
- the variability of the main and exogenous factors.

The sections below present the details of the information on the availability and extent of these variables for SPS-1, SPS-2 and SPS-8 experiments, respectively.

## 3.3 DATA AVAILABILITY IN SPS-1 EXPERIMENT

Table 3-3 presents the overall availability of the relevant data elements within the SPS-1 experiment in Release 17.0 of DataPave. This includes both the main design and construction factors as well as other exogenous factors such as traffic, material, and environmental data. The data is presented as a percentage of the total number of sections for the main factors, while for the exogenous factors, data is expressed as a percentage of the total number of sites (states) included in the experimental design matrix.

The table shows that the data availability for the main factors is high, while that of the exogenous factors is somewhat lower. In particular, the availability of traffic data (61% for monitored data and 50% for estimated/historical data) is lower than expected and should be improved. It should be noted that traffic estimates from construction reports are available for all but one site [MI (26)]. The availability of relevant data elements is discussed in detail in the subsequent sections.

Table 3-3 Summary of SPS-1 data elements availability

| **Data Category** | **Data Type** | **Data Availability, %** |
|---|---|---|
| Site Information | *Construction Reports* | 94 |
| | *Climatic data* | |
| | Virtual Weather Station | |
| | Annual Temperature | **100** |
| | Annual Precipitation | **100** |
| | Automatic Weather Station | |
| | Monthly Temperature | 83 |
| | Monthly Precipitation | 83 |
| | *Traffic data* | |
| | Traffic Open date | **100** |
| | Estimated ESALs | **50** |
| | Monitored ESALs | **61** |
| | Axle Load Spectrum | **72** |
| Material Data | *Asphalt Layer* | |
| | Core Examination | 99 |
| | Bulk Specific Gravity | 89 |
| | Max Specific Gravity | 42 |
| | Asphalt Content | 56 |
| | Asphalt Resilient Modulus | 15 |
| | Penetration | 49 |
| | Viscosity | 48 |
| | Asphalt Specific Gravity | 47 |
| | Aggregate Gradation | 56 |
| | Fine Aggregate Particle Shape | 26 |
| | Layer Thickness | **100** |
| | Unbound Base Gradation | 20 |
| | *Subgrade* | |
| | Subgrade Gradation | 44 |
| | Atterberg Limits | 56 |
| | Subgrade Modulus | 51 |
| Pavement Structure | *Layer details* | |
| | Type | **100** |
| | Representative thicknesses | **100** |
| | Constructed thicknesses | 94 |
| | *Shoulder information* | |
| | Type | 86 |
| | Width | 86 |
| | Thickness | 86 |
| Monitoring** | *FWD data* | |
| | Deflections | **100** |
| | Temperature at Testing | 99 |
| | Backcalculated Moduli | 6 |
| | *Manual Distresses data* | **100** |
| | *Longitudinal Profile (IRI)* | **100** |
| | *Transverse Profile (Rut Depth)* | **100** |

Note: ** Data is said to be available for a section even if it is available for one survey.

### 3.3.1 General Site Information

This section of the report presents the summary of the site identification and location, construction report availability and important dates associated with each of the SPS-1 projects. Also the details of other factors such as climate and traffic, which pertain to a particular site in the SPS-1 experiment, will be discussed in this section.

*Construction Reports*

The construction reports have been prepared for each site by the supervisory consultant on the project. These documents contain the details of the construction process from conception to the completion. In addition, these reports presents information on the geometric layout of various sections within a site, construction issues (deviations from the guidelines, if any), traffic, environmental conditions during the construction and material quality control data. These reports are available for all the sites in the SPS-1 experiment except MI (26). A summary of the construction issues at each of 18 sites is given in Appendix A1. These construction issues can be helpful in explaining any poor performance at a particular site.

*Climate Data*

The climate data were essentially used in defining boundaries between various climatic regions. The *average annual rainfall* for each site is considered as discriminating variable between "wet" and "dry" regions, whereas, *average annual freezing index* is used to locate each site in "freeze" and "no-freeze" regions. The climate data is available form two sources in LTPP database— Automatic Weather Stations (AWS) and Virtual Weather Stations (VWS). The AWS data are collected by a weather station installed at each of SPS-1 experiment site. AWS data for three sites; NV (32), OH (39) and WI (55) are not available in the Release 17.0 of the database. The VWS data are collected from the existing weather stations in the vicinity of a specific site in the SPS-1 experiment. Climate data for all the sites are available from VWS. Therefore, in DataPave, the climate data from VWS have been used to classify each site in a particular climate region/zone.

### *Traffic Data*

Heavy truck traffic plays a vital role in determining the level of performance in flexible pavements. The traffic data in terms of ESALs per year was obtained from different sources. These sources can be summarized as;

- IMS Database: The LTPP IMS database contains traffic data in the following forms;
    - Monitored Data—data obtained from weigh-in-motion equipment installed at each SPS-1 site.
    - Estimated Data—data obtained from the DOT's based on their best estimates from the previous history of the highway section.
    - Axle Load Spectrum—data obtained from the axle weight data; this is essentially similar to monitored data.

The lack of traffic data for various states in the LTPP database has given rise to the quest for reasonable traffic estimates for the missing states. Therefore, other sources were explored, including:

- Construction Reports—the estimated design ESALs were taken from construction reports for all the states in the SPS-1 experiment.
- FHWA VTRIS database—this was used for estimating the average truck factors for each site, once the ADTT is known from the construction reports, the ESALs per year were estimated for a particular site.
- Previous Studies—the available studies on SPS-1 [1, 2] were also used to extract traffic information.

Finally, the ESALs per year were estimated by combining the information from all the sources and confidence levels were assigned to the quality of available traffic data. Table 3-4 summarizes the traffic data availability for all the states within the SPS-1 experiment. The importance of traffic data can not be ignored in pavement design and analysis; however; in this research only the traffic estimate is required to neutralize its effects between different sites.

Traffic opening date is the date on which a newly constructed project was opened to traffic. This data is available in the database for all sites. The age of a section has been calculated using traffic opening date and corresponding last survey date.

Table 3-4 KESAL per year for SPS-1 Experiment

| State | Code | KESALs per year | | | | | | Summary Statistics | | | | **Proposed** | Confidence Level | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | LTPP | | | Other Sources | | | | | | | | | |
| | | Monitored | Estimated | Axle Spectrum | Const. Reports | FHWA-RD-01-166 | NCHRP-499 | Mean | Median | Std | CoV | | | |
| Alabama, AL | 1 | - | - | - | 237 | 237 | - | 237 | 237 | - | - | **237** | Low | Taken from Construction Report |
| Arizona, AZ | 4 | 236 | 277 | 160 | 185 | 185 | 250 | 214 | 211 | 52 | 24% | **214** | High | Mean value of first four columns |
| Arkansas, AR | 5 | 332 | 959$^*$ | 438 | 170 | 170 | 420 | 475 | 385 | 341 | 72% | **385** | Med. | Median value is adopted by ignoring Const. Report and Estimated |
| Delaware, DE | 10 | - | 414 | - | 203 | 203 | 440 | 309 | 309 | 149 | 48% | **309** | Low | Mean of Const. Report and Estimated |
| Florida, FL | 12 | 464 | - | 448 | 530 | 1463$^*$ | 460 | 481 | 464 | 44 | 9% | **464** | High | Median value of first four columns |
| Iowa, IA | 19 | 29$^*$ | 171 | 133 | 130 | 130 | 150 | 116 | 132 | 61 | 52% | **132** | Med. | Median value by ignoring monitored |
| Kansas, KS | 20 | 203 | 241 | 200 | 268 | - | 250 | 228 | 222 | 33 | 14% | **228** | High | Mean value of first four columns |
| Louisiana, LA | 22 | - | - | - | 524 | 524 | - | 524 | 524 | - | - | **524** | Low | Only Const. Report |
| Michigan, MI | 26 | 77 | - | 189 | - | - | 70 | 133 | 133 | 79 | 59% | **189** | Med. | Only from Axle Load Spectrum |
| Montana, MT | 30 | - | - | 81 | 174 | - | - | 127 | 127 | 66 | 52% | **127** | Med. | Mean value of first four columns |
| Nebraska, NE | 31 | 111 | 136 | 87 | 119 | 119 | 100 | 113 | 115 | 21 | 18% | **113** | High | Mean value of first four columns |
| Nevada, NV | 32 | 525 | 492 | 323 | 560 | 799 | 540 | 475 | 509 | 105 | 22% | **475** | High | Mean value of first four columns |
| New Mexico, NM | 35 | 147 | 150 | 125 | 393 | 393 | 150 | 204 | 149 | 127 | 62% | **149** | High | Ignore Const. Report |
| Ohio, OH | 39 | 390 | - | 380 | 507 | - | 70 | 426 | 390 | 71 | 17% | **390** | High | Median value of first four columns |
| Oklahoma, OK | 40 | - | - | - | 281 | 280 | - | 281 | 281 | - | - | **281** | Low | Only Const. Report |
| Texas, TX | 48 | - | - | - | 1000 | 10 | - | 1000 | 1000 | - | - | **360** | Low | *Using construction report traffic data & TF from FHWA |
| Virginia, VA | 51 | 257 | 917$^*$ | 187 | | - | 330 | 454 | 257 | 403 | 89% | **257** | High | Ignore Estimated value |
| Wisconsin, WI | 55 | - | - | 134 | 189 | - | - | 161 | 161 | 39 | 24% | **161** | Med. | Mean value of first four columns |

Note: * Data considered as outlier

### 3.3.2 Material Data

The data pertaining to various material related properties of various pavement layers in the construction of each pavement section have been categorized in material data. The data used in this research mainly include the material properties of the subgrade soil (passing #200 sieve and Atterberg Limits). These data were used to verify the subgrade soil classification (fine or coarse). However, in Release 17.0 of the DataPave this data is only available for 44% and 45% of the sections for soil gradation and plasticity index respectively. Therefore, the materials code available in the materials field was used to get the soil type for each section within SPS-1 experiment.

### 3.3.3 Design versus Actual Construction Review

The SPS-1 experiment is based on the fractional factorial design i.e., all the combinations between levels of various factors were not taken in the design factorial. However, the design matrix was populated with equal number of sites within each climatic zone. To ascertain the homogeneity of the planned experiment with actual sections in the field, in this section the site and structural factors will be compared between as-designed versus as-constructed. First a brief discussion on the construction issues will be presented, and then the deviations in the site and design features within the SPS-1 experiment will be presented.

*Construction Issues*

The construction guidelines as discussed in Chapter 2 were specified for each site within the experiment. However, there were some deviations and construction issues related to the some of the sites. This information was obtained from the construction reports. A brief site wise discussion on construction issues can be found in Appendix A1. Some of major construction issues which may have adverse effects on the pavement performance for some particular sites in SPS-1 experiment are summarized below.

For SPS-1 site in Kansas [KS (20)], it was mentioned in the construction report that:

- The contractor experienced several problems during construction, many of which were caused by the weather. The area experienced much higher than average precipitation during spring 1993, resulting in delays and a wet subgrade. To dry out the subgrade, the contractor was allowed to incorporate fly ash.

- During the FWD testing, high deflections were measured in the base in some areas.
- There was also segregation in the mix; these problems were "corrected" with adjustments in construction methods.

Similarly for Texas [TX (48)], it was found that most of the sections prematurely failed in rutting [3]. This rutting was attributed mainly to asphalt layers because of following reasons:

- Excessive asphalt content in the top layer.
- Change in the gradation of the aggregates without modifying the asphalt mix.

### *Site Factors*

The SPS-1 experiment design stipulates that a total of twenty four (24) similar designs will be replicated across eighteen (18) sites in the US. The experiment, designed in a factorial manner to enhance implementation practicality, permits the construction of 12 test sections (0101-0112 or 0113-0124) at one site with the complementary 12 test sections to be constructed at another site within the same climatic region on a similar subgrade type[4]. **Table 3-5** lists the intended sites in each subgrade type within the SPS-1 experiment [1, 2].

However, the LTPP IMS data (DataPave 3.0) shows that the sites within the SPS-1 experiment design are not balanced. This deviation was found to be mainly due to: (i) different cutoff values used for categorizing the "wet/dry" and "freeze/non-freeze" environments and, (ii) difference between geographical locations and particular climate at a specific site. The climatic data available for the sites were used to categorize sites into four (4) climatic zones according to LTPP definitions for the climatic zones. All the SPS-1 sites were appropriately classified. Figure 3-2 shows the scatter plot between rainfall and freezing Index (FI) for all sites in SPS-1 experiment.

The as-constructed location of the different sites is shown in Table 3-6. Further, it can be seen that there are more sites available in wet climate (8 and 6 in "freeze" and "no-freeze" respectively). There are only four sites in the dry climate (DF and DNF zones); the two sites present in DF zone are constructed on a coarse subgrade type. Therefore, the effect of subgrade type can not be determined in DF zone. These deviations are expected to affect the analysis (the experiment design will become unbalanced). Consequently, the analysis of the SPS-1 experiment design mainly focuses on the WF and WNF zones.

**Table** 3-5 **Intended SPS-1 site factorial** [1]

| Subgrade Type | **Wet** | | **Dry** | | Total |
|---|---|---|---|---|---|
| | **Freeze** | **Non-Freeze** | **Freeze** | **Non-Freeze** | |
| **Fine** | IA, OH | AL | KS | NM | 10 |
| | VA, MI | LA | NE | OK | |
| **Coarse** | DE | FL | NV | TX | 8 |
| | WI | AR | MT | AZ | |
| Total | 6 | 4 | 4 | 4 | 18 |

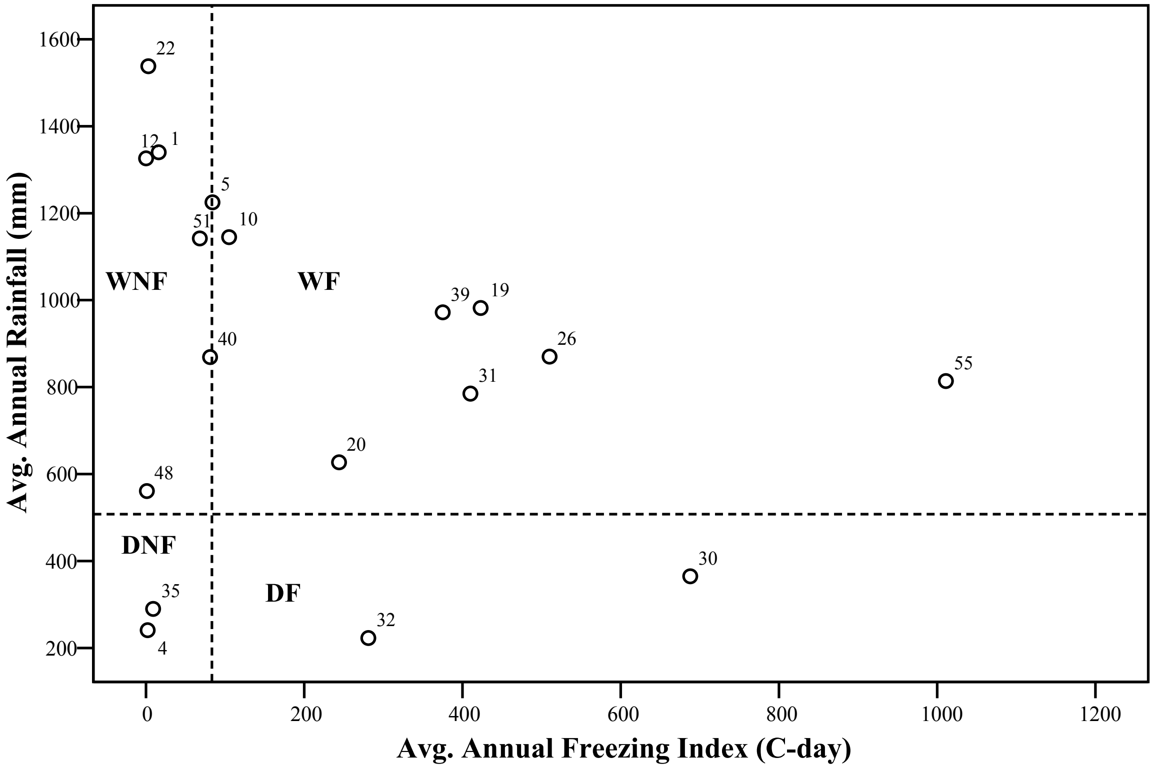


Figure 3-2 Scatter plot showing site distribution by climate

Table 3-6 SPS-1 site factorial — From DataPave 3.0

| Subgrade Type | **Wet**[a] | | **Dry**[b] | | Total |
|---|---|---|---|---|---|
| | **Freeze**[c] | **Non-Freeze**[d] | **Freeze** | **Non-Freeze** | |
| **Fine** | IA (19)<br>OH (39) | AL (1) | - | NM (35) | 9 |
| | KS (20)<br>MI (26)<br>NE (31) | LA (22)<br>VA (51) | - | - | |
| **Coarse** | DE (10) | FL (12)<br>TX (48) | NV (32) | - | 9 |
| | AR (5)<br>WI (55) | OK (40) | MT (30) | AZ (4) | |
| Total | 8 | 6 | 2 | 2 | 18 |

Note:

a. Wet Regions — Average Annual Rainfall > 20 inches (508 mm)
b. Dry Regions — Average Annual Rainfall < 20 inches (508 mm)
c. Freeze Regions — Average Annual Freezing Index > 83.3 °C-day (150 °F-day)
d. Non-Freeze Regions — Average Annual Freezing Index < 83.3 °C-day (150 °F-day)

*Design Factors*

The design or structural features which are considered to be the main experimental factors in the SPS-1 experiment are:

- AC Thickness (4 versus 7 inches)
- Base Thickness (8, 12 and 16 inches)
- Base Type (DGAB, ATB and ATB/DGAB)
- Drainage (No or Yes)

Each of the above features will be reviewed in this section to identify any deviation from the target values. The asphalt and base layers were targeted for 2 and 3 thickness levels respectively; however, the construction of these target values may contribute variability in these thicknesses. The amount of variability introduced by the construction and how this variability can affect the analysis will be discussed in this section.

**Layer Thickness**

The as-constructed asphalt and base thickness were compared with their respective target thickness. The results of this comparison are given below.

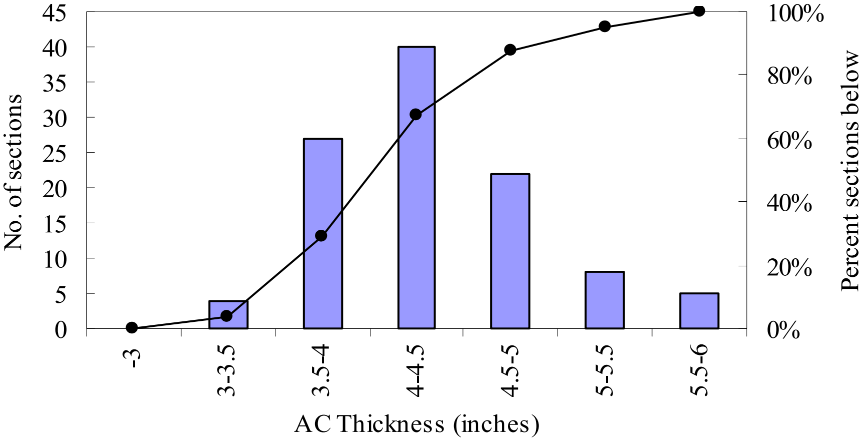
<u>AC Thickness</u>: The SPS-1 experiment has two levels of HMA surface thickness — 4-inch (102 mm) and 7-inch (178 mm). The allowable deviation from the target HMA surface thickness according to guidelines is 6.53 mm. Table 3-7 shows the summary statistics for each level of asphalt thickness. Among sections with target thickness of 102 mm, the as-constructed thicknesses between all 18 sites has a coefficient of variation (CoV) of 12.7% with about 43% of the sections within the allowable deviations and 49% sections having more asphalt thickness than the allowable upper limit. Only 7.5% of the sections have slightly less asphalt thickness than the allowable lower limit. Similarly, for the pavement designs which were targeted for 178 mm, the as-constructed asphalt thickness has a CoV of about 9% with about 78% of the sections meeting the tolerable limits or having higher asphalt thickness than the upper limit. The frequencies of as-constructed asphalt thickness are shown in Figure 3-3, whereas Figure 3-4 shows the scatter of asphalt thickness in different sites within the SPS-1 experiment. The overall low values of CoV for as-constructed asphalt thickness between all sites show that the asphalt thickness was quite well controlled during construction, especially for 7-inch (178 mm)target HMA surface thickness.

Base Thickness: The SPS-1 experiment has three levels of base thickness— 8-inch (203 mm), 12-inch (305 mm) and 16-inch (406 mm). The allowable deviation from the target base thickness according to guidelines is 12.7 mm. The summary statistics for as-constructed base thicknesses at each level are shown in Table 3-7. Among sections with target thickness of 203 mm, the as-constructed thicknesses between all 18 sites has a coefficient of variation (CoV) of 10.1% with about 65% of the section within the allowable deviations and 25.3% sections having more base thickness than allowable higher limit. Only 9.2% of the sections have slightly less thickness than allowable lower limit. Similarly, the designs which were targeted for 305 mm, the as-constructed thickness has a CoV of 4.7% with about 79% of the sections meeting the tolerable limits or either have higher thickness than the higher limit. The designs with targeted 406 mm of base thickness have a CoV of 4.6% with about 22% of the section having slightly less thickness than the lower limit. The frequencies and scatter plots of as-constructed base thicknesses are shown in Figure 3-5. The overall low values of CoV for as-constructed base thickness for all levels between all sites show that the base thickness was also quite well controlled during the construction.

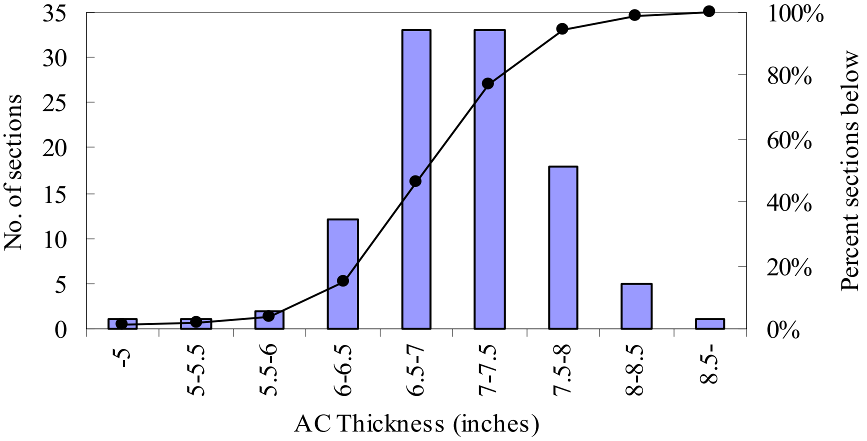
The variations between as-constructed and target thickness for asphalt and base within some sites have shown significant difference (see Figure 3-4 and Figure 3-5). This variation may affect the pavement performance for these sites; therefore, the deviations between target and actual thickness were taken as covariates in the analysis of variance.

Table 3-7 Summary of comparison between target and as-constructed layer thickness

| Pavement Layer / Target thickness | Count | Mean (inches) | Std | CoV (%) | Comparison with allowable deviation | | |
|---|---|---|---|---|---|---|---|
| | | | | | < Lower limit | With tolerable limit | > Upper limit |
| **AC Layer** | | | | | | | |
| 4-inch (102 mm) | 106 | 4.38 | 0.557 | 12.7 | < 3.75=7.5% | 3.75-4.25=43.4% | >4.25=49.1% |
| 7-inch (178 mm) | 106 | 7.12 | 0.654 | 09.2 | < 6.75=21.7% | 6.75-7.25=37.7% | >7.25=40.6% |
| **Base Layer** | | | | | | | |
| 8-inch (203 mm) | 87 | 8.26 | 0.84 | 10.1 | <7.50=9.2% | 7.50-8.50=65.5% | >8.50=25.3% |
| 12-inch (305 mm) | 89 | 11.9 | 0.56 | 04.7 | <11.5=21.3% | 11.5-12.5=66.3% | >12.5=12.4% |
| 16-inch (406 mm) | 36 | 15.9 | 0.74 | 04.6 | <15.5=22.2 | 15.5-16.5=61.1% | >16.5=16.7% |

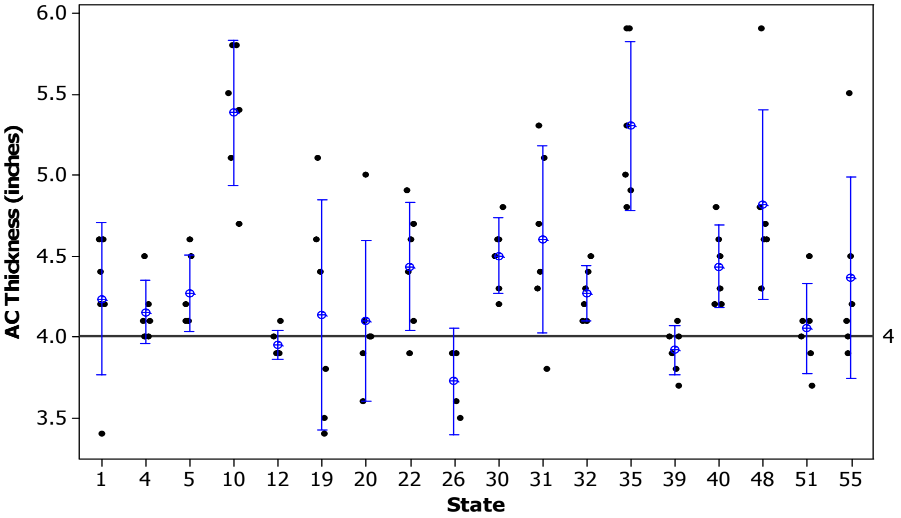


(a) Cumulative frequency for actual AC thickness— 4”target

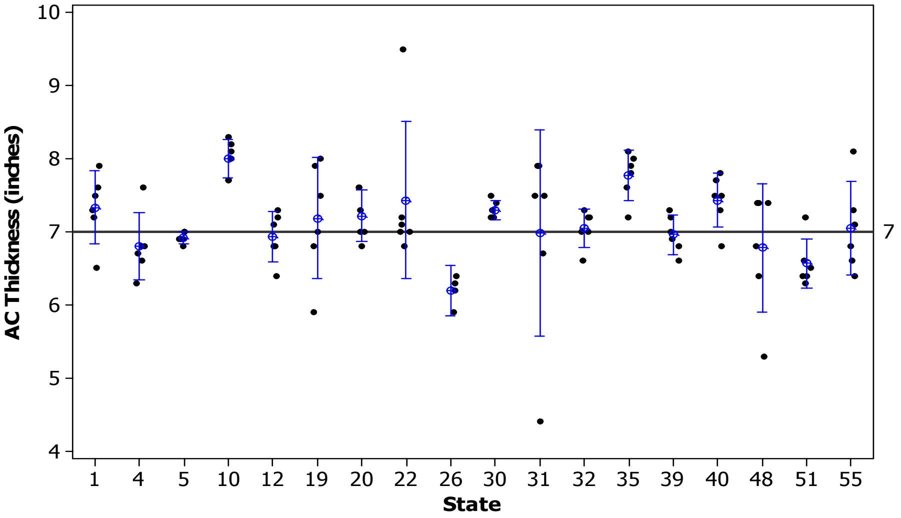


(b) Cumulative frequency for actual AC thickness— 7”target

Figure 3-3 Frequency plot for actual AC thickness

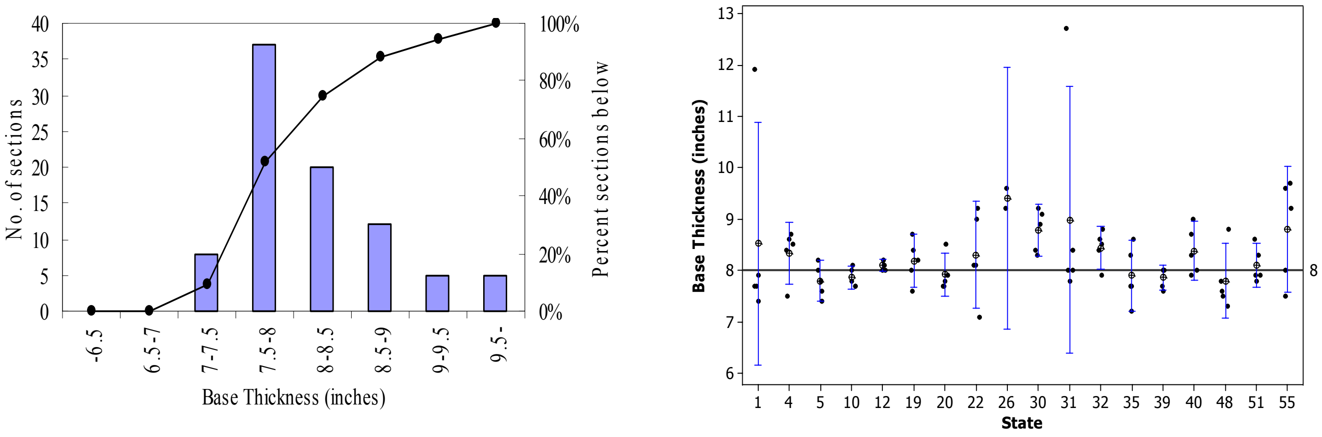


(a) Scatter plot of actual AC Thickness — 4”target



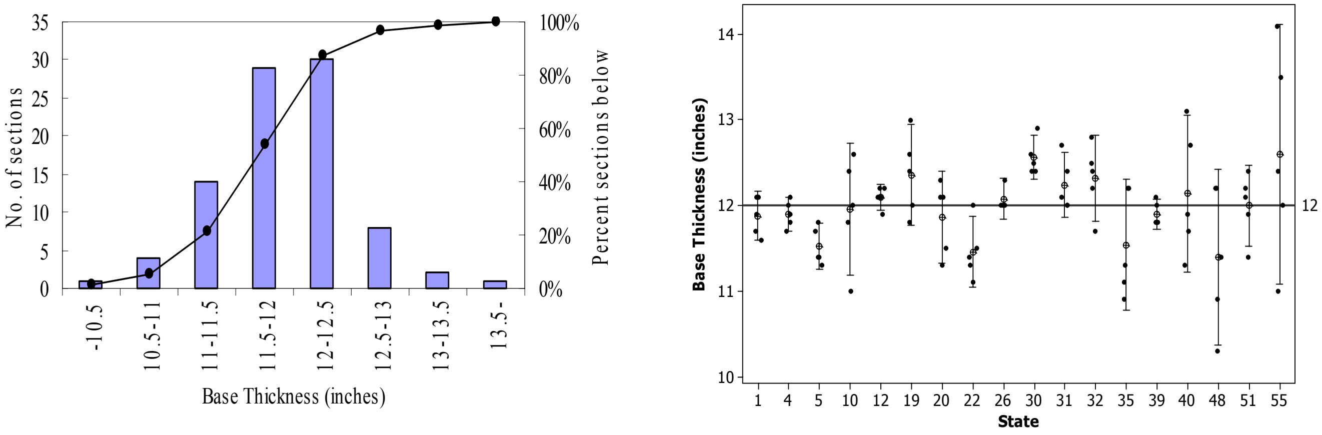
(b) Scatter plot of actual AC Thickness — 7”target

Figure 3-4 Scatter plot for actual AC thickness by site



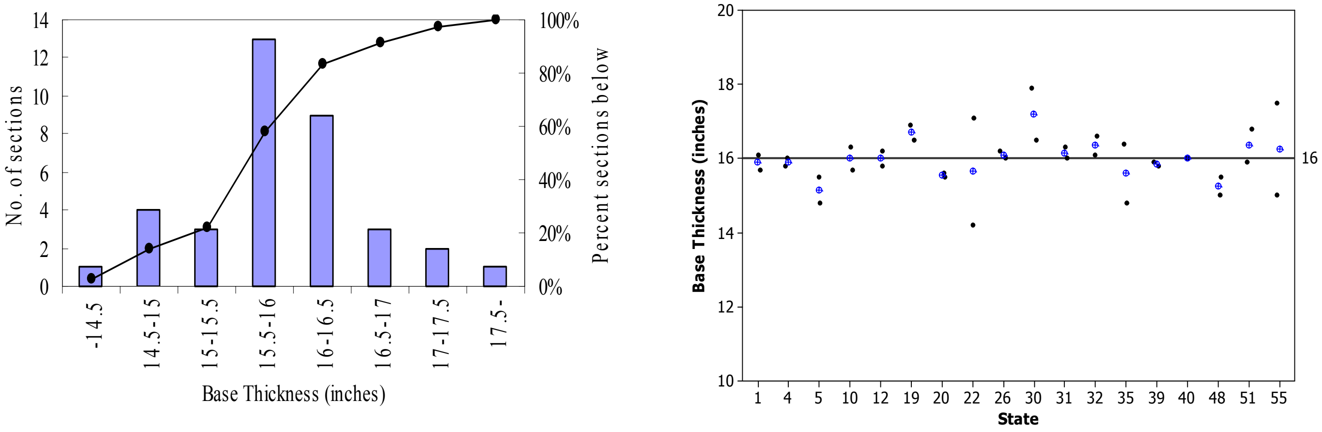
(a) Cumulative frequency for actual base thickness— 8”target

(b) Scatter plot of actual base Thickness — 8”target



(c) Cumulative frequency for actual base thickness— 12”target

(d) Scatter plot of actual base Thickness — 12”target



(e) Cumulative frequency for actual base thickness— 16”target

(f) Scatter plot of actual base Thickness — 16”target

Figure 3-5 Frequency and scatter plots for actual base thickness

### 3.3.4 Extent and Occurrence of Distresses

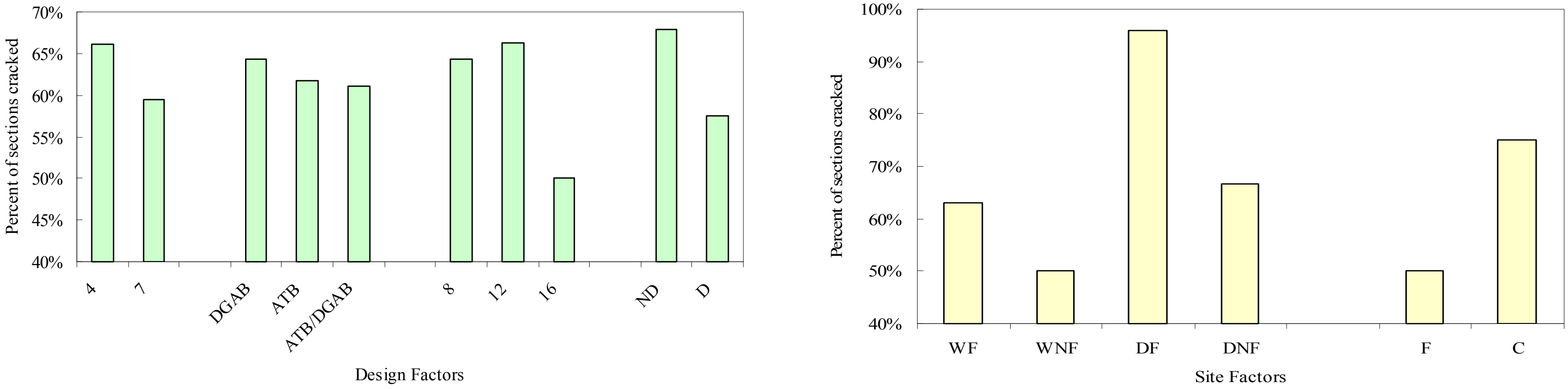
This section of the report presents the availability of the pavement performance data for all SPS-1 sites. The availability of the performance data will be discussed in terms of extent and occurrence of a particular performance measure. The pavement performance measures considered in this research include:

a. Fatigue cracking (total area, sq-m)
b. Longitudinal cracking-WP (length, m)
c. Longitudinal cracking-NWP (length, m)
d. Transverse cracking (length, m)
e. Rut depth (mm)
f. Roughness (IRI, m/km)

It should be noted that various severity levels of the first four distresses were simply added to calculate the total cracking area or length. The change in roughness ($\Delta IRI = IRI_{latest} - IRI_o$) was considered in the roughness analysis. The extent (mean distress) and occurrence (frequency of distress) are presented below for each performance measure based on data from DataPave (Release 17.0).

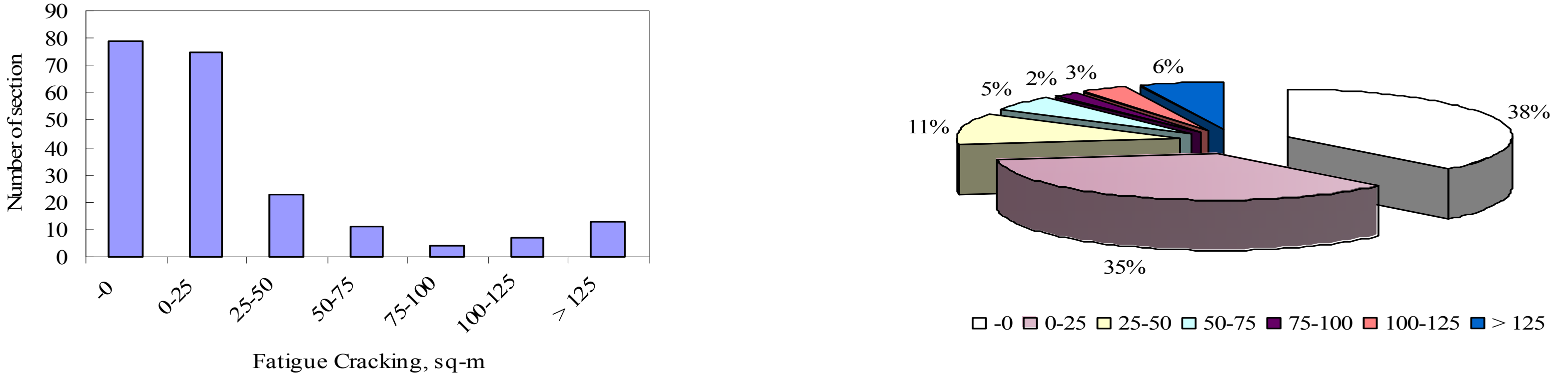
*Fatigue Cracking*

Figure **3-6** shows the occurrence of fatigue cracking in all SPS-1 sections by design and site factors. Based on the latest available data (Release 17.0), about 62% of the sections have exhibited some level of fatigue cracking whereas about 38% of the sections have not yet shown any signs of fatigue [see **Figure** 3-6 (d)]. Similarly, **Figure 3-7** presents the extent of fatigue cracking by design and site factors. The distribution of latest age for all sections is presented in Figure 3-8. It shows that about 10% of the sections can be considered as young (< 3 years), while the overall average for latest age of all sections is 6.5 years. Figure 3-9 shows the variation of fatigue cracking within each site of the SPS-1 experiment.



(a) Extent of occurrence of fatigue cracking by design factors

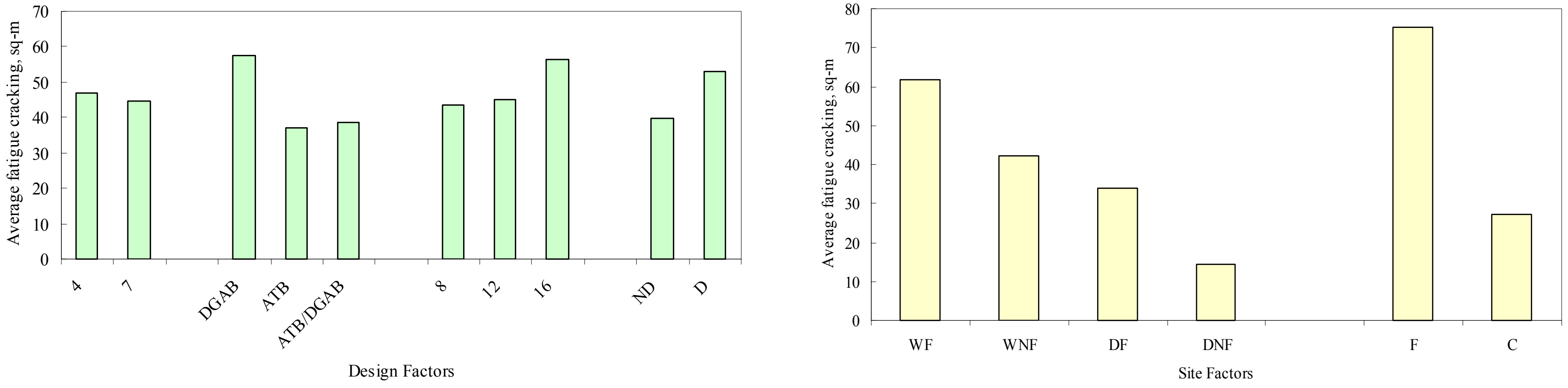
(b) Extent of occurrence of fatigue cracking by site factors



(c) Frequency of sections for fatigue cracking

(d) Distribution of sections for fatigue cracking

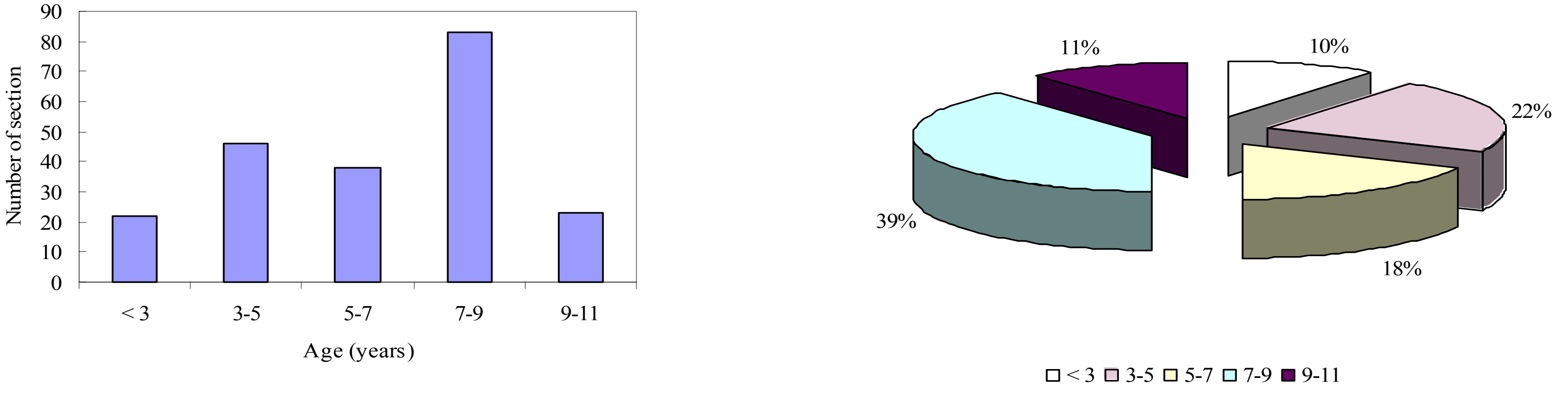
**Figure 3-6 Occurrence of fatigue cracking — SPS-1 experiment**



(a) Average fatigue cracking by design factors

(b) Average fatigue cracking by site factors

**Figure 3-7 Extent of fatigue cracking— SPS-1 experiment**



(a) Frequency of sections for latest age

(b) Distribution of sections for latest age

Figure 3-8 Age distribution of all cracking distresses — SPS-1 experiment

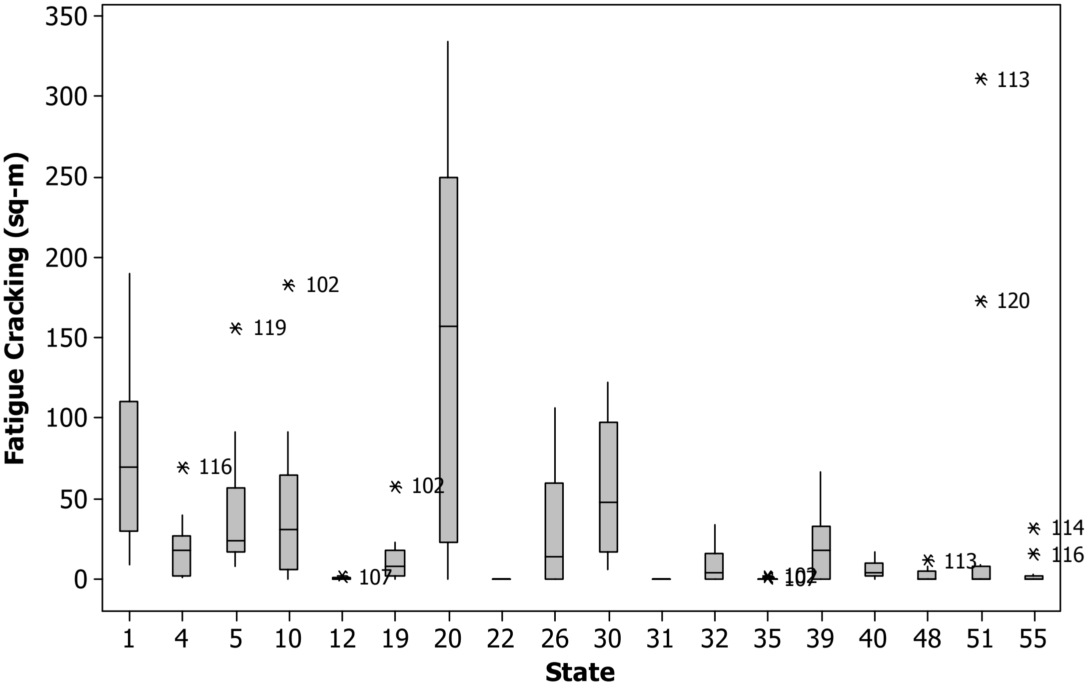


Figure 3-9 Fatigue cracking by site — SPS-1 experiment

*Longitudinal Cracking-WP*

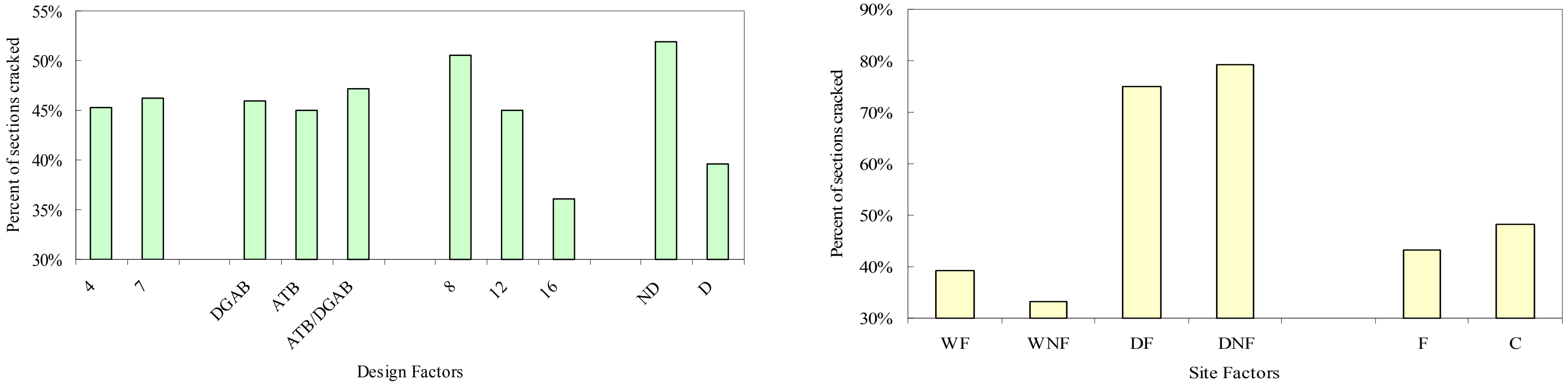
Figure 3-10 shows the occurrence of longitudinal cracking-WP in all SPS-1 sections by design and site factors. Based on the latest available data (Release 17.0), about 46% of the sections have exhibited some level of longitudinal cracking whereas about 54% of the sections have not yet shown any signs of cracking [see Figure 3-10 (d)]. Similarly, Figure 3-11 presents the extent of longitudinal-WP cracking by design and site factors. Figure 3-12 shows the variation of longitudinal cracking-WP within each site of the SPS-1 experiment.

*Longitudinal Cracking-NWP*

Figure 3-13 shows the occurrence of longitudinal cracking-NWP in all SPS-1 sections by design and site factors. Based on the latest available data (Release 17.0), about 68% of the sections have exhibited some level of cracking whereas about 32% of the sections have not yet shown any signs of cracking [see Figure 3-13(d)]. Similarly, Figure 3-14 presents the extent of longitudinal-NWP cracking by design and site factors. Figure 3-15 shows the variation of longitudinal cracking-NWP within each site of the SPS-1 experiment.

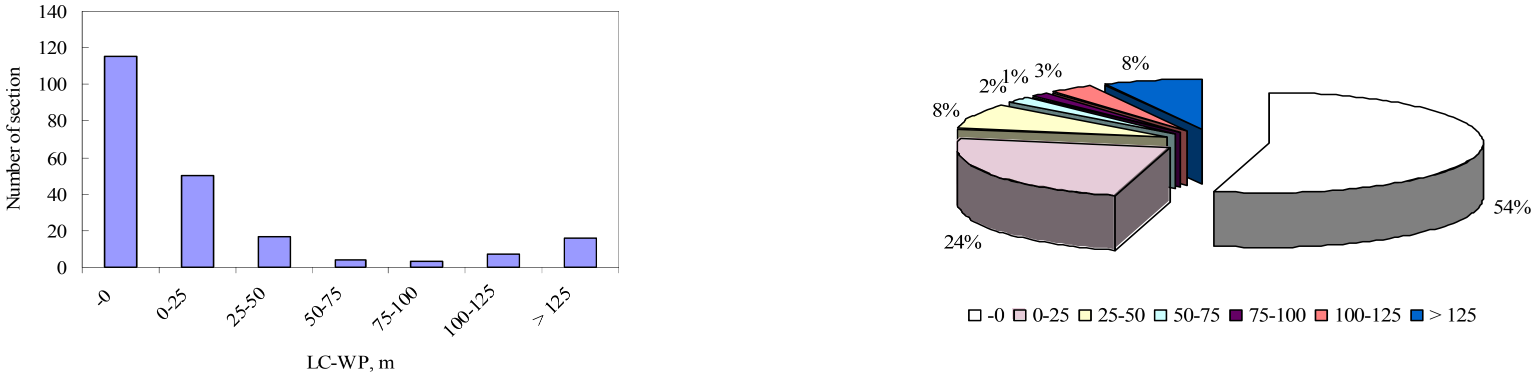
*Transverse Cracking*

Figure 3-16 shows the occurrence of transverse cracking in all SPS-1 sections by design and site factors. Based on the latest available data (Release 17.0), only 35% of the sections have exhibited some level of transverse cracking whereas about 65% of the sections have not yet exhibited any transverse cracking [see Figure 3-16 (d)]. Similarly, Figure 3-17 presents the extent of transverse cracking by design and site factors. Figure 3-18 shows the variation of transverse cracking within each site of the SPS-1 experiment.



(a) Extent of occurrence of LC-WP cracking by design factors

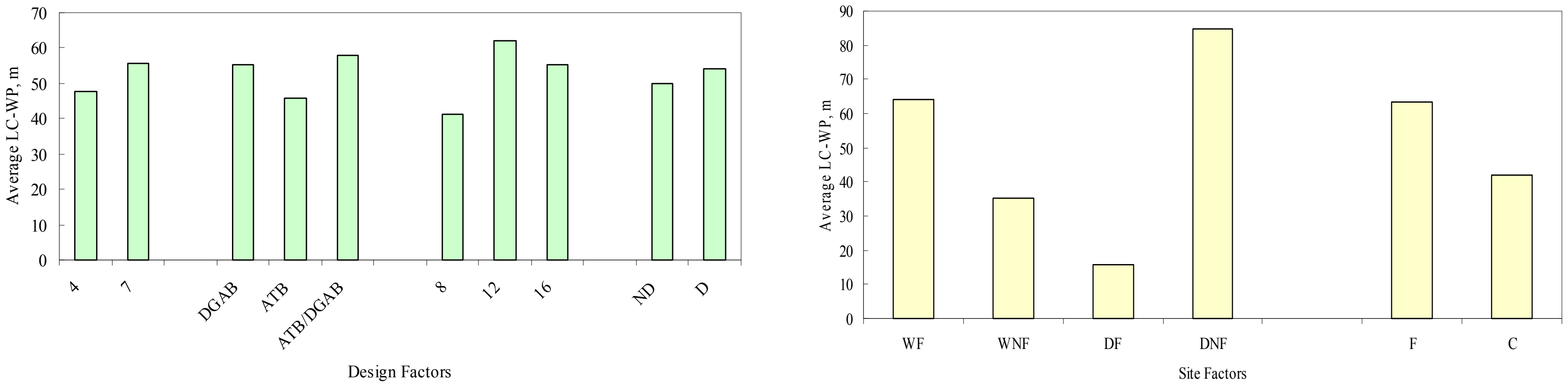
(b) Extent of occurrence of LC-WP cracking by site factors



(c) Frequency of sections for LC-WP cracking

(d) Distribution of sections for LC-WP cracking

Figure 3-10 Occurrence of LC-WP — SPS-1 experiment



(a) Average LC-WP by design factors

(b) Average LC-WP by site factors

Figure 3-11 Extent of LC-WP — SPS-1 experiment

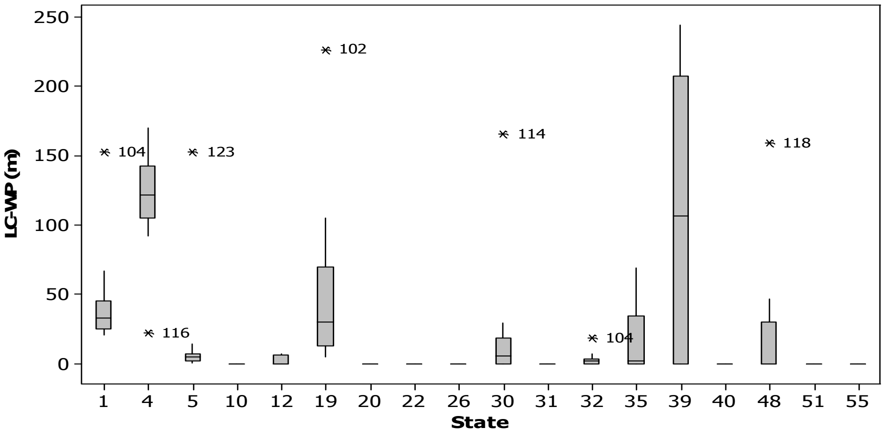
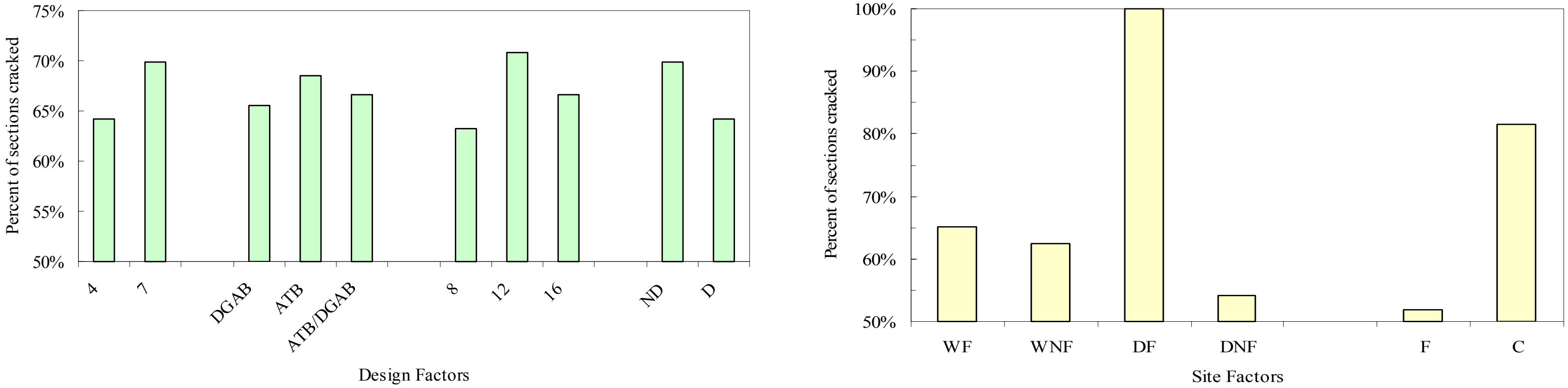
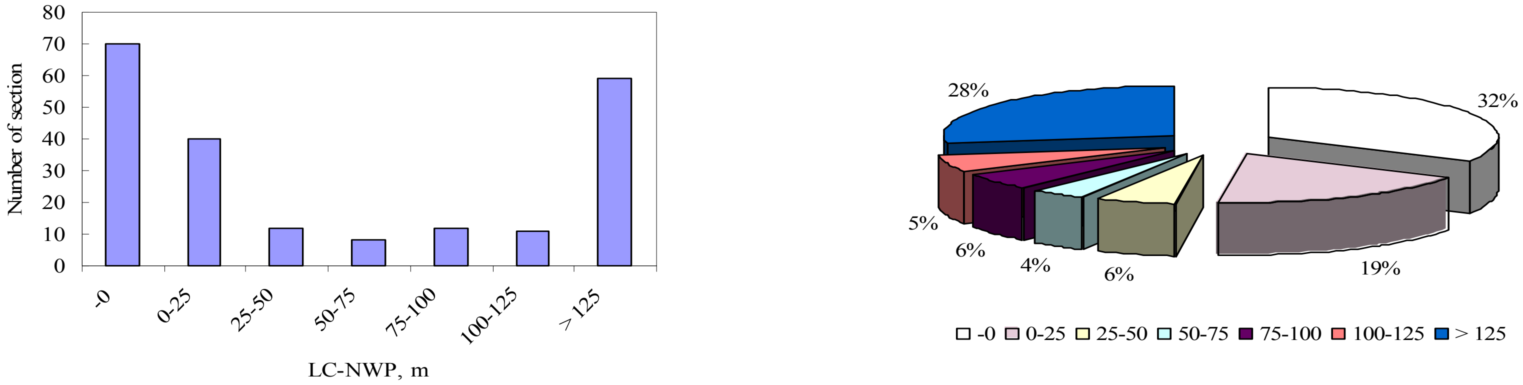


Figure 3-12 LC-WP by site — SPS-1 experiment



(a) Extent of occurrence of LC-NWP cracking by design factors

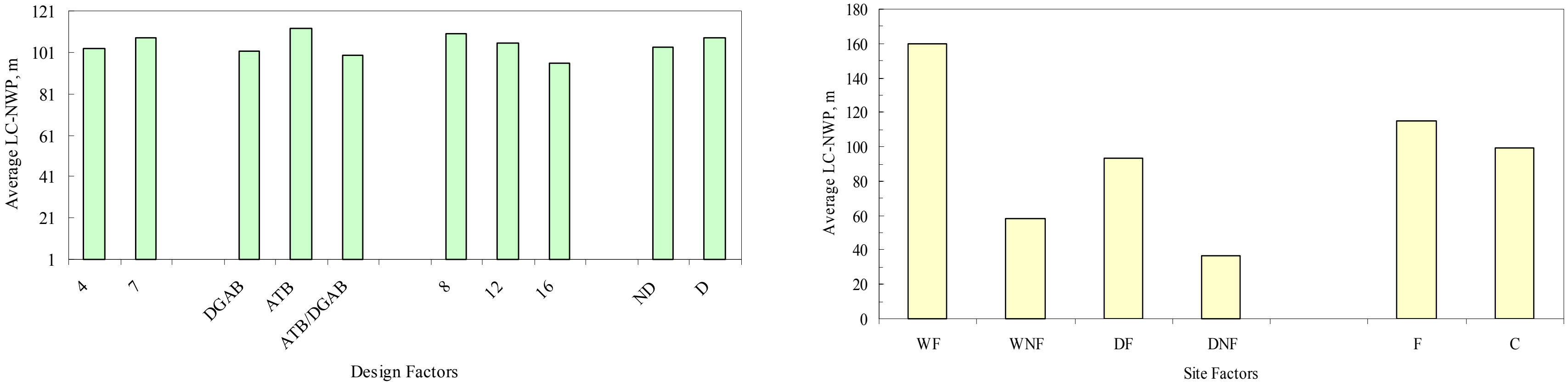
(b) Extent of occurrence of LC-NWP cracking by site factors



(c) Frequency of sections for LC-NWP cracking

(d) Distribution of sections for LC-NWP cracking

Figure 3-13 Occurrence of LC-NWP — SPS-1 experiment



(a) Average LC-NWP by design factors

(b) Average LC-NWP by site factors

Figure 3-14 Extent of LC-NWP — SPS-1 experiment

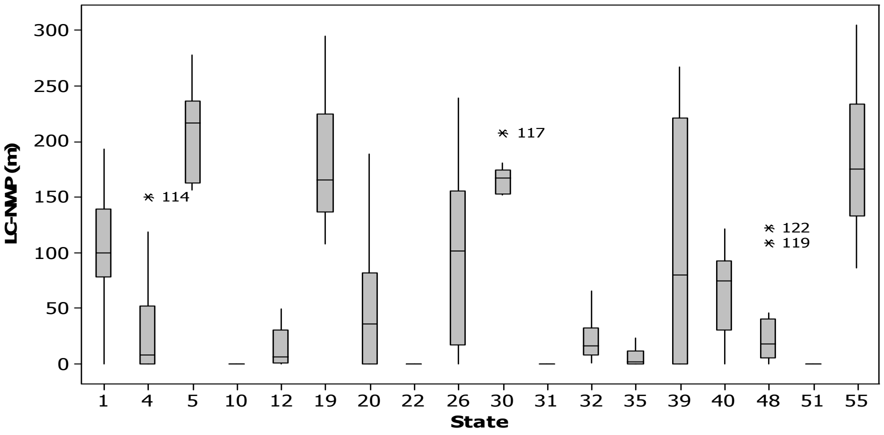
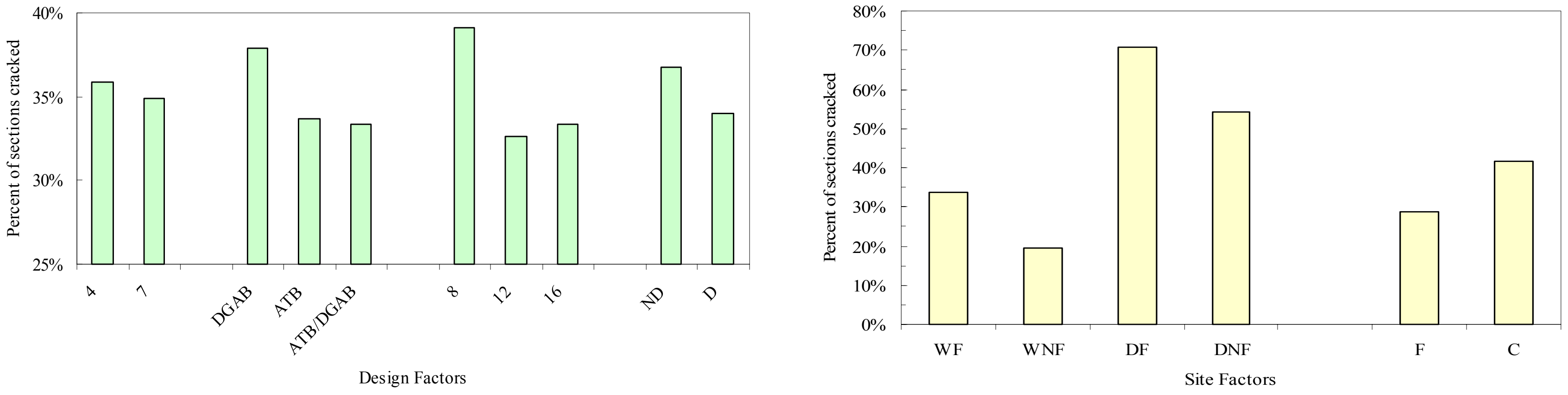
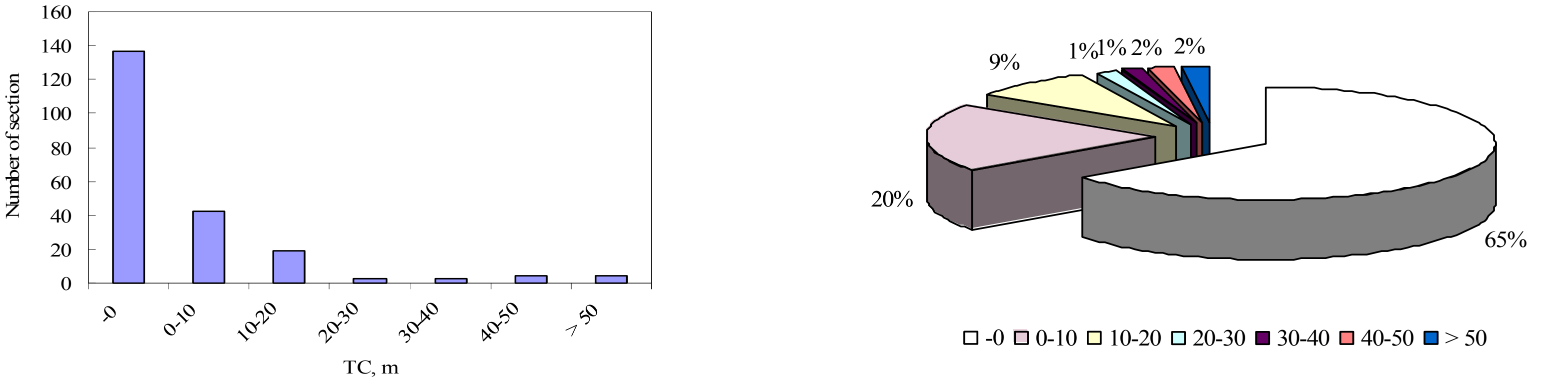


Figure 3-15 LC-NWP by site — SPS-1 experiment



(a) Extent of occurrence of transverse cracking by design factors

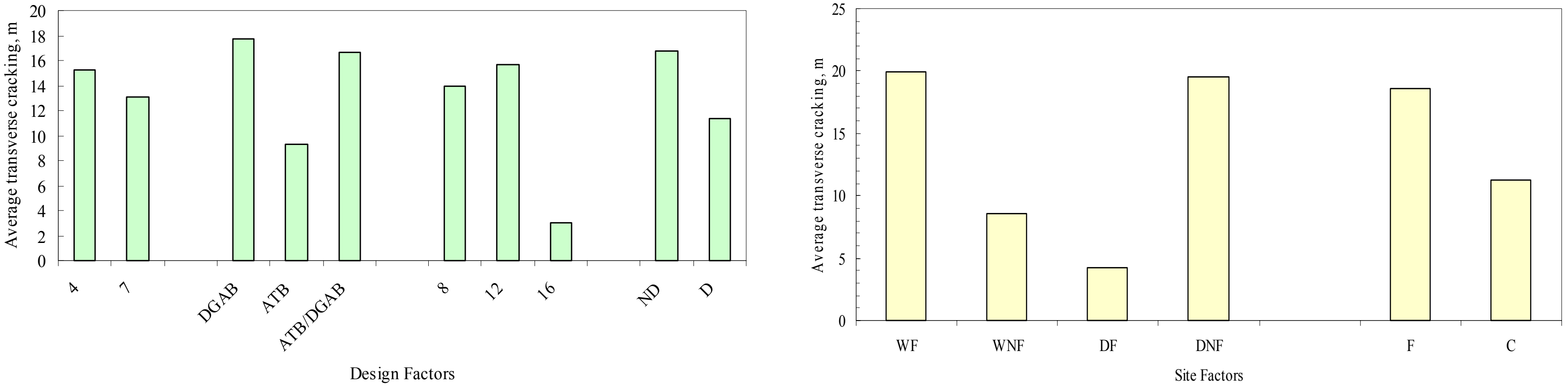
(b) Extent of occurrence of transverse cracking by site factors



(c) Frequency of sections for transverse cracking

(d) Distribution of sections for transverse cracking

Figure 3-16 Occurrence of transverse cracking — SPS-1 experiment



(a) Average transverse cracking by design factors

(b) Average transverse cracking by site factors

Figure 3-17 Extent of transverse cracking — SPS-1 experiment

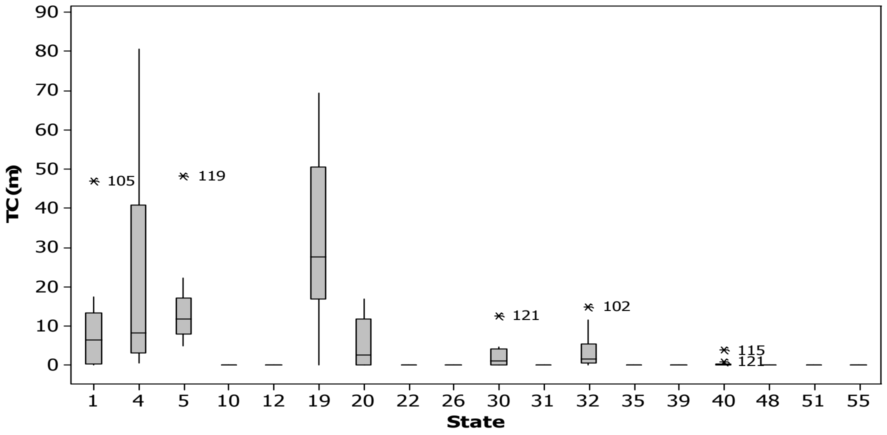


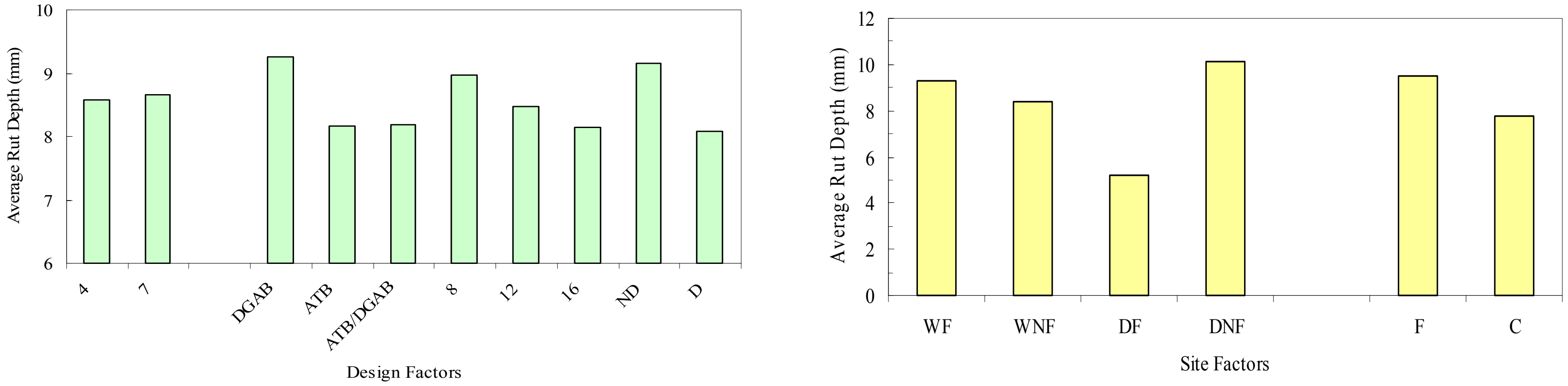
Figure 3-18 Transverse cracking by site — SPS-1 experiment

### *Rut Depth*

Figure 3-19 shows the extent of rut depth in all SPS-1 sections by design and site factors. Based on the latest available data (Release 17.0), about 29% of the sections have exhibited less than 5 mm of rut depth whereas about 71% of the sections have shown more than 5 mm rut depth, with 10% of the section showing more than 15 mm of rut depth [see Figure 3-19 (d)]. Figure 3-20 shows the variation of rut depth within each site of SPS-1 experiment. Figure 3-21 shows the age distribution of all the pavement sections for the latest rut depth measurement.

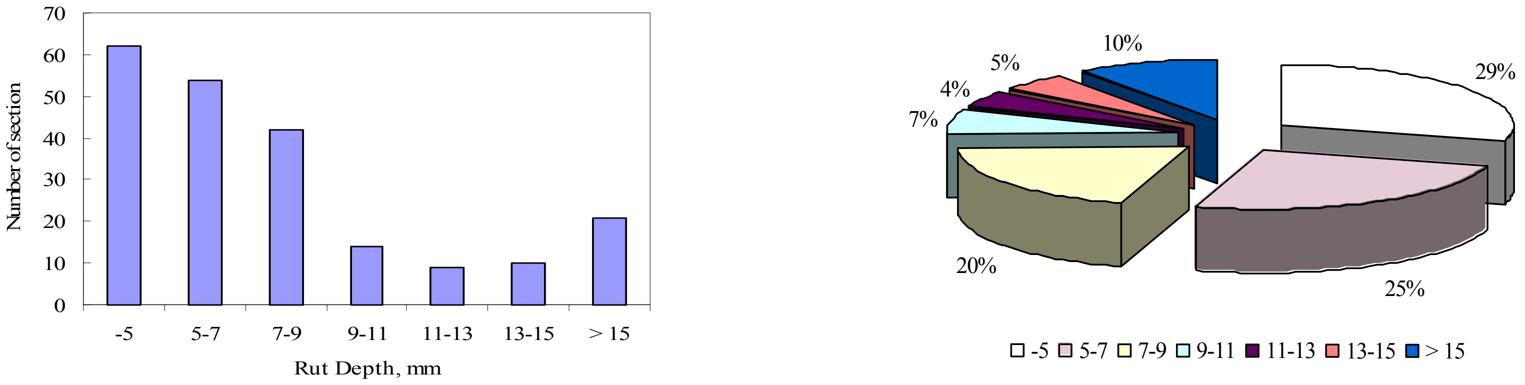
### *Roughness*

**Figure** 3**-**22 shows the extent of change in IRI (ΔIRI) for all SPS-1 sections by design and site factors. Based on the latest available data (Release 17.0), about 23% of the sections have exhibited a negligible change in IRI whereas about 77% of the sections have shown some level of change in IRI, with 10% of the section showing ΔIRI more than 0.4 m/km [see Figure 3-19 (d)]. The data is also summarized for the initial IRI (smoothness just after the construction). Figure 3-23 shows the extent of the initial IRI by design and site factors. It can be seen that about 84% of the sections were built with initial IRI of less than 1.0 m/km and about 16% of the sections with initial IRI more than 1.0 m/km [see Figure 3-23 (d)]. Figure 3-24 shows the variation of roughness within each site of the SPS-1 experiment. Figure 3-25 presents the age distribution of all the sections at the latest roughness profile measurement.



(a) Average rut depth by design factors

(b) Average rut depth by site factors



(c) Frequency of sections for rut depth

(d) Distribution of sections for rut depth

Figure 3-19 Extent of rut depth — SPS-1 experiment

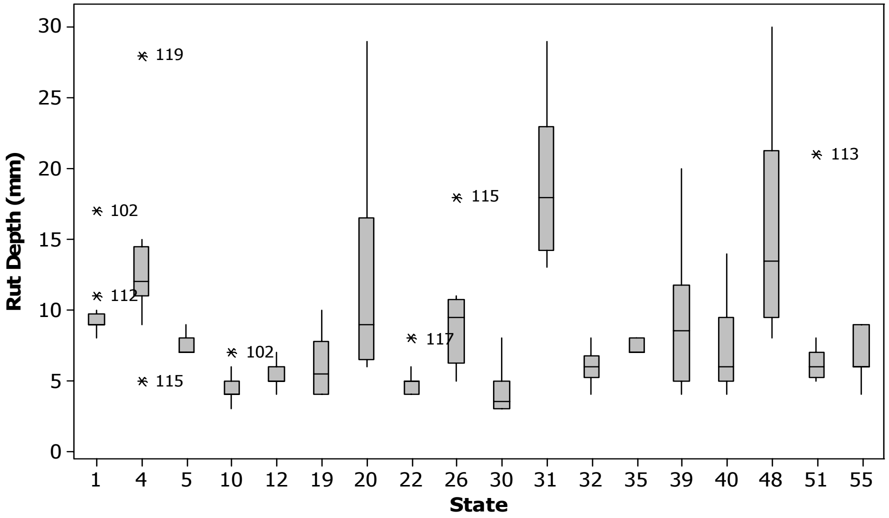
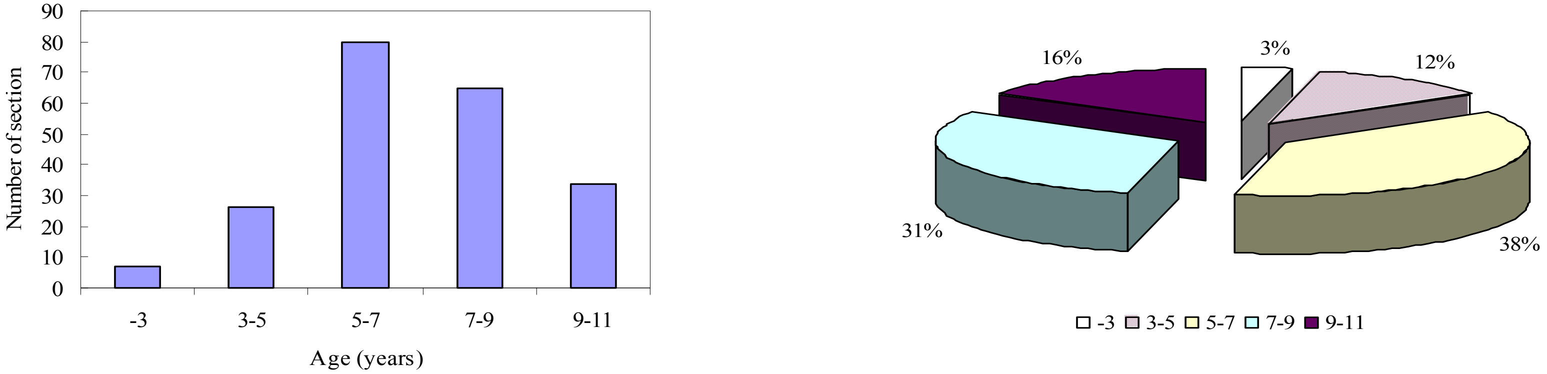


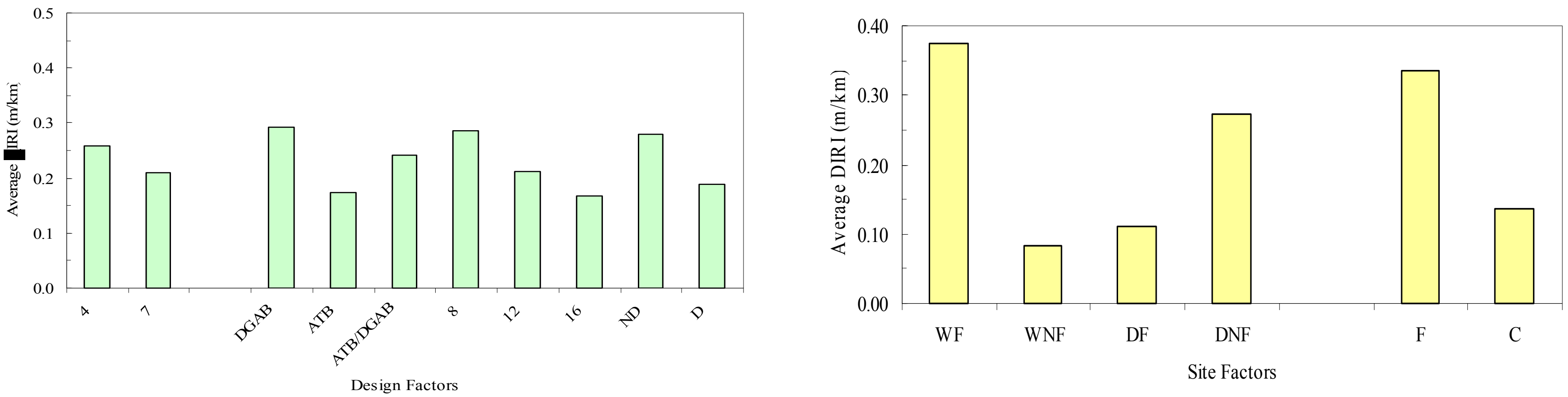
Figure 3-20 Rut depth by site — SPS-1 experiment



(a) Frequency of sections for latest age

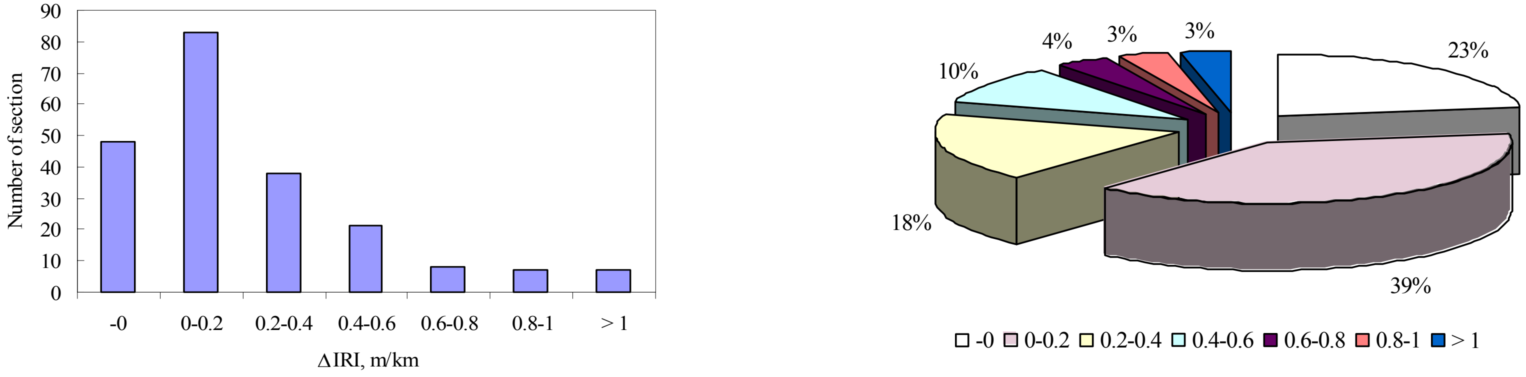
(b) Distribution of sections for latest age

Figure 3-21 Age distribution of rut depth measurement — SPS-1 experiment



(a) Average change in IRI by design factors

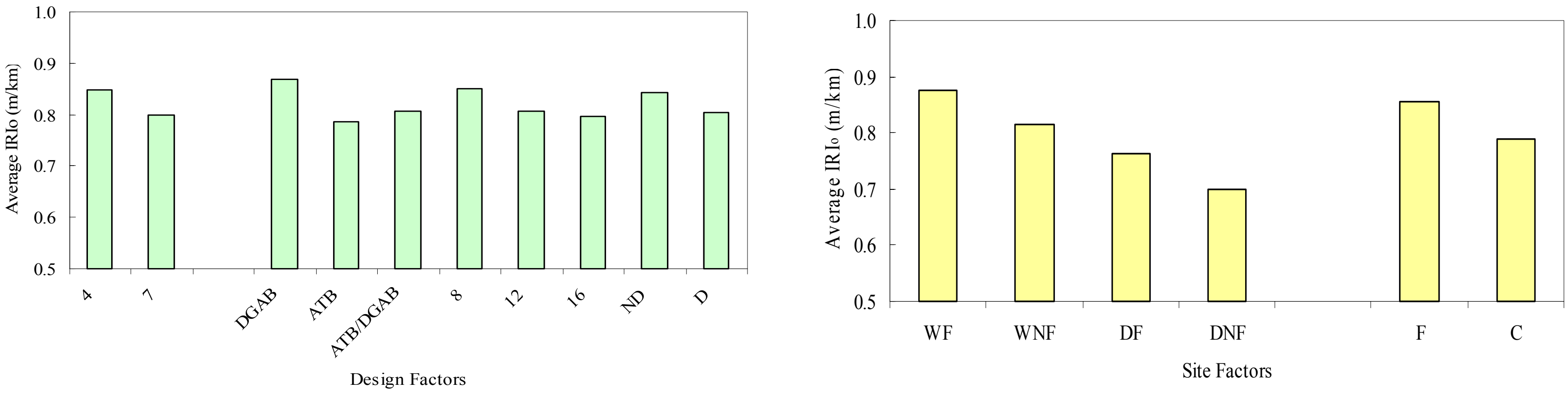
(b) Average change in IRI by site factors



(c) Frequency of sections for change in IRI

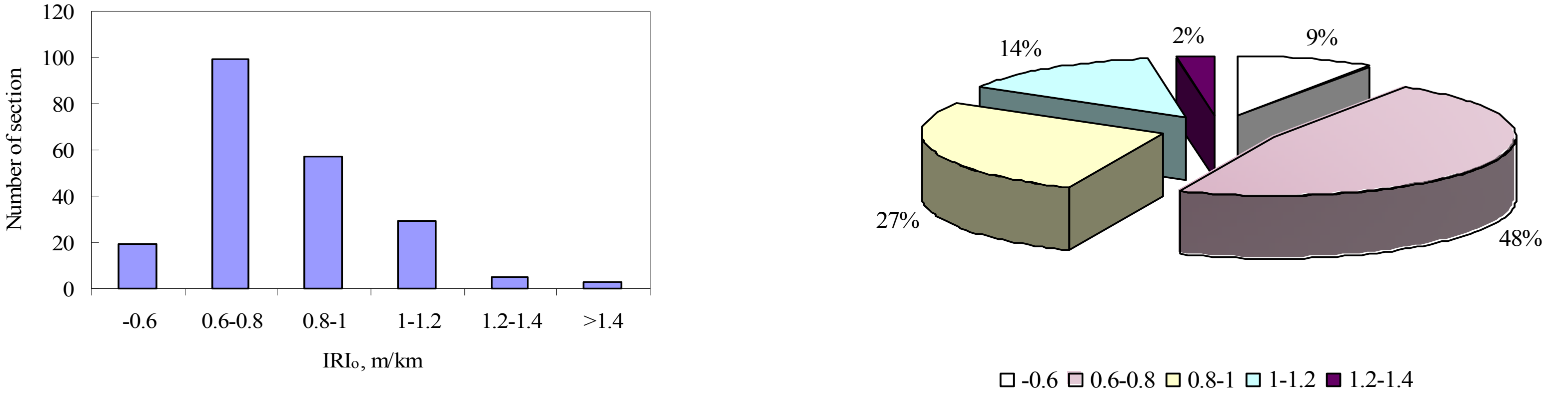
(d) Distribution of sections for change in IRI

**Figure 3-22 Extent of ΔIRI— SPS-1 experiment**



(a) Average initial IRI by design factors

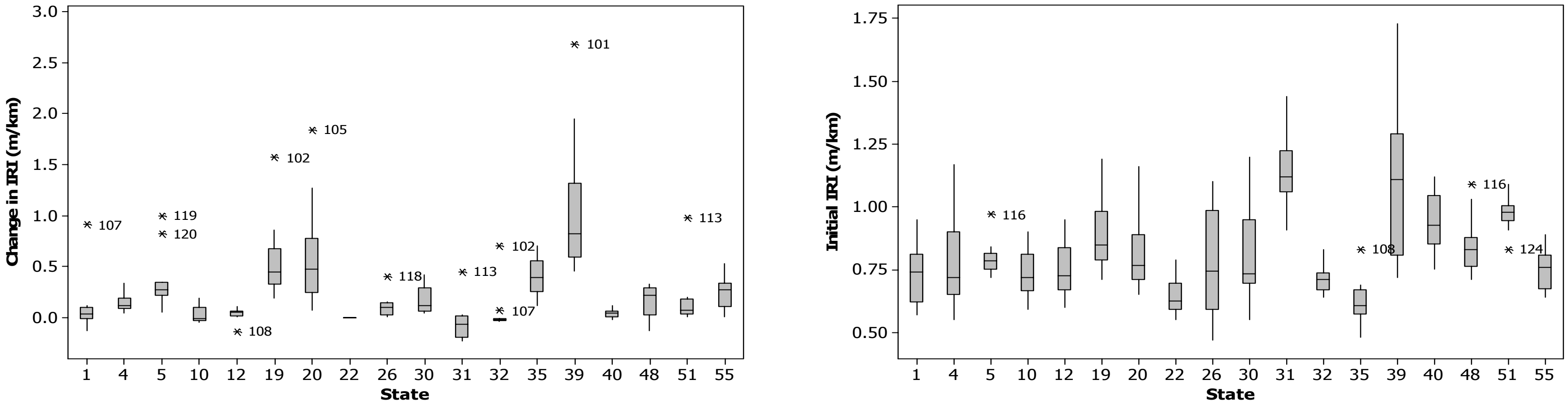
(b) Average initial IRI by site factors



(c) Frequency of sections for initial IRI

(d) Distribution of sections for initial IRI

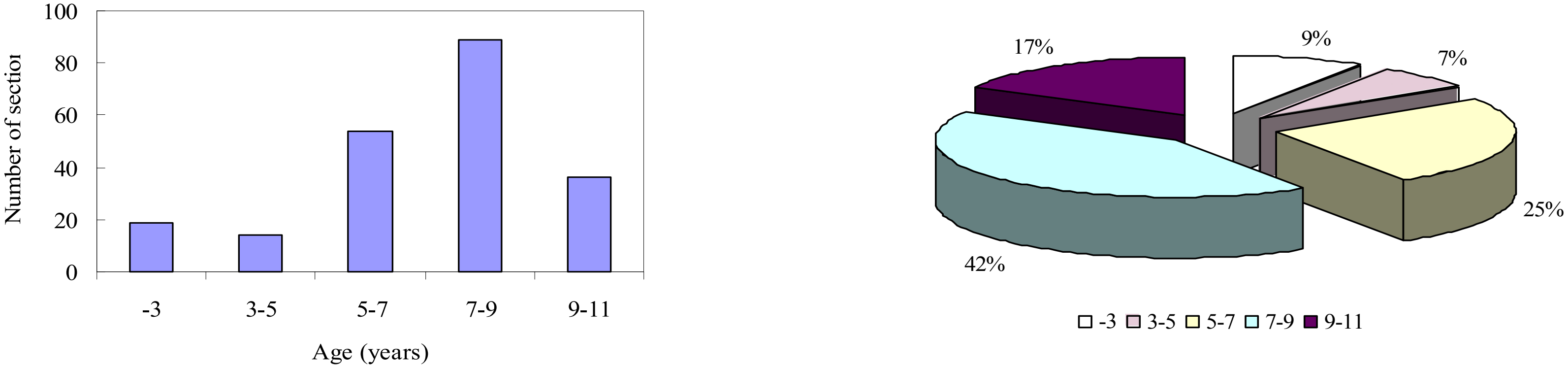
Figure 3-23 Extent of $IRI_o$— SPS-1 experiment



(a) Change in IRI by site

(b) Initial IRI by site

**Figure 3-24 Roughness by site — SPS-1 experiment**



(a) Frequency of sections for latest age

(b) Distribution of sections for latest age

Figure 3-25 Age distribution of roughness measurement — SPS-1 experiment

### 3.3.5 Dynamic Load Response Data (DLR) — Flexible Pavements

This section of the report summarizes the data availability for the instrumented flexible pavement sections in OH (39). According to Ohio University report [5], eight series of controlled truck tests had been completed on these instrumented pavement sections as shown in Table 3-8.

Each series of tests followed a similar pattern with regards to how the tests were setup and conducted. The general steps followed during each test are discussed in reference [5].

Only series II data and part of series IV data are available in DataPave (Release 17.0). Also data pertaining to instrumented SPS-8 sections in Ohio are not available in the database. The testing setup details have been obtained from DLR_TEST_MATRIX table. The locations of strain gauges and LVDTs data were obtained from DLR_STRAIN_CONFIG_AC and DLR_LVDT_CONFIG tables. The depth at which strain gauges were installed is not available in the DataPave; therefore this data was obtained from Ohio University report [5]. The peak strain, deflection and pressure data were extracted from DLR_STRAIN_TRACE_SUM_AC, DLR_LVDT_TRACE_SUM_AC and DLR_PRESSURE_TRACE_SUM_AC tables. Only data collected from these instrumented sections in 1996 and 1997 are available in DataPave. The specifics of the tests during series II (in 1996) are listed in

Table 3-9 and Table 3-10. The test dates for which strain data are available in DataPave are shaded in grey.

Table 3-11 details the series IV test sequence, which is available in the Release 17.0 version of DataPave.

Table 3-8 Controlled vehicle parameters

| Test Dates | Test Series | Truck | No. Passes | Section Monitored | Dynamic Parameters | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Load | Speed | No. Axles | Axle Spacing | Tires | Veh. Dyn. |
| 12/95<br>3/96 | I | CNRC | 144 | 1 | X | X | X | X | | |
| 8/96 | II | Single<br>Tandem | 85<br>87 | 6 | X | X | | | | |
| 6/97 | III | CNRC<br>Tandem | 127<br>122 | 7<br>7 | X<br>X | X<br>X | X | X | X | X |
| 7/97<br>8/97 | IV | Single<br>Tandem | 77<br>77 | 12 | X | X | | | | |
| 10/98 | V | Single<br>Tandem | 72<br>60 | 8 | X | X | | | | |
| 9/99<br>10/99 | VI | Single<br>Tandem | 86<br>86 | 8 | X | X | | | | |
| 10/99 | VII | Single<br>Tandem<br>FWD<br>Dynaflect | 30-60/sec.<br>30-60/sec<br>50 drops/sec.<br>20 read/sec | 7 | X | X | | | | |
| 4/01<br>5/01 | VIII | Single<br>Tandem | 80<br>80 | 10 | X | X | | | | |

Source: [5]

Table 3-9 Series II Truck Parameters – ODOT Single-Axle Dump Truck

| Date | Nominal Load (kips) | Rear Axle (kips) | Nominal Speed (mph) | Load I.D | Run No. |
|---|---|---|---|---|---|
| 8/6/96 | 18 | 18.45 | 30,40,50 | C | 1-14 |
| 8/7/96 | 18 | 18.45 | 30,40,50 | C | 1-14 |
| 8/9/96 | 22 | 22.23 | 30,40,50 | C | 1-13 |

Source: [5]

Table 3-10 Series II Truck Parameters – ODOT Tandem-Axle Dump Truck

| Date | Nominal Load (kips) | Rear Axle Load (kips) | | Nominal Speed (mph) | Load I.D | Run No. |
|---|---|---|---|---|---|---|
| | | Lead | Rear | | | |
| 8/2/96 | 32 | 16.62 | 16.23 | 30,40,50 | A | 1-17 |
| 8/3/96 | 32 | 16.62 | 16.23 | 30,40,50 | A | 1-15 |
| 8/5/96 | 42 | 21.14 | 21.38 | 30,40 | B | 1-11 |
| 8/6/96 | 42 | 21.14 | 21.38 | 30,40,50 | B | 1-16 |

Source: [5]

Table 3-11 Series IV Truck Parameters – ODOT Single-Axle Dump Truck

| Date | Nominal Load (kips) | Rear Axle (kips) | Nominal Speed (mph) | Load I.D | Run No. |
|---|---|---|---|---|---|
| 7/2/97 | 18 | 17.35 | 30,40,50 | K | 1-20 |
| 7/3/97 | 22 | 24.95 | 30,40,50 | L | 1-18 |

Source: [5]

It was also observed that not all the runs conducted during each test series for a specific date and sections are available in the strain data (see Appendix A3). Furthermore, strain data is not available for all gauges or all speed levels. For example, in section 39-102 data recorded for only 3 strain gauges are available in the database, whereas, the instrumentation plan for this section shows that there are 6 strain gauges located under the asphalt layer. Appendix A3 show the average peak strain values of the data for different offset categories.

Data summaries were also prepared for surface deflection data (from LVDT) and pressure data (from pressure cells) within each section, and are attached in Appendix A3.

### *Discrepancies in Dynamic Load Response Data*

The data availability for dynamic load response for the SPS-1 experiment in the current version of DataPave has highlighted several discrepancies. These deficiencies can seriously affect the usefulness of this data for any type of analysis; some of these shortcomings are highlighted here for future improvements:

- Keeping in consideration the amount of data collected for these instrumented sections; only limited data from series II and series IV are currently available (DataPave Release 17.0).
- The direction of strain gauges (Longitudinal or transverse) is not available in DataPave. These had to be obtained from the Ohio University report [5].
- Similarly, the depth of strain gauges from the surface is also currently missing from the database.
- In order to validate the dynamic load response mechanistically, the material properties for pavement layers have to be calculated at the time of testing. To facilitate this objective, the time of testing and temperature should be included as a part of dynamic load response data. Also it would have been useful to have data from FWD testing conducted at the locations at the strain gauges and pressure cells.

## 3.4 DATA AVAILABILITY IN SPS-2 EXPERIMENT

This section of the report is a discussion on data availability for the SPS-2 experiment. DataPave (Release 17, January 2004) was the primary data source for the study. Data from previous releases and other sources were used only to supplement the DataPave (Release 17) data. The construction information for each site was obtained from construction reports, climatic data for WI (55) (not available in Release 17) was obtained from DataPave 3.0, and distress maps were used to determine transverse crack locations. Data that were used for this study can be broadly classified into categories as summarized in Table 3-12. A brief description of each data type and its availability are presented in the subsequent sections.

Table 3-12 Data Categories and their description

| Serial No. | Data Type | Details |
|---|---|---|
| 1 | Site Information | Site Location information, Construction information, Climatic data, Traffic data |
| 2 | Materials data | Properties of materials of different layers for test sections |
| 3 | Pavement Structure data | Layer type and thickness information, and information about other design features such as lane width, shoulders and dowels |
| 4 | Monitoring data | Profile, Distress, Deflection (FWD), and Faulting data |
| 5 | Dynamic Load Response (DLR) data | Instrumentation and testing information, pavement response data |

### 3.4.1 General Site Information

The information that is common to all sections at a test site has been categorized under this heading.

*Construction Reports*

Construction reports were prepared for each site by the concerned consultant and department of transportation. These documents describe the construction process from conception to completion. In addition, the reports present information on the pavement geometric layout, construction issues (and deviations, if any), traffic, environmental conditions during construction, and material quality control data. These reports are available for all the sites in the experiment. A summary of construction issues at each of the 14 sites can be found in Appendix B1.

*Climatic data*

In the LTPP database, climatic data is available from two sources- Virtual Weather Station (VWS) and Automated Weather Station (AWS). A wide range of variables that define the climate are available. The climatic zones in LTPP are defined based on two parameters: average annual precipitation and average annual freezing index. These two variables were used to confirm the climatic classification of each site. AWS data for DE (10) is not available from Release 17 of DataPave. Data for all other sites are available from AWS. Climatic data from VWS is available for all sites except WI (55), in Release 17. VWS data for this site was obtained from DataPave 3.0. VWS data are available for 17 years for all sites expect CA and WI for which 49 years of data are available.

*Traffic data*

The traffic data available in the LTPP database is presented in three forms: Monitored, Estimated and Axle Distribution. Traffic data availability is shown in more detail in Table 3-13. Traffic being one of the most important factors that determine pavement performance, inconsistency in traffic data was compensated, to some extent, by estimating an average annual traffic (called ‘proposed’ traffic) for each of the sites based on all the three sources of traffic data. The ‘proposed’ traffic is used as a covariant in the analyses.

Table 3-13 Summary of Traffic data availability

| State ID | KESALs per year | | | | NCHRP Report 499 | Proposed |
|---|---|---|---|---|---|---|
| | Monitored | Construction reports | Estimated | Axle Distribution | | |
| Arizona, AZ (4) | 1054 | - | 1200 | 1021 | 1220 | 1092 |
| Arkansas, AR (5) | - | 1700 | 1969 | 2041 | 2160 | 1903 |
| California, CA (6) | - | 2405 | - | - | - | 2405 |
| Colorado, CO (8) | 350 | 454 | 395 | 246* | 320 | 400 |
| Delaware, DE (10) | - | 300 | 410 | - | 430 | 355 |
| Iowa, IA (19) | 56* | 330 | 94* | 424 | 70 | 377 |
| Kansas, KS (20) | 732 | 870 | 670 | 1283* | 740 | 757 |
| Michigan, MI (26) | 1872 | 1330 | - | 1313 | 1780 | 1505 |
| Nevada, NV (32) | 813 | 799 | 492* | 499* | 790 | 806 |
| North Carolina, NC (37) | 830 | - | 1499* | 600 | 1300 | 715 |
| North Dakota, ND (38) | - | 419 | 432 | - | - | 426 |
| Ohio, OH (39) | 612 | 797 | - | 415 | 630 | 608 |
| Washington, WA (53) | 462 | 875* | 194* | 286* | 350 | 462 |
| Wisconsin, WI (55) | - | 180 | - | 122 | - | 151 |

Note: * Data considered as an outlier

Traffic opening date is the date on which traffic was allowed to pass over the newly constructed test sections. This data is available in the database for all the sites. The age of a section was calculated using this date and the corresponding last survey date.

### 3.4.2 Materials data

Data pertaining to the materials used in the construction of pavement sections have been categorized as Materials data. The data that were used for this study include the material properties of subgrade soil (percent passing #200 sieve) and PCC layer (mix design information, coefficient of thermal expansion, unit weight, etc.), apart from strength testing results of lean concrete and PCC.

*Subgrade*

Subgrade soil data in the form of percent passing #200 sieve (available for all sites) were used to classify subgrade soil as either “fine” or “coarse” and compare results with subgrade soil classification data that are available from other sources in DataPave.

*Lean Concrete*

The compressive strength data for LCB are available for 96 % of the sections. The 7-day compressive strength was used to compare with the stipulated target strength of 3.5 MPa [4].

*Portland Cement Concrete*

All the details of PCC mix design such as cement content, aggregate content (coarse and fine), water content, and additive type are available for all sites except WI (55). For most of the sites which have data, two types of mixes were used, one for each of the two levels of target 14-day flexural strength. In DE (10) more than two types of mixes were used, and PCC mix design data are available for all the sections. Though not a part of the experiment design, PCC compressive strength, split tensile strength, and modulus of elasticity are also reported in the database. The mechanical properties of concrete were recorded at 7, 14 and 365 days after casting. Compressive strength and split tensile strength data from testing of core samples are also available. Table 3-14 below is a summary of data availability for PCC mechanical properties (except for flexural strength) from DataPave Release 17.

Only 52% of the sections in the SPS-2 experiment have 14-day flexural strength data. Data for sections in CA (6) and ND (38) are not available. The 14-day flexural strength data were used for comparison with specified target strengths. Table 3-15 is a summary of flexural strength data availability.

Coefficient of thermal expansion (CTE) of PCC is an important requirement for conducting a thermal analysis. CTE data are unavailable in DataPave of Release 17. Data were obtained from Portland Cement Concrete Pavements, FHWA. However, CTE data was available only for 16 sections, which are from 8 different sites within the SPS-2 experiment. Table 3-16 below is a summary of CTE data obtained from FHWA.

Figure 3-26 is a plot showing CTE of PCC for as a function of aggregate type.

Table 3-14 Summary of data availability (percent of sections) for PCC properties

| Site ID | Compressive Strength | | Tensile Strength | | Elastic Modulus |
|---|---|---|---|---|---|
| | Core | Fresh | Core | Fresh | |
| 4 | 83 | 50 | 92 | 50 | 92 |
| 5 | 0 | 0 | 0 | 0 | 25 |
| 6 | 25 | 50 | 50 | 0 | 100 |
| 8 | 92 | 100 | 92 | 100 | 100 |
| 10 | 50 | 50 | 67 | 25 | 42 |
| 19 | 83 | 50 | 100 | 50 | 100 |
| 20 | 0 | 92 | 0 | 83 | 0 |
| 26 | 42 | 42 | 42 | 42 | 50 |
| 32 | 92 | 50 | 92 | 50 | 92 |
| 37 | 0 | 50 | 75 | 0 | 100 |
| 38 | 25 | 0 | 25 | 0 | 100 |
| 39 | 92 | 50 | 75 | 42 | 83 |
| 53 | 92 | 58 | 100 | 58 | 100 |
| 55 | 0 | 0 | 0 | 0 | 100 |

Table 3-15 Summary of availability (percent of sections) PCC flexural strength data

| Site ID | % of sections with data | | |
|---|---|---|---|
| | 14-day | 28-day | 365-day |
| 4 | 75 | 75 | 75 |
| 5 | 58 | 58 | 58 |
| 6 | 0 | 0 | 0 |
| 8 | 100 | 100 | 92 |
| 10 | 50 | 50 | 50 |
| 19 | 50 | 50 | 50 |
| 20 | 100 | 100 | 92 |
| 26 | 42 | 42 | 50 |
| 32 | 50 | 50 | 50 |
| 37 | 25 | 33 | 42 |
| 38 | 0 | 42 | 92 |
| 39 | 50 | 50 | 50 |
| 53 | 58 | 58 | 58 |
| 55 | 58 | 58 | 0 |

Table 3-16 CTE data obtained from FHWA

| Site ID | Aggregate Type | SHRP ID | CTE, in/in/°C |
|---|---|---|---|
| 5 | - | 0215 | 10.2 |
| 5 | - | 0220 | 11.3 |
| 10 | Diorite | 0205 | 11.6 |
| 10 | Diorite | 0208 | 9.2 |
| 10 | Diorite | 0211 | 9.5 |
| 19 | Limestone | 0224 | 9.6 |
| 20 | Limestone | 0207 | 10 |
| 20 | Limestone | 0208 | 10.65 |
| 32 | - | 0203 | 10.9 |
| 32 | - | 0208 | 13.9 |
| 32 | - | 0209 | 11.1 |
| 37 | Granite | 0203 | 8.9 |
| 37 | Granite | 0204 | 11.9 |
| 39 | Limestone | 0204 | 10.2 |
| 55 | - | 0222 | 8.8 |
| 55 | - | 0223 | 9.8 |

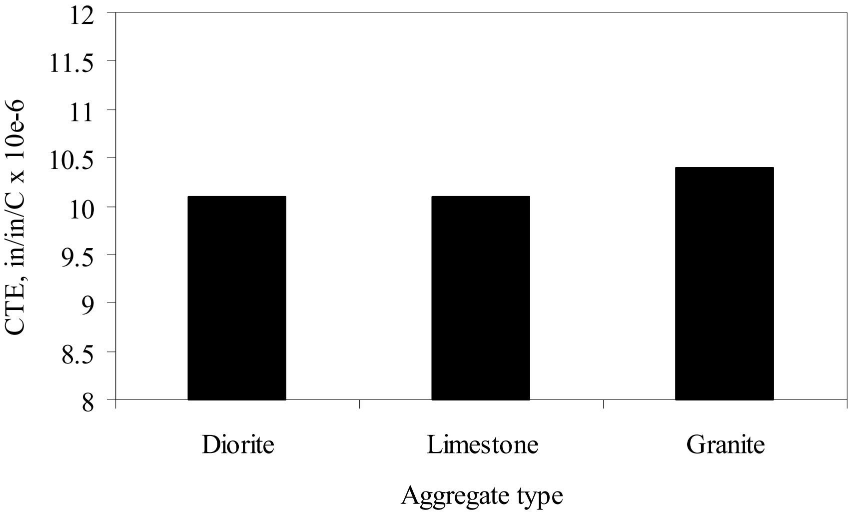


Figure 3-26 CTE of PCC with different aggregate types

### 3.4.3 Pavement Structure data

All data that relates to the structure (cross-section) of the pavement sections have been categorized in this section of the report. The data has been used to compare as-designed thicknesses with as-built thicknesses. Information about layer type and thickness is available for all test sections in the experiment. Information about the size and spacing of dowel bars is available for all the sections except for 4 sections in WA (53). Though not a part of the experiment design, details about the shoulders have been obtained. No information about the shoulders is available for the site WI (55).

### 3.4.4 Monitoring data

All data that are collected during distress surveys and during FWD testing has been categorized as Monitoring data. Longitudinal profile data, distress data, faulting data, and deflection data fall under this category. These data are available for all the sections in the experiment. Table 3-17 is the summary of data availability (from Release 17 of DataPave) in all the classifications of data listed above.

**Table 3-17 Summary of data availability for SPS-2 experiment**

| Data category | Data type | Data Availability, % of sections |
|---|---|---|
| Site information | *Construction reports* | 100 |
| | *Climatic data* | |
| | Virtual Weather Station | |
| | Annual Temperature | 93 |
| | Annual Precipitation | 93 |
| | Automated Weather Station | |
| | Monthly Temperature | 93 |
| | Monthly precipitation | 93 |
| | *Traffic data** | |
| | Traffic Open date | 100 |
| | Monitored | 65 |
| | Estimated | 71 |
| | Axle Distribution data | 78 |
| Materials data | *Subgrade* | |
| | Sieve analysis | 53 |
| | Classification | 100 |
| | Backcalculated moduli | 0 |
| | *Lean Concrete Base* | |
| | Compressive Strength | 96 |
| | *Portland Cement Concrete* | |
| | PCC mix data | 100 |
| | 14-day Flexural Strength | 52 |
| | Compressive Strength | 92 |
| | Split tensile Strength | 91 |
| | Static modulus of Elasticity | 78 |
| | CTE $^{+}$ | 0 |
| | Unit weight | 63 |
| Pavement structure | *Layer details* | |
| | Type | 100 |
| | Representative thickness | 100 |
| | *Dowel bar details* | |
| | Diameter | 98 |
| | Length | 98 |
| | Spacing | 98 |
| | *Shoulder information* | |
| | Type | 93 |
| | Width | 93 |
| | Thickness | 93 |
| Monitoring** | *Profile data (IRI)* | 100 |
| | *Distress data* | 100 |
| | *Faulting data* | 100 |
| | *FWD data* | |
| | Deflection | 100 |
| | Temperature during testing | 100 |

Note:
*Monitored, Estimated, or Axle Distribution data is considered to be available for a site even if the data is available only for one year.
**Data is said to be available for a section even if it is available for just one year. $^{+}$ CTE data is not available in DataPave. It was obtained from FHWA for this study.

A detailed discussion on data availability for each site can be found in Appendix B1.

### 3.4.5 Design versus Actual Construction Review

A brief discussion on construction guidelines was presented in Chapter 2. A review of all the features in the experiment was conducted to identify deviations from design. In this section of the report, a comparison between as-designed and as-constructed features of the experiment is presented. A brief discussion on the construction issues will be followed by a discussion on the deviations, if any, in the design and site features of the experiment. The design versus construction review for each site can be found in Appendix B1.

*Construction Issues*

Information regarding construction issues was obtained from the construction reports. A detailed site-specific discussion on construction issues can be found in Appendix B1. Some of the major issues in the SPS-2 experiment are below:

- Shrinkage cracks in LCB were observed soon after construction at sites AZ (4), CA (6), DE (10), MI (26), NV (32), NC (37), ND (38), and WA (53).
- PCC mixes that were different from what was stipulated were used at DE (10), NV (32) and OH (39) sites, respectively.
- Construction delays occurred due to bad weather at sites MI (26) and ND (38).
- Improper size dowel bars were used at CA (6) and NC (37) sites. At CA (6) site, 32 mm and 38 mm diameter bars were used in both thinner and thicker slab sections. At the NC (37) site, all the sections were constructed with 38 mm – diameter dowel.
- Underground structures were present at sites IA (19) and KS (20) within the monitoring length of the sections.
- Repairing (such as Partial depth repairs, full depth repairs, crack sealing, and shoulder restoration) was done to some sections (20-0201, 32-0201, and all the sections at the sites in AR (5) and ND (38) after opening the sections to traffic.

A review was done for those factors in the experiment that have corresponding guidelines. The features for which the review was conducted include:

- ✓ Site factors
  - Subgrade soil type, and
  - Climatic zone.
- ✓ Design factors
  - Layer thickness, and
  - 14-day flexural strength of PCC.

Each of the above features will be reviewed individually to identify deviations, if any, from the guidelines.

*Site Factors*

**Subgrade type**: In AR (5), sections 0222 and 0223 were constructed on fine-grained soils while all the other sections were constructed on coarse-grained soils. Similarly, in NV (32), sections 0201 and 0205 were built on coarse-grained soils whereas the other sections were built on fine-grained soils. At the CO (8) site, 5 sections were constructed on coarse-grained soils while the other 7 were constructed on fine-grained soils.

**Climatic zone**: The climatic data (VWS data) were used to categorize sites into 4 climatic zones according to the LTPP definitions for climatic zones. All the SPS-2 sites were appropriately classified. Figure 3-27 is a scatter plot showing all the sites in the experiment and LTPP criteria (reference lines at 508 mm and 83.3 $^{o}$C-day) regarding climatic zones.

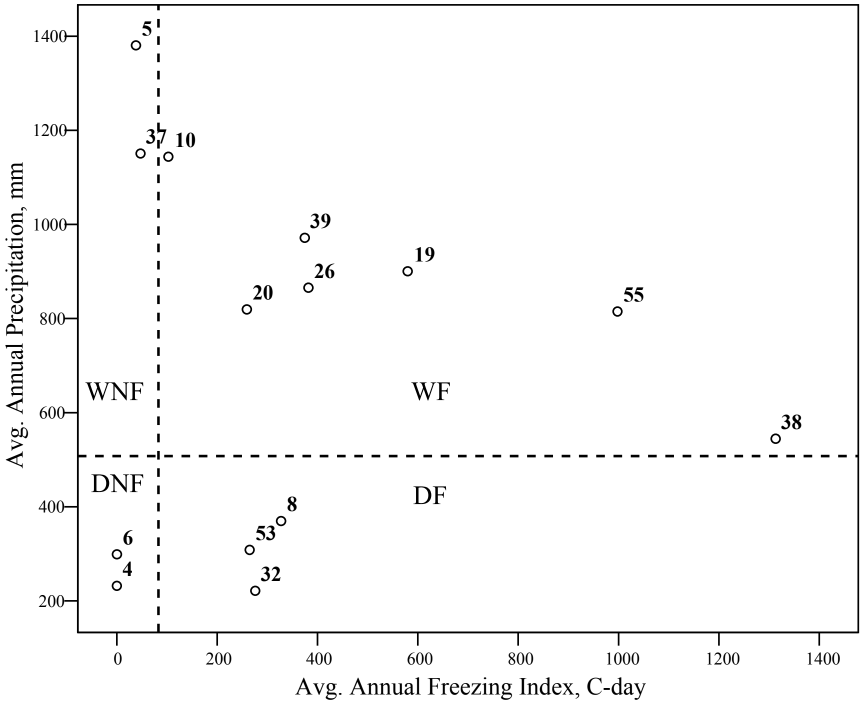


Figure 3-27 Scatter plot showing distribution of sites by climate

*Design Factors*

**Layer Thickness:** PCC thickness and DGAB thickness for the test sections were compared with their respective target thicknesses. Results from the comparison are discussed below. Table 3-18 is a summary of as-designed versus as-constructed comparison for PCC layer and the base layers. The allowable range of thickness does not apply to bases other than DGAB, as the guidelines do not define a range.

PCC thickness: The experiment has two levels of PCC thickness- 203 mm and 279 mm. The allowable deviation from the target PCC thickness according to the guidelines is 6.4 mm. Among sections with target thickness of 203 mm, only 28 sections (33 %) conform to the allowable deviation of 6.4 mm. The remainder of the sections (67%) were built either thicker or thinner by more than 6.4 mm. Figure 3-28 is the cumulative frequency graph of PCC thickness.

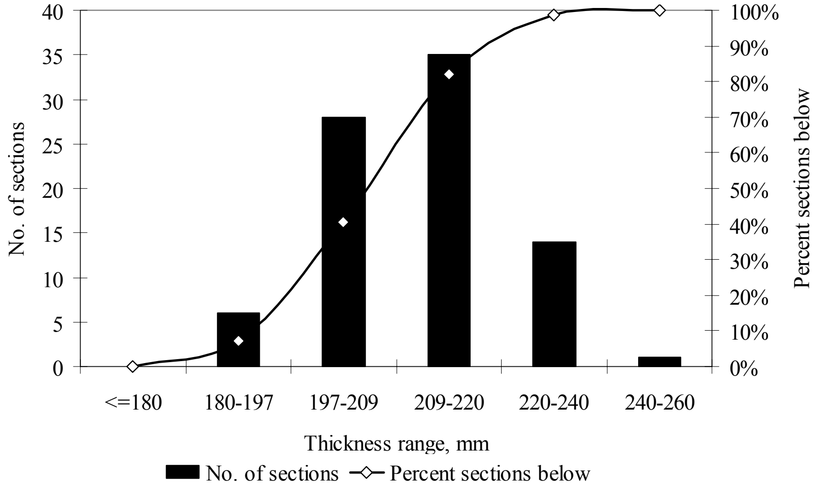


Figure 3-28 Cumulative frequency plot for actual thickness of sections with target thickness of 203 mm

Among sections with a target thickness of 279 mm, 44 sections (53 %) conform to the allowable deviation of 6.4 mm. Figure 3-29 is the cumulative frequency graph showing the percent of sections and number of sections below the corresponding thickness values.

Base thickness: Though there are no guidelines limiting deviation from design thickness for LCB and PATB, the allowable deviation from target elevation for DGAB is 12.7 mm. Figure 3-30 is a cumulative frequency distribution of actual base thickness of DGAB sections (target thickness of 152.4 mm). 80% of the sections built on DGAB have thickness that falls within the allowable range (see Table 3-18), as defined by the guidelines.

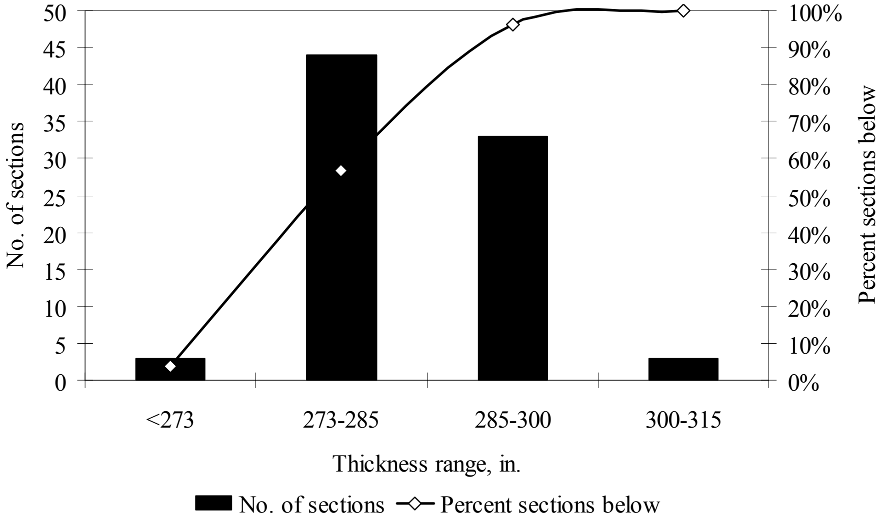


Figure 3-29 Cumulative frequency plot for actual thickness of sections with target thickness of 279 mm

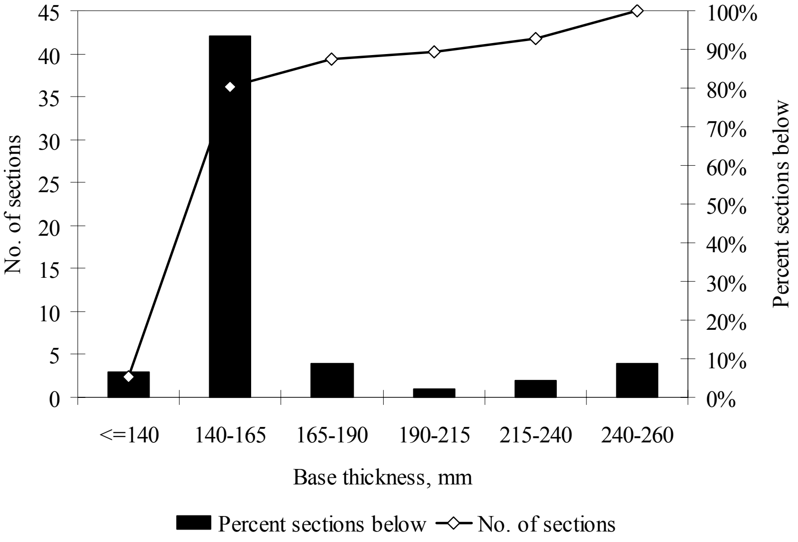


Figure 3-30 Cumulative frequency plot for actual base thickness of sections on DGAB

Table 3-18 Summary of deviation in thickness from design

| Layer Type | Target Thickness, mm | Count, no. of sections | Mean, mm | Standard Deviation, mm | Coefficient of Variance, % | Below allowable range, % sections | Within allowable range, % sections | Above allowable range, % sections |
|---|---|---|---|---|---|---|---|---|
| PCC | 203 | 84 | 212 | 12 | 5 | 7 | 33 | 60 |
|  | 279 | 83 | 286 | 9 | 3 | 4 | 53 | 43 |
| DGAB | 152 | 56 | 163 | 34 | 21 | 4 | 80 | 16 |
| LCB | 152 | 56 | 160 | 10 | 6 | - | - | - |
| PATB | 102 | 55 | 101 | 14 | 14 | - | - | - |
| DGAB below PATB | 102 | 55 | 114 | 36 | 32 | - | - | - |

**PCC Flexural Strength**: At each site, 6 sections have a target 14-day flexural strength of 3.8 MPa and the other 6 sections have target 14-day flexural strength of 6.2 MPa. Comparisons between the actual flexural strengths and target 14-day strength were made. Figure 3-31 through Figure 3-36 are cumulative histograms for flexural strength at 14, 28 and 365 days.

It is evident from the plots that at 365 days most of the sections that failed to reach the target at 14 days have reached their target strengths. Among the sections with target PCC 14-day flexural strength of 3.8 MPa, 7 sections, of the 44 sections for which data are available, failed to meet the criterion of 3.4 MPa at 14-days. At 28-days just 1 of the sections failed to meet the criterion and at 365 days all the sections have met the criterion. Among sections with target 14-day PCC flexural strength of 6.2 MPa flexural strength data are available for 42 sections. Of these sections, 16 sections failed to meet the target of 5.6 MPa at 14-days. Eight sections met the criterion at 28 days and 5 more met the criterion of 5.4 MPa at 365 days.

*Other features*

**Dowel diameter**: It was stipulated in the guidelines that all the sections with 203 mm target PCC slab thickness have 32 mm diameter dowels while the sections with 279 mm have 38 mm diameter dowels. Improper size dowel bars were used at CA and NC sites. At CA site, 32 mm and 38 mm diameter bars were used in both thinner and thicker slab sections. At the NC site, all the sections were constructed with dowels of diameter 38 mm. At all other sites no deviation was observed.

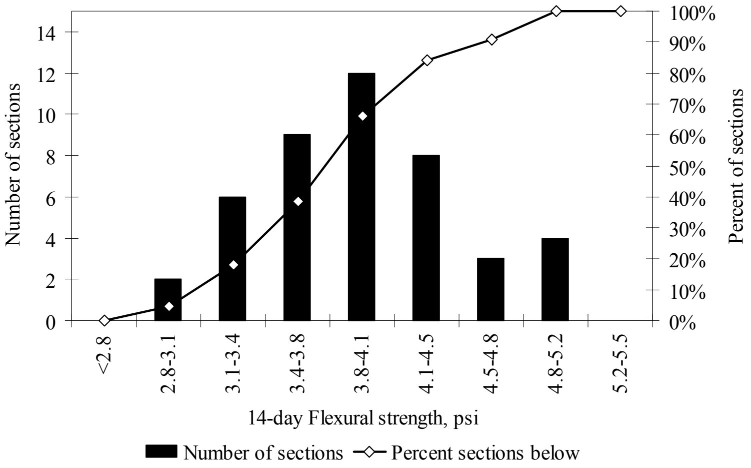


Figure 3-31 Cumulative frequency graph for 14-day flexural strength of sections with target strength of 3.8 MPa

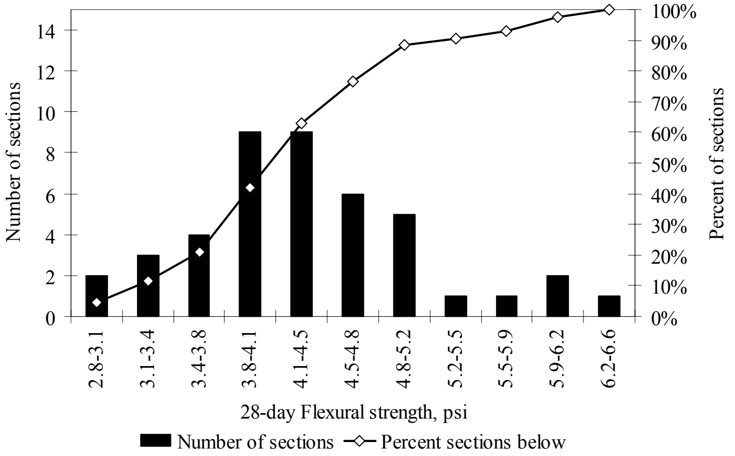


Figure 3-32 Cumulative frequency graph for 28-day flexural strength of sections with target strength of 3.8 MPa

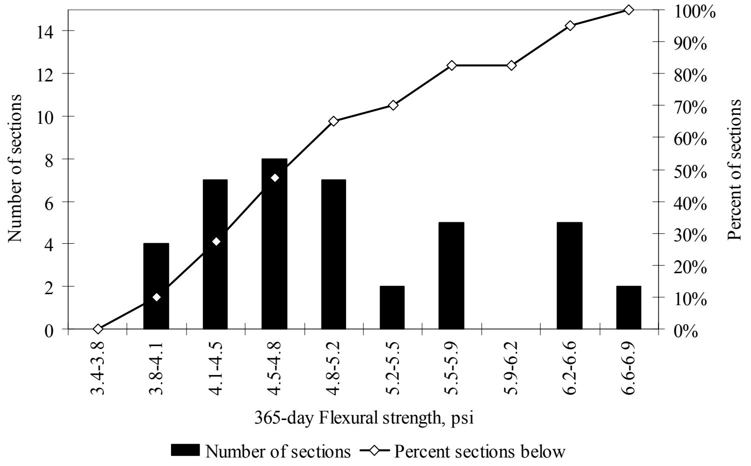


Figure 3-33 Cumulative frequency graph for 365-day flexural strength of sections with target strength of 3.8 MPa

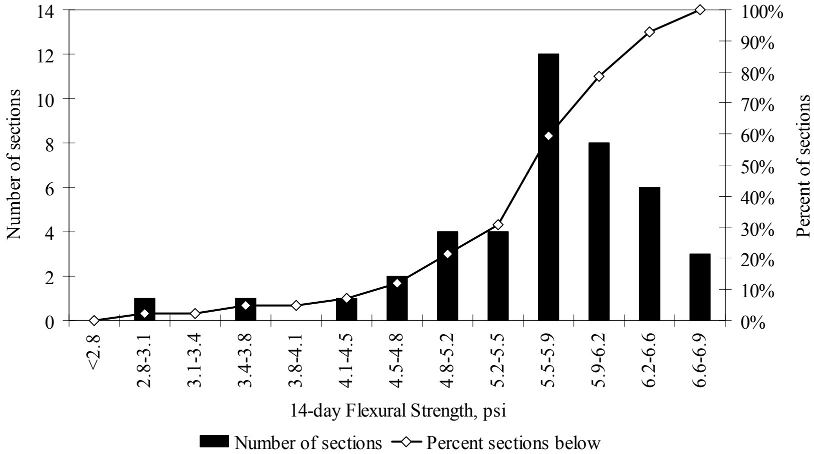


Figure 3-34 Cumulative frequency graph for 14-day flexural strength of sections with target strength of 6.2 MPa

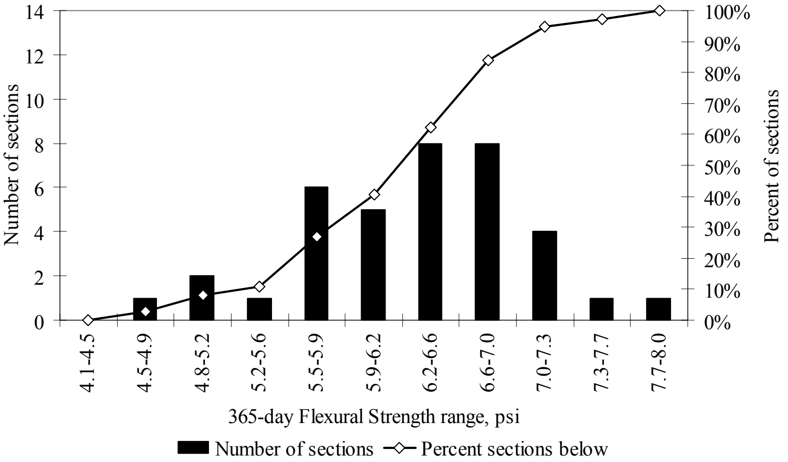


Figure 3-35 Cumulative Frequency graph for 28-day flexural strength of sections with target strength of 6.2 MPa

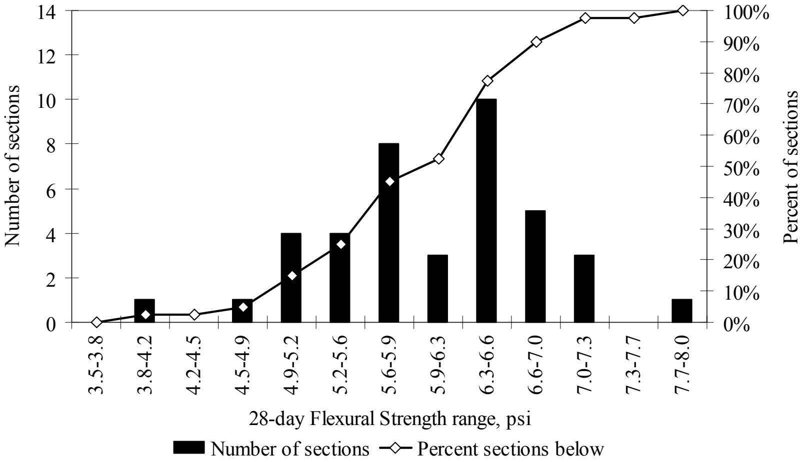


Figure 3-36 Cumulative frequency graph for 365-day flexural strength of sections with target strength of 6.2 MPa

### 3.4.6 Extent and Occurrence of Distresses

This section of the report is a discussion on the extent of selected distresses that have occurred in the test sections of the experiment. The pavement performance measures considered include,

a. Transverse cracking (number of cracks and percentage of slabs cracked),
b. Longitudinal cracking (total length, m),
c. Wheelpath joint faulting (mm), and
d. Roughness (IRI, m/ km).

The list of distresses considered for analyses was determined in agreement with the NCHRP panel for this study. The extent of occurrence (% sections that have shown the distress), and the frequency distribution will be presented for each type of distress based on the latest data available. The extent of occurrence of distresses was studied, as it has a bearing on the selection of the type of analysis procedures to be employed for analysis of the data. Though the analyses procedures help derive conclusions from the data it is imperative that the extent of occurrence of distresses be considered along with the conclusions.

*Transverse Cracking*

As per the latest data, 26% of the sections (excluding the site in NV) have exhibited transverse cracks. Figure 3-37 and Figure 3-38 show the magnitude and extent of cracking in the SPS-2 sections.

Figure 3-39 and Figure 3-40 show the distribution of transverse cracking as a function of design and site factors.

The site-wise occurrence of transverse cracking in the SPS-2 test sections is shown in Figure 3-41. It is evident from the plot that the sections in Nevada, NV (32) have distinctly higher cracking than sections in any of the other sites.

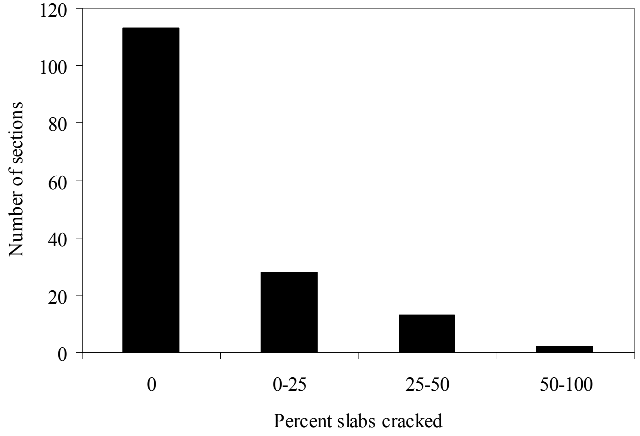


Figure 3-37 Frequency distribution of percent slab cracked

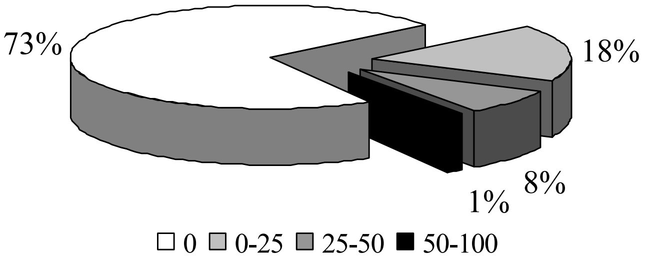


Figure 3-38 Distribution of transverse cracking by percent slabs cracked

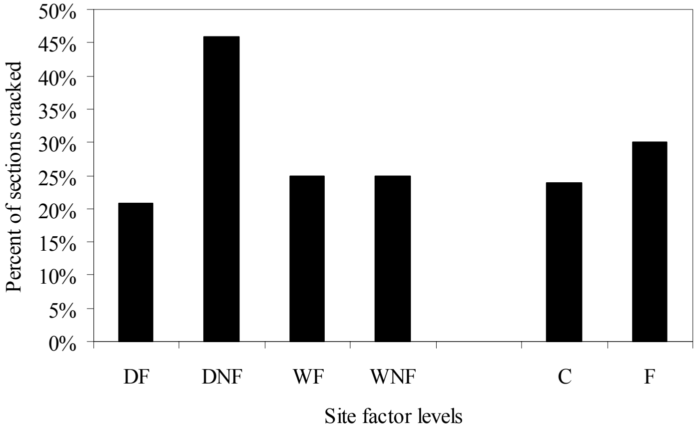


Figure 3-39 Occurrence of transverse cracking by site factor

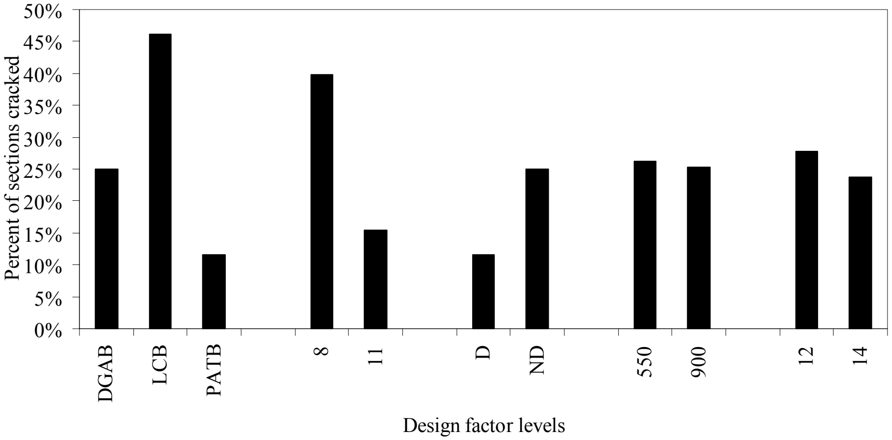


Figure 3-40 Occurrence of transverse cracking by design factor

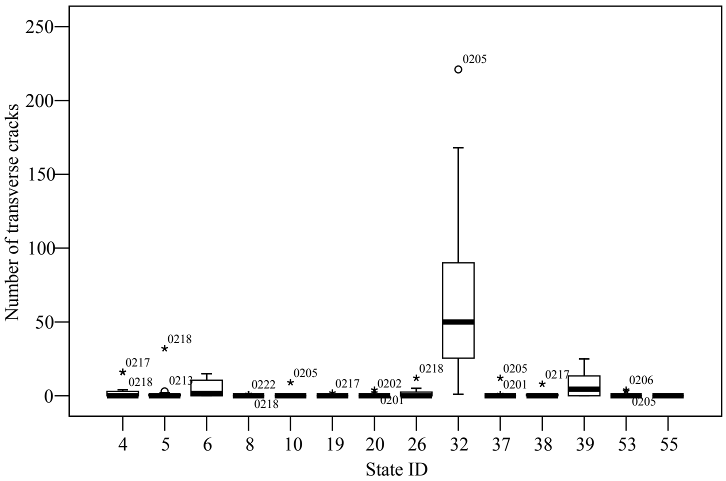


Figure 3-41 Site-wise occurrence of transverse cracking for SPS-2 test sections

*Longitudinal Cracking*

The extent of occurrence of longitudinal cracking is shown in Figure 3-45 and Figure 3-46. As per the latest data from Release 17, 28% of sections exhibited longitudinal cracking. 7% of the sections have the total length of longitudinal cracking of at least 20 m.

Figure 3-47 and Figure 3-48 show the distribution of longitudinal cracking by site and design factors. Like in the case of transverse cracking, the sections at the Nevada site have exhibited notably higher magnitude of distresses compared to sections in other sites.

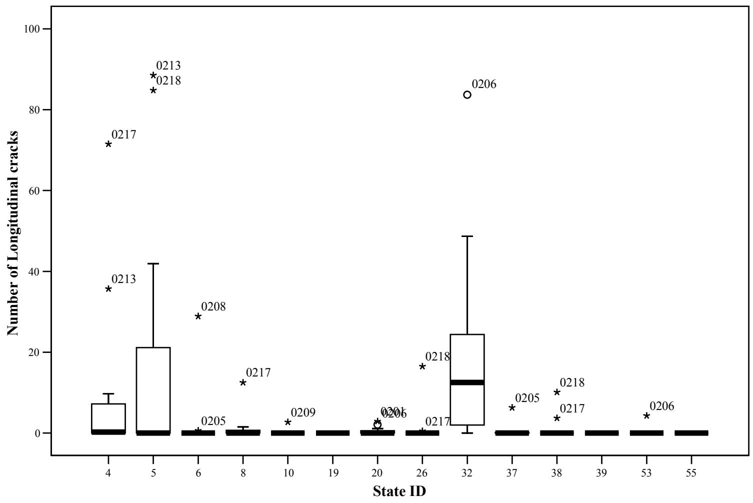


Figure 3-42 Site-wise occurrence of longitudinal cracking in SPS-2 test sections

*Wheel path Joint faulting*

The site-wise occurrence of faulting in the test sections is shown as box plots in Figure 3-43. It is evident from the plot that less than 5 joints per section have faulting greater than 1.0 mm, in a vast majority of the sections. The extent of occurrence of wheel path joint faulting is given in Figure 3-49 and Figure 3-50. Figure 3-51 and Figure 3-52 show the distribution of faulting by site factors and design factors.

*Roughness (IRI)*

The site-wise status of current roughness in the test sections is shown as box plots in Figure 3-44. It is evident from the plot that in most of the sections the current roughness is less than 1.8 m/km. The status of roughness in the test sections is given in Figures 3-53 and 3-54. Figure 3-55 and Figure 3-56 show the distribution of roughness by site factors and design factors.

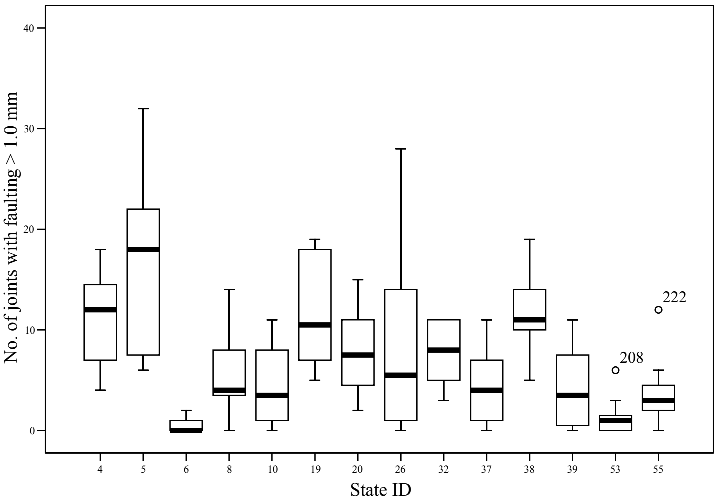


Figure 3-43 Site-wise occurrence of faulting in SPS-2 test sections

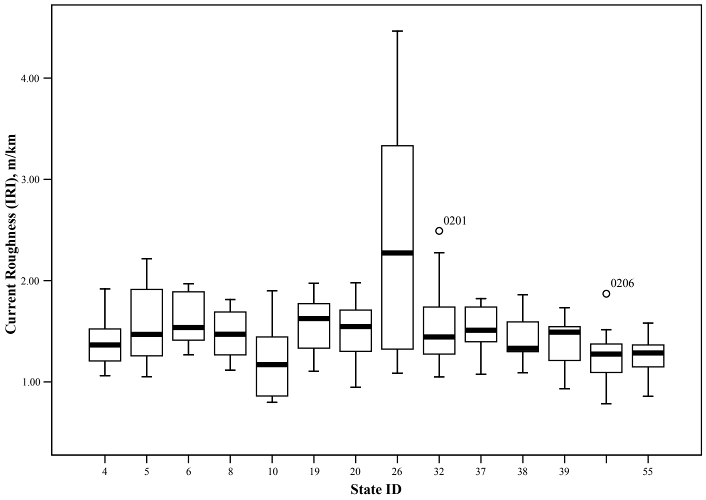


Figure 3-44 Site-wise occurrence of final roughness values for SPS-2 test sections

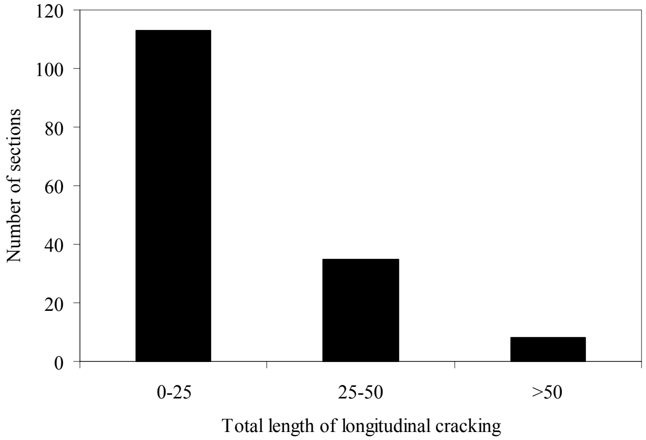


Figure 3-45 Distribution of longitudinal cracking

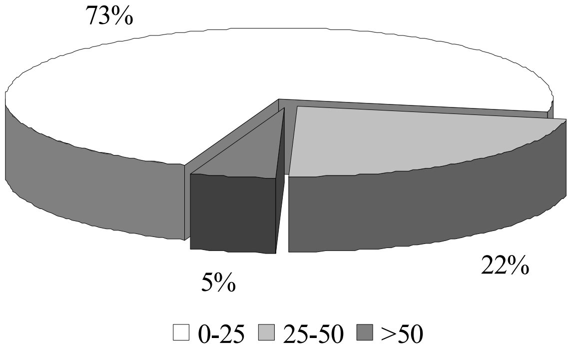


Figure 3-46 Distribution of longitudinal cracking

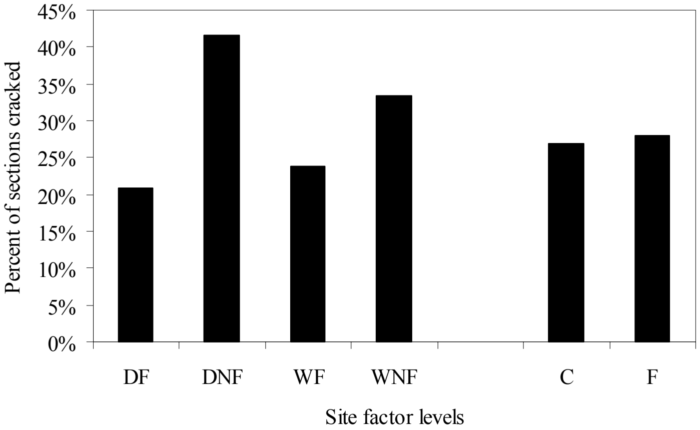


Figure 3-47 Extent of longitudinal cracking by site factors

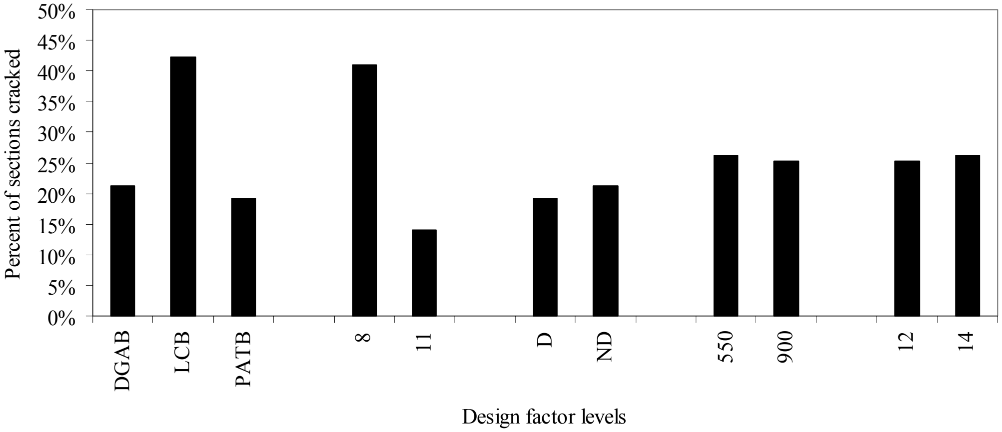


Figure 3-48 Extent of longitudinal cracking by design factors

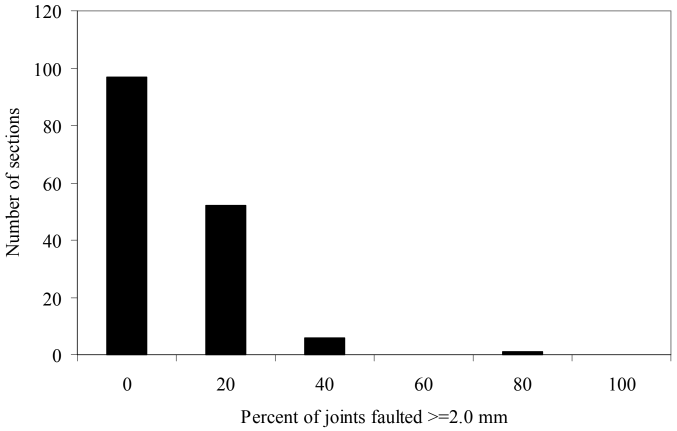


Figure 3-49 Distribution of percent joints faulted >=2.0 mm

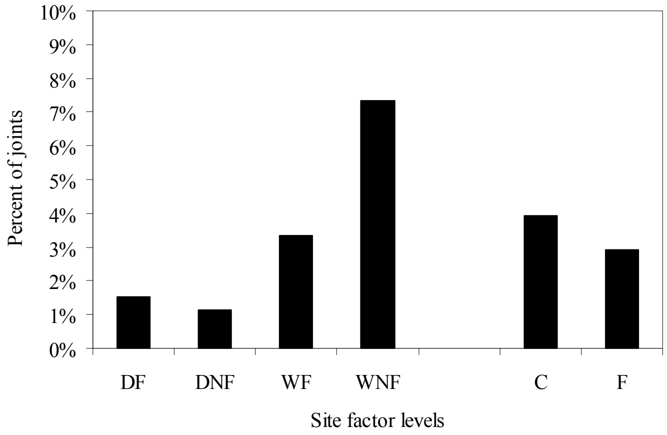


Figure 3-50 Extent of faulting >=2.0 mm in site factors

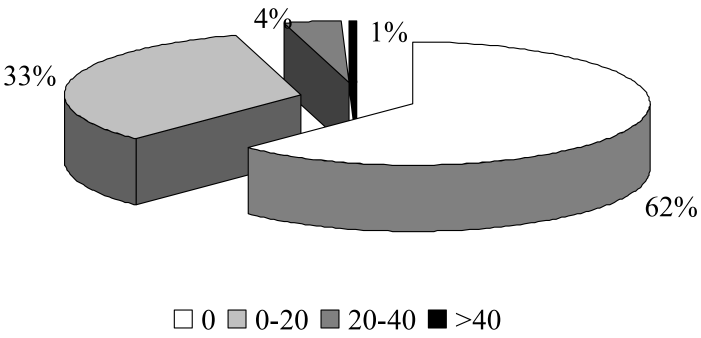


Figure 3-51 Percent of joints that faulted >= 2.0 mm

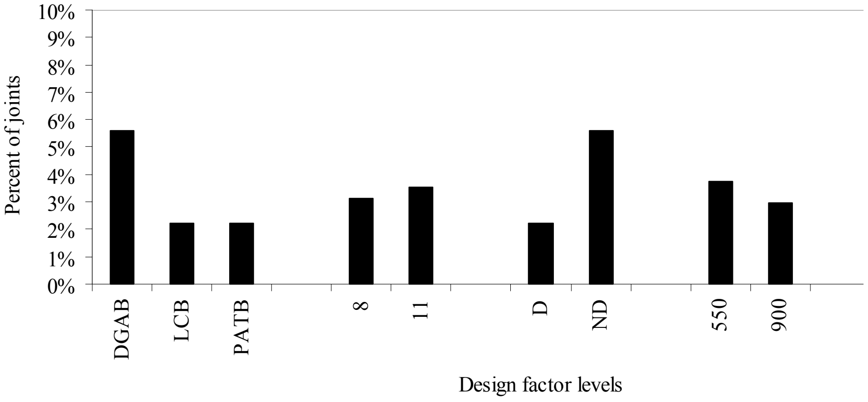


Figure 3-52 Extent of faulting >=2.0 mm in design factors

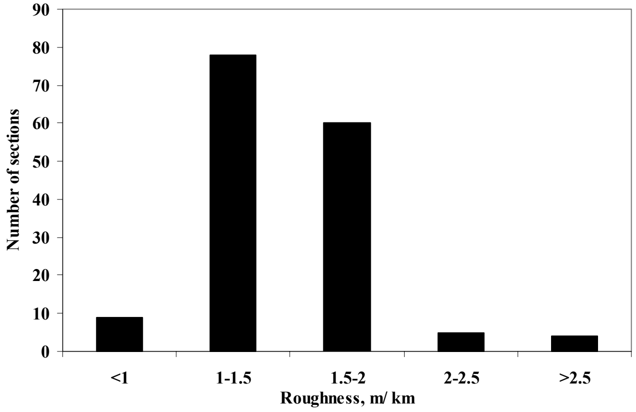


Figure 3-53 Distribution of roughness, m/ km

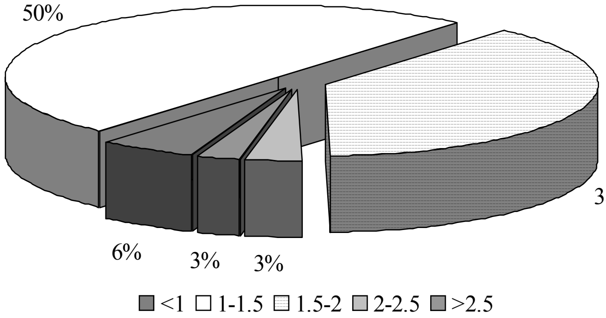


Figure 3-54 Distribution of roughness, IRI/ km

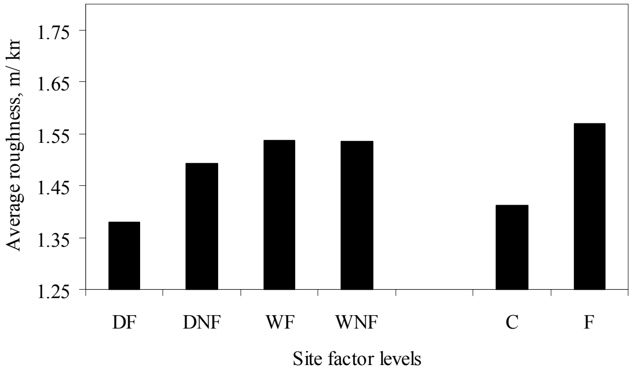


Figure 3-55 Extent of roughness in site factors

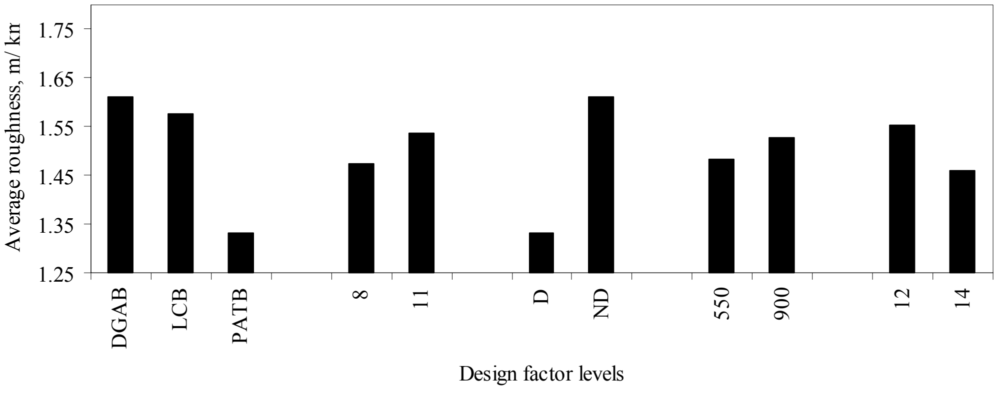


Figure 3-56 Extent of roughness in design factors

### 3.4.7 Dynamic Load Response Data (DLR) — Rigid Pavements

This section of the report summarizes the extent of data available in Release 17 for the DLR experiment.

*Ohio DLR Experiment*

Five series of tests were conducted on the sections. Only data from test series II and IV conducted in 1996 and 1997 are available. The specifics of these tests are summarized in Appendix B3.

*North Carolina DLR Experiment*

The NC DLR data is available for testing conducted in the years 1994 through 1997. For each section data are available for testing series ‘a’ through ‘h’.  Appendix B3 summaries of testing details on the instrumented sections of NC DLR experiment, from the available data. The number of runs for which data are available is also given in Appendix B3.

## 3.5 DATA AVAILABILITY IN SPS-8 EXPERIMENT – FLEXIBLE PAVEMENTS

This section of the report summarizes the data availability for flexible pavement sections in the SPS-8 experiment. The availability of all relevant data elements is summarized in Table 3-19. The table shows that availability of the main factors is high, while that of the exogenous factors is somewhat lower. In particular, the availability of traffic data is low; however, the impact of traffic data may be insignificant for the SPS-8 experiment if all the sites have very limited traffic. The availability of the relevant data elements in SPS-8 experiment is discussed in the following sections of the report.

### 3.5.1 General Site Information

Each site has unique characteristics, which can be mainly explained by the particular climatic and soil conditions at a particular location. The SPS-8 experiment mainly focuses on pavement performance based on the environmental aspects of sites in combination with different subgrade types. The particular site information can be further divided into construction, climate and traffic.

*Construction Issues*

The construction reports prepared by the supervisory consultants for each site were reviewed to identify the deviations/problems during the construction of each site. These deviations might be helpful in explaining the unusual trends in performances (premature failures) at a particular site.

The summary of deviations has been prepared for all 15 sites in the SPS-8 experiment and is given in Appendix C.

Table 3-19 Summary of SPS-8 data element availability –Flexible pavements

| **Data Category** | **Data Type** | **Data Availability, %** |
|---|---|---|
| Site Information | *Construction Reports* | 93 |
| | *Climatic data* | |
| | Virtual Weather Station | |
| | Annual Temperature | **93** |
| | Annual Precipitation | **93** |
| | Automatic Weather Station | |
| | Monthly Temperature | 47 |
| | Monthly Precipitation | 47 |
| | *Traffic data* | |
| | Traffic Open date | **93** |
| | Estimated ESALs | **60** |
| | Monitored ESALs | **33** |
| | Axle Load Spectrum | **33** |
| Material Data | *Asphalt Layer* | |
| | Core Examination | 80 |
| | Bulk Specific Gravity | 75 |
| | Max Specific Gravity | 78 |
| | Asphalt Content | 78 |
| | Asphalt Resilient Modulus | 19 |
| | Penetration | 69 |
| | Viscosity | 65 |
| | Asphalt Specific Gravity | 69 |
| | Aggregate Gradation | 81 |
| | Fine Aggregate Particle Shape | 21 |
| | Layer Thickness | **100** |
| | Unbound Base Gradation | 78 |
| | *Subgrade* | |
| | Subgrade Gradation | 78 |
| | Atterberg Limits | 84 |
| | Subgrade Modulus | 44 |
| Pavement Structure | *Layer details* | |
| | Type | **100** |
| | Representative thicknesses | **100** |
| | Constructed thicknesses | 100 |
| | *Shoulder information* | |
| | Type | 93 |
| | Width | 93 |
| | Thickness | 93 |
| Monitoring** | *FWD data* | |
| | Deflections | **100** |
| | Temperature at Testing | 100 |
| | Backcalculated Moduli | 13 |
| | *Manual Distresses data* | **100** |
| | *Longitudinal Profile (IRI)* | **100** |
| | *Transverse Profile (Rut Depth)* | **100** |

Note: ** Data is said to be available for a section even if it is available from only one survey.

*Climatic Data*

As explained before for the SPS-1 experiment, the average annual rainfall and average annual freezing index were used to classify each site into four climatic regions. The classification definitions for each zone were taken from the LTPP DataPave. The summary of the climatic data from the VWS for all sites in SPS-8 is given in Table 3-20. Only climatic data for CA (6) is not available in Release 17.0 of DataPave.

*Traffic data*

The SPS-8 experiment design stipulates that traffic volume in the study lane be at least 100 vehicles per day but not more than 10,000 ESAL per year. Therefore, it is important to check the traffic not exceeding the threshold specified for this experiment. The traffic data is only available for 8 out of 15 sites from estimate and monitoring modules of DataPave (Release 17.0). No traffic data is available for AR (5), CA (6), MO (29), NJ (34), NM (35), NC (37) and WI (55).

### 3.5.2 Material Data

The material properties of all the layers in a pavement system play a very significant role in its future performance. The SPS-8 Experiment was designed to study the specific effects of a range of environments on the pavement performance; therefore the material properties which are susceptible to climatic changes need to be investigated. In this experiment the subgrade type was a factor (fine or coarse), while the asphalt mix and base material properties were assumed to be uniform across all states. The subgrade material properties were investigated. The summary of soil gradation and Atterberg limit information required for classification is given in Table 3-21.

Table 3-20 Summary of Environmental data of the sections in SPS-8

| State | Climatic Zone | AATP[1] (mm) | AIPD[2] (days) | WDPY[3] (days) | Avg. Days Above 32 °C | Avg. Days below 0 °C | AAT[4] (°C) | FI (deg days) | FT (cycles) |
|---|---|---|---|---|---|---|---|---|---|
| 050800 | WNF | 1374 | 34 | 133 | 64 | 52 | 17 | 46 | 48 |
| 080800 | DF | 372 | 7 | 95 | 31 | 162 | 10 | 326 | 142 |
| 280800 | WNF | 1427 | 37 | 145 | 52 | 65 | 16 | 57 | 60 |
| 290800 | WF | 1079 | 27 | 144 | 37 | 105 | 13 | 167 | 92 |
| 29A800 | WF | 945 | 22 | 137 | 29 | 112 | 12 | 334 | 84 |
| 300800 | DF | 371 | 4 | 132 | 4 | 198 | 6 | 574 | 163 |
| 340800 | WF | 1071 | 27 | 119 | 8 | 68 | 13 | 127 | 56 |
| 350800 | DNF | 346 | 5 | 92 | 83 | 99 | 15 | 9 | 100 |
| 360800 | WF | 891 | 17 | 193 | 5 | 130 | 9 | 437 | 87 |
| 370800 | WNF | 1342 | 33 | 151 | 36 | 46 | 17 | 14 | 47 |
| 390800 | WF | 972 | 24 | 153 | 10 | 130 | 10 | 374 | 96 |
| 460800 | DF | 423 | 8 | 96 | 25 | 175 | 7 | 978 | 107 |
| 480800 | WNF | 1015 | 24 | 131 | 99 | 19 | 20 | 10 | 18 |
| 48A800 | WNF | 846 | 22 | 100 | 94 | 35 | 19 | 21 | 34 |
| 490800 | DF | 473 | 7 | 118 | 8 | 198 | 7 | 498 | 170 |
| 530800 | WF | 510 | 7 | 137 | 30 | 91 | 11 | 169 | 73 |
| 53A800 | WF | 386 | 3 | 135 | 33 | 88 | 11 | 163 | 71 |
| 550800 | WF | 814 | 17 | 151 | 4 | 175 | 6 | 1015 | 96 |

Note: 1-Average Annual Total Precipitation (mm), 2-Average Intense Precipitation Days in a year, 4-Wet Days per Year, 4-Average Annual Temperature

## Table 3-21 Subgrade soil properties for SPS-8 flexible pavements

| State | SHRP ID | -# 200 | HYDRO_02 | HYDRO_002 | HYDRO_001 | COARSE_SAND | FINE_SAND | SILT | CLAY | COLLOIDS | LL | PL | PI | Expansive | SG | Zone | Frost |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 0803 | 77 | 34 | 16 | - | 0 | 24 | 60 | 16 | - | 29 | 17 | 12 | N | F | WNF | Y |
| 5 | 0804 | 58 | 34 | 18 | - | 3 | 30 | 40 | 18 | - | 34 | 15 | 10 | N | F | WNF | Y |
| 6 | A805 | 11 | 5 | 2 | - | 28 | 61 | 9 | 2 | - | - | - | 0 | N | C | DNF | N |
| 6 | A806 | 14 | 5 | 2 | - | 29 | 57 | 12 | 2 | - | - | - | 0 | N | C | DNF | N |
| 29 | 0801 | 63 | 49 | 25 | 22 | 0 | 10 | 38 | 25 | 22 | 44 | 19 | 26 | Y | F | WF | Y |
| 29 | 0802 | 59 | 57 | 43 | 37 | 2 | 6 | 22 | 43 | 37 | 68 | 26 | 42 | Y | F | WF | Y |
| 29 | A801 | 92 | 77 | 41 | 38 | 2 | 2 | 36 | 41 | 38 | 57 | 22 | 35 | Y | F | WF | Y |
| 29 | A802 | 87 | 70 | 36 | 30 | 3 | 3 | 35 | 36 | 30 | 58 | 19 | 40 | Y | F | WF | Y |
| 30 | 0805 | 9 | 6 | 2 | 66 | 11 |  | 6 | 2 | - | - | - | 0 | N | C | DF | N |
| 30 | 0806 | 8 | 6 | 2 | - | 14 | 11 | 6 | 2 | - | - | - | 0 | N | C | DF | N |
| 34 | 0801 | 8 | 3 | 1 | - | 16 | 67 | 7 | 1 | - | - | - | - | N | C | WF | N |
| 34 | 0802 | 7 | 4 | 1 | - | 19 | 67 | 7 | 1 | - | - | - | - | N | C | WF | N |
| 36 | 0801 | 27 | 13 | 7 | 7 | 5 | 54 | 21 | 7 | 7 | 8 | 5 | 2 | N | C | WF | N |
| 36 | 0802 | 6 | 6 | 4 | - | 32 | 57 | 3 | 4 | - | 0 | 0 | 0 | N | C | WF | N |
| 37 | 0801 | 8 | 7 | 2 | - | 6 | 84 | 8 | 2 | - | - | - | 0 | N | C | WNF | N |
| 37 | 0802 | 12 | 8 | 4 | - | 12 | 76 | 8 | 4 | - | - | - | 0 | N | C | WNF | N |
| 39 | 0804 | 71 | 55 | 28 | - | 8 | 15 | 43 | 28 | - | 30 | 17 | 13 | N | F | WF | Y |
| 46 | 0803 |  | 27 | 16 | 12 | 1 | 64 | 20 | 4 | 12 | 36 | 19 | 17 | N | F | DF | Y |
| 46 | 0804 | 35 | 30 | 19 | 10 | 26 | 28 | 35 | 4 | 17 | 39 | 18 | 21 | Y | F | DF | Y |
| 48 | 0801 | 54 | 17 | 10 | 7 | 23 | 38 | 40 | 10 | - | 16 | 9 | 7 | N | F | WNF | N |
| 48 | 0802 | 51 | 23 | 12 | - | 7 | 39 | 33 | 12 | - | 29 | 23 | 6 | N | F | WNF | N |
| 49 | 0803 | 35 | 19 | 10 | - | 9 | 15 | 22 | 10 | - | 29 | 15 | 14 | N | C | DF | N |
| 49 | 0804 | 34 | 21 | 10 | - | 7 | 12 | 23 | 10 | - | 37 | 18 | 19 | Y | C | DF | N |
| 53 | 0801 | 61 | 29 | 9 | - | 8 | 8 | 53 | 9 | - | 31 | 25 | 6 | N | F | WF | N |
| 53 | 0802 | 42 | 21 | 5 | - | 8 | 7 | 37 | 5 | - | - | - | 0 | N | C | WF | N |
| 55 | 0805 | 12 | 7 | 3 | - | 20 | 28 | 8 | 3 | - | - | - | 0 | N | C | WF | N |
| 55 | 0806 | 14 | 9 | 4 | - | 26 | 29 | 11 | 4 | - | - | - | 0 | N | C | WF | N |

Note: Colloidal Content >15% & PI>18, for expansive soils this criterion was adopted (source: Holtz (1959) and U.S.B.R (1974))
Silt, coarse clay having more than 15% material finer than 0.02 mm to be dangerous for frost heave (Source: Holtz & Kovacs, 1981)

In addition, two critical aspects of soil behavior were further investigated from the available soil data: expansion of clayey soils in dry zones and frost susceptibility in freeze zones.

The active soils were identified by using the following criteria [6]:

- Expansive Soils─ colloidal content >15% and PI>18
- Frost Susceptible Soils─ silt, coarse clay having > 15% material finer than 0.02 mm.

By using the above criteria, the subgrade soils in States 29 (Missouri), 46 (South Dakota, section 0804) and 49 (Utah, section 0804) were classified as active (expansive) soils, while sections in States 5 (Arkansas), 29 (Missouri), 39 (Ohio, section 0804) and 46 (South Dakota) were identified as having subgrade soils with frost heave potential.

### 3.5.3 Design versus Actual Construction Review

According to the original experiment design as discussed in chapter 2, 12 sites were essential required with two different structural designs. These sites were selected based on the geographical location so that they may be located in different climatic regions. However, due to site specific climatic data the region identified at the design stage may be different. Similarly, the target layer thickness may have variability due to construction. The specific as-constructed site conditions are discussed in the section below.

*Construction Issues*

The construction guidelines for SPS-8 sections were discussed in chapter 2. The construction deviations for each site were taken from the construction reports and are summarized in Appendix C.

*Site Factors*

The SPS-8 flexible experiment design required that two different structural designs should be repeated in at least 12 sites. However, the actual data on the site factors (climate and subgrade) showed that there are 15 sites in the SPS-8 flexible experiment and currently these are distributed according to Table 2-8. There are 7 sites in WF, and 3 sites each for WNF, DF and DNF zones, respectively. Almost half of the sites were constructed on coarse subgrade, and the others were built on fine subgrade soil.

*Design Factors*

The design or structural features which are considered to be the main experimental factors in SPS-8 flexible pavement experiment include:

- AC Thickness [4-inch (102 mm) versus 7-inches (178 mm)]
- Granular Base Thickness [(8-inch (203 mm) versus 12-inch (305 mm)]

The summary of the as-constructed and target thicknesses for all flexible pavements is given in Table 3-22.

### 3.5.4 Extent and Occurrence of Distress

The age of the section is a very important factor in the SPS-8 experiment, as a higher age of a particular section will translate in higher environment related distresses. Figure 3-57 shows the latest age for all flexible pavement sections in SPS-8. Further age distribution of flexible pavements among the SPS-8 sections is shown in Figure 3-58. The age data for SPS-8 sections shows that most of these sections are aged below seven years and are in the early stage on the performance curve.

The distress data for the SPS-8 sections was obtained from the files MON_DIS_AC_REV (cracking and non-load related distresses data), MON_T_PROF_INDEX_SECTION (rutting data) and MON_PROFILE_MASTER (roughness). Figure 3-59 and Figure 3-60 show the occurrence and distribution of distresses in the SPS-8 Experiment flexible pavements. The available distress data in Data Pave (Release 17) has only shown five types of distresses in all SPS-8 flexible pavements.

Figure 3-60 (a) shows the distribution of rutting in SPS-8 flexible pavement sections. It can be observed that only 9% of the sections have shown more than 5 mm of rutting, where as in the majority of the sections (60%) rutting ranges from 3 to 5 mm. A low amount of rutting is expected in the SPS-8 pavements since load is the major cause of rutting in flexible pavements.

Figure 3-60 (b) shows the distribution of roughness data (IRI) based on its magnitude. The data suggests that the majority of sections did not exhibit high levels of roughness, with only 9% of the population with IRI greater than 2 m/km.

Table 3-22 Construction details of the flexible pavement sections in SPS-8

| State | SHRP_ID | Subgrade Type | AC | GB | GS[1] | SS[2] | TS | Target AC | Target GB |
|---|---|---|---|---|---|---|---|---|---|
| 5 | 0803 | F | 3.8 | 7.3 |  |  |  | 4 | 8 |
| 5 | 0804 | F | 7.2 | 12.7 |  |  |  | 7 | 12 |
| 6 | A805 | C | 4.2 | 8.2 |  |  |  | 4 | 8 |
| 6 | A806 | C | 6.6 | 12.2 |  |  |  | 7 | 12 |
| 28 | 0805 | C | 4 | 9 |  |  |  | 4 | 8 |
| 28 | 0806 | F | 7 | 12 |  |  |  | 7 | 12 |
| 29 | 0801 | F | 4.9 | 7.8 |  |  |  | 4 | 8 |
| 29 | 0802 | F | 7.5 | 11.5 |  |  |  | 7 | 12 |
| 29 | A801 | F | 4.3 | 8.3 |  |  |  | 4 | 8 |
| 29 | A802 | F | 6.9 | 12.3 |  |  |  | 7 | 12 |
| 30 | 0805 | C | 4.5 | 7.1 |  |  |  | 4 | 8 |
| 30 | 0806 | C | 6.9 | 11.8 |  |  |  | 7 | 12 |
| 34 | 0801 | C | 3.5 | 7.8 |  |  |  | 4 | 8 |
| 34 | 0802 | C | 6.8 | 11.6 |  |  |  | 7 | 12 |
| 35 | 0801 | F | 4.4 | 9.7 |  |  |  | 4 | 8 |
| 35 | 0802 | F | 7.3 | 12.6 |  |  |  | 7 | 12 |
| 36 | 0801 | C | 4.9 | 8.4 |  | 168 |  | 4 | 8 |
| 36 | 0802 | C | 7.6 | 10 |  | 156 |  | 7 | 12 |
| 37 | 0801 | C | 4 | 8.7 |  |  |  | 4 | 8 |
| 37 | 0802 | C | 7 | 11.5 |  |  |  | 7 | 12 |
| 39 | 0803 | F | 3.9 | 7.9 | 36 |  |  | 4 | 8 |
| 39 | 0804 | F | 6.6 | 11.9 | 30 |  |  | 7 | 12 |
| 46 | 0803 | F | 4.8 | 8 |  |  |  | 4 | 8 |
| 46 | 0804 | F | 7.2 | 12 |  |  |  | 7 | 12 |
| 48 | 0801 | F | 4 | 8.5 |  |  | 10 | 4 | 8 |
| 48 | 0802 | F | 5.5 | 10.7 |  |  | 10 | 7 | 12 |
| 49 | 0803 | C | 4.9 | 7.8 | 41.2 |  |  | 4 | 8 |
| 49 | 0804 | C | 6.9 | 12 | 41.2 |  |  | 7 | 12 |
| 53 | 0801 | F | 3.7 | 8 | 38.4 |  |  | 4 | 8 |
| 53 | 0802 | C | 6.8 | 11.7 | 38.4 |  |  | 7 | 12 |
| 55 | 0805 | C | 4.4 | 8 |  |  |  | 4 | 8 |
| 55 | 0806 | C | 7 | 12 |  |  |  | 7 | 12 |

Note: 1-Granular subbase, 2-SS represents subgrade layer, the thickness in this column is the fill

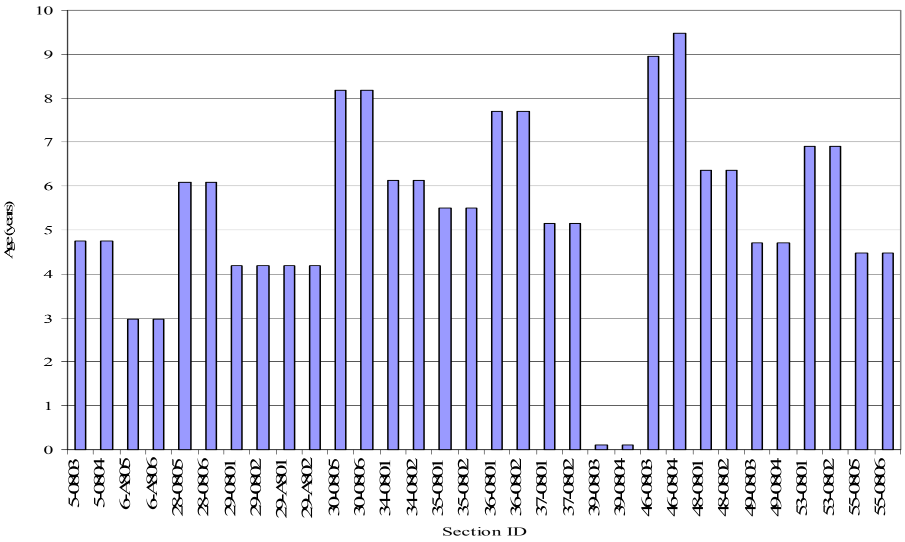
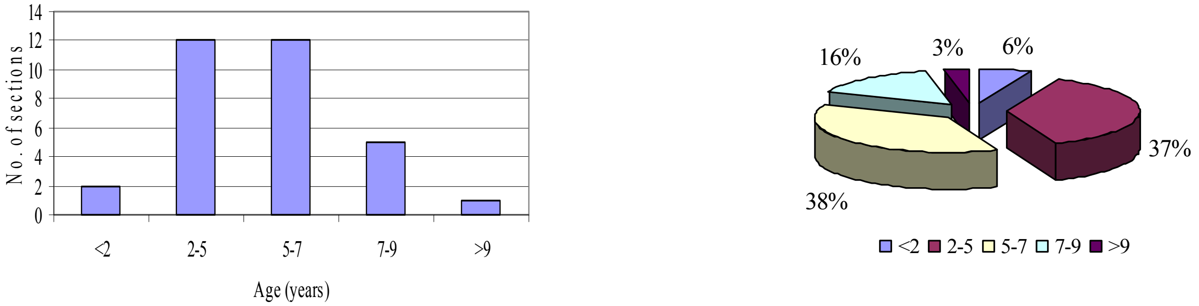


Figure 3-57 Age of the flexible pavements in SPS-8



(a) Frequency of age

(b) Distribution of age

Figure 3-58 Age distribution in the SPS-8 sites ─ flexible pavements

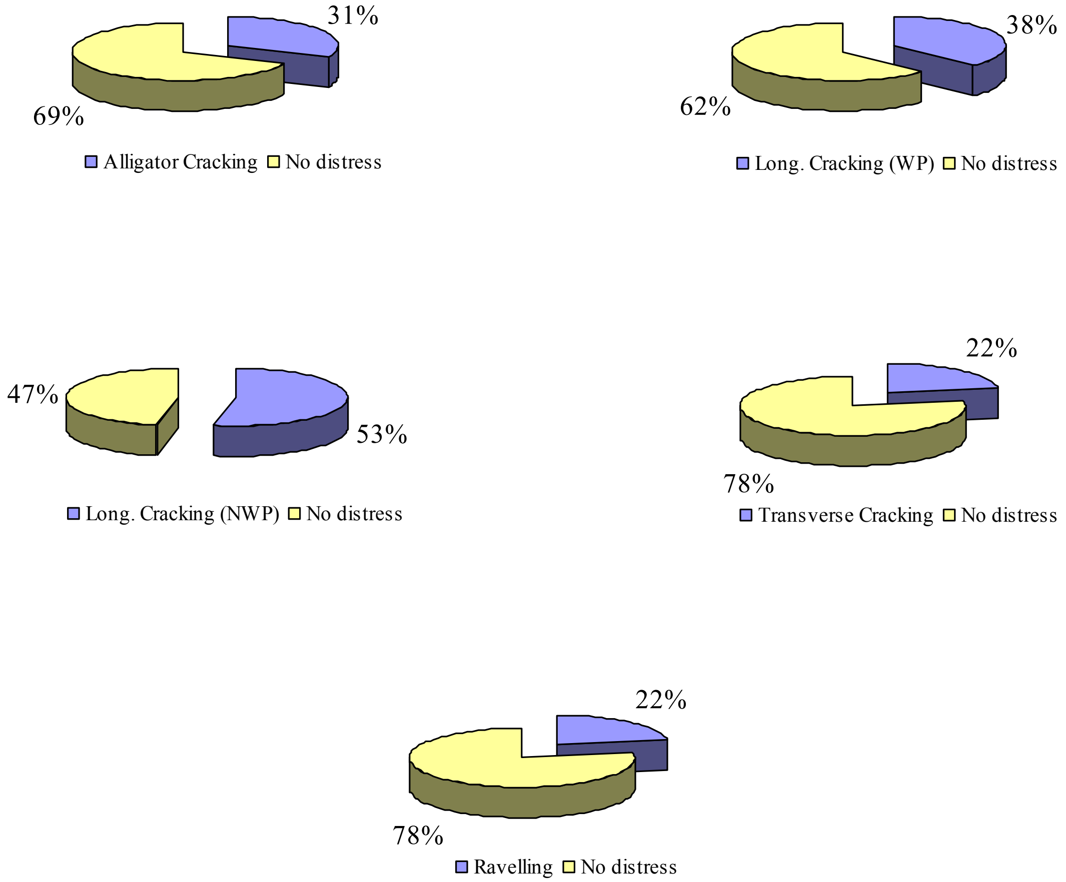


Figure 3-59 Distribution of distresses in SPS-8 flexible pavements sections

(a) Average Rut (mm)

(b) Average IRI (m/km)

Figure 3-60 Distribution of IRI and Rutting in SPS-8 flexible pavements

## 3.6 DATA AVAILABILITY FOR SPS-8 EXPERIMENT– RIGID PAVEMENTS

This section of the report describes data availability for rigid pavement sections in the SPS-8 experiment. All the data types are summarized in Table 3-28; these are similar to the ones described for SPS-2 experiment.

### 3.6.1 General Site Information

*Construction Reports*

Like in the case of SPS-2 sites, the construction reports contain information about the construction process, geometric layout, construction issues, etc. Construction reports are available for all the six sites in the SPS-8 experiment. A summary of the site-specific information can be found in Appendix C.

*Climate Data*

The data on climate at the SPS-8 sites is available from AWS and not from VWS as in the case of SPS-2 sections. This information was used to calculate average annual temperature and precipitation at the sites. Then the classification of the sites was confirmed with the derived data.

*Traffic Data*

Table 3-29 is a summary of the traffic data available for the rigid pavement sections in SPS-8 experiment. It is evident form the data that, the traffic on the sections in Ohio (39) is higher than the stipulated upper limit, which is 10,000 ESAL. Traffic data are also available from the construction reports of the sites. A summary of traffic data obtained from construction reports is Table 3-25. It is evident that the AADT for sections in AR (5), MO (29), and WA (53) is below the lower limit of 100 vehicles/day.

### 3.6.2 Design versus Actual Construction Review

Figure 3-61 and Figure 3-62 show the PCC slab thickness deviations for the two thickness levels. Similarly, Figure 3-64 shows the deviations in the base layer thickness. With the exception of the sections in the sites in Texas (48) and Washington (53), all the other sections are in compliance with the stipulated base thickness.

Table 3-23 Summary of data availability for SPS-8 experiment –Rigid pavements

| Data category | Data type | **Data Availability, % of sections** |
|---|---|---|
| Site location information | *Construction reports* | 100 |
| | *Climatic data* | |
| | Virtual Weather Station | |
| | Annual Temperature | 0 |
| | Annual Precipitation | 0 |
| | Automated Weather Station | |
| | Monthly Temperature | 7 |
| | Monthly precipitation | 7 |
| | *Traffic data** | |
| | Traffic Open date | 0 |
| | Monitored | 14 |
| | Estimated | 14 |
| | Axle Distribution | 0 |
| Materials data | *Subgrade* | |
| | Sieve analysis | 100 |
| | Atterberg Limits | 100 |
| | Classification | 100 |
| | *Lean Concrete Base* | |
| | Compressive Strength | 0 |
| | *Portland Cement Concrete* | |
| | PCC mix data | 100 |
| | Flexural Strength | 71 |
| | Compressive Strength | 86 |
| | Split tensile Strength | 86 |
| | Static modulus of Elasticity | 86 |
| | CTE | 0 |
| Pavement structure | *Layer details* | |
| | Type | 100 |
| | Representative thickness | 100 |
| | *Dowel bar details* | |
| | Diameter | 0 |
| | Length | 0 |
| | Spacing | 0 |
| | *Shoulder information* | |
| | Type | 100 |
| | Width | 100 |
| | Thickness | 100 |
| Monitoring** | Profile data (IRI) | 100 |
| | Distress data | 100 |
| | Faulting data | 100 |

*Monitored, Estimated, or Axle Distribution data is considered to be available for a site even if the data is available only for one year.

**Data is said to be available for a section even if it is available for just one year.

Table 3-24 Summary of available traffic data

| Site ID | SHRP ID | Year | Traffic (ESAL) |
|---|---|---|---|
| 8 | 0811 | 1997 | 1000 (Estimated) |
| 8 | 0811 | 1998 | 1000 (Estimated) |
| 8 | 0811 | 1999 | 1000 (Estimated) |
| 8 | 0812 | 1997 | 1000 (Estimated) |
| 8 | 0812 | 1998 | 1000 (Estimated) |
| 8 | 0812 | 1999 | 1000 (Estimated) |
| 39 | 0809 | 1997 | 66824 (Monitored) |
| 39 | 0810 | 1997 | 69317 (Monitored) |

Table 3-25 Summary of traffic data available from the construction reports

| Site ID | 2-way AADT used to calculate design traffic, vehicles/ day | Design ESAL, KESAL/ yr |
|---|---|---|
| 5 | 38 | Not Available |
| 8 | 2500 | 12.95 |
| 290800 | 50 | 96.5 |
| 29A800 | 118 | Not Available |
| 39 | 500 | Not Available |
| 48 | Not Available | 2.15 |
| 53 | 60 | 182.5 |

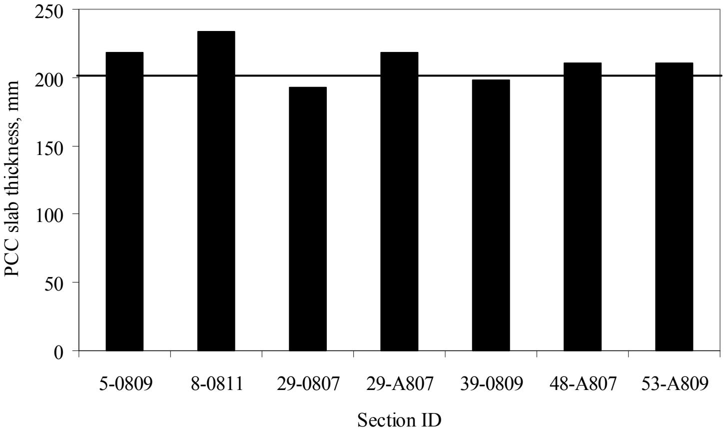


Figure 3-61Thickness deviations in sections with target PCC thickness of 203 mm

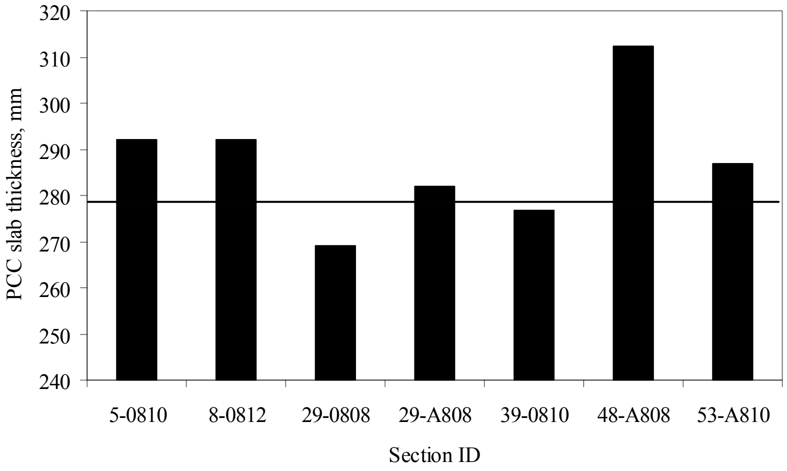


Figure 3-62 Thickness deviations in sections with target PCC thickness of 279 mm

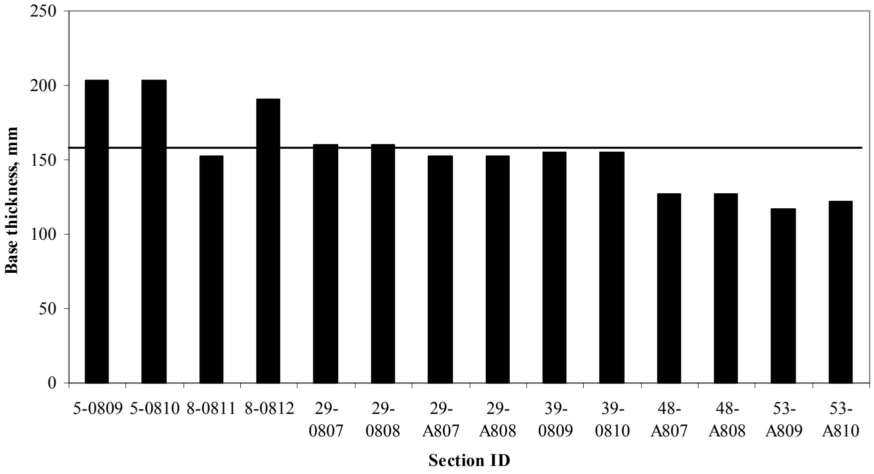


Figure 3-63 Deviation from target base thickness of 152 mm

The experiment design stipulates that the target 14-day flexural strength of the PCC slab concrete be 3.8 MPa (550 psi). Figure 3-64 gives a summary of concrete test data for each section. It can be noted from the table that all the sections for which data are available have concrete of sufficient average 14-day flexural strength as stipulated in the experiment design.

### 3.6.3 Distress Occurrence

The distresses in SPS-8 sections as of Release 17 have been summarized in

Table 3-26. Faulting of joints occurred in all the sections except the ones at the Washington site. In 12 of the 14 sections in the experiment, less than 40% of the joints have measurable faulting. In half of the sections, 3 to 20% of the joints faulted more than 1.0 mm. Figure 3-65 shows the distribution of IRI in SPS-8 sections.

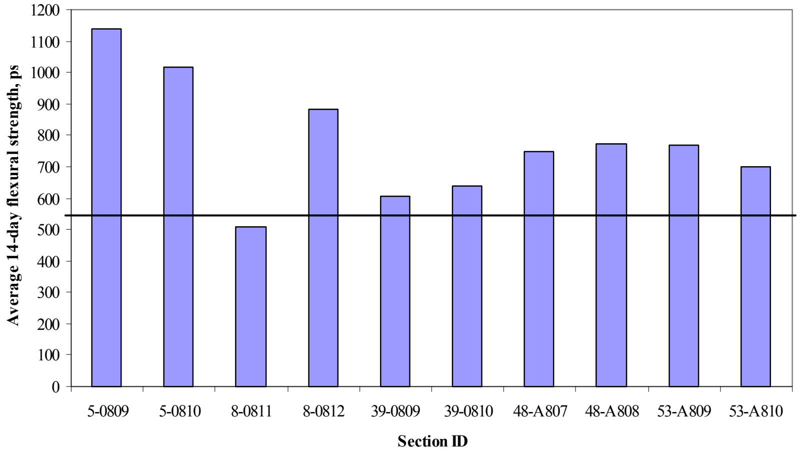


Figure 3-64 Average 14-day flexural strength of PCC

Table 3-26 Distresses in SPS-8 sections

| Site ID | SHRP ID | Trans. Cracks | Long. Cracks | Corner Breaks | Long. Spalling Length | Trans. Spalling | Trans. Spall Length | Scaling No. |
|---|---|---|---|---|---|---|---|---|
| 5 | 809 | 0 | 0 | 0 | 46.2 | 0 | 0 | 0 |
| 5 | 810 | 0 | 0 | 0 | 37.5 | 0 | 0 | 0 |
| 8 | 811 | 5 | 7.7 | 1 | 0 | 2 | 0.8 | 1 |
| 8 | 812 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 29 | 807 | 3 | 0.5 | 0 | 37.4 | 1 | 0.5 | 0 |
| 29 | 808 | 0 | 0 | 0 | 4.5 | 0 | 0 | 0 |
| 29 | A807 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 29 | A808 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 39 | 809 | 1 | 0 | 0 | 0.7 | 0 | 0 | 0 |
| 39 | 810 | 0 | 0 | 0 | 78.8 | 0 | 0 | 0 |
| 48 | A807 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 48 | A808 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 53 | A809 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 53 | A810 | 0 | 0 | 0 | 0 | 1 | 0.4 | 0 |

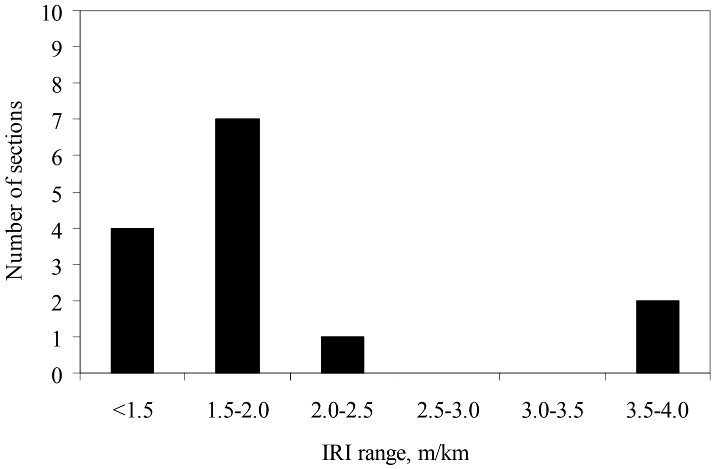


Figure 3-65 Current IRI in SPS-8 sections

# CHAPTER 4 - ANALYSIS METHODS

## 4.1 INTRODUCTION

The purpose of this chapter is to provide a summary of analysis methods that were used to perform this research. Some of the previous studies analyzed LTPP data (GPS and SPS experiments) based on engineering criteria (using basic statistics) and subjective judgment [1-4] . For example, the engineering criteria may include the rate of growth, severity levels and impact of distress on the functionality of the pavement. Several statistical methods were employed for establishing performance criteria to study the effect of design and construction features on pavement performance in this research. The statistical methods range from trend plotting to complex multivariate analysis.

This research focuses on evaluating the effects of specific design and construction features on the response and performance of the flexible and rigid pavements (SPS-1 and SPS-2 Experiments). The selection of statistical methods was founded on the specific objectives of this study and performance data extent/occurrence. These methods, as well as the concept of Performance Index (PI) developed and employed in the analysis, are explained in this chapter.

## 4.2 PERFORMANCE INDICATORS

The performance of a pavement is an accumulation of damage over time. All pavement sections within each SPS-1 and SPS-2 site were monitored over time; however, the monitoring of these sections is staggered with age (i.e., the distresses data were collected at different times for individual sections), and the performance measures (cracking, rutting and roughness) have shown a variable trend with time. Therefore, it was felt necessary to develop a measure that can quantify the overall performance of a pavement section over time. Figure 4-1 through Figure 4-4 show various performance curves for twelve test sections within two sites of the SPS-1 experiment. These figures show the measurement variability with time. The following discussion presents various options that were considered to transform the time series data of a section into a single performance indicator. The options considered are listed below:

- Maximum distress at the latest age/survey.
- Area under the performance curve.
- Area under the performance curve normalized to the latest age.
- Performance Index.

*Maximum distress at the latest age* is one of the options used for time series data analysis. This performance indicator only considers the maximum distress that was recorded for the test section in its monitored lifetime. Also, this performance indictor will not capture the performance trend over time. In addition, the measurement variability over time is not taken into account.

*Area under the curve* represents the actual pavement performance for a distress; larger area indicates poorer performance. The area under the curve can be calculated using the trapezoidal rule by using Equation (1).

$$Area = \sum_{i} \left[ \left( t_{i+1} - t_i \right) \left( \frac{y_i + y_{i+1}}{2} \right) \right] \tag{1}$$

The shortcoming of "area under the curve" is that this indicator cannot discriminate the performance of two sections having the same area but with different times for distress occurrence. For example, the performance curves in Figure 4-5 and Figure 4-6 may have similar "area under the curve" but the curve in Figure 4-6 shows better performance than that in Figure 4-5.

*Area under the curve normalized to the latest age* can be another alternative which can eliminate the discrepancy of using "area" alone (as mentioned above). This indicator can also be calculated based on the trapezoidal rule and can be represented mathematically by Equation (2).

$$\frac{Area}{L_{age}} = \frac{\sum_{i} \left[ \left( t_{i+1} - t_i \right) \left( \frac{y_i + y_{i+1}}{2} \right) \right]}{L_{age}} \tag{2}$$

Where; "$L_{age}$" is the latest age used to normalize the "area".

This indicator distributes the performance of a section (area) evenly over all years. However, performance curves can exhibit highly variable trends with time (see Figure 4-1) and may have gaps in the data for some years. Therefore, an alternative indicator was selected, where the performance is weighted with age.

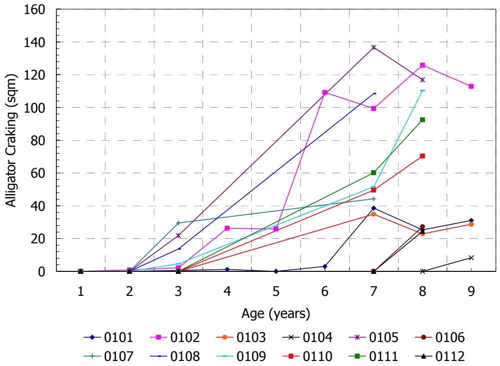


Figure 4-1 Fatigue cracking with age— AL (1)

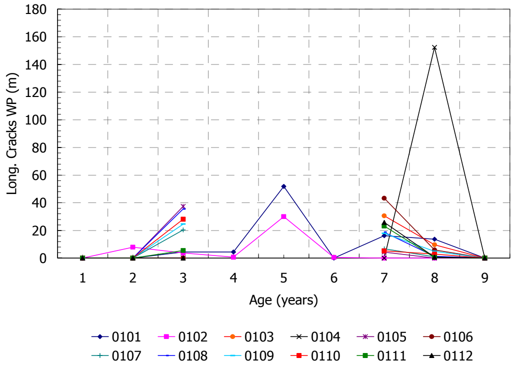


Figure 4-2 Longitudinal cracking-WP with age — AL (1)

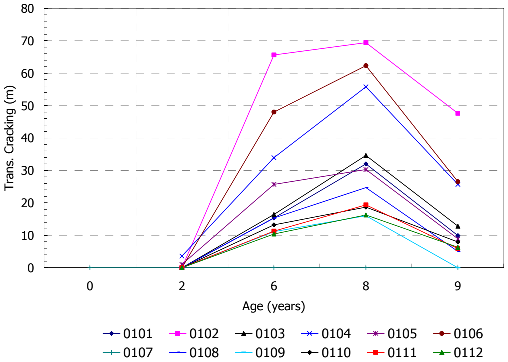


Figure 4-3 Transverse cracking with age — IA (19)

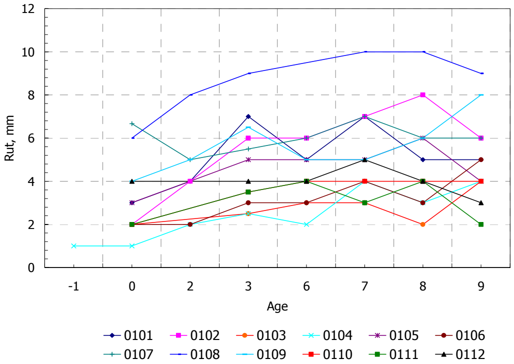


Figure 4-4 Rutting with age — IA (19)

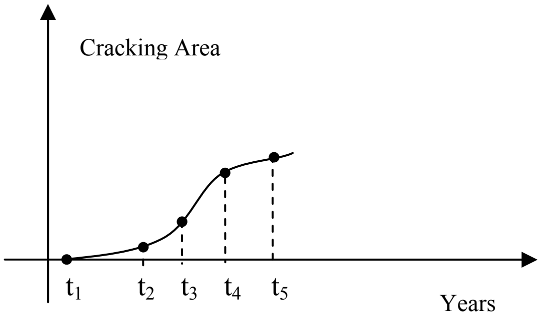


Figure 4-5 Poor Performance

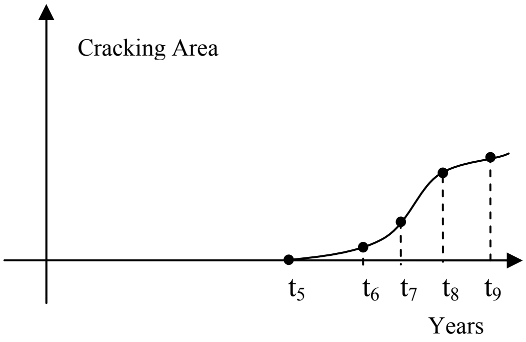


Figure 4-6 Good Performance

The *Performance Index* (PI) is defined as:

$$PI = \frac{\sum_i y_i \cdot t_i}{\sum_i t_i} \qquad (3)$$

Where:

$t_i$ = the age at distress measurement year $i$
$y_i$ = distress measured at year $i$ (for example alligator cracking in sq-m, rut depth in mm and IRI in m/km)

Note that only the ages at which distress measurements were taken are included in the calculation of PI. Equation (3) can be further simplified to the form of a series as shown by Equation (4).

$$PI = \frac{y_1.t_1}{\sum_i t_i} + \frac{y_2.t_2}{\sum_i t_i} + \frac{y_3.t_3}{\sum_i t_i} + ...... + \frac{y_i.t_i}{\sum_i t_i} \qquad (4)$$

It can be seen from Equation (4) that higher weights will be given to the performance measured at the later ages (as $t_{i+1} > t_i$ and $\Sigma\ t_i$ is constant for a given pavement section). This makes the performance index more applicable to the SPS-1 and SPS-2 experiments which stipulate that no maintenance or rehabilitation action should be taken during the life of the pavement. The following hypothetical example illustrates the difference between various performance indicators discussed above.

Figure 4-7 shows the performance curves for five different pavement sections. The best and the worst performing sections are to be identified from the time series data. Three of the performance indicators were calculated for all five sections and the results are summarized in Table 4-1. It is clear from the results that section D is best performing because the distress remains at the same level over the years and all indicators are capturing this well. The second best section according to "Area" and "Area/$L_{age}$" is section B; however according to "PI" section A is second best.

By visual comparison of the performance curves for sections A & B, it can be said that section B will deteriorate at a faster rate compared to section A, given the performance history of the sections (see Figure 4-7). As higher weights are given for later years in the calculation of the Performance Index (PI), it is expected that this indictor will be more suitable to capture the present and relative future performance of each section. Therefore, PI was selected from among various performance indictors for this study.

The performance indices (PIs) were calculated for each section and for the different performance measures such as cracking, rutting and roughness. This was calculated by summing the product of distress and age for all available surveys and dividing it by the sum of ages for available surveys, as shown by Equation (3). All analyses (overall and site level) were performed using PIs for test sections.

Although PI seems to be the best option among all the performance indicators considered, it has some inherent limitations. These limitations are mainly because PI is dependent on the number and timing of the distress surveys. For two pavement sections of the same age and performance, with one monitored each year and the other monitored on alternate years, the PI for the former section will be slightly lower. For the same sections if the monitoring were not performed at a regular time interval, the section with more surveys towards the later age will have a slightly inflated PI. However, this limitation may not have considerable impact in the case of the SPS-1 and SPS-2 experiment as all the pavement sections were monitored with a regular time interval of 1 to 2 years. In SPS-1 and SPS-2 experiments the pavement sections at different sites have different ages. Among pavement sections with different ages and similar performance, the PI of younger sections will be lower than that of older sections. To address this issue, the age of test sections was considered as a covariate in all statistical analyses of PI. This will adjust the PIs according to the age of pavement sections. The statistical methods used in the study are briefly explained next.

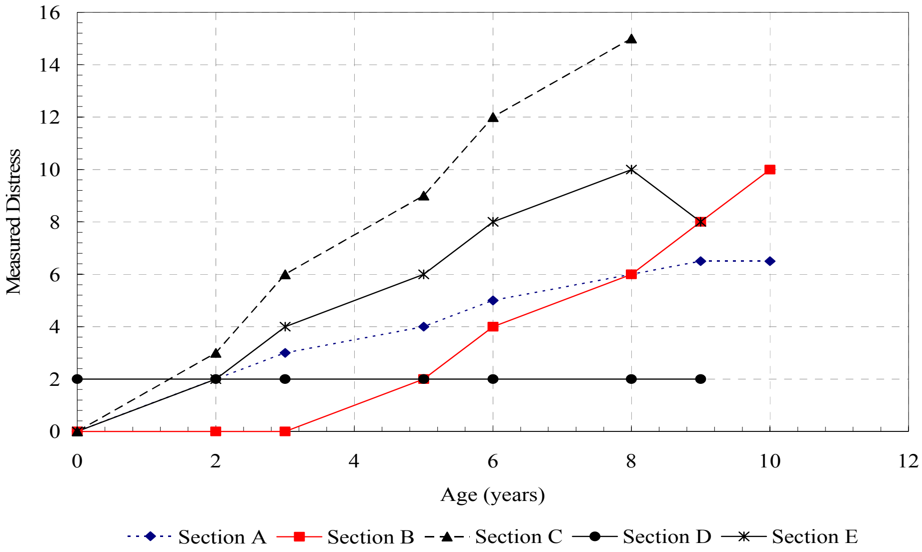


**Figure 4-7 Comparing different performance curves — An Example**

Table 4-1 Calculated performance indicators

| Performance Indicator | Sections | | | | |
|---|---|---|---|---|---|
| | A | B | C | D | E |
| Area | 39.75 | *31* | 67.5 | ***19*** | 53 |
| Area/$L_{age}$ | 4.0 | *3.1* | 8.4 | ***2.1*** | 5.9 |
| PI | *5.5* | 5.9 | 10.9 | ***2.0*** | 7.5 |

## 4.3 OVERALL STATISTICAL ANALYSIS METHODS

Two types of methods were used for overall statistical analysis. One is based on the magnitude of the performance, i.e. comparison of mean performances between the levels of various factors. The other type of methods is based on the frequency of occurrence of distresses i.e. probability of occurrence or non-occurrence. The ANOVA (one-way and multivariate) method belongs to the first type. The Linear Discriminant Analysis (LDA) and the Binary Logistic Regression (BLR) belong to the second type.

### *4.3.1 Analysis of variance (ANOVA)*

The ANOVA is a tool that allows for better understanding of how the independent variables (categorical) influence the dependent variable (continuous). Using the General Linear Model (GLM) univariate procedure, various hypotheses can be tested about the mean of a single dependent variable when cases are classified into groups based on one or more factors (independent variables). For example, the effects of different base types or asphalt thickness (factors as independent variables) on the amount of cracking (dependent variable) are ideal candidates for such an analysis. Moreover, some of these independent variables may be considered to be having a fixed or a random effect on the dependant variable. Also, any other continuous variables (independent) for which the dependent variable is to be adjusted can be included in the model as a covariate. Both balanced and unbalanced models can be tested by ANOVA. A design is considered as a balanced design if each cell in the model contains the same number of cases.

ANOVA can be performed by considering one factor at a time, or by considering more than one factor at a time. ANOVA is “one-way” when the effect of a single factor is studied on a dependant variable, whereas, ANOVA is “multivariate” when the effect of more than one factor is studied on a dependant variable. Also, multivariate ANOVA is more efficient as it adjusts for the effects of various factors at a time. Moreover, interaction effects, if any, between various factors can be studied by multivariate ANOVA.

To apply ANOVA, the observations must be independent random samples from a normally-distributed population with equal variances. The residuals can be used to check these assumptions to have confidence on the observed significance levels. Generally, two common departures from ANOVA model— non-constancy of the error term and non-normality of the distribution of the error terms, are found in the data. The following frequently recommended remedial measures are found in the literature [5-7]:

- Often, non-constancy of the error variance is accompanied by non-normality of the error term. A standard remedial measure here is to transform (e.g., log, natural log or square root etc.,) the response variable (dependent variable).
- If the error terms are normally distributed but the variance of the error term is not constant, a standard remedial measure is to use weighted least squares.
- When there are major departures from the ANOVA model and even transformations are not successful in stabilizing the error variance and error normality, a non-parametric test for the equality of the factor level means may be used instead of ANOVA.

All the assumptions of the ANOVA models used in this research were checked and appropriate remedial measures as discussed above were adopted where ever necessary.

Statistical significance of an effect of a factor implies that there exists a significant mean difference between the performances (in this study) of any two levels within the factor. For example, a statistically significant effect of HMA surface thickness on fatigue cracking implies that there is a significant (statistical) mean difference between fatigue cracking on sections with 4-inch (102 mm) HMA thickness and sections with 7-inch (178 mm) HMA thickness. Moreover, in simple terms, a statistical significance indicates that the effect is not a happenstance.

However, it is important to confirm the practical or operational difference between the means of various levels of a factor, if a factor has a statistically significant effect. An attempt was thus made in this study to gauge the practical or operational significance of statistically significant differences in the analysis. The operational significance adopted for various performance measures is discussed next.

### Practical Significance

The statistical significance of difference between the marginal means for various levels of design and site factors needs to be judged from practical point-of-view. This practical significance is dependent on the magnitude of the mean difference of levels for a particular factor and will vary for each performance measure. For example, if the means for alligator cracking are significantly (statistically) different for pavement sections constructed on DGAB and on ATB, one should check whether this difference has any practical or operational meaning from an engineering point of view. The practical significance therefore depends on the subjective judgment of actual pavement performance observed in the field.

To determine reasonable levels of practical significance for different distress types (fatigue cracking, rut depth, transverse cracking and roughness), the performance curves developed based on the engineering judgment of expert panels were used. These curves for various distress types were developed under two studies [1, 8]. The criteria for fatigue cracking, rut depth, roughness and transverse cracking performances are shown in Figures 4-8, 4-10, 4-12, 4-14 and 4-15, respectively.

As mentioned before, the ANOVA was conducted on PI for all performance measures except roughness. For roughness the change in IRI (Latest IRI- Initial IRI) was used as dependent variable in ANOVA. Because the marginal means from ANOVA are in terms of PI, the performance curves from the expert panel were converted to PI, assuming 1 year monitoring interval. These curves, in terms of PI, for fatigue cracking, rut depth and transverse cracking are shown in Figures 4-9, 4-11 and 4-13, respectively.

It can be seen from these curves that the slopes of the individual performance curves vary with age. For example, the slope of the IRI curve is the same up to year 5 and later can be separated into two parts. From these two slopes, change in IRI per year can be calculated for the first five years and for the next five years (see Figure 4-14). The weighted average of these slopes was used to calculate the change in IRI per year. Furthermore, the above described curves define the boundaries between good and poorly performing pavements for interstate and non-interstate highways, respectively. For SPS-1 experiment, it was estimated that 80% of the designs corresponded to the interstate highway class, while the remaining 20% were non-interstate, based on the asphalt layer thicknesses. Therefore, the slope (change per year) was further weighted for the proportions of the pavement class within the SPS-1 experiment. Table 4-2 shows the threshold values for practical or operational significance for the various distress types.

Table 4-2 Operationally significant differences for various performance measures

| Performance measure | Weighted slope per year | Remarks |
|---|---|---|
| Fatigue cracking (%) | 0.20 | This will translate into 1.0 sq-m of area per year. |
| Rut depth (mm) | 0.80 | The operational significant difference for rut depth is 0.8 mm per year. |
| Transverse cracking (m) | 3.50 | This will translate into 75 m of crack spacing per year. |
| Longitudinal Cracking (m) | 4.50 | The weighted slope was calculated based on 5000 ft/mile failure criterion used in AASHTO 2002. The failure criterion is thus 144 m for a SPS-1 test section. Operational value is based on the slope of the performance curve between 0 and 10 years, assuming zero cracking up to 5 years and failure at 20 years. |
| Roughness<br>ΔIRI(m/km)-Flexible<br>ΔIRI(m/km)-Rigid | <br>0.13<br>0.10 | The change in IRI was calculated based on initial IRI and latest IRI |

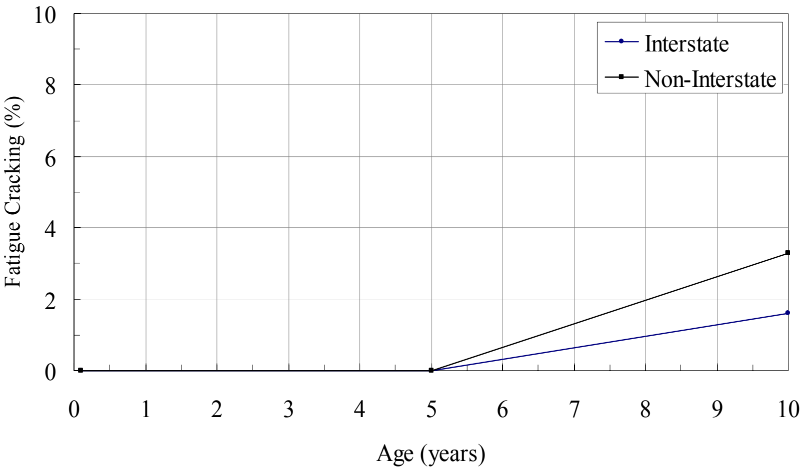


Figure 4-8 Performance criteria for fatigue cracking [1]

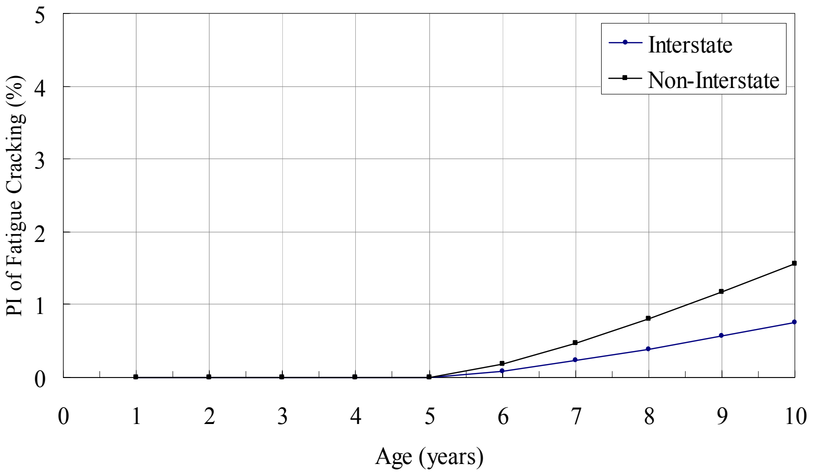


Figure 4-9 Performance criteria for PI of fatigue cracking

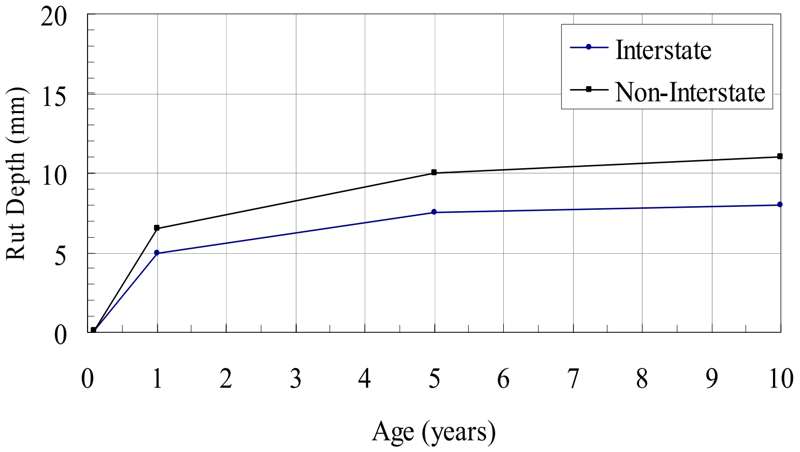


Figure 4-10 Performance criteria for rut depth [1]

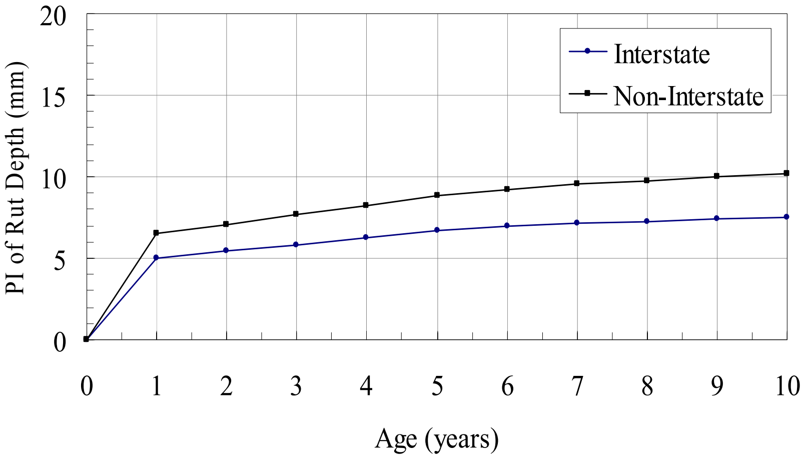


Figure 4-11 Performance criteria for PI of rut depth

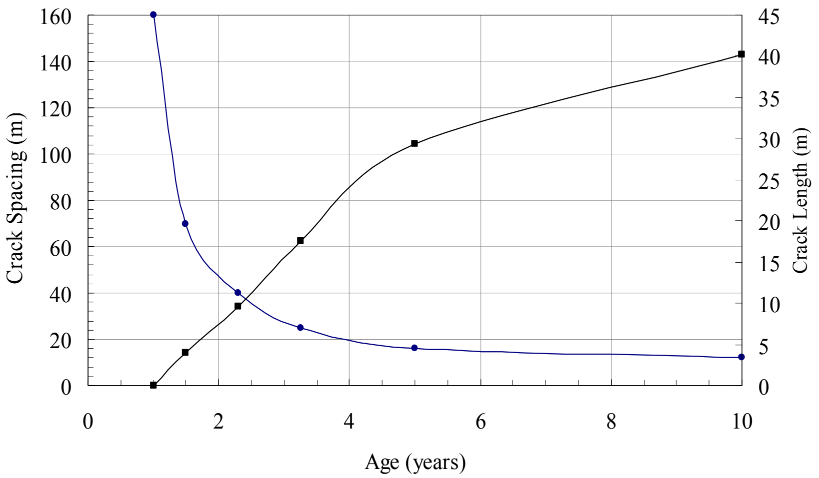


Figure 4-12 Performance criteria for transverse cracking [1]

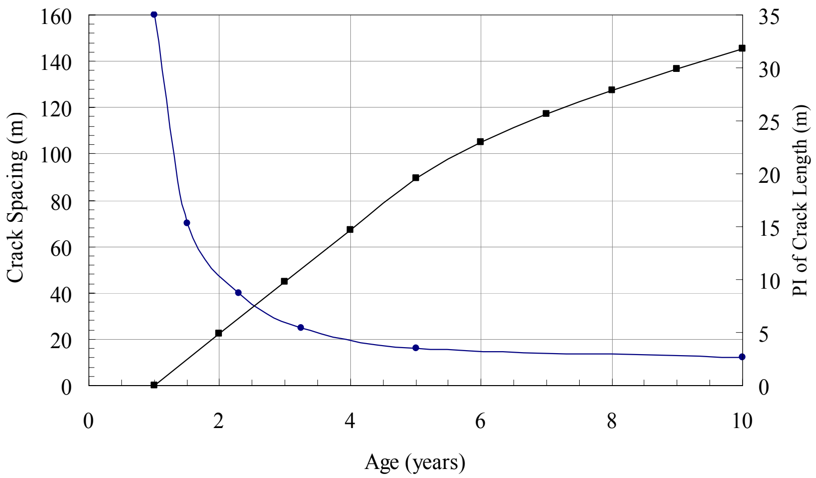


Figure 4-13 Performance criteria for PI of transverse cracking

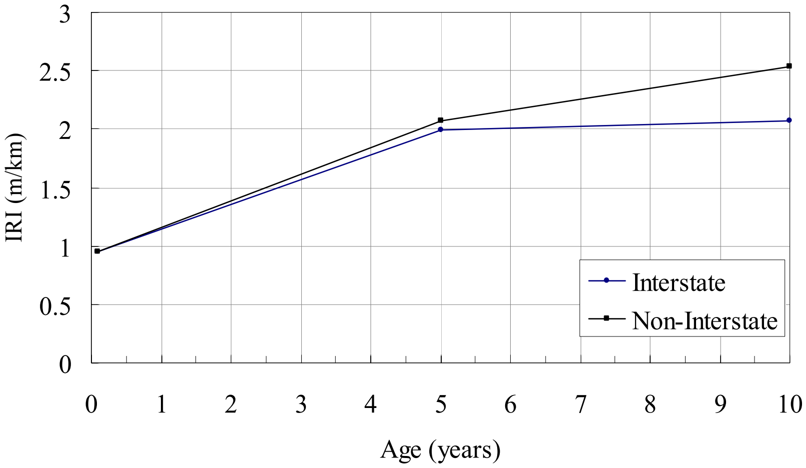


Figure 4-14 Performance criteria for roughness-Flexible [1]

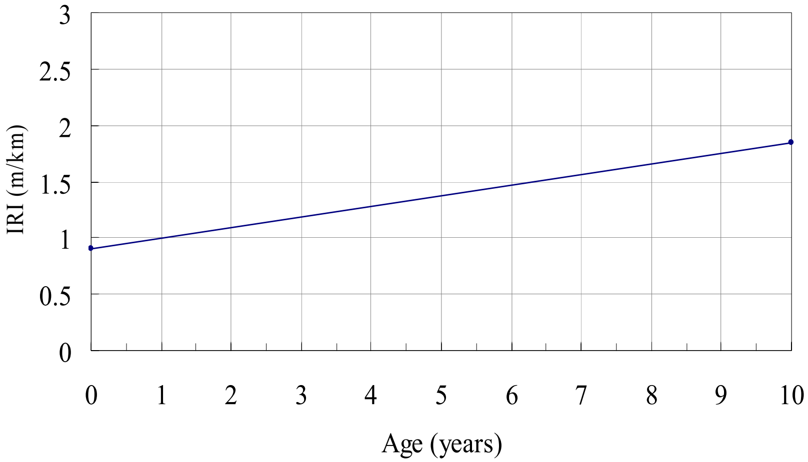


Figure 4-15 Performance criteria for roughness-Rigid [1, 8]

The analysis of variance (ANOVA) is a powerful method; however under certain conditions (limited available data) the application of this method has some restrictions. These issues are briefly summarized below:

- The un-balanced data makes it difficult to meet the equal variance assumption. Therefore, an appropriate transformation of the response variable may be adopted to address this issue.
- In case of fractional factorial design, the higher order interactions (between more than two factors) cannot be studied [9].
- Replication within each cell of the experiment design plays an essential role in determining power of hypothesis testing. The power of a hypothesis test is the probability of correctly rejecting the null hypotheses when the null hypothesis is not true. Lower number of replications within experiment design will reduce the power of detecting a mean difference between levels of a factor for a given variance.
- Time series ANOVA with repeated measures seems to be an appropriate choice of analysis for this type of experiment where each section is monitored over time. However, this type of analysis requires a more balanced data i.e., all pavement sections should be monitored at the same interval and up to an age long enough (about 15 years) for capturing long term pavement performance.

The SPS-1 and SPS-2 experiments were designed as fractional factorials. Further, as same number of sites was not constructed in each zone-subgrade combination and as all the sections did not exhibit distress, the experiment is unbalanced. Thus only two-way interactions may be reliable in the analysis. In addition, transformation of the response variables becomes an essential choice to fulfill requirements of ANOVA. When natural logarithmic transformation is applied to response variables, due to the nature of the transforming function (natural logarithm of zero or a negative value is not defined), only data pertaining to those test sections that have distressed (i.e. non-zero positive data) were considered in ANOVA. Hence, ANOVA results are based only on distressed sections.

In the SPS-1 and SPS-2 experiments, each SHRP ID represents a unique design and thus there are 24 designs in each experiment. The performance of the designs with respect to each other was evaluated using the deviation from mean performance, which is the standard deviate. The designs were evaluated based on their performance (PI), considering one distress at a time. The standard deviate was calculated for each of the twelve designs within each site.

shows a sample calculation of standard deviate with respect to alligator cracking for sections in the AL (1) site, which is calculated by using the following equation.

$$\text{Standard Deviate} = \frac{(\text{PI of a given design - Average PI for the given site})}{(\text{Standard Deviation of PIs for the given site})}$$

As this measure was calculated for each section, considering one site at a time, it indicates the relative standing of the section compared to other sections. It thus helps nullify the variation in performance (due to site conditions) among sites, as the sections are weighed with respect to companion sections in each site. The standard deviate will show the relative comparison of various designs for a specific performance measure. This value can be interpreted in the following three possible ways:

- Lower value indicates better performance than the mean
- Zero value indicates the mean performance
- Higher value indicates worse performance than the mean.

The standard deviate for a particular performance can also be used to compare the effects of design factors, and for this one-way ANOVA was performed on the standard deviates of the sections. The analyses were performed on data from all sections and also on subsets of data stratified by different subgrade types, climates and combinations of these. This helps identify the effects of design factors under different site conditions. The standard deviate values of each design were averaged from the various sites to study the overall as well as the interaction effects of design factors with climate and subgrade soil type.

To consider all available sections, the test sections were categorized as “distressed” and “non-distressed” for frequency based methods (LDA and BLR). The frequency-based analyses methods (discussed below) will help in identifying the significant factors that discriminate between the two categories.

Table 4-3 Calculation of standard deviate for alligator cracking - Alabama (1)

| Section ID | Performance Index | Average | Standard deviation | Standard deviate |
|---|---|---|---|---|
| 0101 | 23.08 | 45.93 | 32.82 | -0.70 |
| 0102 | 90.69 | | | 1.36 |
| 0103 | 25.43 | | | -0.62 |
| 0104 | 3.83 | | | -1.28 |
| 0105 | 95.90 | | | 1.52 |
| 0106 | 16.12 | | | -0.91 |
| 0107 | 21.97 | | | -0.73 |
| 0108 | 70.45 | | | 0.75 |
| 0109 | 75.47 | | | 0.90 |
| 0110 | 52.74 | | | 0.21 |
| 0111 | 65.33 | | | 0.59 |
| 0112 | 10.22 | | | -1.09 |

### *4.3.2 Extent of distress*

The effect of the key experimental factors on performance, through the relationship between the magnitude and relative occurrence of the observed distresses, can be observed from the data. Simple bivariate plots between the percentage of test sections that have exceeded various levels of distress for the key performance measures, categorized by experimental design and site factors were plotted to display and explore the data. Note that the effect of climatic zone will only be shown for the wet regions because of the limited number of sites (4 sites) in the dry regions.

### *4.3.3 Linear Discriminant Analysis*

*Linear Discriminant Analysis (LDA)* allows for distinguishing between two or more groups of data. This is done by identifying variables that are significant in classifying the data into various groups. The procedure for predicting membership is to initially analyze pertinent variables where group membership is already known. The details of theoretical background of LDA is available in relevant literature [6, 10, 11]. For example, groups of observations can include one group of pavements with cracks and the second group with no cracks. The method allows for determining which variables discriminate between cracked and non-cracked pavements.

### *4.3.4 Binary Logistic Regression*

*Binary Logistic Regression (BLR)* is used often in the case where the outcome variable is discrete (dichotomous). The difference between logistic and linear regression is reflected both in the choice of a parametric model and in the assumptions. This method is based on the maximum likelihood method for determining the parameters of interest. The details of theoretical background of BLR are available in relevant literature [12]. The interpretation of effects for various levels of the categorical variables (independent) is very convenient in terms of the odds ratio when this type of model is used. Logistic regression models are also very useful for discrimination analysis (of various groups) when categorical variables are used as independent variables.

## 4.4 SITE-LEVEL ANALYSIS METHODS

In the site level analysis each section is evaluated based on the performance in comparison with similar designs of a site (state). It is assumed that within each site, climatic conditions, subgrade soil type and traffic volume are identical for all test sections. Thus the main advantage of this analysis is that comparisons are made among those sections that were subjected to similar loading and environmental conditions. Furthermore, construction methods, material sources and surveys are also assumed to be identical within each site. All site-level analyses were conducted using the Performance Indices (PIs) of the sections for various performance measures. The difference in performance is assessed based on average values. The details of analysis are discussed below.

### *Comparisons by Design Factors*

The site-level analysis consisted of series of comparisons, each focusing on the effect of a particular design/construction factor, for SPS-1 and SPS-2 experiments. Such comparisons are not possible for SPS-8 sections because of the limited number of sections in the experiment. For the site level analysis, each section's performance was analyzed in terms of its performance index (PI).

Comparisons were done at two levels—A and B. In level-A analyses, all designs (0101 through 0112, or 0113 through 0124) at a given site were compared such that only one factor is held common within the sections of each group. For example, in level-A analysis, the effects of

HMA thickness [102 mm (4-inch) vs. 178 mm (7-inch)] were studied, within a site, by ignoring base type & thickness, and drainage.

In level-B analyses, most of the factors are 'controlled' for comparisons. In other words, individual sections within a given site are paired such that all but one design parameter are the same. This parameter is the factor being studied. Comparing a given pair of sections will allow for determining the effect of the particular design factor, with the highest possible level of constraint (level-B). In this case, there are four factors being studied, so the highest possible number of constraints is three. For example, comparing sections 0111 and 0112 (SPS-1) allows for determining the effect of base thickness [203 mm (8-inch) ATB versus 305 mm (12-inch) ATB], while comparing sections 0216 and 0220 (SPS2) allows for determining the effect of base type (DGAB versus LCB). Table 4-4 and Table 4-5 show possible comparisons within a given site in SPS-1 and SPS-2 experiments, respectively.

The relative effects of levels within each design factor were studied based on the ratio of mean performance of the sections corresponding to a level over the mean performance of all levels of the factor. A sample calculation of relative performance is presented in Table 4-6. In the table, the comparison of relative performance indicates that pavement sections with 178 mm (7-inch) HMA surface thickness are performing better than those with 102mm (4-inch) HMA surface thickness, since the relative performance is lower for sections with 178 mm (7-inch) HMA surface thickness (0.8 versus 1.2).

For factors with two levels (such as HMA surface thickness, PCC thickness, and drainage), the relative performance of each level can range from 0 to 2, a value of 1 indicating no effect of the factor [i.e., the amount of distress (performance) corresponding to the two levels of the factor is the same]. A value less than 1 indicates better performance compared to mean performance of sections corresponding to both the levels of a factor. Consequently, a value higher than 1 indicates worse performance. The best possible performance translates to 0, and the worst possible performance translates to 2. For cases where there is no distress or same level of distress, each level of a given factor will have relative performance of 1 indicating no difference in performance.

For factors with more than two levels, similar logic can be extended. For the effect of base type, the relative performance of each base type ranges from 0 to 5, since there are five base types in SPS-1 experiment. In the case of the SPS-2 experiment, for the effect of base type, the relative performance of each base type ranges from 0 to 3, since there are three base types under comparison. A value of 1 for all base types indicates that the amount of distress is the same for all base types. Values close to 1 for all the base types being compared indicate that there is no significant effect of the base type. A higher value indicates more distress (worse performance) for a particular base type. For SPS-1, the worst possible performance translates to 5 (all other base types would show 0, indicating no distress), and the best possible performance translates to 0 (no distress).

The relative performance for various levels of the main factors was calculated for all the sites in SPS-1 and SPS-2 experiments, and for each performance measure. The concept of relative performance can be utilized across the sites without considering traffic or age variability because it is calculated at site-level.

Table 4-4 Site Level Comparisons for the SPS-1 Experiment

| Effects | Level | Site with Sections 101 to 112 | | Site with Sections 113 to 124 | |
|---|---|---|---|---|---|
| | | Comparisons | Comments | Comparisons | Comments |
| I. Effect of Base Type<br>DGAB vs. ATB vs. ATB/DGAB vs. PATB/DGAB vs. ATB/PATB | A | (101,102) vs.(103,104) vs. (105,106) vs. (107,108,109) vs. (110,111,112) | Ignoring other factors | (113,114) vs.(115,116) vs. (117,118) vs. (119,120,121) vs. (122,123,124) | Ignoring other factors |
| | B | (103 vs. 105)<br>(104 vs. 106) | All other factors controlled | (116 vs. 118)<br>(115 vs. 117) | All other factors controlled |
| II. Effect of Base Thickness<br>203 mm vs. 305 mm vs. 406 mm | A | (101,103,105,107,110) vs. (102,104,106,108,111) vs. (109,112) | Ignoring other factors | (113,115,117,119,122) vs. (114,116,118,110,123) vs. (121,124) | Ignoring other factors |
| | B | (111 vs. 112)<br>(108 vs. 109) | All other factors controlled | (120 vs. 121)<br>(123 vs. 124) | All other factors controlled |
| III. Effect of Drainage | A | (102,103,105,101,104,106) vs. (107,111,112,108,109,110) | Ignoring other factors | (113,116,118,114,115,117) vs. (120,121,122,119,123,124) | Ignoring other factors |
| | B | (103 vs. 111)<br>(101 vs. 108) | Ignoring base thickness | (113 vs. 120)<br>(115 vs. 123) | Ignoring base thickness |
| IV. Effect of AC Thickness 102 mm vs. 178 mm | A | (102,103,105,107,111,112) vs. (101,104,106,108,109,110) | Ignoring other factors | (113,116,118,120,121,122) vs. (114,115,117,119,123,124) | Ignoring other factors |
| | B | (101 vs. 102)<br>(103 vs. 104)<br>(105 vs. 106) | Ignoring the base thickness | (113 vs. 114)<br>(116 vs. 115)<br>(118 vs. 117) | Ignoring the base thickness |

Table 4-5 State Level Comparisons for the SPS-2 Experiment

| Effects | Level | Sites with Sections 101 to 112 | | Sites with Sections 113 to 124 | |
|---|---|---|---|---|---|
| | | Comparisons | Comments | Comparisons | Comments |
| Effect of Drainage DGAB vs. PATB | A | (201, 202, 203, 204) vs..<br>(209, 210, 211, 212) | Ignoring other factors | (213,214,215,216) vs.<br>(221,222,223,224) | Ignoring other factors |
| | B | (201 vs. 209), (202 vs. 210),<br>(204 vs. 212), and (203 vs. 211) | All other factors controlled | (214 vs. 222) (213 vs. 221)<br>(215 vs. 223) (216 vs. 224) | All other factors controlled |
| Effect of Base Type DGAB vs. LCB vs. PATB | A | (201, 202, 203, 204) vs. (205, 206, 207, 208) vs.<br>(209, 210, 211, 212) | Ignoring other factors | (213,214,215,216) vs.<br>(217,218,219,220) vs.<br>(221,222,223,224) | Ignoring other factors |
| | B | (201 v. 205 v. 209),<br>(202 v. 206 v. 210),<br>(203 v. 207 v. 211), and<br>(204 v. 208 v. 212) | All other factors controlled | (213 v. 217 v. 221)<br>(214 v. 218 v. 222)<br>(215 v. 219 v 223)<br>(216 v. 220 v. 224) | All other factors controlled |
| Effect of PCC Thickness 203 mm vs. 279 mm | A | (201, 202, 205, 206, 209, 210) vs.<br>(203, 204, 207, 208, 211, 212) | Ignoring other factors | (214,215,218,219,222,223) vs.<br>(213,216,217,220,221,224) | Ignoring other factors |
| | B | (201 vs. 204), (202 vs. 203),<br>(205 vs. 208), (206 vs. 207),<br>(209 vs. 212), and (210 vs. 211) | By ignoring flexural strength only | (213 vs. 216) (214 vs. 215)<br>(217 vs. 220) (218 vs. 219)<br>(221 vs. 224) (222 vs. 223) | By ignoring flexural strength only |
| Effect of PCC Strength 3.8 MPa vs. 6.2 MPa | A | (201, 203, 205, 205, 207, 209, 211) vs. (202, 204, 206, 208, 210, 202) | By ignoring only lane width | (213, 215, 217, 219, 221) vs.<br>(214, 216, 218, 220, 222, 224) | By ignoring only lane width |
| Effect of Lane Width 3.7 m vs. 4.3 m | A | (201, 204, 205, 208, 209, 212) vs.<br>(202, 203, 206, 207, 210, 211) | Ignoring other factors | (213,216,217,220,221,224) vs.<br>(214,215,218,219,222,223) | Ignoring other factors |

**Table 4-6 Example calculation of relative performance (State 1-Alligator Cracking)**

| 4” AC Thickness | | 7” AC Thickness | |
|---|---|---|---|
| Section ID | Performance Index | Section ID | Performance Index |
| 102 | 90.69 | 101 | 23.08 |
| 103 | 25.43 | 104 | 3.83 |
| 105 | 95.90 | 106 | 16.12 |
| 107 | 21.97 | 108 | 70.45 |
| 111 | 65.33 | 109 | 75.47 |
| 112 | 10.22 | 110 | 52.74 |
| Average | 51.59 | Average | 40.28 |
| Mean Performance | (51.59+40.28)/2 = 45.93 | | |
| Relative performance | 51.59/45.93=1.12 | Relative performance | 40.28/45.93=0.88 |

## 4.5 METHODS FOR INVESTIGATING APPARENT RELATIONSHIP BETWEEN PAVEMENT RESPONSE AND PERFORMANCE

This analysis is aimed at investigating the relationship between the pavement responses (deflections) and performance measures (cracking, rutting, roughness, etc.). The usefulness of such relationships can be further divided in two ways:

- To provide an explanatory information for a given performance trend. For example, a relationship between AC pavement rutting and the farthest FWD sensor would indicate that rutting is related to the subgrade.
- To predict the future performance. For example, a high initial deflection of a pavement may help predict its future cracking and rutting performance.

Relationships were sought by directly relating commonly collected pavement response data to the development of specific distresses, using statistical analyses. This analysis was conducted at the site level as well as for the overall experiment. The following describes statistical techniques used to investigate the apparent relationships between response and performance measures.

### *4.5.1 Univariate Analysis*

*Univariate and Bivariate analyses* are simple statistical methods for data analysis. These methods include determination of data statistics such as mean, standard deviation and data frequencies. Simple histograms and box plots can also be generated to determine data distribution. These methods also allow for determining the degree of dependence between variables. The results of such an analysis can be graphically illustrated. Such an analysis can also provide summary statistics such as the coefficient of correlation. Bivariate analysis can also assist in identifying outliers. This analysis was applied at the site-level for identifying predictive relationships.

### *4.5.2 Multiple Regression Analysis*

*Regression analyses* attempt to explain a dependent variable in terms of many independent (explanatory) variables. The model form (equation) can be either linear or non-linear, and with actual, transformed, or interaction clusters of variables. The model coefficients are estimated using best (least squares) fitting techniques. The objective of this method is to develop models explaining the apparent relationships between pavement performance measures and responses. This analysis was used for investigating explanatory relationship by using the data from the overall experiment.

# CHAPTER 5 - ANALYSIS RESULTS FOR THE SPS-1 EXPERIMENT

## 5.1 INTRODUCTION

The purpose of this chapter is to provide a summary of findings from the previous studies and the results of the various analyses conducted for the SPS-1 experiment on flexible pavements in this study. The performance and structural response indicators used in the analysis include fatigue (alligator) cracking, rutting, longitudinal cracking in the wheel path and outside the wheel path, transverse cracking, IRI, and deflections measured by sensors 1 and 7. In this chapter, results from site-level analyses will be followed by results from overall analysis, and results from apparent relationship between response and performance, leading to the summary of findings. Before presenting the results from analyses, a discussion on the effect of construction on the performance of SPS-1 pavements and a brief discussion of the performance of test sections at each site are presented.

The analyses conducted include:

- Site-level analyses (on performance measures): Evaluation of the consistency of the effects of design factors across sites.

- A comprehensive overall analysis of the performance and response data, which includes the following methods of analysis:
  a) Extent of distress by experimental factors (Frequencies)
  b) Linear Discriminant Analysis (LDA)
  c) Binary Logistic Regression (BLR)
  d) Analysis of Variance (ANOVA)

- An investigation of apparent relationships between response and performance at the site level and for the overall population.

## 5.2 PREVIOUS STUDIES

This section summarizes the findings from the literature review of research reports that deal with pavement performance in the field. The review included FHWA/LTPP reports, NCHRP reports as well as additional literature, and was focused on research that has identified factors affecting pavement response and performance including roughness. The most relevant reports were found to be those from studies addressing the Long Term Pavement Performance (LTPP) experiments.

### *5.2.1 Summary of Findings*

The information obtained from the literature review has been used to identify various factors that have been shown in past research as having an effect on response and performance progression.

#### *5.2.1.1 Factors Affecting Flexible Pavement Performance*

A study [1] entitled “Structural Factors for Flexible Pavements” was conducted using SPS-1 data. The summary of findings from this preliminary study is given below:

*Layer Thickness*

- The SPS-1 test sections with thick (178-mm (7-inch)) AC surface layers appear to be smoother and develop less fatigue cracking than those sections with thin (102-mm (4-inch)) surface layers. This confirms a similar finding from earlier studies.
- In the SPS-1 experiment, AC surface thickness and the age of the project appear to influence the amount of fatigue cracking that occurs. The test sections that are younger and have thicker AC surface layers have the least fatigue cracking.

*Base Layer*

- Hot-mix asphalt (HMA) pavements with unbound aggregate base layers show greater rut depths than those sections with asphalt-treated base layers. This suggests that a portion of the rutting measured at the surface is a result of permanent deformations in the unbound aggregate base layer, which is consistent with a previous finding from analysis of the GPS test sections.

- The HMA pavements with unbound aggregate layers have slightly more fatigue cracking and higher IRI values than those sections with asphalt-treated base layers.
- The test sections with coarse-grained soils, asphalt-treated base layers, permeable base layers, thicker bases, and thicker HMA layers were found to be smoother.
- The test sections with permeable asphalt-treated base layers exhibit more fatigue cracking than those without permeable base layers.

*Subgrade*

- HMA pavements built over coarse-grained subgrade soils are smoother than pavements built over fine-grained subgrade soils. This is consistent with the finding in the SPS-2 JPCP: A stiffer foundation contributes to smoother pavements.
- HMA pavements built over coarse-grained subgrade soils and in a no-freeze climate are smoother and stay smoother over a longer period of time than do those built over fine-grained subgrade soils in a freeze climate. HMA pavements built over fine-grained subgrades and in a wet-freeze climate are substantially rougher than those built in other climates.
- HMA pavements built over fine-grained subgrade soils have more fatigue cracking than those projects built over coarse-grained subgrade soils.
- Subgrade soil type and, to a lesser degree, age are important to the amount of transverse cracking measured at each site. More transverse cracking has occurred on the HMA pavements built on fine-grained soils than on pavements built on coarse-grained soils.

Another study [2]was conducted using SPS-1 data to identify the factors affecting pavement smoothness. A summary of main findings from this research is given below:

- A significant difference between early age IRI of pavements placed on DGAB and ATB was observed. No significant difference in early age IRI was obtained on pavements placed on PATB when compared to other two base types.
- The SPS-1 projects that showed the highest increase in IRI were located in Kansas, Iowa and Ohio, reasons being fatigue and transverse cracking for KS (20), transverse and longitudinal cracking (WP) for IA (19), and rutting for OH (39) site. Some of the test

sections in TX (48) are showing higher increase in IRI of over 10% within an approximate 6-month period, which is attributed to rutting.

- Although the pavements in IA (19), KS (20), and OH (39) achieved a smooth pavement initially, many sections, including very thick sections had high increases in roughness during the initial life of the pavement. Achieving a smooth pavement initially does not guarantee that it will remain smooth even during the initial life.
- Mix design problems in the AC, inadequate preparation of the subgrade prior to placing the pavement, or other construction problems can cause smoothly built pavements to have higher increase in roughness within a short time period.

Two studies[3, 4] were conducted to investigate the effects of sub-drainage on the performance of asphalt and concrete pavements. The following is a summary of their findings for asphalt pavements:

- Based on 7 years (on average) of SPS-1 data, those HMA sections built on permeable bases without edge drains were found to perform better than those with edge drains.
- The ranking of performance in terms of IRI and cracking for various base types with all other design features matched is from poor to good performance: un-drained dense-graded aggregate bases, drained permeable asphalt-treated bases, and un-drained dense-graded asphalt-treated bases.
- The results in terms of rutting for the above three sub-drainage designs were inconclusive.

The results from the site level analysis for SPS-1 experiment are summarized in the next section.

## 5.3 EFFECT OF CONSTRUCTION ON PAVEMENT PERFORMANCE

For the SPS-1 experiment, detailed construction guidelines were developed by LTPP (see Chapter 2) for the participating agencies to control variability in construction across sites. The lesser variability across sites, the lower the "noise", and easier it is to determine the "pure" effects of the design factors on pavement performance. However, some deviations have occurred during construction of various sites and some of those issues were highlighted in the construction reports prepared by the participating agencies (see Chapter 3). In general, sections with serious construction deviations will perform poorer than those with normal construction conditions and inclusion of such sections in the analysis may distort (bias) the effects of design factors. Sections with deviations may be identified at least in three ways, based on:

- Construction issues highlighted in construction reports for each site,
- Unusual performance trend of individual sections, and
- Unusual material properties of pavement layers.

Depending on the nature of construction issues (construction quality) the performance of a pavement is affected. Minor issues (such as minor thickness deviation in base course) may not seriously impact initial performance where as major issues (such as HMA mix issues, compaction or drainage problems) have greater chances of affecting performance early in the life of a pavement. Hence, a construction deviation (poor quality) may be used to identify sections that may potentially show an abnormal performance. Also, some sections with serious early performance concerns were "de-assigned" from LTPP database (for example, 39-101 and 20-101).

In this study, any abnormality in early performance was used as an indicator to identify substandard sections. The performance of all the sections, over time, was observed for this purpose and those sections that had premature "failure" (within first 2 to 3 years of service life) were identified. It was observed that most of the identified sections are from a few sites (for example KS for fatigue cracking and TX for rutting in SPS-1) in the experiments, indicating consistent construction problems in those sites. In such cases, all sections from the identified sites were excluded from related analyses. Material properties (example: HMA mix properties) of pavement layers may also indicate non-compliance in construction. Limited material data are available in DataPave (Release 17). This data were also considered to explain the probable causes of unexpected performance wherever possible.

In order to further investigate the construction-related performance issues, each performance measure for all pavement sections in SPS-1 experiment was examined over time. This analysis helped minimize the bias, if any, in the results. The analysis is discussed next with illustrations. This section of the report is followed by site-wise performance summaries of the test sections.

### *5.3.1 Construction-related Issues*

A brief discussion of construction-related performance issues for each performance measure in SPS-1 is presented in this section of the report. Based on the time-series plots for all distress measures it was found that premature "failure" was predominantly observed in rutting for a relatively large number of pavement sections. Hence, this is presented first among all the performance measures.

#### Rutting

Figure 5-1 shows rutting in all the SPS-1 test sections over time. It can be observed that a considerable number of sections have noticeably high initial rutting. The premature rutting in these pavements can be further classified into two types based on the causes of rutting:

- Mix-related rutting, and
- Base layer rutting (this could be because of wet base and poor drainage or poor compaction in un-bound pavement layers).

Therefore, the premature or early rutting in pavements was separated from the structural rutting in order to study the effects of structural factors on the long-term pavement performance. Table 5-1 is a summary of details regarding the pavement sections that exhibited early (premature) rutting in the SPS-1 experiment. The causes of rutting were identified by using the transverse profile data available in the LTPP database based on the criteria developed in NCHRP Report 468 [5]. Figure 5-3 through Figure 5-6 show the average transverse profiles of some sections, from four of the SPS-1 sites, which showed premature rutting. HMA material-related data from the field cores were extracted from DataPave (Release 17.0). Unfortunately a limited amount of material data is available at this point in time; therefore, only a few of the mix-related properties could be calculated. The summary of the mix-related data for the sites that showed early rutting is given in Table 5-2. It can be seen from these asphalt mix properties that there is high variation in the field air void content between these identified sites. High air voids in the pavement sections at the Kansas site KS (20) and very low air voids (high VFA) at the Texas site TX (48), are noticeable. The pavements built at these two sites have shown extensive cracking and rutting, respectively.

To investigate the effect of structural factors on the rutting performance, the pavement sections were separated, as explained above, into two categories: (a) pavements with premature rutting, and (b) pavements which exhibited structural rutting. Figure 5-2 shows the rutting performance of sections with probable “structural” rutting. The effect of outliers (sections with premature rutting) on the rutting performance for SPS-1 pavements can be observed by comparing Figure 5-7 and Figure 5-8.

An analysis of variance (ANOVA) was performed separately on two subsets of the data as well as on data from all the sections (superset of the two subsets). The first subset represents the pavement sections which have shown higher rutting at an early age (mix-related or material-related). The second subset includes the pavements which have shown normal rutting growth, and these pavements were assumed to be exhibiting “structural rutting”. Table 5-3 is the summary of results from ANOVA. Initially, only the main effects of structural factors were considered in the analysis by blocking the site. The results indicated that none of the structural factors has a significant effect on premature rutting. These results are reasonable, as it is expected that pavements will undergo accelerated rutting early in their service life (irrespective of the pavement structure) if the asphalt layer has mix-related issues or when the base has drainage-related issues. Next, ANOVA was performed by taking all the experimental factors and the results are shown in Table 5-5. The mean rut depths from both analyses by each experimental factor are shown in Table 5-4 and Table 5-6, respectively, to illustrate the effects. A brief discussion of the results from analysis of structural rutting is given below:

*HMA Thickness*: Pavement sections with “thin” 102 mm (4-inch) HMA surface layer have undergone higher rutting compared to those with “thick” 178 mm (7-inch) HMA surface layer. However, this difference was not found to be of practical significance at this point in time.

*Base Type*: The effect of base type on the structural rutting is not statistically significant effect, at this point. On average, sections with DGAB have shown slightly higher rutting than those built with treated bases. A slight (0.05<p-value <0.1) interaction effect was observed between base type and subgrade type. Among pavements built with DGAB, those built on fine-grained soils have shown higher rutting than those built on coarse-grained soils.

*Base Thickness*: Higher rutting occurred in sections with 203 mm (8-inch) base than those with 305 mm (12-inch) or 406 mm (16-inch) base. However, the effect is statistically marginally significant, is not of practical significance.

*Drainage*: On average, sections with no drainage have shown slightly higher rutting than those with drainage. However, this effect of drainage on the structural rutting was not found to be statistically significant at this point in time.

*Subgrade Type*: Rutting in sections built on fine-grained soils is comparable with rutting in sections built on coarse-grained soils. The effect of subgrade types was not found to be statistically significant for structural rutting.

*Climatic Zone*: Effect of climate was found to be statistically significant. Pavements located in WNF zone have shown higher rutting than those located in WF zone. However, this effect is not of practical significance.

Given the above findings, all subsequent statistical analyses on rutting performance, (presented later in this chapter) were performed on data from the sections with structural rutting. This assumes that only pavement sections which have exhibited structural rutting will capture the effects of design factors on the long-term rutting performance.

Table 5-1 Identified sites and sections with rutting problems

| Site | Sections deleted due to extensive rutting | Probable cause of rutting | Comments |
|---|---|---|---|
| Arizona, AZ (4) | All 12 sections | HMA and Base | The rutting is either occurring due to HMA mix problems or base or both (from transverse profile) |
| Kansas, KS (20) | All 12 sections | HMA and Base | Some sections have shown HMA mix related rutting and others showed base problems (from transverse profile ) |
| Michigan, MI (26) | 113, 114, 119, 122<br>120 | HMA | The first four sections were deleted from the LTPP database just after construction |
| Nebraska, NE (31) | All 12 sections | HMA | From transverse profile |
| Ohio, OH (39) | 101, 102 | Base | From transverse profile |
| Texas, TX (48) | All 12 sections | HMA | Premature rutting in HMA layer [6] |
| Virginia, VA (51) | 113 | Base | Only one section has shown accelerated deterioration at this site due to base problems (from transverse profile) |
| Total | 56 sections | | |

Table 5-2 Average asphalt mixture properties in the field

| State | Asphalt Content (%) | Air Void Content (%) | VMA[a] (%) | VFA[a] (%) | Superpave Specifications | |
|---|---|---|---|---|---|---|
| | | | | | VMA[1] (%) | VFA[2] (%) |
| 4 | 4.4 | 10.6 | 19.1 | 44.3 | >14 | 65-75 |
| 19 | 4.2 | 10.5 | - | - | | |
| 20 | 4.1 | 15.3 | 21.4 | 29.1 | | |
| 26 | 5.0 | 6.5 | - | - | | |
| 31 | 4.2 | 6.2 | - | - | | |
| 39 | 6.6 | 11.2 | - | - | | |
| 48 | 4.4 | 1.8 | 12.2 | 85.0 | | |
| 51 | 4.9 | 9.7 | 20.4 | 52.6 | | |

Note: [a] $G_{sb}$ values are missing therefore, these properties can not be calculated, [1] the minimum VMA requirement for nominal maximum size of 12.5 mm, [2] VFA requirements for traffic > 100 million ESALs (Source: Superpave Mix Design, SP-2)

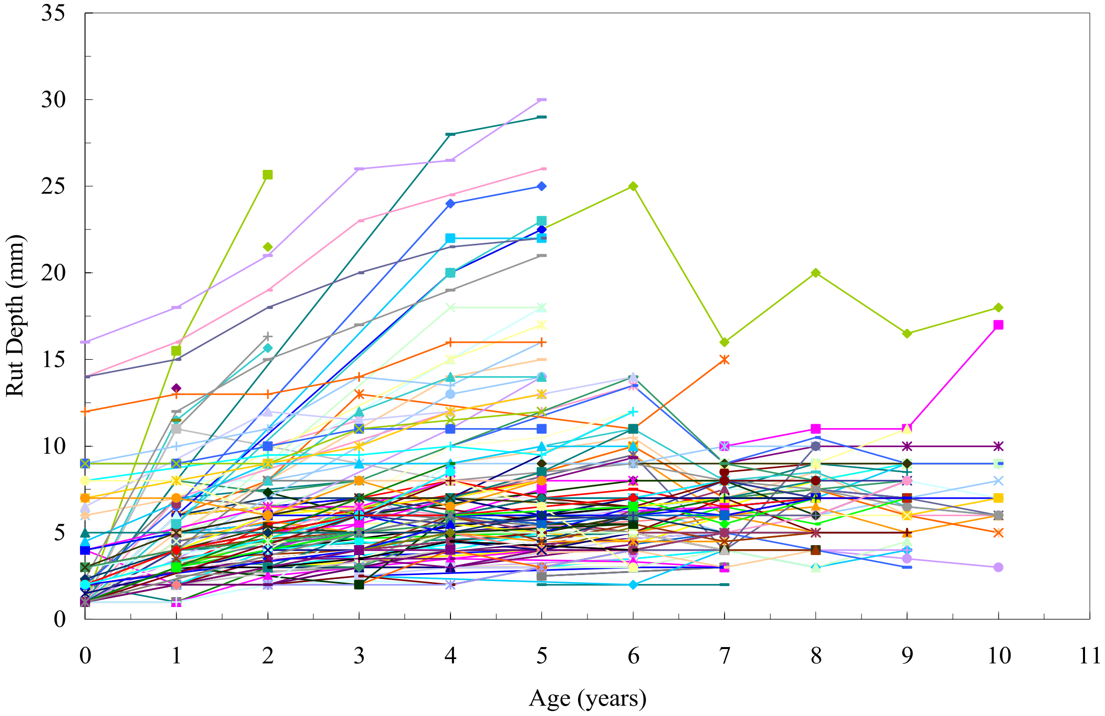


Figure 5-1 Rutting with time for SPS-1 pavements - All sections

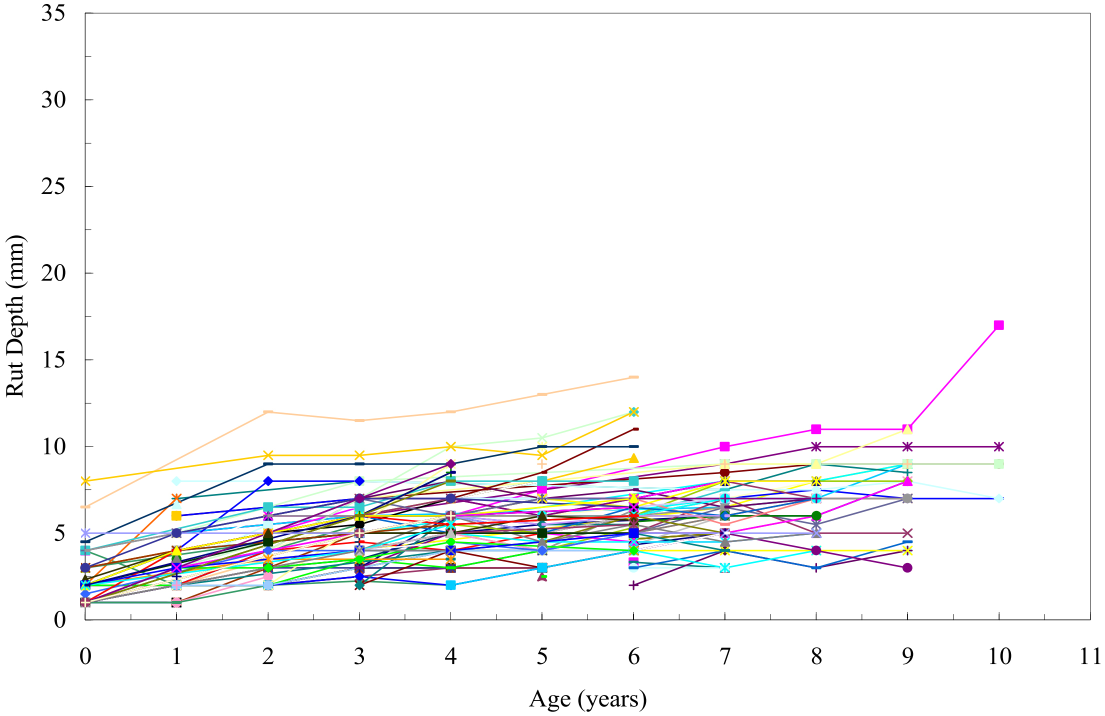


Figure 5-2 Rutting with time for SPS-1 pavements – Selected sections

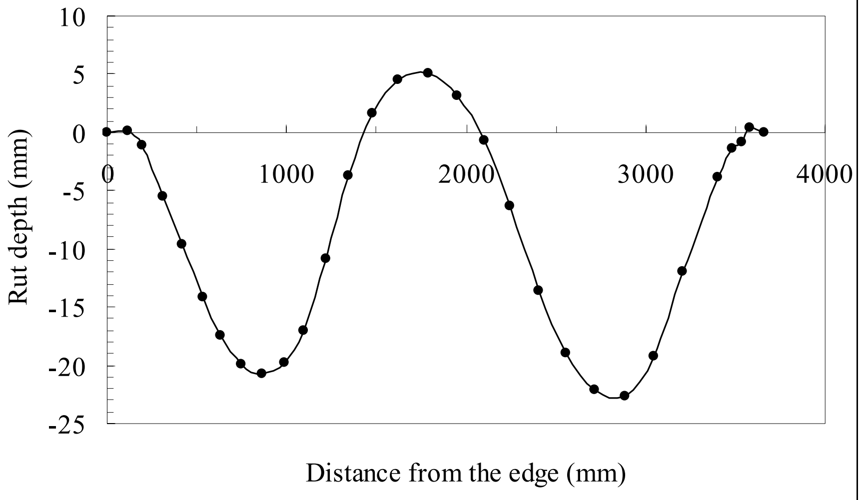


Figure 5-3 Transverse profile for base rutting—Section 20-0102

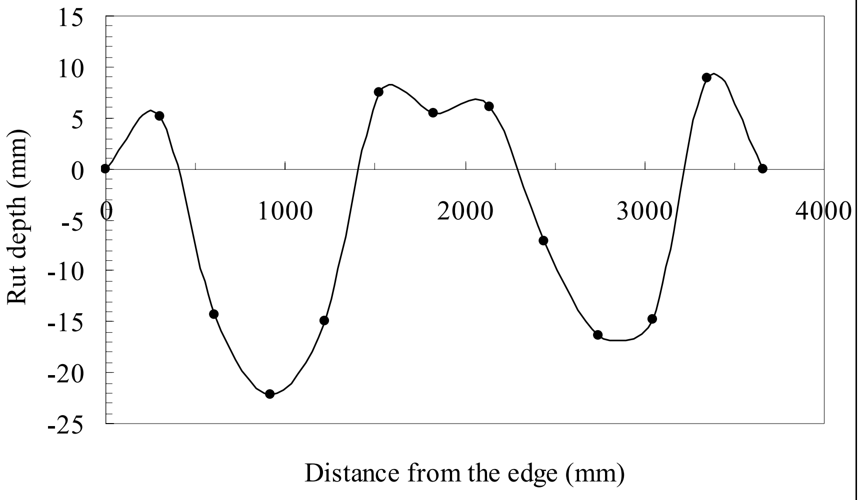


Figure 5-4 Transverse profile for asphalt rutting— Section 31-0113

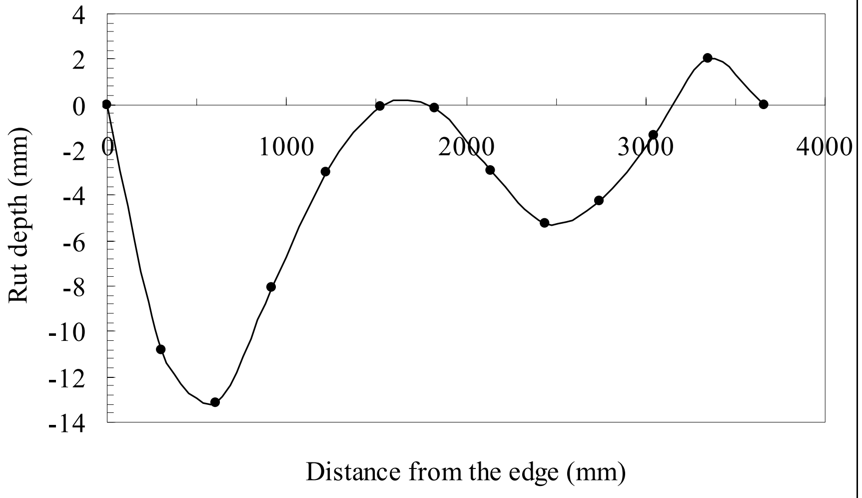


Figure 5-5 Transverse profile for (HMA + base) rutting— Section 39-0101

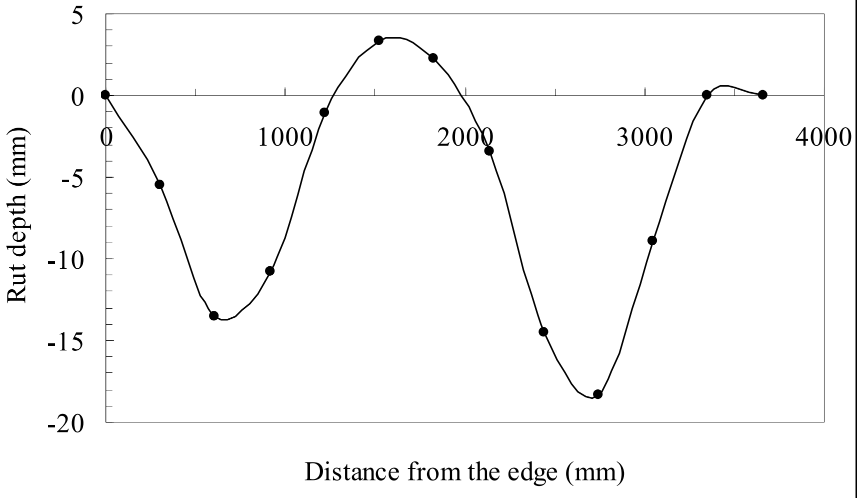


Figure 5-6 Transverse profile for (Base) rutting— Section 51-0113

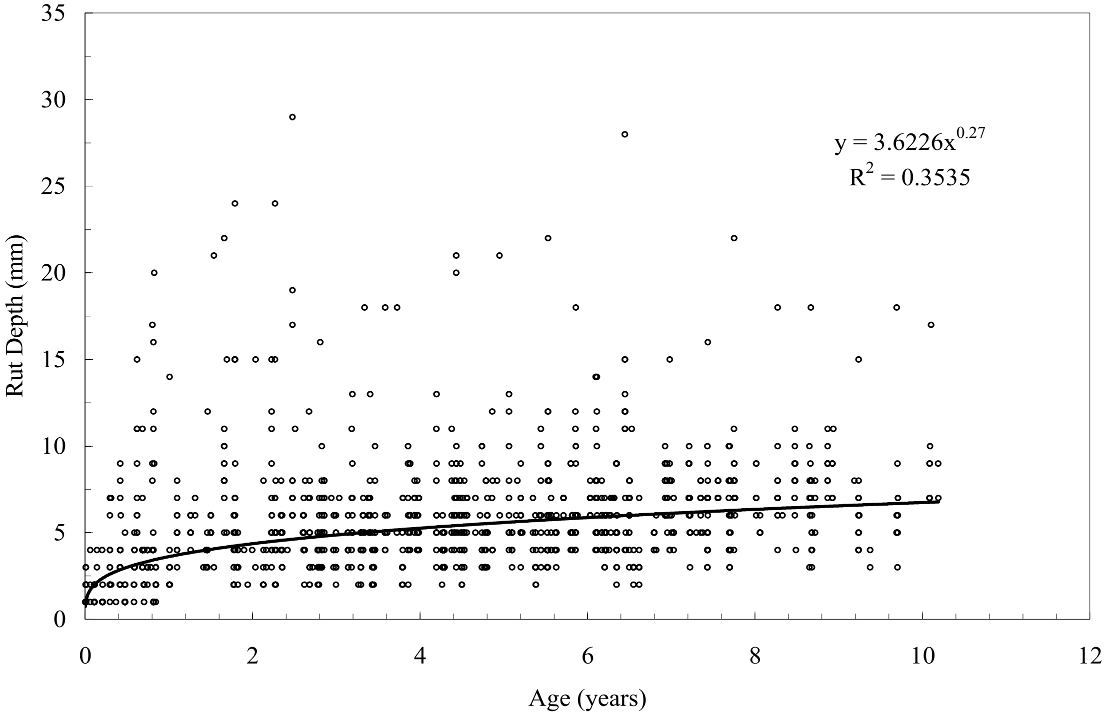


Figure 5-7 Rutting growth with time for SPS-1 pavements – All sections

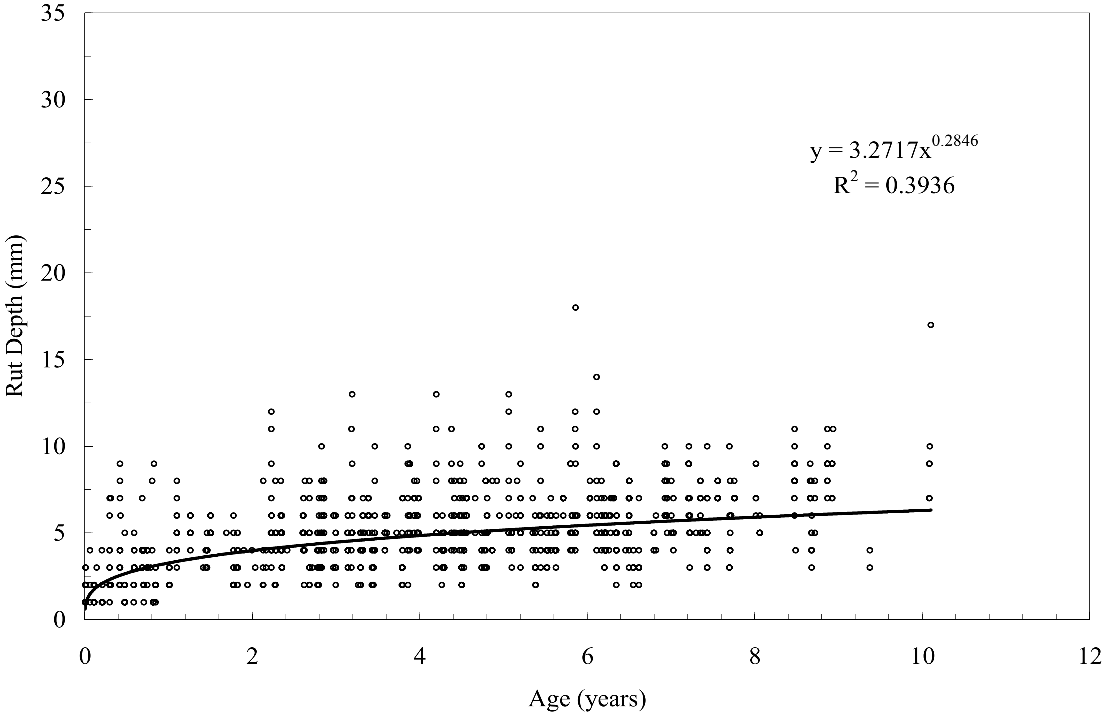


Figure 5-8 Rutting growth with time for SPS-1 pavements – Selected sections

Table 5-3 Summary of p-values from ANOVA for determining the effect of main design factors on pavement rutting

| Design Factor | Rutting Type | | |
|---|---|---|---|
| | Non-structural rutting[a] | Structural rutting | Overall |
| HMA thickness | 0.71 | 0.074 | 0.20 |
| Base type | 0.20 | 0.51 | 0.017 |
| Base thickness | 0.99 | 0.08 | 0.195 |
| Drainage | 0.12 | 0.25 | 0.030 |
| Site (blocked) | 0.15 | 0.00 | 0.00 |
| | $R^2$=0.343<br>N=53 | $R^2$=0.55<br>N=159 | $R^2$=0.57<br>N=212 |

Note: [a] Mix-related or premature rutting in un-bound layers.

Table 5-4 Summary of marginal means from ANOVA for determining the effect of main design factors on pavement rutting

| Design Factor | | Rutting Type | | |
|---|---|---|---|---|
| | | Non-structural (mm) | Structural rutting (mm) | Overall (mm) |
| HMA thickness | 102 mm | 9.0 | 5.3 | 6.1 |
| | 178 mm | 10.0 | 4.9 | 5.8 |
| Base type | DGAB | 11.0 | 5.2 | 6.5 |
| | ATB | 9.05 | 4.9 | 5.7 |
| | ATB/DGAB | 8.2 | 5.1 | 5.6 |
| Base thickness | 203 mm | 10.0 | 5.6 | 6.3 |
| | 305 mm | 10.0 | 5.1 | 5.8 |
| | 406 mm | 9.05 | 5.0 | 5.8 |
| Drainage | N | 11.0 | 5.3 | 6.3 |
| | Y | 9.0 | 4.9 | 5.6 |
| MSE[a] | | 0.206 | 0.062 | 0.10 |

Note: [a] MSE is in natural log. 1 inch = 25.4 mm

Table 5-5 Summary of p-values from ANOVA for determining the effect of experimental factors on pavement rutting

| Experimental Factor | Rutting Type | |
|---|---|---|
| | Non-structural rutting[a] | Structural rutting |
| HMA thickness | 0.16 | 0.043 |
| Base type | 0.94 | 0.54 |
| Base thickness | 0.76 | 0.09 |
| Drainage | 0.50 | 0.28 |
| Subgrade | 0.46 | 0.43 |
| Zone | 0.27 | 0.00 |
| Traffic | 0.000 | 0.013 |
| | $R^2$=0.552<br>N=53 | $R^2$=0.55<br>N=159 |

Note: [a] Mix-related or premature rutting in un-bound layers.

Table 5-6 Summary of marginal means from ANOVA for determining the effect of experimental factors on pavement rutting

| Design Factor | | Rutting Type | |
|---|---|---|---|
| | | Non-structural rutting | Structural rutting |
| HMA thickness | 102 mm | 9.7 | 5.7 |
| | 178 mm | 11.8 | 5.0 |
| Base type | DGAB | 10.7 | 5.4 |
| | ATB | 10.7 | 5.2 |
| | ATB/DGAB | 10.7 | 5.3 |
| Base thickness | 203 mm | 9.7 | 5.7 |
| | 305 mm | 10.7 | 5.0 |
| | 406 mm | 10.7 | 5.2 |
| Drainage | N | 11.8 | 5.5 |
| | Y | 10.7 | 5.1 |
| Subgrade | F | 13 | 5.2 |
| | C | 9.7 | 5.4 |
| Zone | WF | 6.5 | 4.9 |
| | WNF | 13 | 5.6 |
| | DF | 14.4 | 4.0 |
| | DNF | - | 7.1 |
| MSE[a] | | 0.137 | 0.091 |

Note: [a] MSE is in natural log. 1 inch = 25.4 mm

### Fatigue Cracking

It was observed that sections from the Kansas, KS (20), site exhibited the highest area of cracking at an early age compared to sections from other sites. The sections at KS (20) site had a wet subbase during construction (based on the construction report). Also, from the materials data (DataPave) it was found that the test sections at KS (20), on average, have "high" air void content in the HMA (see Table 5-2). These reasons could have caused the abnormally high cracking in the sections at this site. Figure 5-9 and

Figure 5-10 are time-series plots of fatigue cracking for all the pavements sections, before and after exclusion of sections from the Kansas site, KS (20). All statistical analyses pertaining to fatigue cracking, presented in this chapter, were conducted without including data from sections at Kansas site, KS (20).

### Roughness and other Performance Measures

Figure 5-11, through Figure 5-14 show the time-series plots for IRI, transverse cracking and longitudinal (WP and NWP) cracking, respectively. It can be observed that only a few sections have exhibited an abnormal performance. Exclusion of data from these sections was not considered necessary as their inclusion will not impact the results considerably. Therefore, all the pavement sections were included in the analyses of roughness, longitudinal cracking (WP and NWP) and transverse cracking.

### *5.3.2 Drainage-related issues*

In the above section, construction-related issues have been linked to the poor performance of some pavement sections. Some construction and/or maintenance related issues with respect to the in-pavement drainage were also identified in previous research [3, 4]. The in-pavement drainage for some of the SPS-1 flexible pavement sections was found to have some deviations from design.

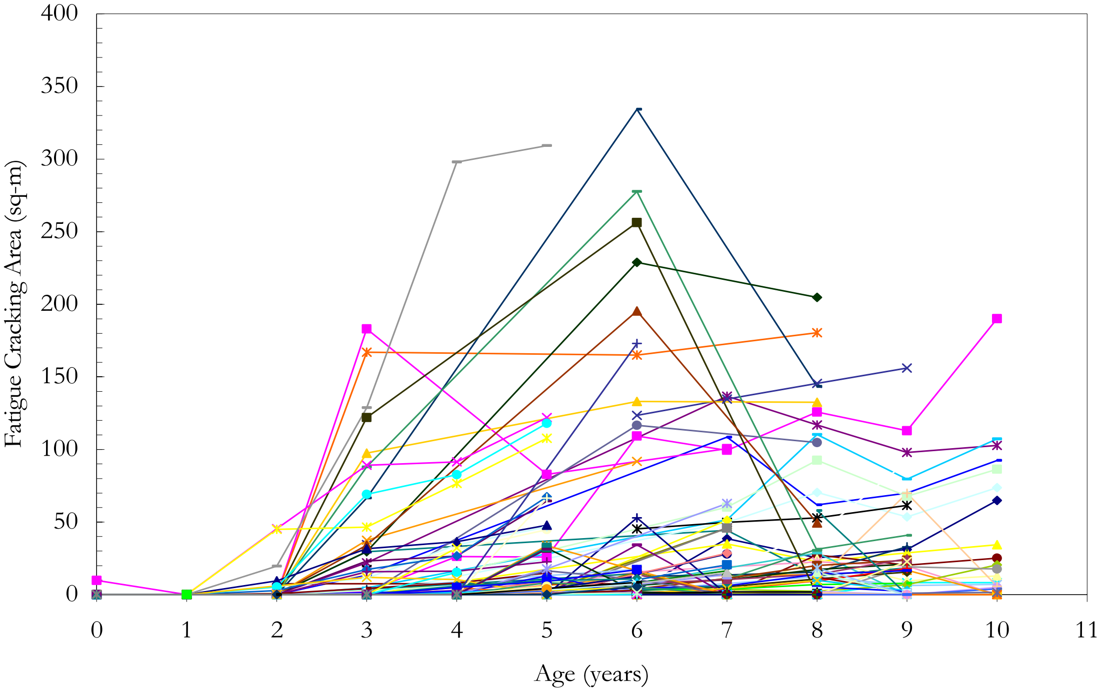


Figure 5-9 Fatigue cracking with time for SPS-1 pavements – All sections

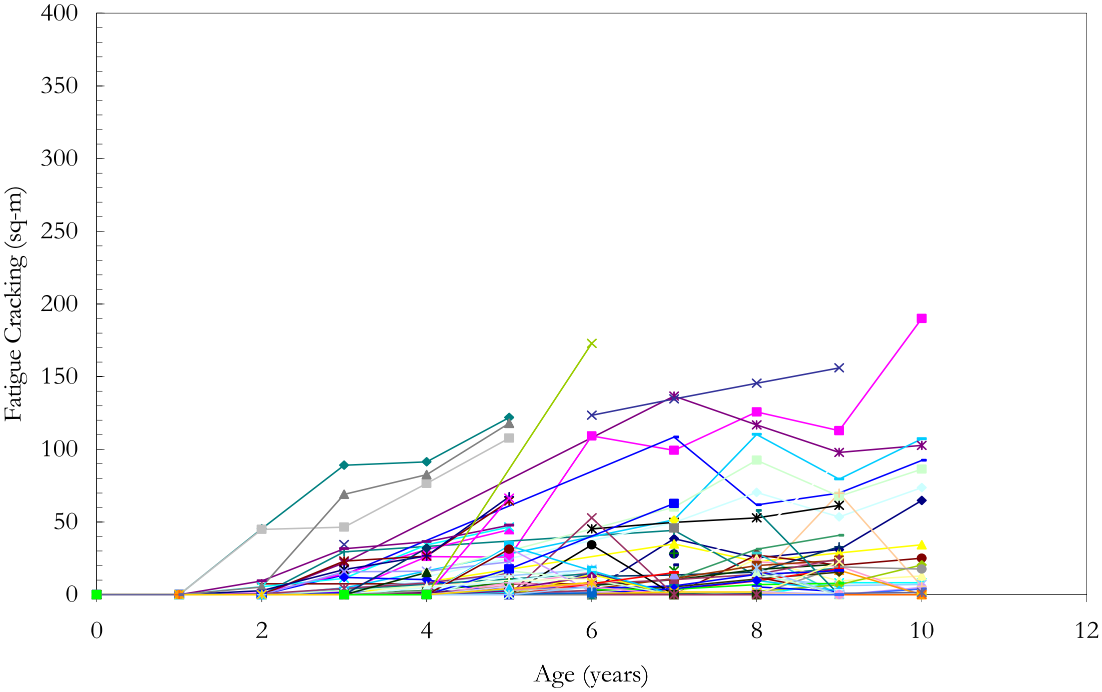


Figure 5-10 Fatigue cracking with time for SPS-1 pavements – Selected sections

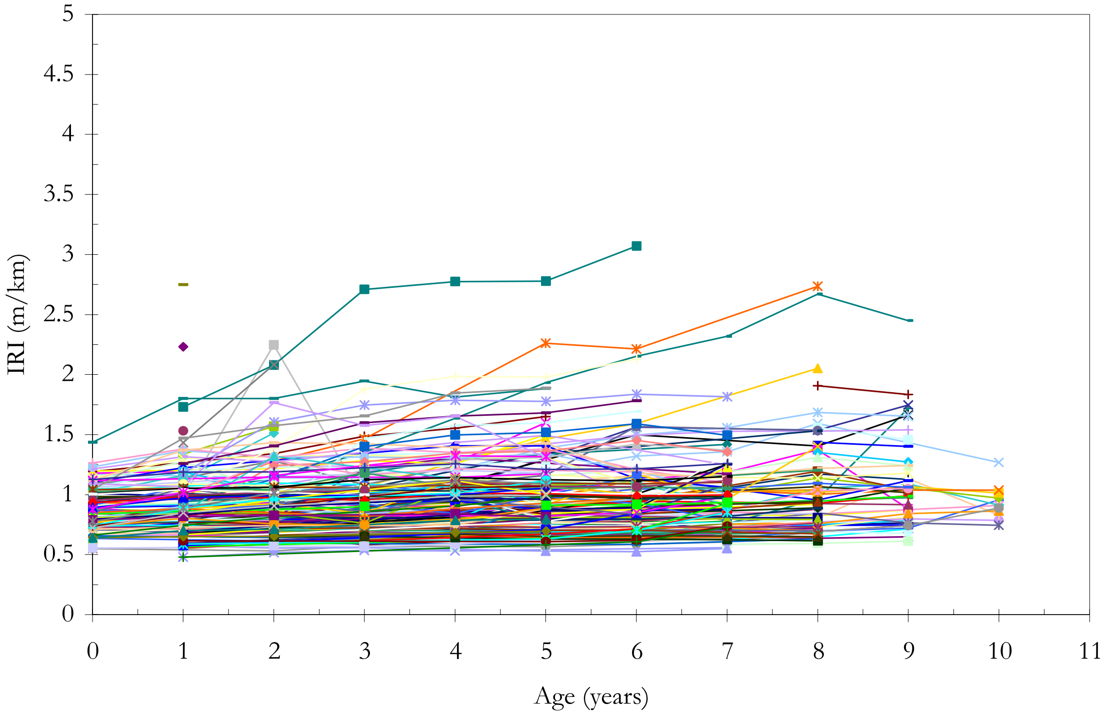


Figure 5-11 IRI with time for SPS-1 pavements – All sections

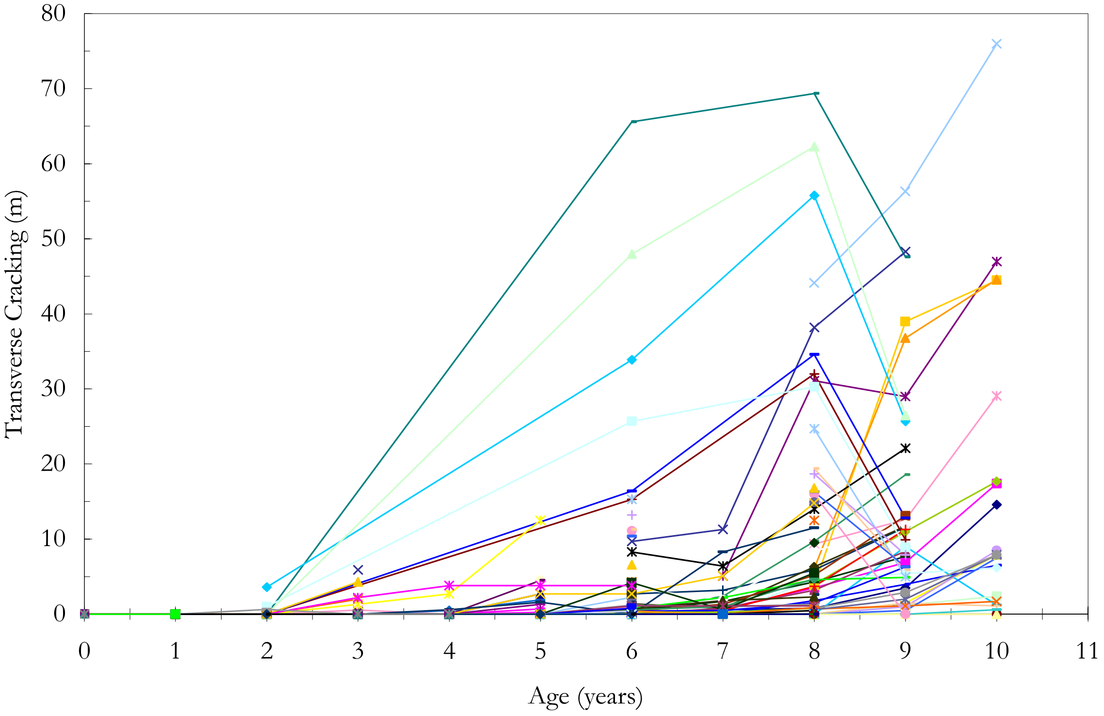


Figure 5-12 Transverse cracking with time for SPS-1 pavements – All sections

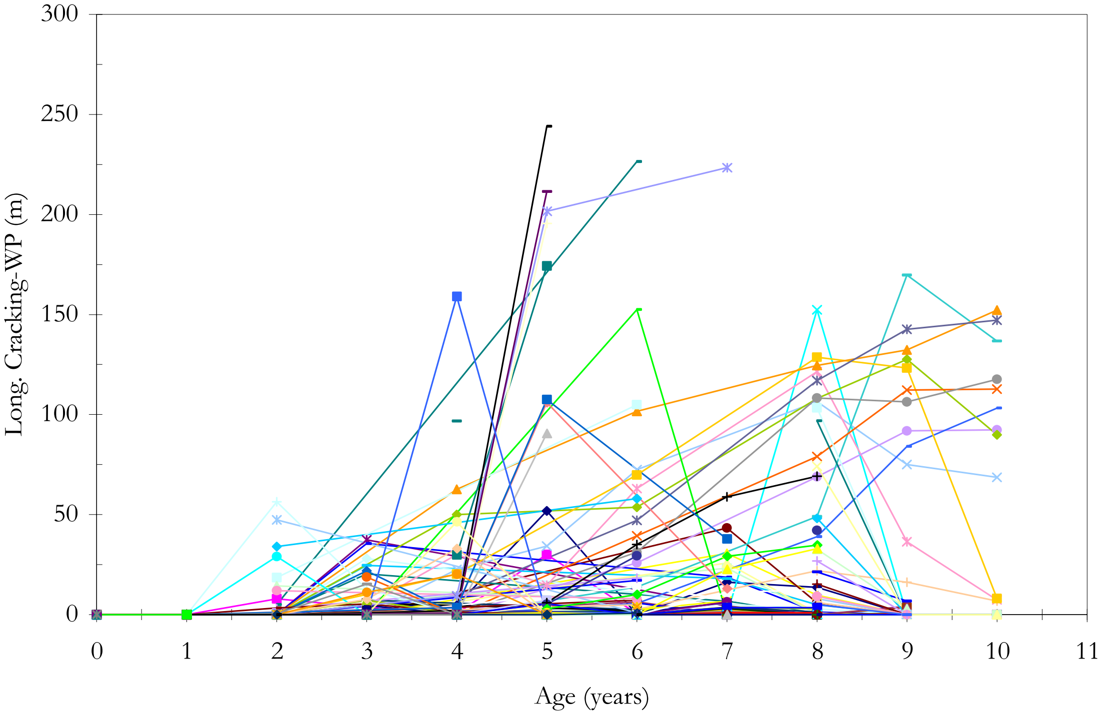


Figure 5-13 Longitudinal cracking-WP with time for SPS-1 pavements – All sections

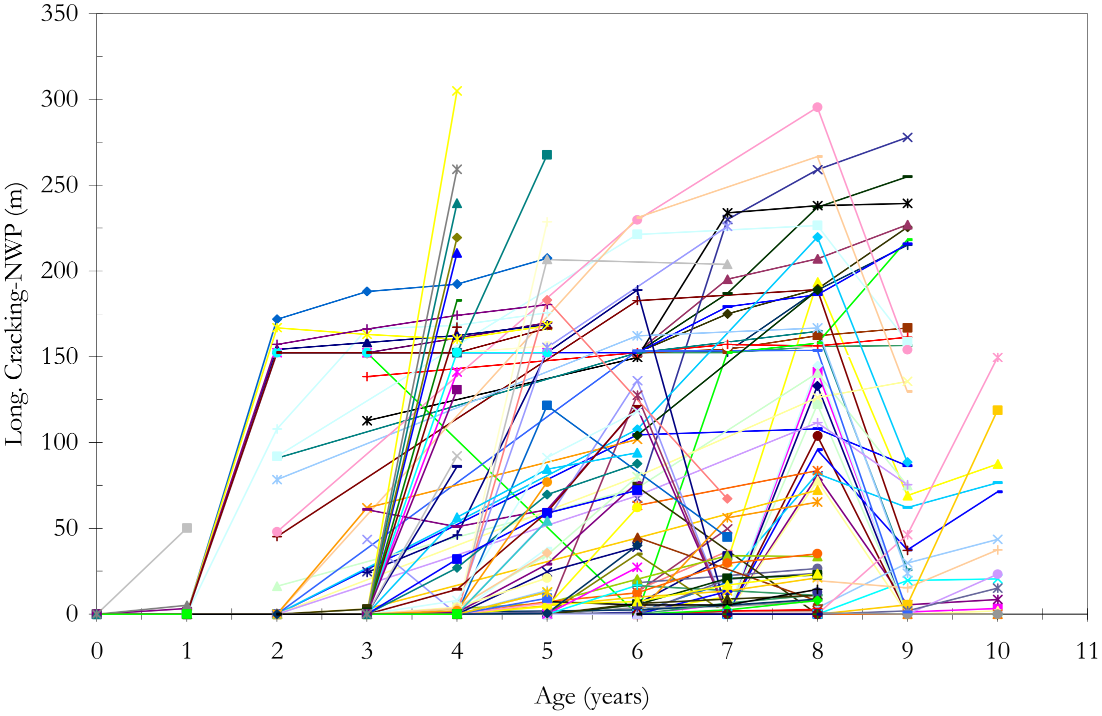


Figure 5-14 Longitudinal cracking-NWP with time for SPS-1 pavements – All sections

All the drained sections of the SPS-1 experiment were video taped to assess the condition of the drainage in the project 1-34C [4]. A subjective assessment of the quality of the drainage functioning in each test section as “good” or “poor” was reported. The ratings assigned to each section are summarized in Table 5-7. The “poor” rating was indicative of; (i) buried lateral outlet, (ii) outlet fully blocked with silt, gravel or other debris (iii) longitudinal drains being fully blocked, or (iv) a considerable amount of stagnant water in the longitudinal drain. A “good” rating was given to the drainage if a reasonably sufficient flow of water was evident even if some amount of material was present in the drains. Hall et al [4] conducted preliminary analysis of the performance of SPS-1 test sections in light of their assessment of drainage, and a brief summary of their findings are presented below:

- Undrained pavement sections built on DGAB may develop cracking, rutting and roughness more rapidly than drained sections built on ATB.
- Undrained pavement sections built on ATB may develop roughness and cracking more slowly than those built with drained DGAB, while the un-drained sections may develop rutting more rapidly.
- Undrained pavement sections built on ATB/DGAB may develop roughness and rutting more quickly than those on drained DGAB, while the undrained sections may develop cracking more slowly.
- Also, among the drained sections, those with “good” rating for drainage performed better than undrained sections, while those with “poor” rating did not.

However, the above trends were based only on the average performance and in no case, were the differences detected statistically significant. These preliminary findings (from Hall et al) should be considered during the interpretation/validation of the results (from this study) regarding the effect of drainage.

Table 5-7 Subjective ratings of drainage functioning at SPS-1 test sections based on video inspection results (source: [4])

| State | Test Section | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0101<br>0113 | 0102<br>0114 | 0103<br>0115 | 0104<br>0116 | 0105<br>0117 | 0106<br>0118 | 0107<br>0119 | 0108<br>0120 | 0109<br>0121 | 0110<br>0122 | 0111<br>0123 | 0112<br>0124 |
| | Base Type | | | | | | | | | | | |
| | DGAB | | ATB | | ATB/DGAB | | PATB/DGAB | | | ATB/PATB | | |
| | Un-drained | | | | | | Drained | | | | | |
| AL (1) | | | | | | | G[1] | G | G | G | G | G |
| AZ (4) | | | | | | | G | G | G | G | G | ?[2] |
| AR (5) | | | | | | | P[3] | P | P | P | P | P |
| DE (10) | | | | | | | G | G | G | G | G | G |
| FL (12) | | | | | | | P | P | P | P | P | P |
| IA (19) | | P | G | P | P | G | ? | G | P | ? | ? | P |
| KS (20) | | | | | | | ? | P | ? | ? | ?*[4] | ? |
| LA (22) | | | | | | | ? | P | P | ? | ? | ? |
| MI (26) | | | | | | P | ? | ? | P | ? | P | ? |
| MT (30) | | | | | | | G | G | G | G | G | G |
| NE (31) | | | | | | | G | G | G | G | G | G |
| NV (32) | | | | | | | P | P | P | P | P | P |
| NM (35) | | | | | | | P | P | ? | P | P | P |
| OH (39) | | G | G | G | | P | ? | G | ? | G | G | G |
| OK (40) | | | | | | | ?* | ?* | ?* | ?* | ?* | ?* |
| TX (48) | | | | | | | P | P | P | P | P | P |
| VA (51) | | | G | G | G | | ? | G | G | G | G | G |
| WI (55) | | | | | | | ? | ? | ? | ? | ? | ? |

[1] G= Drainage function rated as good

[2] ? = Drainage outlet not found

[3] P = Drainage function rated as poor

[4] ?*= Camera could not be inserted

## 5.4 SPS-1 PROJECT PERFORMANCE SUMMARIES

This section is a summary of the performance trends for each site within the SPS-1 experiment based on the latest year data. The performance summary for each site is based on the data available in the Release 17.0 of the DataPave. The severity levels for all types of cracking were combined to calculate its total magnitude. This descriptive summary is intended to help the reader gain an understanding of performance of test sections at each site. The performance of pavement sections regarding selected distresses is presented here, for each site. The identified distresses include fatigue cracking (sq-m), longitudinal cracking-WP (m), longitudinal cracking-NWP (m), transverse cracking (m), rutting (mm) and roughness (m/km).

Additional details about each of the sites can be found in site-level summaries presented in Appendix A1 and performance data tables in Appendix A2.

### Alabama, AL (1)

Performance data is available for 10 years (1994-2003) at this site. The ‘proposed’ traffic is 237 KESAL per year. Fatigue cracking is the dominant distress at this site. Sections 103, 104, 106, 107 and 112 have less than 10% (area) cracking while all other sections have fatigue cracking of range 10% to 15%. A wide range of longitudinal cracking-WP (between 5 m and 30 m) occurred on all the sections. Longitudinal cracking-NWP, between 80 m and 200 m, occurred on all the sections, by year 8. Transverse cracking, of range 15 m to 50 m, was observed in sections 101, 102, and 105 respectively. Sections 102 and 105 have shown 10 mm and 17 mm of rutting, respectively, while other sections have rutting between 6 mm to 9 mm. Sections 102 and 107 have IRI of 1.4 m/km and 1.7 m/km, respectively, while other sections have IRI less than 1.0 m/km.

### Arizona, AZ (4)

The performance data is available for 10 years (1994-2003) at this site. The ‘proposed’ traffic is 214 KESAL per year. Less than 3% (of area) of fatigue cracking occurred in sections 113, 119 and 124, while less than 1% cracking occurred in other sections. Longitudinal cracking-WP is the dominant type of cracking with all the sections showing a cracking between 10 to 150 m. Longitudinal cracking-NWP of 150 m and 120 m occurred on sections 114 and 120, respectively; while in other sections longitudinal cracking-NWP is less than 50 m. Transverse cracking of length 76 m and 45 m occurred on sections 113 and 121, while other sections have less than 30 m of transverse cracking. Rutting of 14 mm and 25 mm occurred on sections 114 and 119, respectively, after 6 years. In other sections rutting ranged from 3 mm to 9 mm. All sections except 113, 120 and 122 have IRI greater than 1 m/km while other sections have IRI less than 1.0 m/km.

### Arkansas, AR (5)

The performance data is available for 9 years (1995-2003) for this site. The 'proposed' traffic is 385 KESAL per year. Fatigue cracking area ranged from 10% to 25% in sections 119, 120 and 121; whereas, all other sections have exhibited less than 10% of fatigue cracking area. All the sections exhibited longitudinal cracking-WP less than 10 m. All the sections have exhibited longitudinal cracking-NWP, which ranged from 140m to 280 m. Transverse cracking of 48 m was observed only in section 119, whereas all other sections have less than 20 m of cracking. Rutting between 5 mm to 9 mm was observed at the site. Sections 119 and 120 have IRI of about 1.7 m/km while other sections have IRI of about 1 m/km.

### Delaware, DE (10)

The performance data is available for 7 years (1996-2003) for this site. The 'proposed' traffic is 309 KESAL per year. Fatigue cracking is the dominant distress at this site. Sections 101 and 102 have cracking of about 10% and 20%, while in other sections cracking was less than 10%. Longitudinal and transverse cracking did not occur on any of the sections. All sections except 102 have shown rutting of range 2 to 4 mm while, sections 102 has 7 mm of rut depth. IRI for all the test section is less than 1.0 m/km.

### Florida, FL (12)

The performance data is available for 7 years (1996-2003) for this site. The 'proposed' traffic is 464 KESAL per year. Fatigue cracking less than 1% occurred in the sections. Longitudinal cracking-WP, less than 10 m, occurred in sections 107, 108, 110, and 112. Longitudinal cracking-NWP, less than 50 m was observed in sections 101,105,108 and 110. Transverse cracking was not observed on any of the sections. Rutting of about 4 mm occurred in all sections, except sections 103, 105, 110 and 111, which exhibited rutting of about 6 mm. All the test sections have shown less than 1 m/km of IRI.

**Iowa, IA (19)**

The performance data is available for 9 years (1995-2003) at this site. The 'proposed' traffic is 132 KESAL per year. Fatigue cracking of 10% (area) was observed on section 102, and all other sections have fatigue cracking less than 2%. Longitudinal cracking-WP of range 50 m to 100m occurred in 102, 104, 105, and 107, while in other sections this cracking is less than 30 m. Longitudinal cracking-NWP of range 110 m to 295 m occurred at this site, in all the sections. Transverse cracking of 30 m to 70 m was also observed in sections 101 through 106, while in other sections this cracking is less than 20 m. Sections 107, 108, and 109 have rut depth of about 7 mm while other sections have rutting between 3 mm and 6 mm. Sections 101 and 102 have IRI values of 1.8 m/km and 2.5 m/km, while IRI in other sections ranged from 1.0 m/km to 1.6 m/km.

**Kansas, KS (20)**

The performance data is available for 8 years (1993-2001) at this site. The 'proposed' traffic is 228 KESAL per year. Fatigue cracking is the main distress type in all the sections. Fatigue cracking ranged from 5% to 20%. Longitudinal cracking-WP has not occurred at this site. Sections 103, 104, 105 and 110 have longitudinal cracking-NWP of 72 m to 189 m, while in other sections the this cracking is less than 20 m. Sections 103, 105 and 110 have transverse cracking less than 16 m. Sections 101, 102, 107 (data available for first 2 years only) have shown rut depth between 16 mm to 25 mm, whereas section 105 has exhibited 13 mm of rutting, after 3 years. Other sections have rutting less than 5 mm. Section 105 has an IRI of 2.7 m/km while sections 104, 109 through 112 have IRI less than 1.2 m/km. Other remaining sections have IRI between 1.5 and 2.0 m/km.

**Louisiana, LA (22)**

The cracking data is available for only 2 years (1997-1999) at this site. The 'proposed' traffic is 524 KESAL per year. The rutting data is available for 6 years (1998-2003) while roughness data is available only for one year (1997). No cracking occurred on any of the sections. Sections 119, 122 and 123 have rutting less than 4.0 mm while; other sections have rutting of about 5 mm. All sections have initial roughness less than 0.8 m/km.

### Michigan, MI (26)

The performance data is available for 7 years (1996-2003) for this site. The 'proposed' traffic is 189 KESAL per year. The performance data is only available for eight sections for this site, as four sections (112, 114, 119 and 122) have been 'deassigned' from LTPP due to construction issues. Fatigue cracking of 2 to 10% was observed on sections 115, 116, 117 and 124, while no cracking occurred in other sections. Longitudinal cracking-WP and transverse cracking has not occurred on any of the test sections. Longitudinal cracking-NWP was observed on all test sections. Section 116 has longitudinal cracking-NWP of 35 m while this cracking in other sections ranged from 120 m to 188 m. Sections 115 and 117 have rutting of 9 mm and 12 mm while other sections have rutting of about 6 mm. Sections 118 and 117 have IRI of 1.2 m/km and 1.4 m/km whereas other sections have IRI less than 1.0 m/km.

### Montana, MT (30)

The performance data is available for 5 years (1998-2003) at this site. The 'proposed' traffic is 127 KESAL per year. Fatigue cracking was observed in sections 115, 117, 120, 121, and 122, with a range of 5% to 10%. Other sections have fatigue cracking of less than 5%. Longitudinal cracking-WP occurred only in sections 113, 114, 115, 118, and 124, with a range of 5 to 10 m. Longitudinal cracking-NWP occurred in all sections, with a range of 150 to 208 m. Transverse cracking were observed only in sections 113, 115 and 121, and this cracking was between 5 m to 10 m. Rutting of 8 mm occurred in sections 120 and 121, while it ranged from 3 to 5 mm in other sections. Sections 120 and 121 have IRI of about 1.5 m/km whereas other sections have IRI of range 0.8 m/km to 1.1 m/km.

### Nebraska, NE (31)

The performance data is available for 7 years (1995-2002) at this site. The 'proposed' traffic is 113 KESAL per year. Fatigue cracking has just initiated only in sections 113 and 114. Longitudinal cracking-WP of 97 m was observed in section 113. Longitudinal cracking-NWP and transverse cracking did not occur in any of the sections. Rutting of 29 mm was observed on section 113 by year 5. Among other sections, 114, 115, 118, 123, and 124 have rutting between 11 mm and 15 mm, while others have rutting between 5 mm and 8 mm. Sections 113 has an IRI of 1.9 m/km and all other sections have IRI of about 1.0 m/km. All test sections have an initial IRI between 0.9 and 1.4 m/km.

**Nevada, NV (32)**

The performance data was collected for 8 years (1996-2003) for this site. The 'proposed' traffic is 475 KESAL per year. Fatigue cracking area is less than 1% in all the test sections. No noticeable longitudinal cracking-WP was observed in any of the sections. More than 50 m of longitudinal cracking-NWP was observed only in section 103 and sections 101, 102, 104, 105 and 109 have less than 35 m of longitudinal cracking-NWP. Less than 15 m of transverse cracking occurred in sections 102, 107 and 109. Sections 101, 104, 107, and 108 have rut depth less than 4 mm while other sections have rut depth of about 5 mm. All sections except 102 have IRI less than 1 m/km. Section 102 has an IRI value of 1.4 m/km.

**New Mexico, NM (35)**

The performance data was collected for 8 years (1997-2003) at this site. The 'proposed' traffic is 149 KESAL per year. Fatigue cracking, less than 1% of area, occurred in sections 102 to 104. Sections 101, 103,105 and 107 have exhibited less than 45 m of longitudinal cracking-WP, while section 102 has 70 m of this cracking. Furthermore, less than 25 m of longitudinal cracking-NWP was observed only in sections 101, 102, and 107. No transverse cracking was observed at this site. All sections at this site have exhibited rut depth of about 7 mm. All sections except 101, 102, 103, 107 and 112 have IRI between 1.0 to 1.3 m/km while other sections have less than 1.0 m/km of IRI.

**Ohio, OH (39)**

The performance data was collected for 7 years (1996-2002) for this site. The 'proposed' traffic is 390 KESAL per year. At this site, cracking data for sections 101, 102,105 and 107 are only available for the initial year. These sections were 'deassigned' from the LTPP because of premature rutting. Fatigue cracking is the dominant cracking distress within all sections at this site. All sections, except 109, have fatigue cracking between 3 to 15% of area. All sections, except 104, 111, and 112, have between 175 to 245 m of longitudinal cracking-WP. Also, all sections except 109, 110, 111 and 112, have longitudinal cracking-NWP between 200 to 260 m. No transverse cracking was observed in any section at this site. Sections 101 and 102 had more than 10 mm of rut depth after only 1 year. Also sections 103 108, and 109 have exhibited rutting of about 10 mm. IRI more than 2 m/km was observed on sections 101 and 102 after only 1 year of construction. All sections have IRI greater than 1.4 m/km, while sections 103 and 108 have IRI of 3 and 2 m/km, respectively.

**Oklahoma, OK (40)**

The performance data was collected for 6 years (1997-2003) for this site. The 'proposed' traffic is 281 KESAL per year. Less than 3% (area) of fatigue cracking was observed in all the sections. No longitudinal cracking-WP occurred on any section at this site. Longitudinal cracking-NWP between 20 m and 120 m was observed in all sections except, section 113, which has no longitudinal cracking-NWP. Transverse cracking less than 4 m was observed in sections 113, 115 and 121. Sections 113, 117 and 122 have more than 10 mm of rut depth, while the other sections have rutting between 4 to 8 mm. Sections 113 through 118 have IRI of about 1.1 m/km whereas, all other sections have less than 1.0 m/km of IRI.

**Texas, TX (48)**

At this site, performance data was collected for 5 years (1997-2002). The 'proposed' traffic is 360 KESAL per year. Fatigue cracking, less than 1% (area) and longitudinal cracking-WP (between 20 m and 50 m), was observed only in sections 113, 117, 118 and 122. Only sections 112 and 119 have exhibited longitudinal cracking-NWP of 54 m and 77 m, respectively. No transverse cracking was observed in any of the sections. Severe early rutting, between 10 mm to 18 mm, was observed in sections 114, 115, 116, 119, 123 and 124, after 1 year. Rutting in these sections progressed to about 14 mm to 26 mm, by year 4. All other sections have rutting less than 11 mm, by year 4. Sections 115, 116 and 119 have IRI between 1.2 and 1.8 m/km, after only 2 years and all other sections have IRI less than 1.0 m/km.

**Virginia, VA (51)**

The performance data was collected for 6 years (1995-2002) for this site. The 'proposed' traffic is 257 KESAL per year. More than 25% of fatigue cracking was observed only on sections 103 and 120. Longitudinal cracking-WP and transverse cracking has not occurred on any of the sections. Sections 114 and 120 have exhibited longitudinal cracking-NWP of 40 m and 4 m, respectively. Section 103 has rut depth of 12 mm just after 1 year and this progressed to 21 mm by year 5. All other sections have exhibited rutting ranging between 4 mm and 6 mm. All sections, except 113, have IRI less than 1.3 m/km. Section 113 has an IRI of 1.9 m/km.

**Wisconsin, WI (55)**

The performance data was collected for only 4 years (1998-2002) at this site. The 'proposed' traffic is 161 KESAL per year. Fatigue cracking less than 5% was observed only on sections 113, 114, and 116. Longitudinal cracking-WP and transverse cracking has not occurred on any of the sections. A wide range (between 90 m and 300 m) of longitudinal cracking-NWP was observed on all the sections. Sections 120 and 121 have rutting of 4.0 mm while all other sections have rutting between 6 to 9 mm. All sections have IRI less than 1.3 m/km.

## 5.5 SITE-LEVEL ANALYSIS

The site-level analysis deals with each SPS-1 project separately. The main advantage of this analysis is that it is unaffected by the variability between SPS-1 sites. For each site, the climatic conditions, subgrade type and traffic are the same. Construction conditions, material sources and surveys can also be considered the same for a given SPS-1 project.

As described in Chapter 4, the site-level analyses consists of two types of comparisons: (i) Level-A— In this analysis all designs (0101 through 0112, or 0113 through 0124) at a given site are compared such that only one factor is held common within the sections of each group. For example in level-A analysis, the effects of HMA thickness (102 mm vs. 178 mm) were considered for all twelve sections within a site by ignoring base type & thickness, and drainage. (ii) Level-B—analysis- In this analyses, most of the factors are 'controlled' for comparisons. In level B analysis, the effect of HMA thickness (102 mm vs. 178 mm) was compared for only those sections for which all other factors are the same.

The concepts of Performance Index (PI) and the relative performance were used in the site level analysis. These concepts were introduced in Chapter 4 of this report. The site-level analysis process is summarized in Figure 5-15.

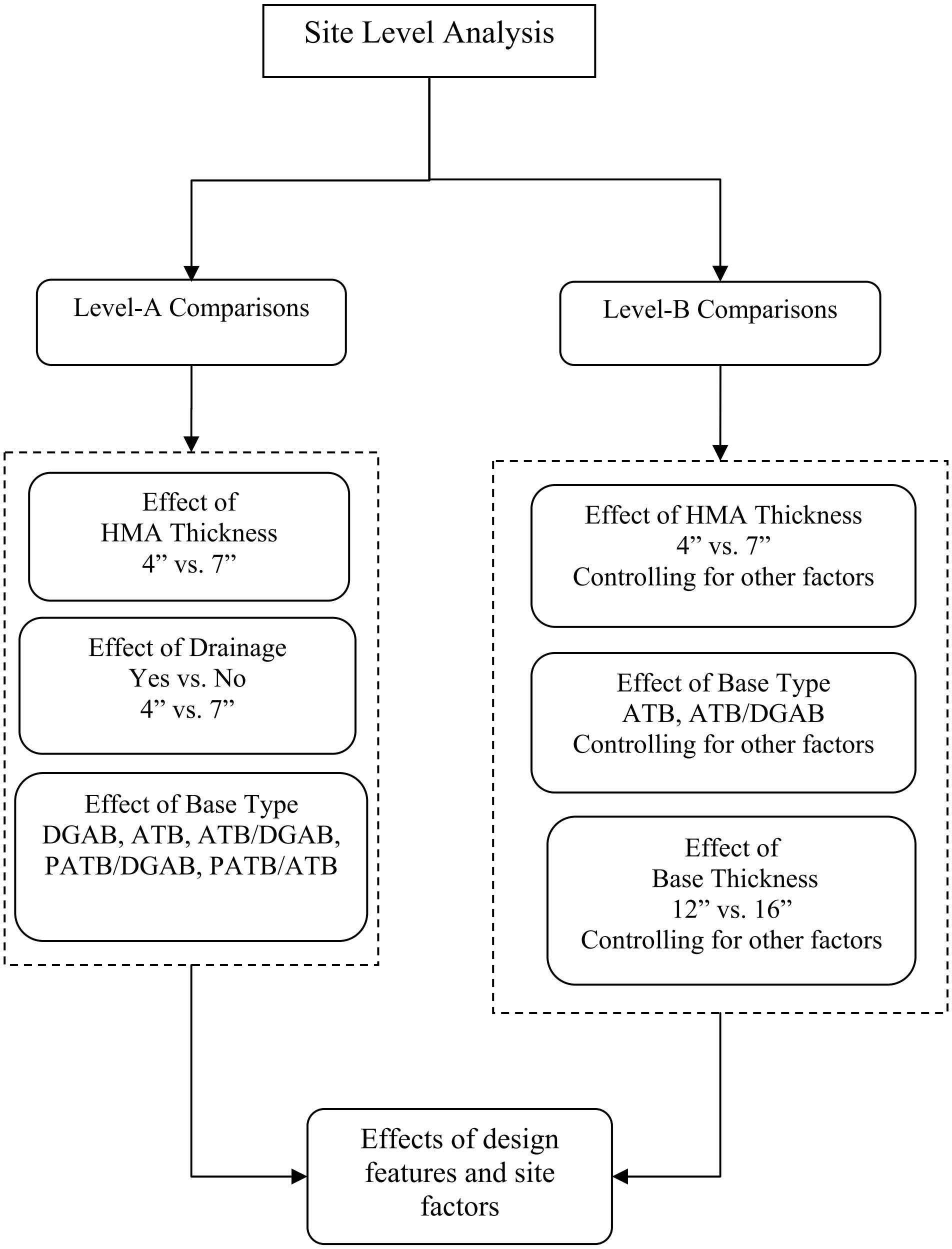


Figure 5-15 Methodology for site level analysis (SPS-1)

Each analysis was conducted separately for each performance measure. The pavement performance measures considered include:

- Fatigue cracking
- Rutting
- Roughness (IRI)
- Transverse cracking, and
- Longitudinal cracking (WP and NWP)

The PIs and relative performance ratios for the main design factors were calculated at all sites. Because the relative performance is a ratio, it can be used across the sites. The relative performance ratios for a given design factor from all eighteen states were used to test the significance of its effect. A two-level non-parametric (Wilcoxon Signed Ranks) test was done to evaluate the effect of HMA thickness and drainage, and a multiple level non-parametric comparison test was done to evaluate the effect of base type. The p-values from these tests are reported in the discussion of the results. To evaluate the interactive effect of the design factors with climatic zone and subgrade type, the average relative performance ratios within the same climatic zones and for both subgrade types were compared.

The computed PIs and relative performance ratios for all the distresses are summarized and presented in Appendix A4. The following is a summary of the main findings from each method of analysis, categorized by design factor and performance measure.

### *5.5.1 Effects of design features on performance – Paired Comparisons at Level-A*

A summary of p-values obtained from the non-parametric tests on RPIs (for all 18 sites) from level-A analyses is in Table 5-8. It is important to note that the significance of a factor indicates consistency in its effect across all the sites but not necessarily a significance of its effect on the magnitude of distress.

Table 5-8 Summary of p-values (non-parametric test) for Site Analysis - Level-A

| Design Factor | Performance Measures | | | | | |
|---|---|---|---|---|---|---|
| | Fatigue cracking | Rutting | Roughness | Transverse cracking | Longitudinal cracking | |
| | | | | | WP | NWP |
| HMA thickness | 0.013 | 0.408 | 0.009 | 0.050 | 0.311 | 0.368 |
| Base type | 0.033 | 0.529 | 0.000 | 0.079 | 0.599 | 0.883 |
| Base thickness | - | - | - | - | - | - |
| Drainage | 0.047 | 0.056 | 0.020 | 0.040 | 0.035 | 0.028 |

The following is a summary of the main findings from paired comparisons at level-A categorized by design factor and performance measures:

*HMA Thickness*

The effect of HMA thickness is consistent on roughness (IRI), fatigue cracking, and transverse cracking, with 7-inch HMA pavements showing better performance. It is not consistent for longitudinal cracking (WP and NWP)) and rutting (see Table 5-8).

- **Fatigue Cracking**: HMA thickness appears to have a consistent effect on fatigue cracking. Sections with 178 mm HMA thickness have consistently (across sites) performed better than those with 102 mm HMA thickness. Twelve sites show a positive effect, compared to five sites showing a negative effect and one site showing no effect.

  The effect of HMA thickness is less seen among the sites located in WF zone. Also, on average, the superior performance of 178 mm over 102 mm HMA sections can be seen more for sections on coarse-grained subgrade than for those on fine-grained subgrade.
- **Rutting**: The effect of HMA thickness on rutting is not consistent. Nine sites show a positive (lesser rutting in sections with 178 mm HMA surface thickness) effect and the other nine show a negative effect, which shows no definitive trend of the effect across sites.

- **Roughness (IRI)**: The effect of HMA thickness on IRI is consistent across sites. On average, sections with 178 mm HMA surface thickness have consistently performed better than those with 102 mm HMA thickness. This trend was observed in thirteen out of eighteen sites and two sites showed no effect.
- **Transverse Cracking**: The effect of HMA thickness on transverse cracking is consistent across sites. Sections with 178 mm HMA thickness have consistently performed better than those with 102 mm HMA thickness. Eight out of eighteen sites showed less transverse cracking for 178 mm sections; seven sites showed no transverse cracking, while three sites showed more transverse cracking for 178 mm HMA sections.

  In terms of climatic zones, the positive effect of HMA thickness was observed in all zones except for WF. This could be attributed to the severe environmental conditions in WF zone where even thicker HMA may not be able to inhibit cracking. Averaging over all climatic zones, the effect of HMA thickness is essentially the same for both subgrade types.
- **Longitudinal Cracking-WP**: The effect of HMA thickness on longitudinal cracking-WP is not consistent. Nine sites show a positive effect and the other nine sites show a negative effect, which shows no definitive trend of the effect across sites.
- **Longitudinal Cracking-NWP**: HMA thickness seems to have no consistent effect on longitudinal cracking-NWP. Nine sites show a positive effect and the eight sites show a negative effect, indicating no definitive trend of the effect across sites.

### *Effect of Base Type*

The effect of base type on fatigue cracking, roughness, and transverse cracking is consistent across sites, with sections on DGAB showing the worst performance and sections on ATB+PATB showing the best performance.

- **Fatigue cracking**: Base type has a consistent effect, across sites, on fatigue cracking. Sections with DGAB have shown the most amount of cracking while sections with ATB+PATB have shown least amount of cracking. The order of performance from best to worst is as follows: (1) PATB+ATB, (2) ATB, (3) ATB+DGAB (4) PATB+DGAB and (5) DGAB.
- **Rutting**: The effect of base type is not consistent. However, on average, sections with PATB+ATB have slightly lesser rutting compared to sections with DGAB.

- **Roughness (IRI)**: The effect of base type on IRI is consistent across sites. Sections with DGAB have consistently shown the highest IRI-values while sections with ATB+PATB have shown the lowest values. The order of performance from best to worst is as follows: (1) PATB+ATB, (2) ATB+DGAB, (3) ATB, (4) PATB+DGAB, and (5) DGAB.
- **Transverse cracking**: The effect of base type appears to be marginally consistent across sites (p=0.079). Sections with PATB+ATB have somewhat lesser cracking than sections with DGAB.
- **Longitudinal cracking-WP**: The effect of base type is not consistent across sites. Nonetheless, on average, the permeable bases appear to be performing better. The worst performance was shown by the sections with DGAB.
- **Longitudinal cracking-NWP**: The effect of base type is not consistent across sites. However, on average, the best performing bases are the permeable bases- PATB+ATB and PATB+DGAB, and the worst performing base is DGAB.

### *Effect of Drainage*

The effect of drainage on all performance measures is consistent across sites, with drained pavements showing better performance than un-drained pavements (see Table 5-8).

- **Fatigue cracking**: Drainage has a consistent effect across sites on fatigue cracking. Sections with drainage have performed better than those without drainage. Twelve sites show a positive effect (better performance of drained sections), compared to five sites that show a negative effect. Averaging over all climatic zones, the effect of drainage can be seen better for sections with fine-grained subgrade as opposed to coarse-grained subgrade.
- **Rutting**: The effect of drainage on rutting is consistent. Sections with drainage have consistently performed better than those without drainage. Twelve sites show a positive effect, compared to four sites showing a negative effect and two sites showing no effect.
- **Roughness (IRI)**: Drainage has a consistent effect on roughness. Sections with drainage have consistently (across sites) performed better than those without drainage. In fifteen out of eighteen sites drained sections have shown a better performance, while reverse trend was found in only three sites. This effect is less seen among sections in DF zone and could be attributed to the fact that drainage is not as important in this zone.

- **Transverse cracking**: Drainage has somewhat consistent effect on transverse cracking. Sections with drainage have performed better than those without drainage in most of the sites. Seven sites show a positive effect, while no transverse cracking occurred in seven of the sites. Averaging over all climatic zones, the effect of drainage is better seen for sections built on fine-grained subgrade than for sections built on coarse-grained subgrade.
- **Longitudinal cracking-WP**: The effect of drainage on longitudinal cracking-WP is consistent across sites. On average, sections with drainage have consistently performed better than those without drainage. Eleven sites show a positive effect, compared to three sites showing a negative effect and four sites showing no effect. Moreover, the effect is more prominent for sections on fine-grained subgrades as opposed to those on coarse-grained subgrades.
- **Longitudinal cracking-NWP**: Drainage has a consistent effect on longitudinal cracking-NWP. On average, sections with drainage have consistently performed better than those without drainage. Thirteen sites show a positive effect, compared to three sites showing a negative effect and two sites showing no effect.

### *5.5.2 Effects of design features – Paired Comparisons at Level-B*

As explained in Chapter 4, level-B comparisons are more "controlled" compared to level-A comparisons. To study the consistency of the effect of HMA thickness across sites, nonparametric testing was performed on relative performance corresponding to 102 mm and 178 mm HMA thicknesses, within each base type. Similarly, to investigate the effect of base thickness, nonparametric testing was performed on relative performance corresponding to 305 mm and 406 mmbase thicknesses, within PATB/DGAB and ATB/PATB. Also, nonparametric testing was performed on relative performance corresponding to ATB and ATB/DGAB, within 203 mm and 305 mm base thicknesses. For each of these effects, the corresponding p-values are presented in Table 5-9. A brief summary of results from the level-B comparisons follows.

Table 5-9 Summary of p-values (non-parametric test) for Site Analysis - Level-B

| Design Factor | Performance Measures | | | | | |
|---|---|---|---|---|---|---|
| | Fatigue cracking | Rutting | Roughness | Transverse cracking | Longitudinal cracking | |
| | | | | | WP | NWP |
| HMA thickness | 0.041 | 0.080 | 0.005 | 0.010 | 0.203 | 0.110 |
| Base type | 0.969 | 0.214 | 0.150 | 0.552 | 0.929 | 0.551 |
| Base thickness | 0.307 | 0.022 | 0.046 | 0.933 | 0.499 | 0.387 |

#### *HMA Thickness*

The effect of HMA thickness can be examined for sections with different base types. Among sections with DGAB, it was observed that HMA thickness has a positive effect of on fatigue cracking, transverse cracking, and roughness (IRI). Also, on average, a positive effect of HMA thickness was observed on sections with ATB for fatigue cracking, but it is not consistent. The same effect was observed for rutting. This suggests that increasing HMA thickness is more effective in pavement sections with unbound bases as compared to those with treated bases.

#### *Base Type*

The effect of all five base types cannot be evaluated effectively for Level-B comparisons since the only base types that can be compared are ATB and ATB+DGAB. Nonetheless, the results show that the difference in performance between these two base types is not statistically significant.

### *Base Thickness*

The effect of base thickness can be better seen when using Level-B comparisons, mainly because it is a more secondary effect relative to HMA layer thickness and base type (treated versus untreated). Therefore it is more useful to look at this effect for two types of (permeable) bases: (1) DGAB and (2) ATB.

The effect of base thickness was found to be consistent for rutting and roughness in pavement sections with DGAB. The effect of base thickness is not consistent for fatigue cracking and longitudinal cracking-NWP. However, on average, thicker (16-inch) bases have shown better performance than thinner (305 mm) bases. Finally, the effect of base thickness is not consistent for transverse cracking and longitudinal cracking-WP.

## 5.6 OVERALL ANALYSIS

The results obtained from statistical analyses performed on the SPS-1 data are presented in this section. Both the performance and response variables were analyzed to study the effects of various design and site-factors on the pavement sections. Analyses were performed combining all data and is referred to as ‘Overall’ analyses. Analyses were also conducted in each climatic zone combining data from all sections within a zone as per the recommendation of the project panel. Linear Discriminant Analysis (LDA), Binary Logistic Regression (BLR), and Analysis of Variance (ANOVA) are the statistical methods that were employed for analyses. Before presenting the results from statistical analyses, the extent of distresses that occurred on the test sections is discussed.

### *5.6.1 Extent of Distress by Experimental Factor*

This section discusses the effect of the key experimental factors on performance through the relationship between the magnitude and relative occurrence of the observed distresses. Figure 5-16 through Figure 5-21 show the percentage of test sections that have exceeded various levels of distress for the key performance measures, categorized by experimental (design and site) factors. Note that the effect of climatic zone is only shown for the wet regions because of the limited number of sites in the dry regions (only four). The following is a brief interpretation of these figures:

*Fatigue cracking*: Figure 5-16 indicates that about 70% of all test sections have shown some fatigue cracking, with about 10% of all test sections showing 20% or higher cracking by area. The effects of specific design and site factors are discussed below.

a) HMA Thickness: About 75% of sections with thin HMA surface layer have shown some fatigue cracking as compared to about 65% of sections with thick HMA surface layer; the effect of HMA thickness tends to be larger for higher levels of fatigue cracking.
b) Base Type: The difference in the percentage of test sections that have shown fatigue cracking between those with unbound (DGAB) and those with treated (ATB) bases is highest among all experimental factors (about 15%), with sections built on DGAB bases showing the highest percentages.

c) Base Thickness: The effect of base thickness on fatigue cracking was found to be insignificant.
d) Drainage: The effect of drainage in terms of higher percentage of test sections showing fatigue cracking is more pronounced at the lower levels of fatigue; the effect becomes insignificant at the later stages of fatigue. This could mean that drainage is more effective in the early life of the pavement, and becomes less effective later in the pavement life. Also, the effect of drainage is slightly more visible for fine-grained than for coarse-grained subgrade soils [Figure 5-16 (d)].
e) Climate: There are consistently more sections in wet-freeze (WF) than wet-no-freeze (WNF) climate that have shown fatigue cracking exceeding various levels, with about 10% more sections in WF than in WNF climate.
f) Subgrade Type: There are consistently about 15% more sections built on fine-grained than coarse-grained subgrade soils that have shown fatigue cracking exceeding various levels, and the effect of subgrade soils tends to be larger for higher levels of fatigue cracking.

*Rutting*: Figure 5-17 indicates that about 60% of all test sections have shown rut depths higher than 0.25 inch (6.25 mm), and about 20% of all test sections showing rut depths higher than 0.5 inch (12.5 mm). The effects of specific design and site factors are discussed below.

a) HMA Thickness: The effect of HMA thickness on rutting was found to be negligible.
b) Base Type: There are about 10% to 15% more sections with unbound (DGAB) bases that have rut depths greater than 7.5 mm than those with treated (ATB) bases. This difference is relatively constant even at higher rut depths.
c) Base Thickness: There is a slight effect of base thickness for sections that have rut depths that are less than 7.5 mm, with about 5% more sections with thinner (8 inch) bases than those with thicker (16 inch) bases. The effect becomes less apparent for rut depths greater than 7.5 mm.
d) Drainage: There are consistently about 5% more sections without drainage than with drainage that have exceeded various rut depth levels. Also, the effect of drainage is slightly more noticeable at the higher rut depths and for fine-grained subgrade soils [Figure 5-17 (d)].

e) Climate: The effect of climate (within wet regions) on rutting appears to be more significant at rut depth higher than 7.5 mm, with about 10% more sections in wet-freeze than in wet-no-freeze climate exceeding various rut depths.
f) Subgrade Type: There are consistently about 10% more sections built on fine-grained than coarse-grained subgrade soils that exceed various rut depths.

*Roughness (IRI)*: Figure 5-18 indicates that about 60% of all test sections have shown IRI values higher than 1 m/km, with about 20% of all test sections showing IRI values higher than 1.4 m/km. The effects of specific design and site factors are discussed below.

a) HMA Thickness: The percentage of test sections with thin (102 mm) HMA surface layer that have exceeded an IRI of 1.2 m/km is about 40% as compared to about 20% for test sections with thick (7 inch) HMA surface layer. The percentage of test sections with thin (102 mm) HMA surface layer exceeding higher IRI levels is 5% to 10% more than that of test sections with thick (7 inch) HMA surface layer.
b) Base Type: The percentage of test sections with unbound aggregate base (DGAB) that have exceeded an IRI of 1.2 m/km is about 40% as compared to about 20% for test sections with asphalt treated base (ATB). The percentage of test sections with a 203 mm base exceeding higher IRI levels is about 10% to 15% more than that of test sections with a 406 mm base thickness.
c) Base Thickness: The effect of base thickness on roughness is more pronounced than for other performance measures, showing a percentage of test sections with a DGAB base exceeding 1.2 m/km and higher IRI levels that is about 10% to 15% more than that of test sections with an ATB base.
d) Drainage: There are consistently about 5% more sections without drainage than with drainage that have exceeded various IRI levels.
e) Climate: The effect of climate (within wet regions) on roughness appears to be the most significant, with about 20% to 30% more sections in wet-freeze than in wet-no-freeze climate exceeding 1.2m/km and higher IRI levels.
f) Subgrade Type: The effect of subgrade type on roughness is more pronounced than for other performance measures, with about 15% to 30% more sections on fine-grained than on coarse-grained subgrade exceeding 1.2m/km and higher IRI levels.

*Transverse cracking*: Figure 5-19 indicates that about 40% of all test sections have shown some transverse cracking, with about 10% of all test sections showing 20m or higher length of transverse cracking. The effects of specific design and site factors are discussed below.

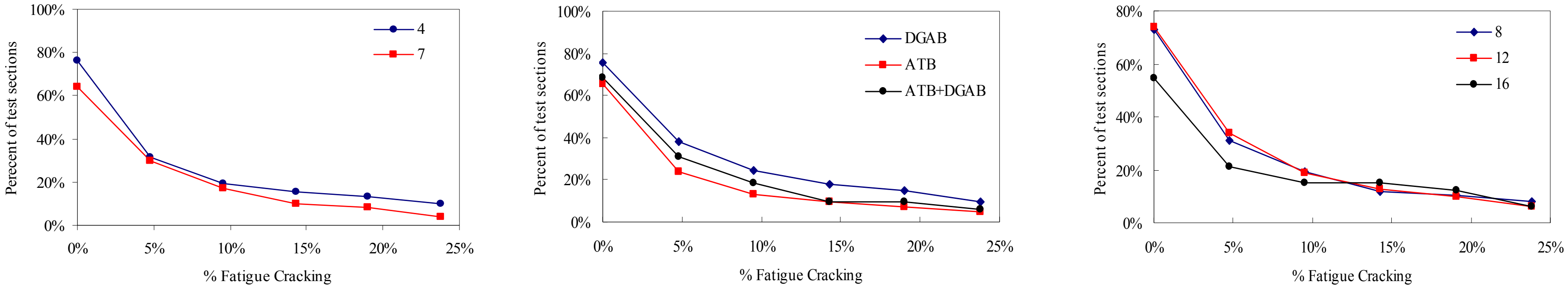
a) HMA Thickness: Only a slight effect of HMA thickness was found on transverse cracking.
b) Base Type: Base type appears to be a significant factor affecting transverse cracking. About 10% to 15% more test sections with unbound aggregate base (DGAB) than those built with an asphalt treated base (ATB) at various levels of transverse cracking.
c) Base Thickness: Only a slight effect of base thickness was observed.
d) Drainage: Only a slight effect of drainage on transverse cracking was observed.
e) Climate: Climate seems to be a significant factor affecting transverse cracking. There are about 15% to 20% more test sections in WF zone than those built in WNF zone at various levels of transverse cracking.
f) Subgrade Type: Subgrade soil type seems to have some effect on transverse cracking, in that, slightly higher proportion of sections built on fine-grained soils have shown cracking compared to those built on coarse-grained soil.

*Longitudinal cracking*: Figure 5-20 and Figure 5-21 indicate that about 50% of all test sections have shown some longitudinal cracking-WP and about 75% of all test sections have shown some longitudinal cracking-NWP. The effects of experimental factors are discussed below.

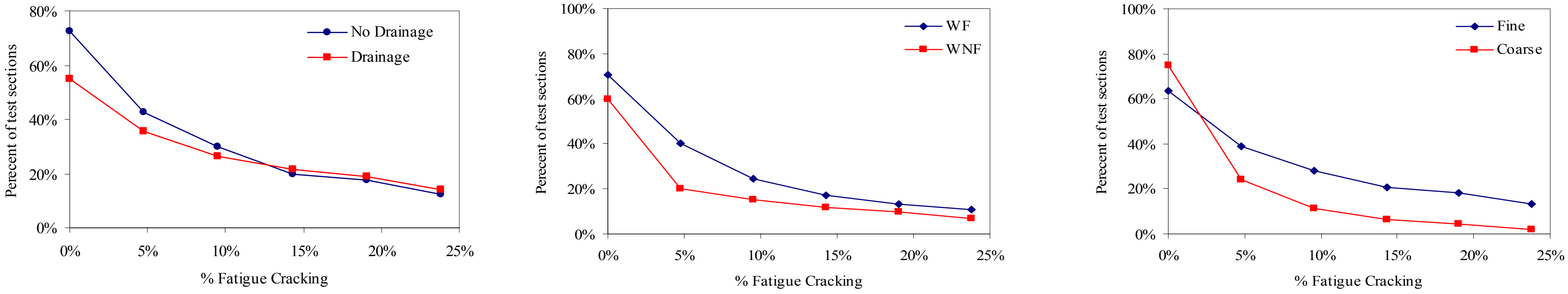
a) HMA thickness: HMA thickness appears have a negligible effect on longitudinal cracking.
b) Base Type: There seems to be a slight effect of base type on longitudinal cracking, in that sections with ATB has shown lesser cracking than those with DGAB.
c) Base Thickness: Only a slight effect of base thickness was observed. Sections with 406 mm base thickness have slightly less occurrence of cracking than those with 203 mm base.
d) Drainage: There appears to be some positive effect of drainage on lower levels of longitudinal cracking-WP. However this effect was observed to be negligible for higher levels of cracking.

e) Climatic Zone: The effect of climatic zone (within wet regions) on longitudinal cracking is more pronounced than other effects, especially for longitudinal cracking-NWP. About 10% to 20% more test sections in wet-freeze than in wet-no-freeze climate exceed 100 m or more of longitudinal cracking-WP, and about 20% to 35% more test sections in wet-freeze than in wet-no-freeze climate exceed 100 m or more of longitudinal cracking-NWP.

f) Subgrade Type: Only a slight positive effect of subgrade type was observed for longitudinal cracking-WP.

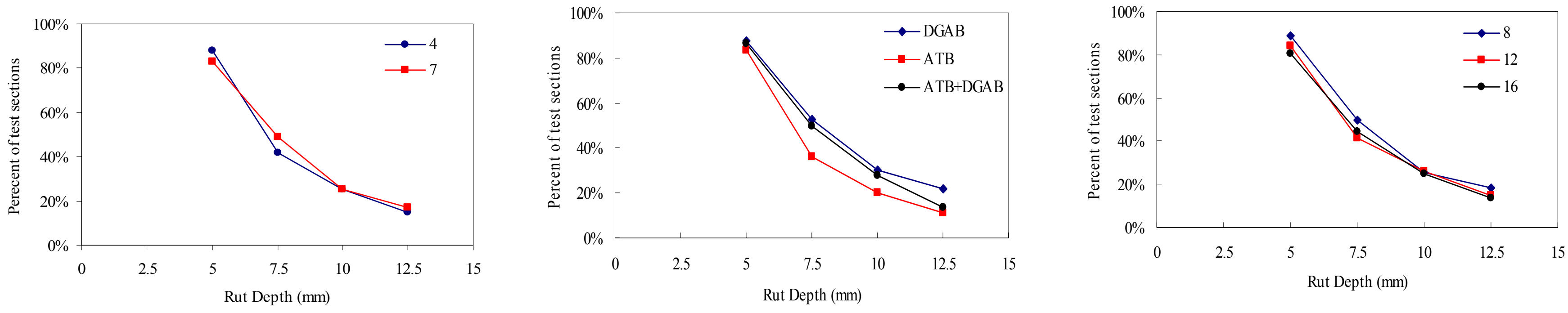


(a) HMA thickness (b) Base type (c) Drainage



(d) Drainage with fine-grained subgrade e) Climatic zone (f) Subgrade type

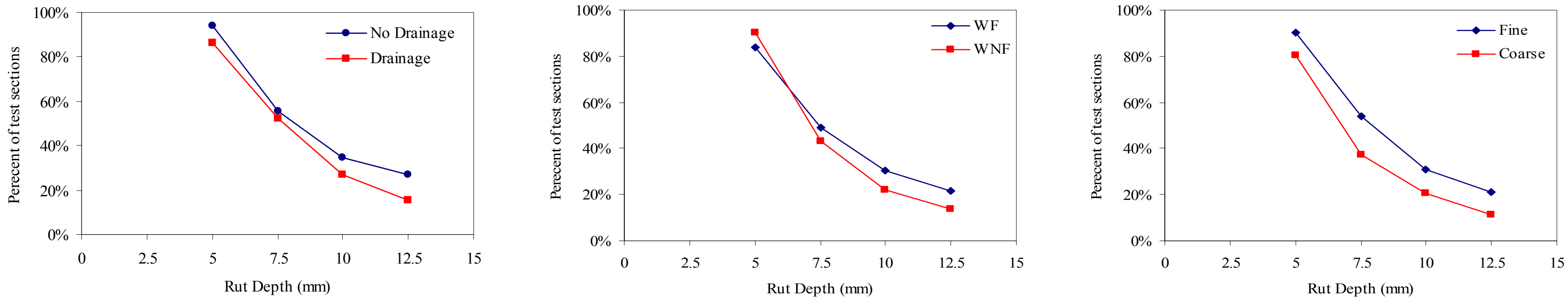
Figure 5-16 Effect of experimental factors on fatigue cracking



(a) HMA Thickness

(b) Base type

(c) Base thickness

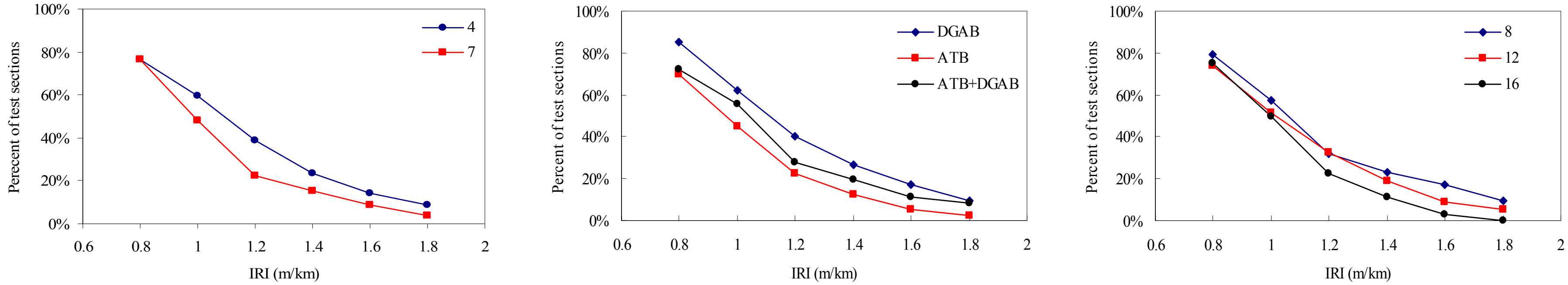


(d) Drainage with fine-grained subgrade

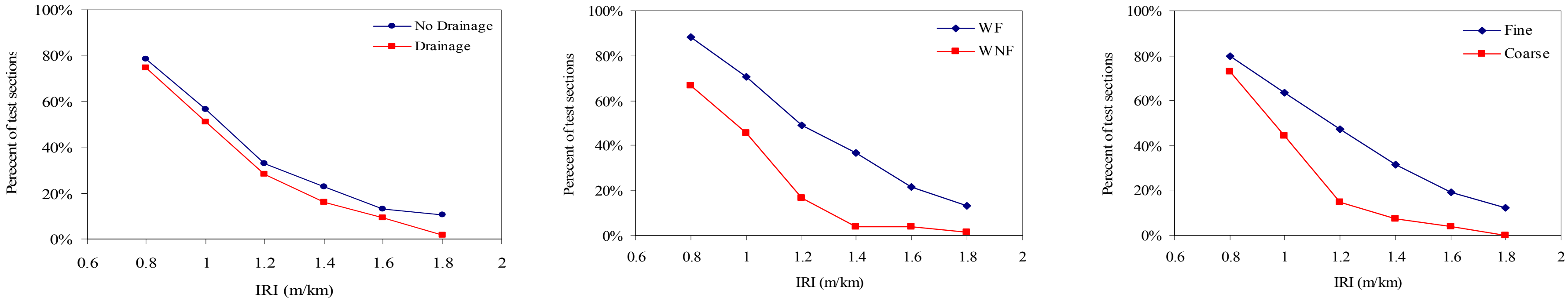
(e) Climatic zone

(f) Subgrade type

Figure 5-17 Effect of experimental factors on rutting

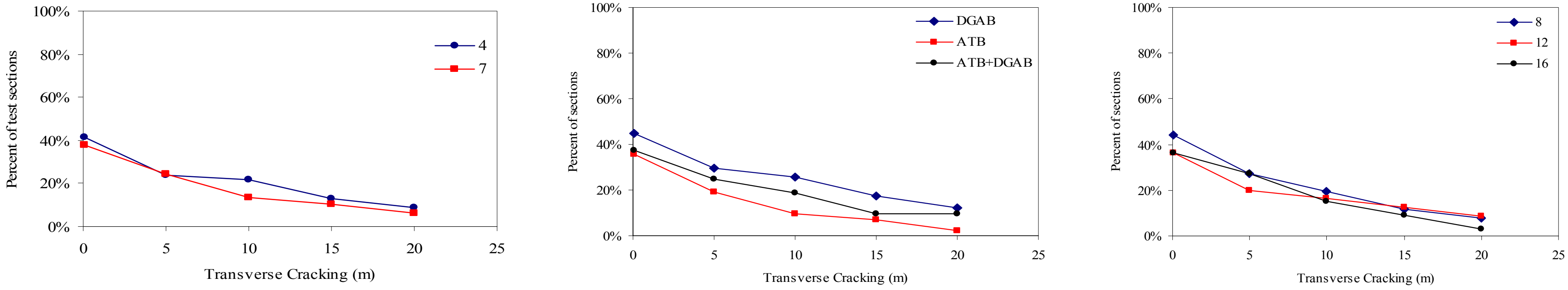


(a) HMA thickness (b) Base type (c) Base thickness



(d) Drainage (e) Climatic zone (f) Subgrade type

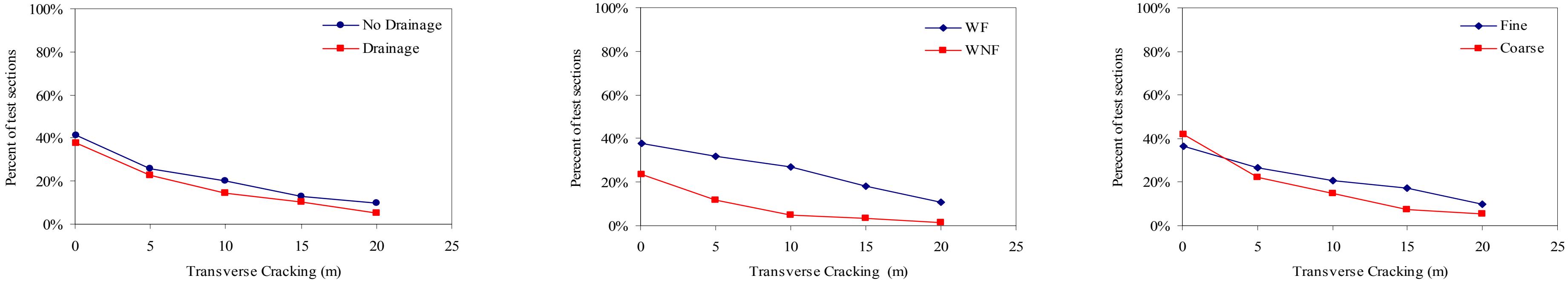
Figure 5-18 Effect of experimental factors on roughness



(a) HMA thickness

(b) Base type

(c) Base thickness

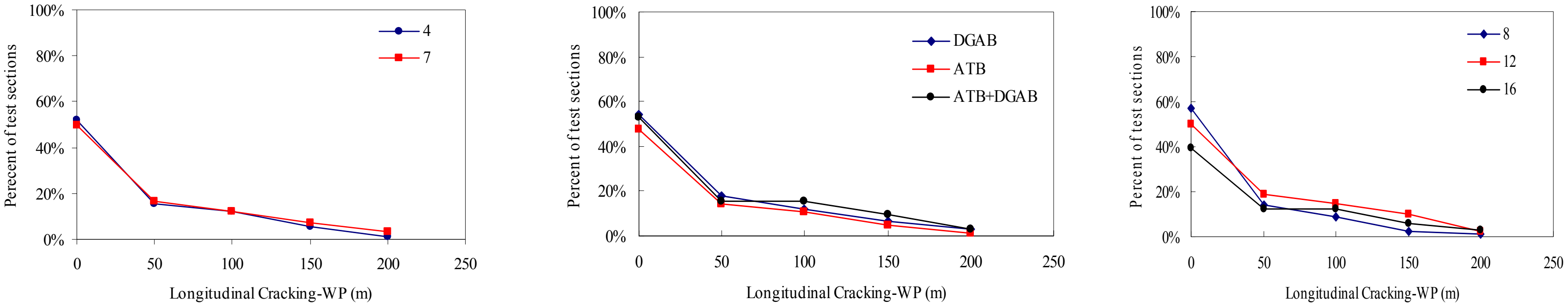


(d) Drainage

(e) Climatic zone

(f) Subgrade type

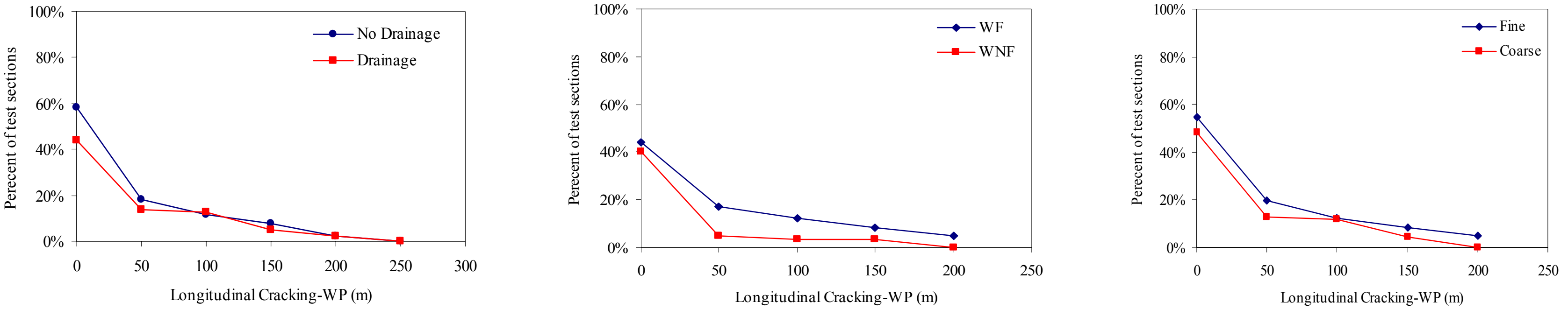
Figure 5-19 Effect of experimental factors on transverse cracking



(a) HMA thickness

(b) Base type

(c) Base thickness

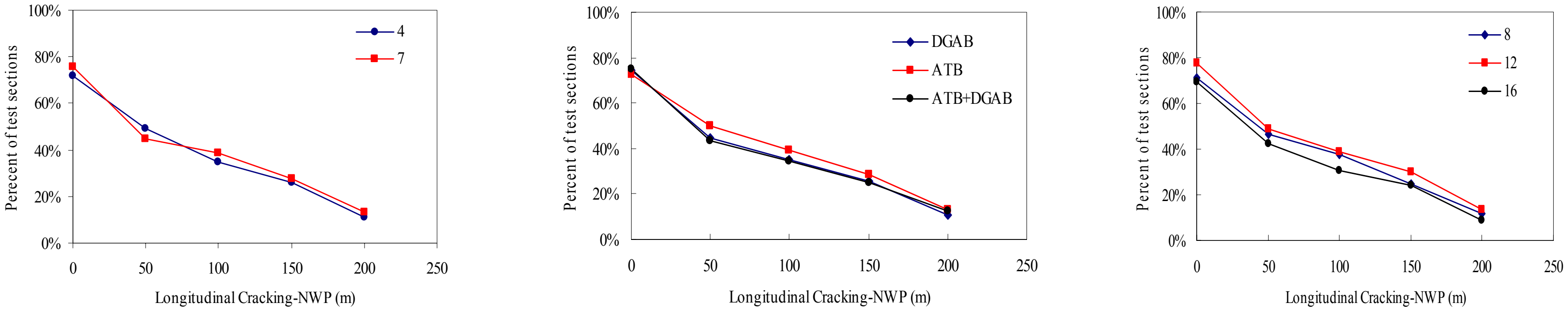


(d) Drainage

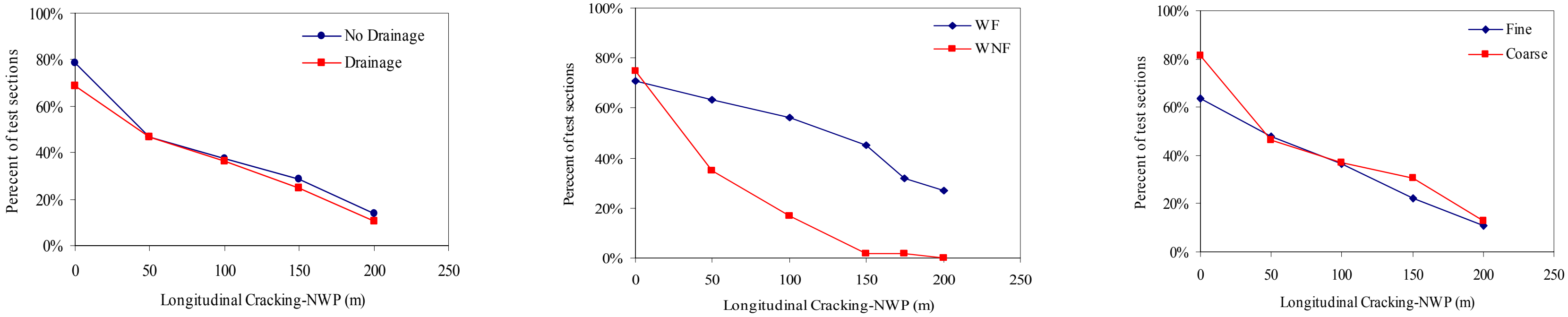
(e) Climatic zone

(f) Subgrade type

Figure 5-20 Effect of site factors on longitudinal cracking-WP



(a) HMA thickness (b) Base type (c) Base thickness



(d) Drainage (e) Climatic zone (f) Subgrade type

Figure 5-21 Effect of site factors on longitudinal cracking-NWP

### *5.6.2 Frequency-based methods*

Two frequency-based methods were used- Linear Discriminant Analysis and Binary Logistic Regression (details in Chapter 4). The results from these analyses are as follows:

#### *Discriminant Analysis*

In this analysis, two mutually exclusive groups were defined as follows:

- Alligator, transverse and longitudinal cracking: Cracked versus non-cracked.
- Rutting: Rut depth < 7 mm versus rut depth > 7mm
- Roughness: IRI < 1.4 m/km versus IRI>1.4 m/km

This analysis was intended to identify the experimental factors which help in discriminating the cracked versus non-cracked pavement sections. As most of the pavements in the SPS-1 experiment have not shown a high level of distress, this analysis will help in finding the significant design and site factors contributing to occurrence of distress. In order to include the effect of traffic and pavement age, these were considered as covariate in this analysis. Table 5-10 summarizes the results of network level analysis.

The performance measures were defined as dichotomous variables and all design and site factors were used as independent variables. The following summarizes the results from this analysis:

- *Fatigue cracking*: The effects of drainage condition and base type were found to discriminate between cracked and non-cracked sections. Test sections without drainage built on unbound (DGAB) bases are more likely to crack.
- *Rutting*: The effects of drainage condition, subgrade soil, base thickness were found to discriminate between sections having rut depths greater or less than 7mm. Test sections without drainage with thinner bases and built on fine-grained subgrade soils in wet zones are more likely to exhibit severe rutting.
- *Roughness*: The effects of climatic zone, subgrade soil and base thickness were found to discriminate between sections having IRI greater or less than 1.4 m/km. Test sections with thinner bases built on fine-grained subgrade soil and in wet freeze zone are more likely to exhibit higher roughness. Sections with higher initial roughness are more likely to become rougher with age.

- *Transverse cracking*: The effect of base type to a lesser degree was found to discriminate between cracked and non-cracked sections. Test sections in wet freeze zone with unbound (DGAB) bases are more likely to crack. Also, older sections are more likely to crack.
- *Longitudinal cracking*: The effect of climatic zone was found to discriminate between cracked and non-cracked sections (inside the wheel path). Test sections built in wet-freeze zone are more likely to crack outside the wheel path. Also, older sections are more likely to crack (in and outside the wheel path).

Table 5-10 Summary of p-values from LDA for determining the effect of experimental factors on pavement performance measures

| Design Factor | Performance Measures | | | | | |
|---|---|---|---|---|---|---|
| | Fatigue cracking | Rutting | Roughness | Transverse cracking | Longitudinal cracking | |
| | | | | | WP | NWP |
| HMA thickness | 0.39 | 1.000 | 0.370 | 0.320 | 0.88 | 0.310 |
| Base type | 0.098 | 0.517 | 0.250 | 0.139 | 0.77 | 0.690 |
| Base thickness | 0.92 | 0.077 | 0.076 | 0.736 | 0.19 | 0.421 |
| Drainage | 0.09 | 0.056 | 0.370 | 1.000 | 0.47 | 0.310 |
| Subgrade type | 0.045 | 0.011 | 0.000 | 0.177 | 0.184 | 0.001 |
| Climatic Zone | 0.392 | 0.578 | 0.000 | 0.417 | 0.002 | 1.000 |

### ***Logistic Regression***

The binary logistic regression model was used to model the probability of occurrence for the various performance measures. This method requires fewer assumptions than discriminant analysis and even when the assumptions required for discriminant analysis are not satisfied, it performs well. The overall models for each of the performance measures were found to be significant. The results using the maximum likelihood method are summarized in Tables 5-18 and 5-19.

- Fatigue cracking:

  HMA Thickness— Thin (102 mm) pavement sections have a slightly higher probability of cracking than thick (178 mm) sections when all other variables are held constant.

  Base Type— Pavement sections with unbound (DGAB) base have a significantly higher probability of cracking than those with bound (ATB/DGAB) bases.

  Drainage— Pavement sections with no drainage have a higher probability than those sections with drainage.

  Climatic Zone— Pavement sections in freeze zones have a significantly higher probability of cracking than those in the no-freeze environments.

- Rutting:

  Drainage— Pavement sections with no drainage have a slightly higher probability of rutting (rut depth > 7 mm) than those sections with drainage.

  Subgrade Type— Pavement sections built on fine-grained subgrade soils have a significantly higher probability of rutting than those sections built on coarse-grained subgrade soils.

  Climatic Zone— Pavement sections in WNF zones have a significantly higher probability of rutting than those in the WF environments.

Table 5-11 Summary of p-values from BLR for determining the effect of experimental factors on pavement performance measures (Wet zones)

| Design Factor | Performance Measures | | | | | |
|---|---|---|---|---|---|---|
| | Fatigue cracking | Rutting | Roughness | Transverse cracking | Longitudinal cracking | |
| | | | | | WP | NWP |
| HMA thickness | 0.160 (1.8) | 0.833 (1.1) | 0.068 (3.7) | 0.493 (0.6) | 0.360 (1.5) | 0.31 (0.7) |
| Base type | 0.024 (2.4) | 0.972 (1.0) | 0.006 (33) | 0.711 (1.2) | 0.437 (1.7) | 0.396 (1.7) |
| Base thickness | 0.420 (1.7) | 0.212 (2.5) | 0.038 (14) | 0.632 (1.3) | 0.410 (1.8) | 0.733 (0.8) |
| Drainage | 0.045 (2.8) | 0.124 (2.2) | 0.278 (2.4) | 0.316 (2.7) | 0.40 (0.6) | 0.837 (0.9) |
| Subgrade type | 0.960 (1.0) | 0.015 (3.4) | 0.000 (571) | 0.345 (0.005) | 0.000 (22) | 0.009 (0.34) |
| Climatic Zone | 0.088 (2.2) | 0.098 (.42) | 0.000 (420) | 0.316 (10) | 0.976 (1.0) | 0.73 (0.862) |

Note: The values in parenthesis are odds ratios

Table 5-12 Summary of p-values from BLR for determining the effect of experimental factors on pavement performance measures (All zones)

| Design Factor | Performance Measures | | | | | |
|---|---|---|---|---|---|---|
| | Fatigue cracking | Rutting | Roughness | Transverse cracking | Longitudinal cracking | |
| | | | | | WP | NWP |
| HMA thickness | 0.19 (1.5) | 0.98 (1.0) | 0.068 (3.7) | 0.224 (0.5) | 0.527 (1.25) | 0.34 (0.7) |
| Base type | 0.013 (2.2) | 0.98 (1.0) | 0.006 (33) | 0.043 (3.2) | 0.55 (1.4) | 0.22 (2.0) |
| Base thickness | 0.81(0.8) | 0.4 (2.3) | 0.038 (14) | 0.974 (1.0) | 0.376 (1.6) | 0.77 (1.2) |
| Drainage | 0.009 (3.1) | 0.22 (1.7) | 0.278 (2.4) | 0.473 (1.6) | 0.700 (1.2) | 0.297 (1.5) |
| Subgrade type | 0.073 (0.5) | 0.87 (1.1) | 0.000 (571) | 0.006 (0.001) | 0.076 (2.2) | 0.019 (0.42) |
| Climatic Zone | 0.000 | 0.747 | 0.001 | 0.019 | 0.254 | 0.002 |
| WF-DNF | 0.000 (12) | 0.72 (0.83) | - | - | - | 0.003 (5.1) |
| WNF-DNF | 0.002 (9) | 0.611(1.4) | - | - | - | 0.003 (6.4) |
| DF-DNF | 0.000 (23) | | - | - | - | 0.000 (27) |
| WF-WNF | (1.4) | (0.6) | (420) | (17) | (0.76) | (0.8) |

Note: Very high value of odds ratio is caused by the un-balanced data or too few sections in one of the categories.

- Roughness:

  HMA Thickness— Thin (102 mm) pavement sections have a higher probability of showing higher roughness (IRI > 1.4 m/km) than thick (7 inch) sections.

  Base Type— Pavement sections with unbound (DGAB) base have a significantly higher probability of showing higher roughness than those with bound (ATB/DGAB) bases.

  Base Thickness— Pavement sections with thin bases have a significantly higher probability of showing higher roughness than those with thick bases.

  Subgrade Type— Pavement sections built on fine-grained subgrade soils have a significantly higher probability of showing higher roughness than those sections built on coarse-grained subgrade soils.

  Climatic Zone— Pavement sections built in wet-freeze zone have a significantly higher probability of showing higher roughness than those sections built in wet-no-freeze zone.

- Transverse cracking:

  Climatic Zone— Pavement sections built in wet-freeze zone have a higher probability of cracking than those sections built in wet-no-freeze zone.

  Also, older pavement sections have a significantly higher probability of cracking.

- Longitudinal cracking:

  Subgrade Type— Pavement sections built on fine-grained subgrade soils have a higher probability of longitudinal cracking in the wheel path than those sections built on coarse-grained subgrade soils.

  Climatic Zone— Pavement sections built in freeze zone have a significantly higher probability of cracking (outside the wheel path) than those sections built in no-freeze zone.

  Also, older pavement sections have a significantly higher probability of cracking.

### *5.6.3 Analysis of Variance*

Several analyses of variance (ANOVA) were conducted for each of the performance measures and response indicators. The first ANOVA was targeted at determining the significance of only the main structural design factors considered in the experiment. This was achieved by blocking the site factor (to neutralize the effects of subgrade type, climatic conditions, traffic, age, and construction variability) as well as accounting for the variability in target layer thicknesses. The main structural design factors included in the ANOVA are listed below:

- HMA thickness (102 mm versus 178 mm)
- Base type (DGAB, ATB or DGAB+ATB)
- Base thickness (8 inch, 12 inch or 16 inch)
- Drainage condition (with versus without Permeable ATB)

To meet the assumptions of ANOVA, the dependent variables (performance measures) had to be transformed using the natural logarithm (see Chapter 4). This was particularly relevant for all cracking distresses because of the large number of zeroes in those populations. A negative consequence from this is that the number of sections used in the analysis is reduced.

#### *5.6.3.1 Effect of Design Factors on Pavement Performance*

The results from this analysis are summarized in Table 5-13 and indicate that the most significant design factor is the base type, which has a significant effect, statistically as well as operationally, on all performance measures. The ΔIRI (which is the change in IRI between initial and latest value) is also significantly affected by base thickness. The initial roughness is significantly affected by all the design factors except for drainage. Also, the effect of drainage condition on rutting, and the effect of base thickness on longitudinal cracking-NWP and change in roughness are statistically significant.

For investigating the mean difference between the levels of design factors, the marginal means (predicted cell means from the model) were transformed back to the original scale of the distress. These conversions were necessary in order to find out the practical/operational mean difference. The marginal means were back transformed using the properties of lognormal distribution. A random variable X is considered to have a lognormal distribution if Y=ln (X) has a normal probability distribution, where ln (X) is the natural logarithm to the base e. Equations (5-1) and (5-2) are used to calculate the mean and variance of a random variable X.

$$\mu_x = \exp\left( \mu_y + \frac{1}{2}\sigma_y{}^2 \right) \tag{5-1}$$

$$\sigma_x{}^2 = \mu_x{}^2 \left[ \exp\left( \sigma_y{}^2 \right) - 1 \right] \tag{5-2}$$

where $\mu_y$ and $\sigma_y^2$ are the mean and the variance of lognormal distribution.

The marginal means of performance measures (for which natural logarithmic transformation was necessary to meet the ANOVA assumptions) were estimated by using equation 5-1. The mean squared error (MSE) was considered as the "best" estimate of the variance for lognormal distribution in all analyses. Table 5-14 shows the back transformed marginal means for all levels of design factors in the SPS-1 Experiment. The following discussion summarizes the effect of key design factors on performance:

- **Effect of base type**: The effect of base type was found to be significant for all performance measures except for rutting. Pavement sections with dense-graded aggregate bases (DGAB) have shown the worst performance for all distresses while those with asphalt treated bases (ATB) have shown the best performance. Sections built with DGAB have shown significantly (operationally and statistically) higher fatigue cracking compared to those built with ATB. On average higher rutting was observed on pavement sections built with DGAB than those constructed with ATB. In the case of other distresses (change in roughness, transverse cracking, and longitudinal cracking) the difference in the performance of sections built on DGAB and sections built on ATB were only found to be statistically significant (i.e., they are not of operational significance at this point in time).
- **Effect of HMA thickness**: In general, thin [102 mm (4-inch)] pavement sections were built rougher than thick [178 mm (7-inch)] pavements. On an average, thin pavements [102 mm (4-inch)] have shown slightly higher fatigue cracking and rutting than thick [178 mm (7-inch)] pavements. However, this effect was found to be of marginal statistical significant.
- **Effect of base thickness**: Sections with thicker bases [305 mm (12-inch) and 406 mm (16-inch)] were built smoother compared to those with thinner base [203 mm (8-inch)]. Also,

sections with thinner base [203 mm (8-inch)] have shown more change in roughness than those with thicker base [305 mm (12-inch) and 406 mm (16-inch)]. However, this change in roughness is not of practical significance. On an average, pavement sections with 203 mm (8-inch) base have shown more rut depths than those with 305 mm (12-inch) and 406 mm (16-inch) thick bases. However, this effect is not of practical significance. More longitudinal cracking-NWP occurred in sections built with 203 mm (8-inch) base compared to those with 406 mm (16-inch) base.

- **Effect of drainage condition**: On average, pavement sections with drainage have shown slightly lower rutting than those without drainage; however this difference in performance is not statistically significant.

Table 5-13 Summary of p-values from ANOVA for determining the effect of main design factors on pavement performance measures—Overall

| Design Factor | Performance Measures | | | | | | |
|---|---|---|---|---|---|---|---|
| | Fatigue cracking | Rut[1] depth | IRI | | Transverse cracking | Longitudinal cracking | |
| | | | $\Delta$IRI | IRI$_o$ | | WP | NWP |
| HMA Thickness | 0.163 | 0.074 | 0.870 | 0.006 | 0.758 | 0.737 | 0.787 |
| Base Type | 0.000* | 0.510 | 0.004 | 0.000 | 0.016 | 0.079 | 0.031 |
| Base Thickness | 0.951 | 0.080 | 0.027 | 0.028 | 0.697 | 0.488 | 0.008* |
| Drainage | 0.347 | 0.250 | 0.293 | 0.160 | 0.544 | 0.645 | 0.874 |
| Site (blocked) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | $R^2$=0.712<br>N=133 | $R^2$=0.55<br>N=159 | $R^2$=0.624<br>N=163 | $R^2$=0.603<br>N=212 | $R^2$=0.630<br>N=75 | $R^2$=0.72<br>N=97 | $R^2$=0.770<br>N=140 |

Note: The model considered for this analysis only has main effects for all design factors.
* Also shows operational/practical significance, [1] Structural rutting only

Table 5-14 Summary of marginal means from ANOVA for determining the effect of main design factors on pavement performance measures—Overall

| Design Factor | | Average Performance | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Fatigue cracking (sq-m) | Rut depth (mm) | IRI | | Transverse cracking (m) | Longitudinal cracking | |
| | | | | $\Delta$IRI (m/km) | IRI$_o$ (m/km) | | WP (m) | NWP (m) |
| HMA Thickness | 102 mm | 10.5<br>(1.6) | 5.3<br>(1.76) | 0.45<br>(-0.86) | 0.837 | 1.5<br>(-0.204) | 8.2<br>(1.43) | 21<br>(2.6) |
| | 178 mm | 7.6<br>(1.28) | 4.9<br>(1.7) | 0.45<br>(-0.85) | 0.786 | 1.7<br>(-.12) | 7.6<br>(1.346) | 22.6<br>(2.68) |
| Base Type | DGAB | 17.4<br>(2.1) | 5.2<br>(1.82) | 0.5<br>(-0.77) | 0.87 | 2.8<br>(0.40) | 9.8<br>(1.6) | 26.8<br>(2.85) |
| | ATB | 6.3<br>(1.04) | 4.9<br>(1.69) | 0.4<br>(-0.975) | 0.79 | 1.2<br>(-0.48) | 5.4<br>(1.0) | 18<br>(2.45) |
| | ATB/DGAB | 7.0<br>(1.12) | 5.1<br>(1.67) | 0.47<br>(-0.825) | 0.776 | 1.3<br>(-0.38) | 9.4<br>(1.56) | 21.5<br>(2.63) |
| Base Thickness | 203 mm | 9.2<br>(1.46) | 5.6<br>(1.78) | 0.51<br>(-0.74) | 0.843 | 1.8<br>(-0.054) | 9<br>(1.51) | 34.4<br>(3.1) |
| | 305 mm | 8.5<br>(1.39) | 5.1<br>(1.7) | 0.45<br>(-0.87) | 0.79 | 1.4<br>(-0.313) | 6.4<br>(1.18) | 25.5<br>(2.8) |
| | 406 mm | 9.3<br>(1.47) | 5.0<br>(1.71) | 0.42<br>(-0.94) | 0.80 | 1.7<br>(-0.12) | 8.7<br>(1.48) | 12.6<br>(2.2) |
| Drainage | N | 10<br>(1.55) | 5.3<br>(1.79) | 0.47<br>(-0.82) | 0.838 | 1.8<br>(-0.06) | 8.5<br>(1.46) | 21.5<br>(2.63) |
| | Y | 8<br>(1.32) | 4.6<br>(1.67) | 0.44<br>(-0.89) | 0.785 | 1.4<br>(-0.264) | 7.4<br>(1.32) | 22<br>(2.65) |
| MSE | | (1.51) | (0.06) | (0.13) | - | (1.3) | (1.4) | (0.87) |

Note: Values in parenthesis are the lognormal marginal mean values.

The ANOVA was conducted for the design factors within each climatic zone as per the project panel recommendations. However, this analysis suffers from the lack of data within zones, especially within "Dry" zones, where only 2 sites each are available for DF and DNF zones. The results of ANOVA for "Wet" zones are more reliable as 8 and 6 sites are available within WF and WNF zones, respectively. The following discussion summarizes the effect of key design factors on performance in WF climatic zone (see Table 5-15 and Table 5-16):

- **Effect of HMA thickness**: In general, thin (102 mm) pavement sections were built rougher than thick (7-inch) pavements. On average, thin pavements (102 mm) have shown slightly more fatigue cracking and rutting than thick (178 mm) pavements. However, this effect was not found to be statistically significant.
- **Effect of base type**: The effect of base type was found to be significant for all performance measures except for transverse and longitudinal cracking. In the case of distresses that are significantly affected by base type, pavement sections with dense-graded aggregate bases (DGAB) have shown the worst performance while those with asphalt treated bases (ATB) have shown the best performance. Sections built with DGAB have shown significantly (operationally and statistically) more fatigue cracking, rutting, and change in roughness compared to those built with ATB.
- **Effect of base thickness**: Sections with 305 mm (12-inch) bases were built smoother compared to those with 203 mm (8-inch) base. Also, sections with 203 mm (8-inch) base have shown significantly (practically and statistically) higher change in roughness than those with 406 mm base. However, the change in roughness was not found to be practically significant between sections with 8-inch (406 mm) base and those with 305 mm (12-inch) base. On average, pavement sections with 203 mm (8-inch) base have shown more rut depth than those with 305 mm (12-inch) and 406 mm (16-inch) thick bases. However, this effect was not found to be statistically significant. More longitudinal cracking-NWP occurred in sections built with 203 mm base compared to those with 406 mm base.
- **Effect of drainage condition**: Pavement sections with drainage have shown less rutting than those without drainage. This difference in performance was found to be both statistically and practically significant.

Table 5-15 Summary of p-values from ANOVA for determining the effect of design factors on flexible pavement performance—WF Zone

| Design Factor | Performance Measures | | | | | | |
|---|---|---|---|---|---|---|---|
| | Fatigue cracking | Rut Depth | IRI | | Transverse cracking | Longitudinal cracking | |
| | | | ΔIRI | $IRI_o$ | | WP | NWP |
| HMA thickness | 0.745 | 0.688 | 0.277 | 0.133 | 0.560 | 0.893 | 0.762 |
| Base type | 0.004* | 0.001* | 0.076* | 0.012 | 0.128 | 0.232 | 0.400 |
| Base thickness | 0.832 | 0.504 | 0.040* | 0.084 | 0.278 | 0.873 | 0.069* |
| Drainage | 0.674 | 0.012* | 0.874 | 0.003* | 0.359 | 0.813 | 0.885 |
| Site (blocked) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | $R^2$=0.638<br>N=58 | $R^2$=0.631<br>N=92 | $R^2$=0.620<br>N=76 | $R^2$=0.628<br>N=92 | $R^2$=0.71<br>N=31 | $R^2$=0.695<br>N=36 | $R^2$=0.813<br>N=60 |

* Also shows operational/practical significance

Table 5-16 Summary of marginal means from ANOVA for determining the effect of main design factors on pavement performance measures— WF Zone

| Design Factor | | Average Performance | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Fatigue cracking (sq-m) | Rut depth (mm) | IRI | | Transverse cracking (m) | Longitudinal cracking | |
| | | | | ΔIRI (m/km) | $IRI_o$ (m/km) | | WP (m) | NWP (m) |
| HMA Thickness | 102 mm | 17.6<br>(2.3) | 6.1<br>(1.76) | 0.50<br>(-0.773) | 0.891 | 8.7<br>(1.92) | 24.5<br>(2.26) | 29.3<br>(3.22) |
| | 178 mm | 15.9<br>(2.2) | 5.9<br>(1.73) | 0.55<br>(-0.673 | 0.844 | 7.4<br>(1.76) | 23.1<br>(2.2) | 31.75<br>(3.3) |
| Base Type | DGAB | 34.4<br>(3.0) | 7.5<br>(1.96) | 0.55<br>(-0.665) | 0.932 | 11.0<br>(2.15) | 23.1<br>(2.2) | 26.5<br>(3.12) |
| | ATB | 10.3<br>(1.8) | 5.7<br>(1.68) | 0.45<br>(-0.865) | 0.833 | 5.7<br>(1.5) | 11.5<br>(1.5) | 33.4<br>(3.35) |
| | ATB/DGAB | 14.0<br>(2.1) | 5.2<br>(1.6) | 0.56<br>(-0.64) | 0.84 | 8.3<br>(1.87) | 47.5<br>(2.92) | 30.2<br>(3.25) |
| Base Thickness | 203 mm | 17.1<br>(2.3) | 6.4<br>(1.8) | 0.61<br>(-0.561) | 0.91 | 11.5<br>(2.2) | 28.5<br>(2.41) | 38.8<br>(3.5) |
| | 305 mm | 18.8<br>(2.4) | 5.8<br>(1.7) | 0.55<br>(-0.673) | 0.833 | 8.3<br>(1.87) | 23.6<br>(2.22) | 33.0<br>(3.34) |
| | 406 mm | 15.4<br>(2.2) | 6.0<br>(1.74) | 0.42<br>(-0.94) | 0.86 | 5.7<br>(1.49) | 19.7<br>(2.04) | 21.3<br>(2.9) |
| Drainage | N | 18.1<br>(2.4) | 6.8<br>(1.86) | 0.53<br>(-0.714) | 0.924 | 9.4<br>(2.0) | 22<br>(2.15) | 30.5<br>(3.26) |
| | Y | 15.4<br>(2.2) | 5.4<br>(1.63) | 0.52<br>(-0.732) | 0.811 | 6.9<br>(1.69) | 25.5<br>(2.3) | 29.6<br>(3.23) |
| MSE | | (1.073) | (0.113) | (0.139) | | (0.493) | (1.881) | (0.316) |

Note: Values in parenthesis are the lognormal marginal mean values.

The following discussion summarizes the effect of key design factors on performance in WNF climatic zone (see Table 5-17 and Table 5-18):

- **Effect of base type**: The effect of base type was found to be significant only for the change in roughness. Pavement sections with dense-graded aggregate bases (DGAB) have shown higher change in roughness compared to those with asphalt treated bases (ATB). However, difference was not practically significant.
- **Effect of HMA thickness**: On average, thin pavements (102 mm) have shown slightly more fatigue cracking compared to thick (178 mm) pavements. This effect was found to be both statistically and practically significant.
- **Effect of base thickness**: The effect of base thickness on various performance measures was found to be statistically insignificant. However, on average, higher change in roughness was observed in sections with 203 mm base compared to those with 305 mm or 406 mm base.
- **Effect of drainage condition**: Pavement sections with drainage have shown less rutting than those without drainage. This difference in performance was found to be both statistically and practically significant.

The fractional factorial design for the SPS-1 experiment calls for a tradeoff between selecting the number of "runs" and testing all possible interactions. Therefore, all possible two-way interactions were considered in the analysis. An ANOVA was run with two-way interaction effects between the main structural design factors. No significant interaction effect was detected.

Table 5-17 Summary of p-values from ANOVA for determining the effect of design factors on flexible pavement performance—WNF Zone

| Design Factor | Performance Measures | | | | | | |
|---|---|---|---|---|---|---|---|
| | Fatigue cracking | Rut Depth | IRI | | Transverse cracking | Longitudinal cracking | |
| | | | ΔIRI | IRI$_o$ | | WP | NWP |
| HMA thickness | 0.077* | 0.576 | 0.948 | 0.141 | 0.383 | 0.759 | 0.532 |
| Base type | 0.545 | 0.547 | 0.065* | 0.117 | 0.470 | 0.803 | 0.110 |
| Base thickness | 0.703 | 0.476 | 0.144 | 0.559 | 0.806 | 0.937 | 0.265 |
| Drainage | 0.298 | 0.031* | 0.725 | 0.032 | 0.306 | 0.760 | 0.142 |
| Site (blocked) | 0.000 | 0.000 | 0.008 | 0.000 | 0.276 | 0.037 | 0.000 |
| | $R^2$=0.834<br>N=36 | $R^2$=0.561<br>N=72 | $R^2$=0.503<br>N=49 | $R^2$=0.680<br>N=72 | $R^2$=0.965<br>N=14 | $R^2$=0.662<br>N=24 | $R^2$=0.579<br>N=45 |

* Also shows operational/practical significance

Table 5-18 Summary of marginal means from ANOVA for determining the effect of main design factors on pavement performance measures— WNF Zone

| Design Factor | | Average Performance | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Fatigue cracking (sq-m) | Rut depth (mm) | IRI | | Transverse cracking (m) | Longitudinal cracking | |
| | | | | ΔIRI (m/km) | IRI$_o$ (m/km) | | WP (m) | NWP (m) |
| HMA Thickness | 102 mm | 6.4<br>(1.2) | 6.2<br>(1.78) | 0.34<br>(-1.157) | 0.82 | 0.3<br>(-1.412) | 3.5<br>(0.562) | 13.7<br>(1.96) |
| | 178 mm | 2.9<br>(0.43) | 5.9<br>(1.74) | 0.33<br>(-1.165) | 0.785 | 1.0<br>(-0.363) | 4.1<br>(0.73) | 17.5<br>(2.2) |
| Base Type | DGAB | 5.5<br>(1.05) | 5.9<br>(1.744) | 0.40<br>(-0.989) | 0.84 | 0.6<br>(-0.872) | 3.7<br>(0.614) | 19.7<br>(2.32) |
| | ATB | 3.2<br>(0.524) | 6.4<br>(1.815) | 0.29<br>(-1.3) | 0.81 | 1.6<br>(0.143) | 2.8<br>(0.356) | 8.5<br>(1.48) |
| | ATB/DGAB | 4.4<br>(0.84) | 5.8<br>(1.712) | 0.32<br>(-1.2) | 0.764 | 0.2<br>(-1.93) | 5.2<br>(0.97) | 21.8<br>(2.42) |
| Base Thickness | 203 mm | 5.8<br>(1.104) | 6.4<br>(1.82) | 0.39<br>(-1) | 0.82 | 0.4<br>(-1.171) | 4.5<br>(0.812) | 26.6<br>(2.62) |
| | 305 mm | 4.7<br>(0.89) | 5.8<br>(1.72) | 0.31<br>(-1.23) | 0.793 | 0.5<br>(-0.982) | 3.6<br>(0.603) | 14.7<br>(2.03) |
| | 406 mm | 2.9<br>(0.42) | 5.9<br>(1.73) | 0.30<br>(-1.26) | 0.79 | 0.8<br>(-0.51) | 3.3<br>(0.523) | 9.6<br>(1.6) |
| Drainage | N | 3.3<br>(0.54) | 6.6<br>(1.85) | 0.57<br>(-1.136) | 0.833 | 0.9<br>(-0.385) | 3.4<br>(0.54) | 11.1<br>(1.75) |
| | Y | 5.8<br>(1.1) | 5.2<br>(1.6) | 0.53<br>(-1.2) | 0.772 | 0.3<br>(-1.391) | 4.2<br>(0.752) | 21.3<br>(2.4) |
| MSE | | (1.3) | (0.09) | (0.146) | | (0.647) | (1.37) | (1.321) |

Note: Values in parenthesis are the lognormal marginal mean values.

### *5.6.3.2 Effect of Site Factors on Pavement Performance*

The third ANOVA was targeted at determining the significance of subgrade type and climatic zone. Traffic, age and variability in target layer thicknesses were considered as covariates. The subgrade type and climatic zone were included as main factors in addition to the structural design factors. For fatigue cracking, the analysis was run with and without the Kansas (20) data, since the test sections in Kansas (20) have a large amount of fatigue cracking and the project is known to have had construction problems with a wet subbase and variable densities. The analysis for rutting was also done with and without the Texas (48) data since rutting for these sections is believed to be due to the asphalt mix [6].

The results from this analysis are summarized in Tables 5-19 and 5-20, and generally show lower $R^2$ values than those in Table 5-13. This may be partially due to the effects of variations in environmental conditions within a given climatic zone and variations in material properties within different pavement layers among sites. In addition, construction and material variability is not accounted for in this analysis, since the site factor is not blocked. The results seem to indicate that the effect of the climatic zone is significant for all performance measures and that the effect of subgrade type can be significant for most of them. However, caution must be exercised in interpreting these results given the unbalanced nature of the design with respect to climatic zone: there are only two projects in each of the dry zones, Dry-Freeze (DF) and Dry-No-Freeze (DNF), as opposed to eight projects in the Wet-Freeze (WNF) and six projects in the Wet-No-Freeze (WF) zones.

Finally, ANOVA was conducted by considering the main and interaction (two-way) effects for all six experimental factors. The results of this analysis are summarized in Tables 5-21 and 5-22. The conclusions are based on the main effects when interaction between site factors is not significant.

Table 5-19 Summary of p-values from ANOVA for determining the effect of site factors on pavement performance measures (Main effects only)

| Site Factor | Performance Measures | | | | | | |
|---|---|---|---|---|---|---|---|
| | Fatigue cracking | Rut Depth | IRI | | Transverse cracking | Longitudinal cracking | |
| | | | ΔIRI | $IRI_o$ | | WP | NWP |
| Subgrade type | 0.680 | 0.432 | 0.000* | 0.067 | 0.020 | 0.015 | 0.013 |
| Climatic Zone | 0.000* | 0.000* | 0.000* | 0.001 | 0.000* | 0.000 | 0.000 |
| Traffic Level | 0.000 | 0.024 | 0.083 | - | 0.000 | 0.437 | 0.000 |
| Age | 0.068 | 0.013 | 0.091 | - | 0.000 | 0.050 | 0.009 |
| | $R^2$=0.288<br>N=124 | $R^2$=0.305<br>N=159 | $R^2$=0.401<br>N=163 | $R^2$=0.215<br>N=212 | $R^2$=0.674<br>N=67 | $R^2$=0.434<br>N=95 | $R^2$=0.534<br>N=134 |

Note: The model considered for this analysis has main effects for all six experiment factors. KS (20) was not considered for analysis of all cracking measures, whereas, rut depth analysis was conducted without TX (48). * Also shows operational/practical significance.

Table 5-20 Summary of marginal means from ANOVA for determining the effect of site factors on pavement performance measures (Main effects only)

| Site Factor | | Performance Measures | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Fatigue cracking | Rut Depth | IRI | | Transverse cracking | Longitudinal cracking | |
| | | | | ΔIRI | $IRI_o$ | | WP | NWP |
| Subgrade type | F | 15.4<br>(1.16) | 5.2<br>(1.6) | 0.59<br>(-0.62) | 0.81 | 1.2<br>(-0.38) | 44<br>(2.5) | 20.8<br>(2.2) |
| | C | 18.5<br>(1.34) | 5.4<br>(1.65) | 0.44<br>(-0.92) | 0.76 | 4.9<br>(1) | 13.2<br>(1.3) | 42.0<br>(2.9) |
| Climatic Zone | WF | 53.4<br>(2.4) | 4.9<br>(1.56) | 0.59<br>(-0.628) | 0.86 | 13.2<br>(2) | 26.5<br>(2.0) | 139<br>(4.1) |
| | WNF | 24.0<br>(1.6) | 5.6<br>(1.68) | 0.336<br>(-1.186) | 0.797 | 1.5<br>(-0.15) | 16.1<br>(1.5) | 25.4<br>(2.4) |
| | DF | 26.5<br>(1.7) | 4.0<br>(1.34) | 0.58<br>(-0.641) | 0.784 | 3.2<br>(0.6) | 5.92<br>(0.5) | 56.5<br>(3.2) |
| | DNF | 4.5<br>(-0.08) | 7.1<br>(1.92) | 0.596<br>(-0.613) | 0.695 | 0.4<br>(-1.5) | 177<br>(3.9) | 3.12<br>(0.3) |
| MSE | | (3.156) | (0.091) | (0.19) | | (1.161) | (2.556) | (1.668) |

Table 5-21 Summary of p-values from ANOVA for determining the effect of site factors on pavement performance measures (With interaction effects)

| Site Factor | Performance Measures | | | | | | |
|---|---|---|---|---|---|---|---|
| | Fatigue cracking | Rut Depth | IRI | | Transverse cracking | Longitudinal cracking | |
| | | | ΔIRI | $\mathrm{IRI}_o$ | | WP | NWP |
| Subgrade type | 0.626 | 0.886 | 0.018 | 0.653 | 0.247 | 0.480 | 0.191 |
| Climatic Zone | 0.049 | 0.007* | 0.000* | 0.003 | 0.004* | 0.002 | 0.000* |
| Subgrade*Zone | 0.000* | 0.257 | 0.562 | 0.000* | 0.092 | 0.000* | 0.496 |
| Traffic Level | 0.031 | 0.028 | 0.150 | - | 0.197 | 0.655 | 0.000 |
| Age | 0.068 | 0.025 | 0.565 | - | 0.077 | 0.014 | 0.202 |
| | $R^2$=0.575<br>N=124 | $R^2$=0.47<br>N=159 | $R^2$=0.525<br>N=163 | $R^2$=0.435<br>N=212 | $R^2$=0.931<br>N=67 | $R^2$=0.755<br>N=95 | $R^2$=0.648<br>N=134 |

Note: The model considered for this analysis has main effects for all six experiment factors and all possible two-way interactions between them. * Also shows operational/practical significance.

Table 5-22 Summary of marginal means from ANOVA for determining the effect of site factors on pavement performance measures (Interaction effects only)

| Site Factor | | | Performance Measures | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Fatigue cracking | Rut Depth | IRI | | Transverse cracking | Longitudinal cracking | |
| | | | | | ΔIRI | $\mathrm{IRI}_o$ | | WP | NWP |
| Subgrade type | | | - | - | - | - | - | - | - |
| Climatic Zone | | | - | - | - | - | - | - | - |
| Subgrade* Zone | WF | F | 22.4<br>(1.7) | - | - | 0.95 | - | 60.8<br>(3.1) | - |
| | | C | 67<br>(2.8) | - | - | 0.76 | - | 3.0<br>(0.1) | - |
| | WNF | F | 135<br>(3.5) | - | - | 0.78 | - | 27.3<br>(2.3) | - |
| | | C | 2.5<br>(-0.5) | - | - | 0.83 | - | 5.5<br>(0.7) | - |
| MSE | | | (2.816) | | | | | (2.015) | |

Note: The cell means are only given when interaction is significant. For main effects see Table 5-20 for marginal means.

In case of significant interaction between site factors, the interpretation of results are based on the comparison of cell means, i.e., the mean performance of sections corresponding to each subgrade type should be compared within each climatic zone.

The following discussion summarizes the effect of climatic zone and subgrade type on the key performance measures:

- Fatigue cracking: More fatigue cracking was observed on sections located in “wet” climates. The interaction effect between subgrade soil type and climatic zone is statistically significant (see Table 5-21); therefore the conclusions are based on the interaction effect. More cracking was observed in pavement sections built on fine-grained subgrade especially in WNF zone. Among the sections located in WNF zone, the difference between the mean cracking of sections built on fine-grained and sections built on coarse-grained soil is also practically significant.
- Structural Rutting: Rutting was higher among sections located in “wet” climate and was generally higher for pavement sections on fine-grained subgrade. Both of these effects statistically and practically significant. There were high rut depths observed in the Dry-No-Freeze (DNF) zone; however, it is believed that this is more related to the asphalt mix as opposed to structural rutting.
- Roughness: Both subgrade type and climatic zone are very significant factors affecting roughness growth (see Table 5-19). The pavements constructed on fine-grained soils have shown higher changes in roughness than those constructed on coarse-grained soils. Also, pavements located in the WF zone have shown higher change in roughness than those located in WNF zone. These effects were found to be statistically and practically significant (see Table 5-20). The effect of subgrade soil appears to be mainly caused by the initial roughness being significantly higher in sites with fine-grained subgrade. The initial IRI ($IRI_o$) was found to be associated with future roughness, especially among sections built on fine-grained soils and among sections located in “wet” climate.
- Transverse cracking: The effects of subgrade type and climate on transverse cracking are significant. More cracking was observed in sections built on coarse-grained soil compared to those built on fine-grained soil. However, the magnitude of cracking at this point in time is too low to conclude on the effect. More cracking occurred in sections located in WF zone

compared to those located in other zones, and this effect was found to be statistically and practically significant.

- Longitudinal cracking: As the interaction effect between subgrade type and climatic zone is significant for longitudinal cracking-WP, the conclusions are based on comparing cell means for sections built on each subgrade type within each climatic zone. It was found that among pavements located in WF zone, those constructed on fine-grained soils have shown significantly more cracking than those constructed on coarse-grained soils. The effects of subgrade type and climate were significant in the case of longitudinal cracking-NWP. Significantly more cracking was observed in the sections built on coarse-grained soil compared to those built on fine-grained soil. Also pavements located in "freeze" climate have shown significantly more cracking compared to those in "no-freeze" climate.

Given the unbalanced design of the experiment with respect to climatic zone, a one-way ANOVA was performed to investigate the effects of subgrade type (fine-grained versus coarse-grained soils) and climatic zones (wet versus dry, freeze versus no-freeze), one at a time. The p-values and mean performances by site factors, from this analysis, are summarized in Tables 5-23 and 5-24, respectively. To indicate the direction of effects for site factors, the "+" and "-" signs are also reported along with the p-values. The "+" indicates that, within a factor, the first level is exhibiting more distress than the second level, while "-" indicates otherwise. For example, in the case of the effect of subgrade on fatigue cracking, the "+" indicates more cracking in pavements constructed on fine-grained soils (first level for subgrade) compared to those constructed on coarse-grained soils (second level for subgrade).

The p-values indicate that subgrade type appears to be significantly affecting fatigue cracking, rut depth, roughness, transverse and longitudinal cracking-WP. The pavements built on fine-grained subgrade have shown higher distress than those constructed on coarse-grained subgrade. The effect was found to be practically significant in the case fatigue cracking, rutting, change in roughness and transverse cracking. The effects of site factors by performance measure are listed below:

- Fatigue Cracking: Climate appears to be significantly affecting fatigue performance. Pavements located in "wet" or "freeze" climate have exhibited significantly higher amount of fatigue cracking than those located in "dry" or "no-freeze" climate, respectively. This effect was found to be practically significant.
- Rut Depth: On average, rutting appears to be higher in wet climate. Also pavements located in DNF zone were found to have significantly more rutting compared to those located in DF zone. However, it is believed that this is more related to the asphalt mix as opposed to structural rutting, as mentioned before at the beginning of this chapter.
- Roughness: Significantly higher growth in roughness was observed for pavements located in WF zone compared to those located in WNF zone. This effect was found to be practically significant.
- Transverse Cracking: It was found that pavements located in WF zone have exhibited significantly higher transverse cracking than those located in WNF zone. This effect was found to be practically significant.
- Longitudinal Cracking-WP: Significantly more longitudinal cracking-WP was observed in pavements located in WF zone compared to those located in WNF zone. Also, significantly more longitudinal cracking-WP was exhibited by the pavements located in DNF zone compared to those located in DF. In DNF zone, longitudinal cracking-WP and rutting is mainly contributed by sections in the Arizona, AZ (4), site, where HMA-related issues are believed to be causing the distresses.
- Longitudinal Cracking-NWP: Significantly more longitudinal cracking-NWP was exhibited by the pavements located in WF zone compared to those located in other zones. Also, more cracking was observed in pavements located in DF zone compared to those built in DNF zone. These effects indicate that this distress could be related to "freeze" environment.

It should be noted that the data from the four projects in the dry climatic zones show negative trends in several performance measures. This may be in part due to the lower number of projects in these zones.

Table 5-23 Summary of p-values from one-way ANOVA for determining the effect of site factors on pavement performance measures

| Site Factor | Performance Measures | | | | | | |
|---|---|---|---|---|---|---|---|
| | Fatigue cracking | Rut depth | IRI | | Transverse cracking | Longitudinal cracking | |
| | | | $\Delta$IRI | IRI$_o$ | | WP | NWP |
| **Subgrade Type** | | | | | | | |
| Fine vs. Coarse | 0.03 (+)* | 0.002 (+)* | 0.00 (+)* | 0.011 (+)* | 0.016 (+)* | 0.001 (+) | 0.26 (-) |
| **Climatic Zone** | | | | | | | |
| Wet vs. Dry | 0.021 (+)* | 0.087 (+) | 0.596 (-) | 0.000 (+)* | 0.005 (+)* | 0.919 (+) | 0.040 (+) |
| Freeze vs. No Freeze | 0.011 (+)* | 0.001 (-) | 0.000 (+)* | 0.010 (+)* | 0.06 (+)* | 0.038 (-) | 0.000 (+) |
| WF vs. WNF | 0.063 (+)* | 0.893 (-) | 0.000 (+)* | 0.030 (+)* | 0.00 (+)* | 0.096 (+) | 0.000 (+) |
| DF vs. DNF | 0.054 (+)* | 0.000 (-) | 0.281 (-) | 0.231 (+) | 0.055 (-) | 0.000 (-) | 0.001 (+) |

* Also shows operational/practical significance

Table 5-24 Summary of marginal means from one-way ANOVA for determining the effect of site factors on pavement performance measures

| Site Factor | | Performance Measures | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Fatigue cracking | Rut depth | IRI | | Transverse cracking | Longitudinal cracking | |
| | | | | $\Delta$IRI | IRI$_o$ | | WP | NWP |
| Subgrade Type | Fine | 54.2 | 5.8 | 0.613 | 0.86 | 18.97 | 64.5 | 163.0 |
| | Coarse | 24.2 | 4.8 | 0.451 | 0.79 | 6.70 | 17.4 | 113.0 |
| Climatic Zone | Wet | 41.7 | 5.4 | 0.524 | 0.85 | 15.10 | 39.7 | 150.5 |
| | Dry | 17.4 | 4.7 | 0.552 | 0.73 | 04.83 | 38.1 | 74.0 |
| | Freeze | 45.6 | 4.8 | 0.616 | 0.85 | 13.57 | 24.5 | 189.7 |
| | No Freeze | 18.4 | 5.8 | 0.425 | 0.78 | 06.20 | 57.7 | 27.1 |
| | WF | 53.7 | 5.2 | 0.635 | 0.88 | 24.3 | 31.3 | 244.7 |
| | WNF | 24.5 | 5.6 | 0.360 | 0.81 | 2.80 | 14.8 | 29.4 |
| | DF | 26.2 | 4.0 | 0.480 | 0.76 | 2.25 | 4.10 | 83.1 |
| | DNF | 07.8 | 6.8 | 0.572 | 0.70 | 6.00 | 108.8 | 14.7 |

#### *5.6.3.3 Effect of Design Factors on Pavement Performance (univariate) based on standard deviate*

As explained before, the experiment design and the performance of the test sections have rendered the SPS-1 experiment "unbalanced". Fourteen out of eighteen sites, in the experiment are located in "wet" climate, of which eight are in the WF zone. In addition, all 24 unique designs were not built in every soil-climate combination. Furthermore, non-occurrence of distresses in a considerable number of sections contributed to the unbalance. This could be a reason for insignificance of interaction effects between the design and site factors from multivariate analyses presented above. In light of the above concerns, a simplified analysis considering one design factor at a time (univariate) was performed using one-way ANOVA (as in the case of analysis of the effects for site factors).

The performance of test sections was not found to be consistent across sites indicating the influence of site conditions (see Chapter 3). The site conditions that could have contributed to this variation in performance are traffic, age, construction quality, measurement variability, and material properties, apart from the experimental site factors (i.e. subgrade and environment). In order to separate the "true" effects of the experimental factors, this "noise" had to be nullified.

The standard deviate for each performance measure was calculated, within each site, for all the sections using equation 5-3. This measure indicates the relative performance of a design compared to the other designs. As this measure was calculated for each section, considering one site at a time, it indicates the relative standing of the section compared to other sections. It thus helps nullify the variation in performance (due to site conditions) among sites, as the sections are weighed with respect to companion sections in each site.

$$Std.Deviate = \left(\frac{x-\mu}{\sigma}\right) \tag{5-3}$$

The above approach of using the standard deviate is similar to blocking of the site factors performed in the multivariate analysis. One-way analysis of variance (univariate) was performed on the standard deviates of the sections to study the effects of each design factor by taking one design factor at a time. The analyses were performed on data from all sections and also on subsets of data stratified by different subgrade types, climates and combinations of these. This helps identify the effects of design factors under different site conditions.

In the SPS-1 experiment, HMA thickness and drainage have two levels (i.e. 102 mm vs. 178 mm and drainage vs. no drainage). But for base thickness and base type, three levels (203 mm vs. 305 mm vs. 406 mm and DGAB vs. ATB vs. ATB/DGAB) are present. Moreover, 406 mm base thickness was provided only for drained sections and ATB/DGAB was built only for un-drained sections making the design unbalanced. Therefore, for studying the effects of base thickness and base type, analyses were done separately among drained sections and among un-drained sections.

To see the "pure" effect of each design factor, comparisons of standard deviates were also made between the levels of each design factor while controlling the other factors, as in the case of level-B analyses (site-level). The results from this analysis are in Appendix A5.

The effects of design factors, based on the above-mentioned analyses, on each performance measure are discussed next.

### Fatigue Cracking

The effects of the design and site factors, in terms of standard deviate, are shown in Figure 5-22. In addition, the summary of p-values corresponding to the analyses performed to study the effects of design factors on fatigue cracking is shown in Table 5-25. The mean area ($m^2$) of fatigue cracking (PI) corresponding to each comparison presented in Table 5-25 is shown in Table 5-26. Though the univariate analyses were performed on standard deviates, the mean cracking was used to identify operationally significant effects. The effects of design factors on fatigue cracking, based on this analysis, are presented below:

*HMA thickness*: The effect of HMA surface thickness is statistically and operationally significant, especially among sections located in WNF zone. Sections built with "thin" [102 mm (4-inch)] HMA surface have exhibited higher fatigue cracking than those built with "thick" [178 mm (7-inch)] HMA surface. On average, among sections built on fine-grained soils, higher fatigue cracking was observed on "thin" [102 mm (4-inch)] sections compared to "thick" [178 mm (7-inch)] sections. However, this effect is not significant. Similar trend was found among sections built on coarse-grained soils and the effect is statistically and operationally significant.

*Base thickness*: The effect of base thickness is marginal among sections built on fine-grained subgrade soil, in that sections with thick 406 mm (16-inch) permeable base have exhibited lesser cracking than those with 305 mm (12-inch) or 203 mm (8-inch) base thickness. Also among sections located in WF zone the effect of base thickness on alligator cracking is statistically and operationally significant. Sections built with 406 mm (16-inch) permeable base have exhibited lesser cracking than those with 305 mm (12-inch) or 203 mm (8-inch) base.

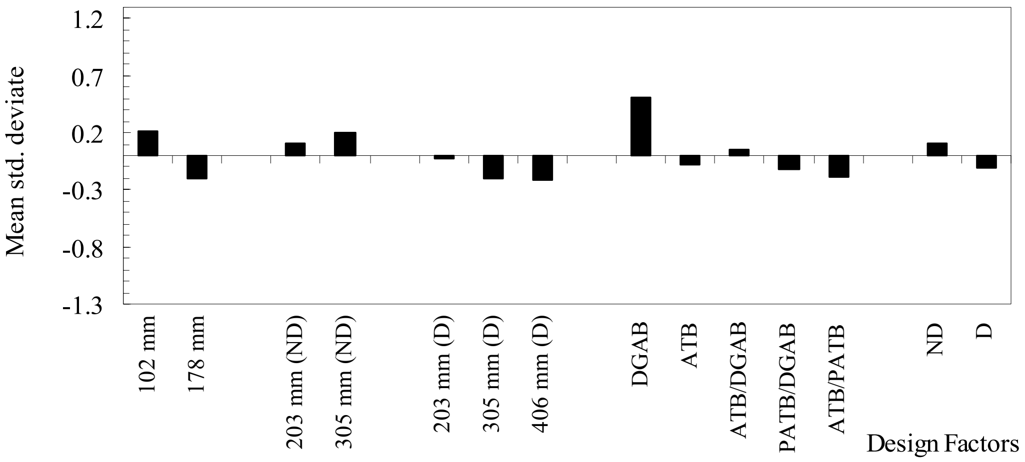
*Base Type*: The effect of base type (unbound versus treated base) is statistically and operationally significant, with ATB giving the "best" performance and DGAB showing the "worst" performance. This effect is more prominent among sections built on fine-grained soils compared to sections built on coarse-grained soils. Also, this effect is more noticeable among sections located in WF zone.

*Drainage*: The effect of drainage is significant (statistically and operationally) among those in WF zone and built on fine-grained subgrade soils. Sections with drainage have lesser cracking than those without drainage. This effect is more prominent for the sections constructed with DGAB than those with ATB. This shows that drainage is more effective if provided with DGAB than when with ATB.

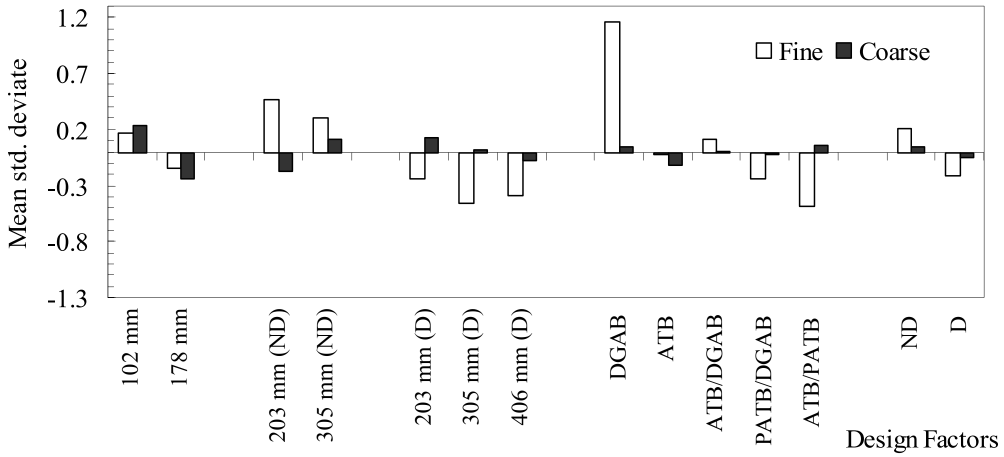
The interaction effects among the experimental factors, on fatigue cracking, are reported below:

In general, "thin" sections with DGAB on fine-subgrade soils have exhibited the most alligator cracking while "thick" sections with ATB on coarse-grained subgrade soils have exhibited the least alligator cracking. Among un-drained pavements, on average, an increase in HMA surface thickness from 102 mm (4-inch) to 178 mm (7-inch) has a slightly higher effect on fatigue cracking for pavements with DGAB than for pavements with ATB.

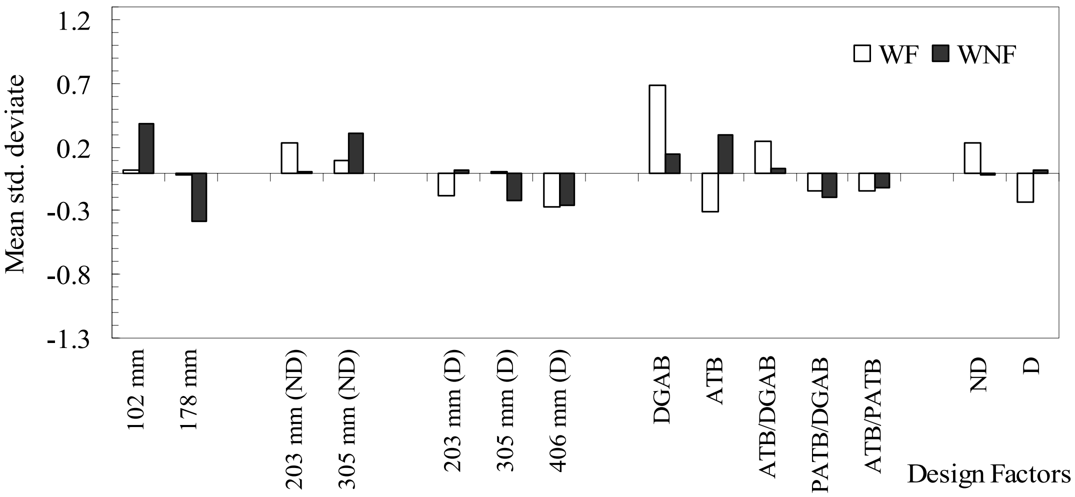
Among sections located in the WF zone, those with DGAB have shown the highest amount of cracking while those with ATB have the least. In addition, among pavements located in WF zone, those with 406 mm (16-inch) drained base have less fatigue cracking than others. These effects were found to be statistically and practically significant. Among pavements with DGAB and built on fine-grained soils, those with drained base have lesser fatigue cracking than others. Also, among sections with drainage and built on fine-grained soils, those with 406 mm base have lesser cracking. These effects were found to be statistically and practically significant.



(a) Overall



(b) By subgrade type



(c) By zone type

Figure 5-22 Effect of design factors on fatigue cracking (1 inch = 25.4 mm)

Table 5-25 Summary of p-values for comparisons of standard deviates— Fatigue cracking

| Design Factor | | Comparison | Overall | By subgrade | | By climatic zone | | | | By subgrade and zone | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Fine | Coarse | WF | WNF | DF | DNF | WF | | WNF | | DF | | DNF | |
| | | | | | | | | | | F | C | F | C | F | C | F | C |
| HMA thickness | | 102 mm vs. 178 mm | **0.003** | 0.167 | **0.008** | 0.890 | **0.002** | **0.102** | 0.213 | 0.900 | 0.900 | 0.160 | **0.005** | | | | |
| Base thickness | Overall | 203 mm vs. 305 mm vs. 406 mm | 0.211 | **0.086** | 0.890 | **0.043** | 0.410 | 0.63 | 0.265 | **0.070** | **0.040** | 0.850 | 0.420 | | | | |
| | ND | 203 mm vs. 305 mm | 0.737 | 0.802 | 0.480 | 0.271 | 0.168 | 0.181 | **0.028** | 0.817 | **0.062** | 0.336 | 0.374 | | | | |
| | D | 203 mm vs. 305 mm vs. 406 mm | 0.381 | **0.020** | 0.512 | 0.137 | 0.609 | 0.977 | 0.159 | **0.060** | 0.523 | 0.207 | 0.587 | | | | |
| Base type | Overall | DGAB vs. ATB vs. ATB/DGAB | **0.000** | **0.004** | **0.011** | **0.003** | **0.057** | 0.390 | 0.500 | **0.060** | **0.050** | 0.150 | 0.350 | | | | |
| | ND | DGAB vs. ATB vs. ATB/DGAB | **0.002** | **0.003** | 0.207 | **0.003** | 0.140 | 0.881 | 0.449 | **0.024** | **0.095** | 0.254 | 0.557 | | | | |
| | D | DGAB vs. ATB | **0.001** | **0.058** | **0.008** | **0.027** | 0.157 | 0.101 | 0.313 | 0.186 | **0.060** | 0.270 | 0.680 | | | | |
| | All Bases | DGAB vs. ATB vs. ATB/DGAB vs. DGAB/PATB vs. ATB/PATB | **0.000** | **0.000** | **0.036** | **0.000** | 0.165 | 0.522 | 0.290 | **0.003** | **0.060** | 0.270 | 0.680 | | | | |
| Drainage | Overall | Drainage vs. No-Drainage | 0.111 | **0.058** | 0.610 | **0.038** | 0.884 | 0.740 | 0.180 | **0.050** | 0.330 | 0.870 | 0.750 | | | | |
| | DGAB | Drainage vs. No-Drainage | **0.070** | **0.010** | 0.770 | **0.030** | 0.720 | 0.370 | 0.220 | **0.040** | 0.300 | 0.430 | 0.840 | | | | |
| | ATB | Drainage vs. No-Drainage | 0.160 | 0.580 | 0.200 | **0.040** | 0.190 | 0.500 | 0.250 | 0.170 | 0.150 | 0.240 | 0.500 | | | | |
| N | | | 188 | 80 | 108 | 80 | 60 | 24 | 24 | 44 | 36 | 24 | 36 | | | | |

Note: Shaded cells show statistically significant at 90% or higher level of confidence.

Table 5-26 Summary of means of PI for fatigue cracking

| Design Factors | | Comparison | Overall | By subgrade | | By climatic zone | | | | By subgrade and zone | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | WF | | WNF | | DF | | DNF | |
| | | | | Fine | Coarse | WF | WNF | DF | DNF | F | C | F | C | F | C | F | C |
| HMA thickness | | 102 mm | 14.6 | 19.2 | 11.8 | 10.7 | 19.8 | 24.3 | 3.4 | 5.5 | 15.2 | 47.0 | 1.6 | | 24.3 | 0.2 | 6.5 |
| | | 178 mm | 9.4 | 10.3 | 8.7 | 11.2 | 8.4 | 13.0 | 2.3 | 7.4 | 15.5 | 20.3 | 0.6 | | 13.0 | 0.0 | 4.5 |
| Base thickness | Overall | 203 mm | 13.4 | 17.2 | 10.9 | 11.8 | 16.5 | 21.9 | 1.4 | 6.9 | 16.4 | 40.1 | 0.8 | | 21.9 | 0.0 | 2.9 |
| | | 305 mm | 11.9 | 14.8 | 9.9 | 12.4 | 13.5 | 14.3 | 3.6 | 8.4 | 16.5 | 31.8 | 1.2 | | 14.3 | 0.2 | 7.0 |
| | | 406 mm | 8.8 | 7.8 | 9.5 | 5.6 | 9.7 | 21.5 | 4.2 | 2.0 | 9.9 | 22.1 | 1.4 | | 21.5 | 0.0 | 8.5 |
| | ND | 203 mm | 13.4 | 22.3 | 7.5 | 8.7 | 22.1 | 18.0 | 1.1 | 8.3 | 9.1 | 54.4 | 0.6 | | 18.0 | 0.0 | 2.2 |
| | | 305 mm | 9.8 | 10.5 | 9.4 | 14.0 | 8.1 | 5.9 | 5.9 | 8.3 | 19.6 | 18.7 | 1.0 | | 5.9 | 0.4 | 11.5 |
| | D | 203 mm | 13.4 | 8.8 | 16.2 | 17.0 | 8.2 | 27.9 | 1.9 | 4.5 | 27.4 | 18.7 | 1.2 | | 27.9 | 0.1 | 3.8 |
| | | 305 mm | 14.9 | 21.4 | 10.5 | 10.1 | 21.6 | 26.9 | 0.2 | 8.5 | 11.8 | 51.5 | 1.6 | | 26.9 | 0.0 | 0.4 |
| | | 406 mm | 8.8 | 7.8 | 9.5 | 5.6 | 9.7 | 21.5 | 4.2 | 2.0 | 9.9 | 22.1 | 1.4 | | 21.5 | 0.0 | 8.5 |
| Base type | Overall | DGAB | 18.8 | 23.4 | 16.1 | 18.5 | 22.5 | 26.0 | 3.2 | 7.7 | 27.2 | 53.8 | 1.7 | | 26.0 | 0.2 | 6.3 |
| | | ATB | 6.8 | 7.7 | 6.2 | 5.8 | 6.8 | 14.7 | 2.7 | 5.3 | 6.4 | 15.8 | 0.8 | | 14.7 | 0.0 | 5.4 |
| | | ATB/DGAB | 8.8 | 13.4 | 5.7 | 8.2 | 11.5 | 10.3 | 2.0 | 8.2 | 8.3 | 28.0 | 0.5 | | 10.3 | 0.0 | 4.1 |
| | ND | DGAB | 20.6 | 34.3 | 13.0 | 20.0 | 30.6 | 13.9 | 3.8 | 11.3 | 25.9 | 74.3 | 1.4 | | 13.9 | 0.5 | 7.2 |
| | | ATB | 6.4 | 6.0 | 6.7 | 7.7 | 3.2 | 11.5 | 4.7 | 6.9 | 8.9 | 7.3 | 0.4 | | 11.5 | 0.1 | 9.3 |
| | | ATB/DGAB | 8.8 | 13.4 | 5.7 | 8.2 | 11.5 | 10.3 | 2.0 | 8.2 | 8.3 | 28.0 | 0.5 | | 10.3 | 0.0 | 4.1 |
| | D | DGAB | 17.7 | 16.9 | 18.1 | 17.6 | 17.1 | 34.0 | 2.8 | 5.9 | 28.0 | 40.1 | 1.8 | | 34.0 | 0.0 | 5.7 |
| | | ATB | 7.2 | 8.9 | 5.9 | 4.3 | 9.1 | 16.8 | 1.4 | 4.0 | 4.7 | 21.4 | 1.0 | | 16.8 | 0.0 | 2.8 |
| Drainage | Overall | ND | 11.6 | 16.4 | 8.5 | 11.3 | 15.1 | 11.9 | 3.5 | 8.3 | 14.4 | 36.5 | 0.8 | | 11.9 | 0.2 | 6.8 |
| | | D | 12.3 | 12.7 | 12.0 | 10.6 | 13.1 | 25.4 | 2.1 | 4.8 | 16.3 | 30.7 | 1.4 | | 25.4 | 0.0 | 4.2 |
| | DGAB | ND | 20.6 | 34.3 | 13.0 | 20.0 | 30.6 | 13.9 | 3.8 | 11.3 | 25.9 | 74.3 | 1.4 | | 13.9 | 0.5 | 7.2 |
| | | D | 17.7 | 16.9 | 18.1 | 17.6 | 17.1 | 34.0 | 2.8 | 5.9 | 28.0 | 40.1 | 1.8 | | 34.0 | 0.0 | 5.7 |
| | ATB | ND | 6.4 | 6.0 | 6.7 | 7.7 | 3.2 | 11.5 | 4.7 | 6.9 | 8.9 | 7.3 | 0.4 | | 11.5 | 0.1 | 9.3 |
| | | D | 7.2 | 8.9 | 5.9 | 4.3 | 9.1 | 16.8 | 1.4 | 4.0 | 4.7 | 21.4 | 1.0 | | 16.8 | 0.0 | 2.8 |

### Structural Rutting

The effects of the design and site factors, in terms of standard deviate, are shown in Figure 5-23. The summary of p-values corresponding to the analyses performed to study the effects of design factors on structural rutting is presented in Table 5-27. The mean rut depth (PI), in mm, corresponding to each comparison presented in Table 5-27 are shown in Table 5-28. The effects of design factors on rutting, based on this analysis, are presented below:

*HMA thickness*: Among sections built on coarse-grained soils, the sections built with "thin" [102 mm (4-inch)] HMA surface have exhibited higher rut depths than those built with "thick" [178 mm (7-inch)] HMA surface. This effect is statistically significant but not operationally significant, at this point in time. Thus increasing HMA thickness from 102 mm to 178 mm may be more effective in retarding rutting in the case of sections with coarse-grained soils than in the case of sections with fine-grained soils. On average, sections built on fine-grained soils have slightly higher rutting than those with coarse-grained soils.

*Base thickness*: The effect of base thickness is significant (statistical and operational) among sections located in WNF zone where higher rutting was observed for the sections built with 203 mm (8-inch) thick base than for those built on 406 mm (16-inch) thick base. In addition, this effect seems to be more apparent for the sections built on coarse-grained subgrade soils.

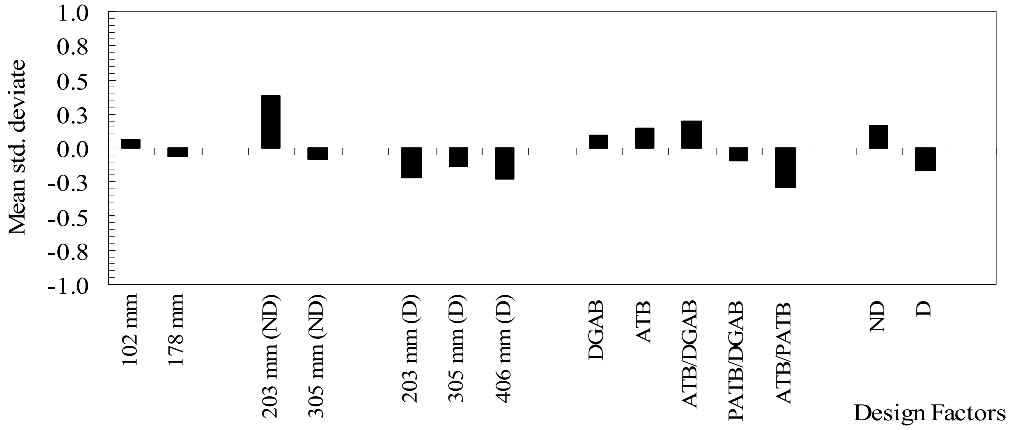
*Base Type*: In general, the effect of base type (unbound versus treated base) is not statistically significant. However on average, sections built on ATB have shown the better performance than those sections built on DGAB. This effect (DGAB vs. ATB) is more prominent among sections located in WF zone and built on fine-grained soils.

*Drainage*: In general, the effect of drainage is statistically significant with un-drained sections showing higher rutting than those with drainage. However, this effect is not operationally significant. This effect is significant (statistical and operational) among sections located in WNF zone and built on fine-grained soils. Also the effect is significant (statistical and operational) among sections in WF zone and built on coarse-grained soils. The results suggest that drainage may be more effective in inhibiting rutting for pavements on fine-grained soils, when located in WNF zone.

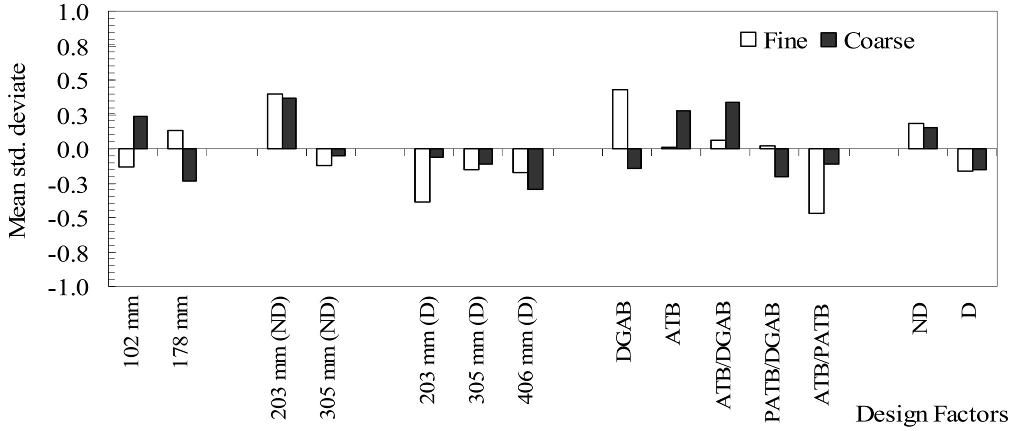
The interaction effects among the experimental factors, on structural rutting, are reported below:

A marginal effect of drainage was observed on pavements built with ATB and on fine-grained soils. Also, among drained pavements located in WF zone, those with DGAB have shown higher rutting than those with ATB. Furthermore, among sections located in WF zone and built with ATB, those with drainage have shown significantly less amount of rutting than those without drainage. Both of the above effects were found to be statistically significant and are of operational significance.

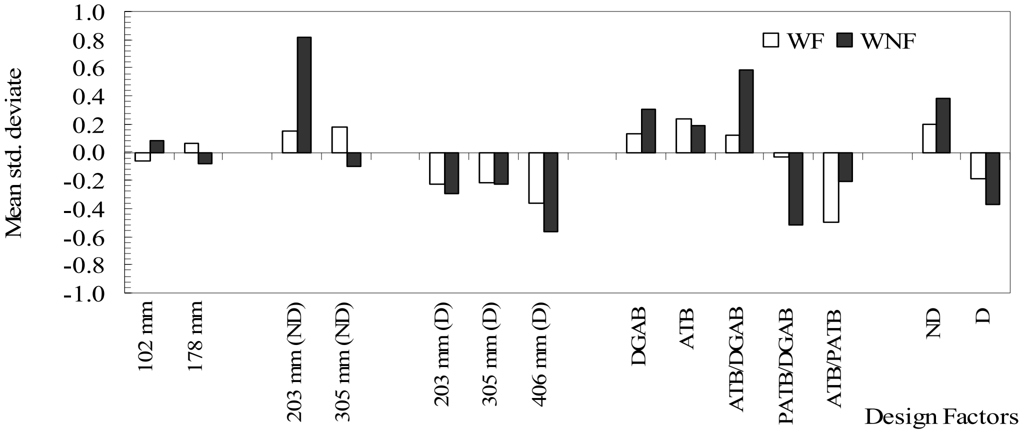
Among un-drained sections located in WNF zone, those with 305 mm (12-inch) base thickness have less amount of rutting than those with 203 mm (8-inch) base thickness. This effect was found to be statistically significance and is practically meaningful.  For sections built on DGAB and located in WNF zone, those with drainage have shown slightly lesser rutting than those without drainage. The effect was not found to be statistically significant.



(a) Overall



(b) By subgrade type



(c) By zone type

Figure 5-23 Effect of design factors on structural rutting (1 inch = 25.4 mm)

Table 5-27 Summary of p-values for comparisons of standard deviates— Structural rutting

| Design Factor | | Comparison | Overall | By subgrade | | By climatic zone | | | | By subgrade and zone | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Fine | Coarse | WF | WNF | DF | DNF | WF | | WNF | | DF | | DNF | |
| | | | | | | | | | | F | C | F | C | F | C | F | C |
| HMA thickness | | 102 mm vs. 178 mm | 0.458 | 0.210 | 0.0270 | 0.580 | 0.501 | 0.001 | 0.078 | 0.420 | 0.900 | 0.900 | 0.300 | | | | |
| Base thickness | Overall | 203 mm vs. 305 mm vs. 406 mm | 0.270 | 0.850 | 0.240 | 0.560 | 0.046 | 0.390 | 0.620 | 0.600 | 0.200 | 0.300 | 0.002 | | | | |
| | ND | 203 mm vs. 305 mm | 0.080 | 0.193 | 0.245 | 0.947 | 0.049 | 0.241 | 0.745 | 0.036 | 0.159 | 0.990 | 0.001 | | | | |
| | D | 203 mm vs. 305 mm vs. 406 mm | 0.675 | 0.438 | 0.695 | 0.907 | 0.283 | 0.669 | 0.712 | 0.784 | 0.496 | 0.358 | 0.126 | | | | |
| Base type | Overall | DGAB vs. ATB vs. ATB/DGAB | 0.180 | 0.225 | 0.230 | 0.520 | 0.003 | 0.770 | 0.370 | 0.004 | 0.170 | 0.002 | 0.440 | | | | |
| | ND | DGAB vs. ATB vs. ATB/DGAB | 0.579 | 0.879 | 0.497 | 0.931 | 0.240 | 0.632 | 0.161 | 0.660 | 0.527 | 0.095 | 0.823 | | | | |
| | D | DGAB vs. ATB | 0.332 | 0.110 | 0.692 | 0.044 | 0.070 | 0.471 | 0.487 | 0.000 | 0.400 | 0.156 | 0.308 | | | | |
| | All Bases | DGAB vs. ATB vs. ATB/DGAB vs. DGAB/PATB vs. ATB/PATB | 0.140 | 0.274 | 0.368 | 0.214 | 0.004 | 0.323 | 0.409 | 0.017 | 0.053 | 0.030 | 0.578 | | | | |
| Drainage | Overall | Drainage vs. No-Drainage | 0.028 | 0.110 | 0.140 | 0.095 | 0.002 | 0.069 | 0.980 | 0.700 | 0.007 | 0.004 | 0.170 | | | | |
| | DGAB | Drainage vs. No-Drainage | 0.810 | 0.760 | 0.860 | 0.940 | 0.100 | 0.180 | 0.710 | 0.590 | 0.370 | 0.110 | 0.550 | | | | |
| | ATB | Drainage vs. No-Drainage | 0.030 | 0.100 | 0.170 | 0.010 | 0.250 | 0.120 | 0.270 | 0.290 | 0.006 | 0.580 | 0.310 | | | | |
| N | | | 161 | 77 | 84 | 66 | 59 | 24 | 12 | 30 | 36 | 35 | 24 | | | | |

Note: Shaded cells show statistically significant at 90% or higher level of confidence.

Table 5-28 Summary of means of PI for structural rutting

| Design Factors | | Comparison | Overall | By subgrade | | By climatic zone | | | | By subgrade and zone | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | WF | | WNF | | DF | | DNF | |
| | | | | Fine | Coarse | WF | WNF | DF | DNF | F | C | F | C | F | C | F | C |
| HMA thickness | | 102 mm | 5.4 | 5.7 | 5.1 | 5.2 | 5.8 | 4.7 | 6.3 | 5.3 | 5.1 | 5.9 | 5.7 | | 4.7 | 6.3 | |
| | | 178 mm | 5.2 | 5.8 | 4.6 | 5.4 | 5.5 | 3.3 | 6.7 | 5.7 | 5.1 | 5.7 | 5.1 | | 3.3 | 6.7 | |
| Base thickness | Overall | 203 mm | 5.5 | 5.9 | 5.2 | 5.4 | 6.1 | 4.0 | 6.5 | 5.8 | 5.1 | 5.7 | 6.7 | | 4.0 | 6.5 | |
| | | 305 mm | 5.2 | 5.7 | 4.7 | 5.2 | 5.4 | 3.8 | 6.4 | 5.1 | 5.4 | 6.0 | 4.5 | | 3.8 | 6.4 | |
| | | 406 mm | 5.1 | 5.7 | 4.5 | 5.0 | 4.9 | 4.7 | 6.7 | 5.6 | 4.4 | 5.3 | 4.3 | | 4.7 | 6.7 | |
| | ND | 203 mm | 5.9 | 6.3 | 5.5 | 5.7 | 6.8 | 3.9 | 6.5 | 6.3 | 5.3 | 6.2 | 7.5 | | 3.9 | 6.5 | |
| | | 305 mm | 5.1 | 5.5 | 4.6 | 5.2 | 5.4 | 3.2 | 6.4 | 4.2 | 5.9 | 6.2 | 4.2 | | 3.2 | 6.4 | |
| | D | 203 mm | 5.0 | 5.3 | 4.8 | 4.9 | 5.3 | 4.0 | 6.4 | 5.0 | 4.9 | 5.1 | 5.6 | | 4.0 | 6.4 | |
| | | 305 mm | 5.3 | 6.0 | 4.7 | 5.3 | 5.4 | 4.7 | 6.3 | 6.2 | 4.5 | 5.7 | 5.0 | | 4.7 | 6.3 | |
| | | 406 mm | 5.1 | 5.7 | 4.5 | 5.0 | 4.9 | 4.7 | 6.7 | 5.6 | 4.4 | 5.3 | 4.3 | | 4.7 | 6.7 | |
| Base type | Overall | DGAB | 5.4 | 6.1 | 4.7 | 5.5 | 5.3 | 4.3 | 6.5 | 6.8 | 4.7 | 5.4 | 5.2 | | 4.3 | 6.5 | |
| | | ATB | 5.1 | 5.4 | 4.9 | 5.0 | 5.6 | 3.7 | 6.5 | 4.7 | 5.2 | 5.7 | 5.4 | | 3.7 | 6.5 | |
| | | ATB/DGAB | 5.6 | 6.0 | 5.2 | 5.4 | 6.5 | 3.8 | 6.1 | 5.1 | 5.8 | 6.9 | 5.8 | | 3.8 | 6.1 | |
| | ND | DGAB | 5.3 | 6.0 | 4.9 | 5.2 | 5.9 | 3.5 | 6.5 | 5.6 | 5.1 | 6.0 | 5.8 | | 3.5 | 6.5 | |
| | | ATB | 5.4 | 5.7 | 5.1 | 5.6 | 5.8 | 3.3 | 6.8 | 5.3 | 5.9 | 5.7 | 5.8 | | 3.3 | 6.8 | |
| | | ATB/DGAB | 5.6 | 6.0 | 5.2 | 5.4 | 6.5 | 3.8 | 6.1 | 5.1 | 5.8 | 6.9 | 5.8 | | 3.8 | 6.1 | |
| | D | DGAB | 5.4 | 6.2 | 4.6 | 5.7 | 5.0 | 4.9 | 6.6 | 7.1 | 4.4 | 5.1 | 4.7 | | 4.9 | 6.6 | |
| | | ATB | 4.9 | 5.2 | 4.7 | 4.5 | 5.4 | 4.1 | 6.3 | 4.2 | 4.8 | 5.6 | 5.2 | | 4.1 | 6.3 | |
| Drainage | Overall | ND | 5.5 | 5.9 | 5.1 | 5.4 | 6.1 | 3.5 | 6.5 | 5.2 | 5.6 | 6.2 | 5.8 | | 3.5 | 6.5 | |
| | | D | 5.1 | 5.7 | 4.7 | 5.1 | 5.2 | 4.5 | 6.5 | 5.7 | 4.6 | 5.4 | 5.0 | | 4.5 | 6.5 | |
| | DGAB | ND | 5.3 | 6.0 | 4.9 | 5.2 | 5.9 | 3.5 | 6.5 | 5.6 | 5.1 | 6.0 | 5.8 | | 3.5 | 6.5 | |
| | | D | 5.4 | 6.2 | 4.6 | 5.7 | 5.0 | 4.9 | 6.6 | 7.1 | 4.4 | 5.1 | 4.7 | | 4.9 | 6.6 | |
| | ATB | ND | 5.4 | 5.7 | 5.1 | 5.6 | 5.8 | 3.3 | 6.8 | 5.3 | 5.9 | 5.7 | 5.8 | | 3.3 | 6.8 | |
| | | D | 4.9 | 5.2 | 4.7 | 4.5 | 5.4 | 4.1 | 6.3 | 4.2 | 4.8 | 5.6 | 5.2 | | 4.1 | 6.3 | |

### Roughness

The effects of the design and site factors, in terms of standard deviate, are shown in Figure 5-24. The summary of p-values corresponding to the analyses performed to study the effects of design factors on roughness is shown in Table 5-28. The mean PI corresponding to each comparison presented in Table 5-28 is shown in Table **5-29**. The effects of design factors on roughness, based on this analysis, are presented below:

*HMA thickness*: In general, the effect of HMA surface thickness is statistically significant. Sections built with “thin” [102 mm (4-inch)] HMA surface have exhibited higher change in roughness than those built with “thick” [178 mm (7-inch)] HMA surface. This effect is more prominent among sections built on fine-grained soils.

*Base thickness*: On the whole, the effect of base thickness is statistically and operationally significant. Sections with “thick” [406 mm (16-inch)] permeable base have exhibited the least change in roughness whereas sections with “thin” [203 mm (8-inch)] base thickness have shown the highest change in roughness. This effect is more significant among sections located in “wet” climate than among sections located in “dry” climate.

*Base Type*: In general, the effect of base type is statistically and operationally significant. Sections built with DGAB have exhibited higher change in roughness than those built with ATB. This effect is more prominent among sections built on fine-grained soils.

*Drainage*: By and large, the effect of drainage is only statistically significant i.e. it is not of practical significance at this point in time. Sections without drainage have exhibited higher change in roughness than those built with drainage. This effect is significant (statistical and operational) among sections built on fine-grained soils and located in WF zone. This effect is more prominent for sections with DGAB. This suggests that drainage is more effective for pavements with DGAB on fine-grained soils, especially when in WF zone.

The interaction effects among the experimental factors, on the change in roughness, are reported below:

Also for un-drained pavements built on fine-grained soils, the effect of base type is significant, in that pavements with ATB have significantly lower ΔIRI. Furthermore, the effect of drainage for sections with DGAB and built on fine-grained soils, is significant. The above effects were found to be statistically significant and are of practical significance.

For un-drained pavements built on coarse-grained soils, an increase in base thickness from 203 mm (8-inch) to 305 mm (12-inch) has a marginally significant effect, in that sections with thicker base have lower ΔIRI. However, this effect is not of practical significance at this point in time. It should be noted that, in general, pavements built on fine-grained soils have shown higher ΔIRI than those built on coarse-grained soils, especially among sections in WF zone. Also, the change in roughness among sections located in WF zone is higher than those in WNF zone.

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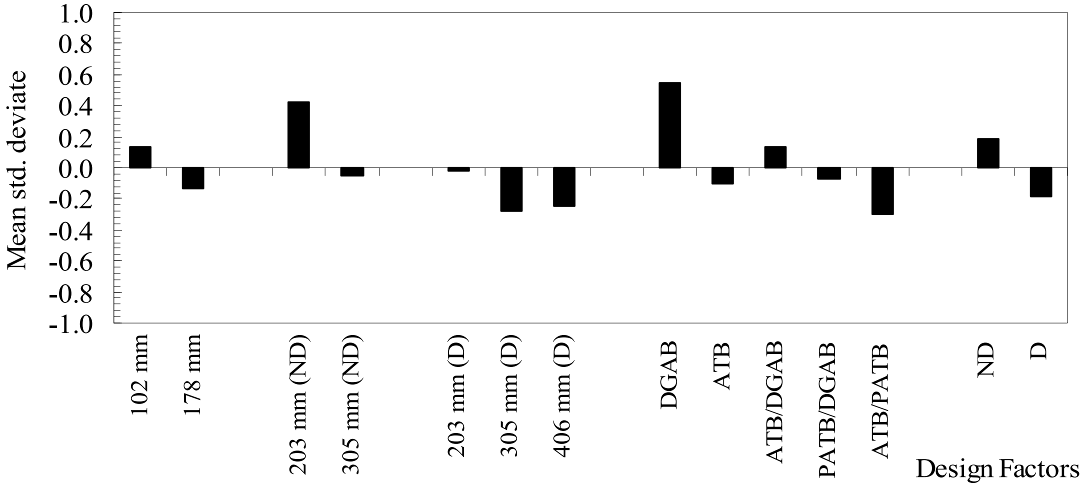
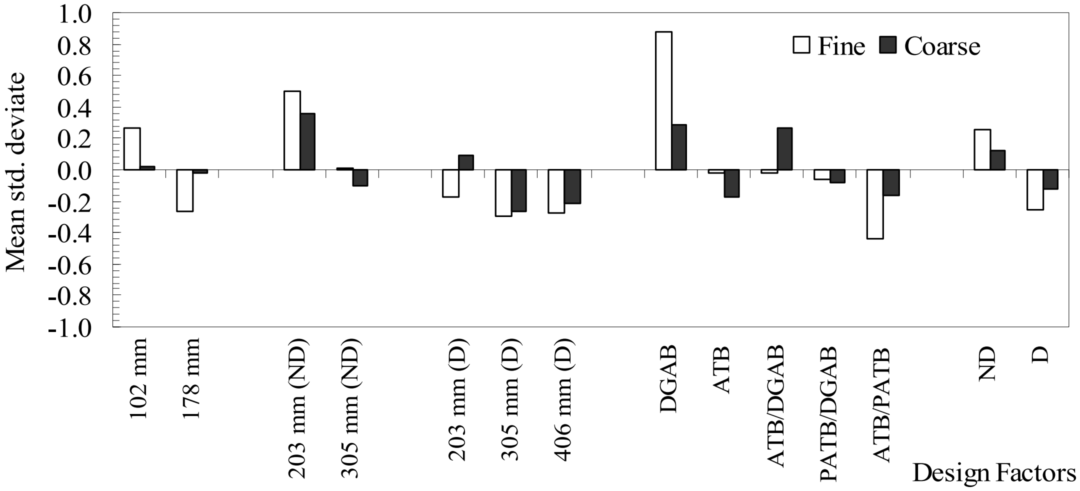
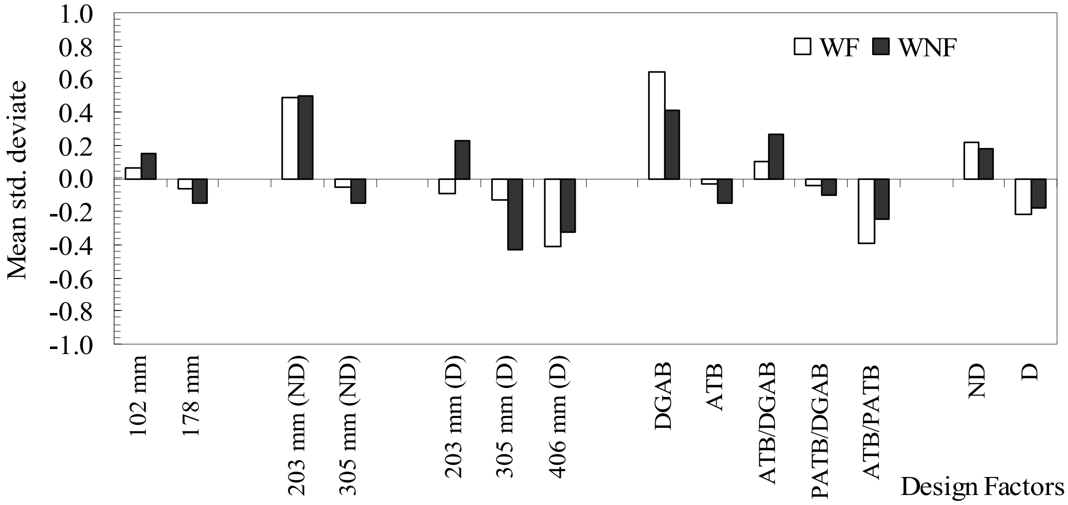


(a) Overall



(b) By subgrade type



(c) By zone type

Figure 5-24 Effect of design factors on change in IRI (1 inch = 25.4 mm)

Table 5-29 Summary of p-values for comparisons of standard deviates— Change in IRI

| Design Factor | | Comparison | Overall | By subgrade | | By climatic zone | | | | By subgrade and zone | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Fine | Coarse | WF | WNF | DF | DNF | WF | | WNF | | DF | | DNF | |
| | | | | | | | | | | F | C | F | C | F | C | F | C |
| HMA thickness | | 102 mm vs. 178 mm | 0.047 | 0.008 | 0.800 | 0.540 | 0.220 | 0.038 | 0.660 | 0.140 | 0.400 | 0.160 | 0.670 | | | | |
| Base thickness | Overall | 203 mm vs. 305 mm vs. 406 mm | 0.008 | 0.120 | 0.070 | 0.045 | 0.028 | 0.900 | 0.340 | 0.320 | 0.069 | 0.200 | 0.145 | | | | |
| | ND | 203 mm vs. 305 mm | 0.019 | 0.128 | 0.076 | 0.083 | 0.068 | 0.861 | 0.540 | 0.372 | 0.056 | 0.242 | 0.185 | | | | |
| | D | 203 mm vs. 305 mm vs. 406 mm | 0.445 | 0.898 | 0.498 | 0.501 | 0.265 | 0.884 | 0.133 | 0.287 | 0.381 | 0.448 | 0.629 | | | | |
| Base type | Overall | DGAB vs. ATB vs. ATB/DGAB | 0.023 | 0.036 | 0.220 | 0.100 | 0.340 | 0.180 | 0.810 | 0.110 | 0.740 | 0.190 | 0.180 | | | | |
| | ND | DGAB vs. ATB vs. ATB/DGAB | 0.028 | 0.030 | 0.252 | 0.193 | 0.418 | 0.205 | 0.992 | 0.086 | 0.997 | 0.446 | 0.416 | | | | |
| | D | DGAB vs. ATB | 0.212 | 0.087 | 0.754 | 0.150 | 0.691 | 0.484 | 0.750 | 0.136 | 0.443 | 0.236 | 0.601 | | | | |
| | All Bases | DGAB vs. ATB vs. ATB/DGAB vs. DGAB/PATB vs. ATB/PATB | 0.002 | 0.001 | 0.331 | 0.032 | 0.423 | 0.331 | 0.744 | 0.003 | 0.934 | 0.528 | 0.223 | | | | |
| Drainage | Overall | Drainage vs. No-Drainage | 0.006 | 0.011 | 0.170 | 0.028 | 0.163 | 0.920 | 0.160 | 0.007 | 0.834 | 0.900 | 0.055 | | | | |
| | DGAB | Drainage vs. No-Drainage | 0.014 | 0.009 | 0.300 | 0.060 | 0.340 | 0.520 | 0.180 | 0.001 | 0.830 | 0.900 | 0.23 | | | | |
| | ATB | Drainage vs. No-Drainage | 0.420 | 0.120 | 0.970 | 0.260 | 0.720 | 0.280 | 0.610 | 0.240 | 0.580 | 0.630 | 0.800 | | | | |
| N | | | 200 | 92 | 108 | 92 | 60 | 24 | 24 | 56 | 36 | 24 | 36 | | | | |

Note: Shaded cells show statistically significant at 90% or higher level of confidence.

Table 5-30 Summary of means of PI for change in IRI

| Design Factors | | Comparison | Overall | By subgrade | | By climatic zone | | | | By subgrade and zone | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | WF | | WNF | | DF | | DNF | |
| | | | | Fine | Coarse | WF | WNF | DF | DNF | F | C | F | C | F | C | F | C |
| HMA thickness | | 102 mm | 0.27 | 0.44 | 0.14 | 0.38 | 0.13 | 0.18 | 0.31 | 0.52 | 0.17 | 0.20 | 0.08 | | 0.18 | 0.50 | 0.11 |
| | | 178 mm | 0.22 | 0.32 | 0.14 | 0.37 | 0.07 | 0.04 | 0.24 | 0.45 | 0.24 | 0.05 | 0.08 | | 0.04 | 0.29 | 0.19 |
| Base thickness | Overall | 203 mm | 0.30 | 0.48 | 0.16 | 0.46 | 0.16 | 0.10 | 0.29 | 0.59 | 0.26 | 0.24 | 0.11 | | 0.10 | 0.45 | 0.14 |
| | | 305 mm | 0.22 | 0.34 | 0.12 | 0.35 | 0.05 | 0.14 | 0.23 | 0.47 | 0.17 | 0.03 | 0.06 | | 0.14 | 0.34 | 0.12 |
| | | 406 mm | 0.18 | 0.25 | 0.11 | 0.23 | 0.06 | 0.08 | 0.33 | 0.28 | 0.15 | 0.08 | 0.05 | | 0.08 | 0.41 | 0.24 |
| | ND | 203 mm | 0.35 | 0.59 | 0.16 | 0.56 | 0.15 | 0.09 | 0.34 | 0.77 | 0.24 | 0.21 | 0.11 | | 0.09 | 0.51 | 0.17 |
| | | 305 mm | 0.24 | 0.38 | 0.12 | 0.37 | 0.05 | 0.15 | 0.29 | 0.52 | 0.13 | 0.03 | 0.07 | | 0.15 | 0.43 | 0.15 |
| | D | 203 mm | 0.22 | 0.29 | 0.17 | 0.29 | 0.17 | 0.11 | 0.22 | 0.29 | 0.30 | 0.28 | 0.09 | | 0.11 | 0.34 | 0.10 |
| | | 305 mm | 0.21 | 0.29 | 0.13 | 0.34 | 0.06 | 0.12 | 0.14 | 0.41 | 0.22 | 0.04 | 0.06 | | 0.12 | 0.20 | 0.07 |
| | | 406 mm | 0.18 | 0.25 | 0.11 | 0.23 | 0.06 | 0.08 | 0.33 | 0.28 | 0.15 | 0.08 | 0.05 | | 0.08 | 0.41 | 0.24 |
| Base type | Overall | DGAB | 0.31 | 0.49 | 0.16 | 0.47 | 0.14 | 0.19 | 0.27 | 0.63 | 0.24 | 0.24 | 0.07 | | 0.19 | 0.41 | 0.12 |
| | | ATB | 0.18 | 0.27 | 0.11 | 0.28 | 0.06 | 0.05 | 0.27 | 0.34 | 0.18 | 0.05 | 0.06 | | 0.05 | 0.38 | 0.15 |
| | | ATB/DGAB | 0.26 | 0.38 | 0.15 | 0.39 | 0.10 | 0.07 | 0.30 | 0.51 | 0.19 | 0.04 | 0.14 | | 0.07 | 0.39 | 0.21 |
| | ND | DGAB | 0.41 | 0.73 | 0.16 | 0.66 | 0.15 | 0.27 | 0.34 | 1.02 | 0.18 | 0.26 | 0.07 | | 0.27 | 0.53 | 0.14 |
| | | ATB | 0.23 | 0.37 | 0.10 | 0.36 | 0.06 | 0.02 | 0.32 | 0.47 | 0.18 | 0.06 | 0.06 | | 0.02 | 0.50 | 0.14 |
| | | ATB/DGAB | 0.26 | 0.38 | 0.15 | 0.39 | 0.10 | 0.07 | 0.30 | 0.51 | 0.19 | 0.04 | 0.14 | | 0.07 | 0.39 | 0.21 |
| | D | DGAB | 0.25 | 0.35 | 0.16 | 0.35 | 0.14 | 0.13 | 0.22 | 0.40 | 0.28 | 0.23 | 0.08 | | 0.13 | 0.33 | 0.11 |
| | | ATB | 0.16 | 0.21 | 0.11 | 0.22 | 0.05 | 0.08 | 0.23 | 0.25 | 0.17 | 0.04 | 0.06 | | 0.08 | 0.31 | 0.16 |
| Drainage | Overall | ND | 0.30 | 0.48 | 0.14 | 0.46 | 0.10 | 0.12 | 0.32 | 0.64 | 0.19 | 0.12 | 0.09 | | 0.12 | 0.47 | 0.16 |
| | | D | 0.20 | 0.28 | 0.14 | 0.29 | 0.10 | 0.10 | 0.23 | 0.33 | 0.22 | 0.14 | 0.07 | | 0.10 | 0.32 | 0.14 |
| | DGAB | ND | 0.41 | 0.73 | 0.16 | 0.66 | 0.15 | 0.27 | 0.34 | 1.02 | 0.18 | 0.26 | 0.07 | | 0.27 | 0.53 | 0.14 |
| | | D | 0.25 | 0.35 | 0.16 | 0.35 | 0.14 | 0.13 | 0.22 | 0.40 | 0.28 | 0.23 | 0.08 | | 0.13 | 0.33 | 0.11 |
| | ATB | ND | 0.23 | 0.37 | 0.10 | 0.36 | 0.06 | 0.02 | 0.32 | 0.47 | 0.18 | 0.06 | 0.06 | | 0.02 | 0.50 | 0.14 |
| | | D | 0.16 | 0.21 | 0.11 | 0.22 | 0.05 | 0.08 | 0.23 | 0.25 | 0.17 | 0.04 | 0.06 | | 0.08 | 0.31 | 0.16 |

## Transverse Cracking

The effects of the design and site factors, in terms of standard deviate, are shown in Figure 5-25. The summary of p-values corresponding to the analyses performed to study the effects of design factors on transverse cracking is presented in Table 5-31. The mean PI corresponding to each comparison presented in Table 5-31 is shown in Table 5-32. The effects of design factors on transverse cracking, based on this analysis, are presented below:

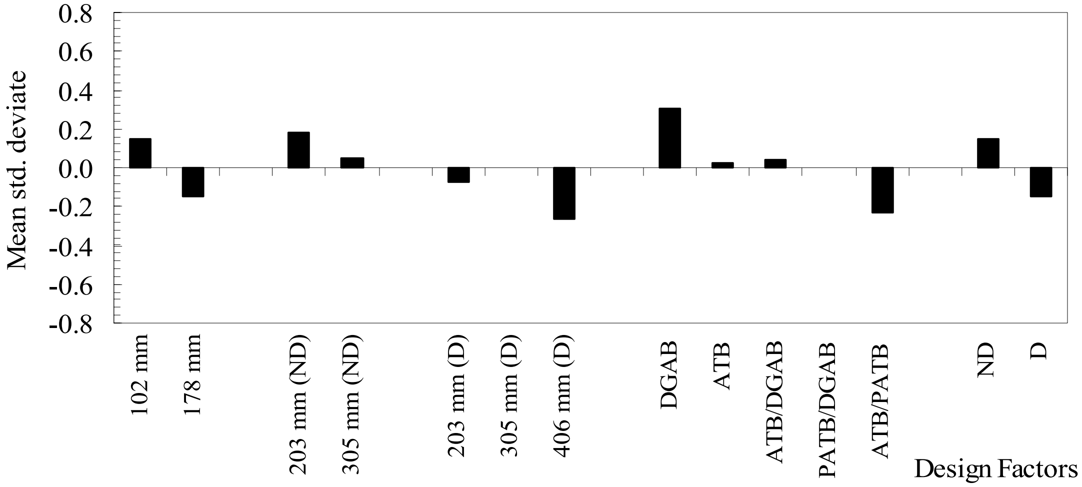
*HMA thickness*: The effect of HMA surface thickness is not significant. However, on an average, sections with "thin" HMA surface have slightly higher cracking than sections with "thick" HMA layer.

*Base thickness*: The effect of base thickness is marginally significant among sections located in WF zone, especially among sections built on fine-grained soils. Sections built with 406 mm base have shown the least cracking while sections with 203 mm or 305 mm base have shown the highest cracking.

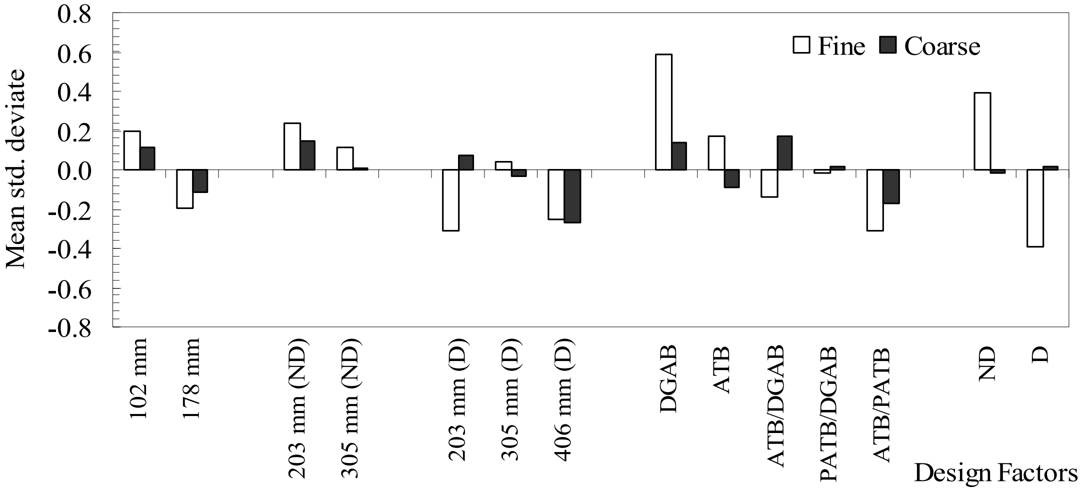
*Base Type*: On the whole, the effect of base type is statistically significant. Sections with ATB have exhibited the least cracking while sections with DGAB have shown the highest cracking. However, this effect is not operationally significant at this point in time.

*Drainage*: In general, sections with un-drained sections showing higher cracking than those with drainage. In addition, this effect is significant (statistically and operationally) among sections built on fine-grained subgrade and located in WF zone.

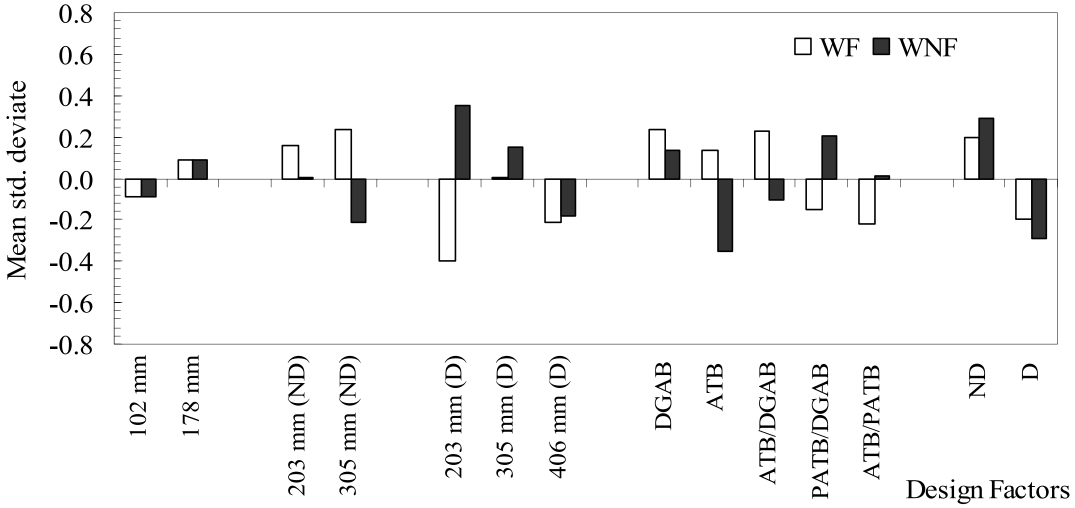
On the whole, at this point in time, sections in WF zone have shown higher cracking than those located in WNF zone indicating that transverse cracking is associated with low temperatures. Also, among drained pavements built on coarse-grained soils, those with ATB performed better than those with DGAB. However, among pavements with DGAB and built on fine-grained soils, those with drainage have shown significantly less transverse cracking than those without drainage. These effects were statistically significant and are of practical importance.



(a) Overall



(b) By subgrade type



(c) By zone type

Figure 5-25 Effect of design factors on transverse cracking (1 inch = 25.4 mm)

Table 5-31 Summary of p-values for comparisons of standard deviates— Transverse cracking

| Design Factor | | Comparison | Overall | By subgrade | | By climatic zone | | | | By subgrade and zone | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Fine | Coarse | WF | WNF | DF | DNF | WF | | WNF | | DF | | DNF | |
| | | | | | | | | | | F | C | F | C | F | C | F | C |
| HMA thickness | | 102 mm vs. 178 mm | 0.100 | 0.170 | 0.330 | 0.610 | 0.310 | 0.310 | 0.097 | 0.850 | 0.630 | 0.180 | 0.940 | | | | |
| Base thickness | Overall | 203 mm vs. 305 mm vs. 406 mm | 0.480 | 0.410 | 0.255 | 0.342 | 0.038 | 0.405 | 0.880 | 0.100 | 0.700 | 0.200 | 0.240 | | | | |
| | ND | 203 mm vs. 305 mm | 0.391 | 0.865 | 0.168 | 0.083 | 0.022 | 0.830 | 0.840 | 0.013 | 0.713 | 0.123 | 0.135 | | | | |
| | D | 203 mm vs. 305 mm vs. 406 mm | 0.814 | 0.745 | 0.698 | 0.681 | 0.992 | 0.508 | 0.688 | 0.545 | 0.591 | 0.828 | 0.368 | | | | |
| Base type | Overall | DGAB vs. ATB vs. ATB/DGAB | 0.008 | 0.240 | 0.012 | 0.353 | 0.240 | 0.025 | 0.013 | 0.660 | 0.120 | 0.345 | 0.370 | | | | |
| | ND | DGAB vs. ATB vs. ATB/DGAB | 0.172 | 0.215 | 0.618 | 0.770 | 0.824 | 0.370 | 0.040 | 0.914 | 0.235 | 0.548 | 0.644 | | | | |
| | D | DGAB vs. ATB | 0.003 | 0.630 | 0.001 | 0.240 | 0.474 | 0.040 | 0.049 | 0.374 | 0.120 | 0.794 | 0.318 | | | | |
| | All Bases | DGAB vs. ATB vs. ATB/DGAB vs. DGAB/PATB vs. ATB/PATB | 0.011 | 0.006 | 0.037 | 0.542 | 0.285 | 0.107 | 0.010 | 0.167 | 0.185 | 0.329 | 0.434 | | | | |
| Drainage | Overall | Drainage vs. No-Drainage | 0.089 | 0.004 | 0.910 | 0.330 | 0.037 | 0.440 | 0.530 | 0.008 | 0.330 | 0.140 | 0.160 | | | | |
| | DGAB | Drainage vs. No-Drainage | 0.210 | 0.008 | 0.520 | 0.760 | 0.170 | 0.610 | 0.160 | 0.160 | 0.370 | 0.160 | 0.850 | | | | |
| | ATB | Drainage vs. No-Drainage | 0.070 | 0.110 | 0.190 | 0.050 | 0.250 | 0.710 | 0.850 | 0.070 | 0.260 | 0.810 | 0.240 | | | | |
| N | | | 120 | 48 | 72 | 24 | 48 | 24 | 24 | 12 | 12 | 24 | 24 | | | | |

Note: Shaded cells show statistically significant at 90% or higher level of confidence.

Table 5-32 Summary of means of PI for transverse cracking

| Design Factors | | Comparison | Overall | By subgrade | | By climatic zone | | | | By subgrade and zone | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | WF | | WNF | | DF | | DNF | |
| | | | | Fine | Coarse | WF | WNF | DF | DNF | F | C | F | C | F | C | F | C |
| HMA thickness | | 102 mm | 4.5 | 6.1 | 3.4 | 12.5 | 1.4 | 1.5 | 5.7 | 18.9 | 6.2 | 2.8 | 0.0 | | 1.5 | 0.0 | 11.4 |
| | | 178 mm | 3.7 | 5.7 | 2.4 | 14.5 | 0.6 | 0.8 | 2.1 | 20.7 | 8.2 | 1.0 | 0.3 | | 0.8 | 0.0 | 4.1 |
| Base thickness | Overall | 203 mm | 4.0 | 5.0 | 3.4 | 11.2 | 1.9 | 1.1 | 4.2 | 13.2 | 9.1 | 3.4 | 0.3 | | 1.1 | 0.0 | 8.4 |
| | | 305 mm | 4.7 | 8.1 | 2.4 | 18.6 | 0.4 | 0.9 | 3.1 | 30.9 | 6.3 | 0.8 | 0.0 | | 0.9 | 0.0 | 6.1 |
| | | 406 mm | 2.9 | 2.5 | 3.1 | 6.6 | 0.3 | 2.0 | 5.1 | 8.8 | 4.3 | 0.6 | 0.1 | | 2.0 | 0.0 | 10.3 |
| | ND | 203 mm | 4.7 | 7.1 | 3.1 | 11.5 | 2.8 | 0.7 | 5.7 | 18.1 | 4.8 | 5.1 | 0.5 | | 0.7 | 0.0 | 11.4 |
| | | 305 mm | 5.6 | 11.2 | 1.8 | 24.4 | 0.4 | 1.1 | 1.7 | 43.4 | 5.5 | 0.7 | 0.0 | | 1.1 | 0.0 | 3.4 |
| | D | 203 mm | 3.1 | 2.0 | 3.8 | 10.8 | 0.5 | 1.7 | 1.9 | 5.9 | 15.6 | 1.0 | 0.0 | | 1.7 | 0.0 | 3.7 |
| | | 305 mm | 3.3 | 3.5 | 3.2 | 9.9 | 0.5 | 0.5 | 5.1 | 12.1 | 7.7 | 0.9 | 0.0 | | 0.5 | 0.0 | 10.2 |
| | | 406 mm | 2.9 | 2.5 | 3.1 | 6.6 | 0.3 | 2.0 | 5.1 | 8.8 | 4.3 | 0.6 | 0.1 | | 2.0 | 0.0 | 10.3 |
| Base type | Overall | DGAB | 5.4 | 5.2 | 5.5 | 15.1 | 0.7 | 2.2 | 8.3 | 18.3 | 11.9 | 1.3 | 0.0 | | 2.2 | 0.0 | 16.6 |
| | | ATB | 2.5 | 4.7 | 1.1 | 10.5 | 0.5 | 0.4 | 0.8 | 17.4 | 3.6 | 0.7 | 0.3 | | 0.4 | 0.0 | 1.6 |
| | | ATB/DGAB | 4.8 | 10.6 | 1.0 | 17.0 | 3.1 | 0.4 | 0.5 | 29.8 | 4.2 | 6.3 | 0.0 | | 0.4 | 0.0 | 0.9 |
| | ND | DGAB | 7.0 | 9.8 | 5.1 | 21.1 | 1.0 | 1.8 | 10.0 | 35.3 | 6.9 | 1.9 | 0.0 | | 1.8 | 0.1 | 20.0 |
| | | ATB | 3.6 | 7.1 | 1.4 | 15.8 | 0.7 | 0.5 | 0.7 | 27.2 | 4.4 | 0.6 | 0.8 | | 0.5 | 0.0 | 1.3 |
| | | ATB/DGAB | 4.8 | 10.6 | 1.0 | 17.0 | 3.1 | 0.4 | 0.5 | 29.8 | 4.2 | 6.3 | 0.0 | | 0.4 | 0.0 | 0.9 |
| | D | DGAB | 4.3 | 2.2 | 5.8 | 11.1 | 0.5 | 2.5 | 7.2 | 7.0 | 15.3 | 0.9 | 0.0 | | 2.5 | 0.0 | 14.3 |
| | | ATB | 1.8 | 3.1 | 0.9 | 7.0 | 0.4 | 0.4 | 0.9 | 10.9 | 3.1 | 0.7 | 0.0 | | 0.4 | 0.0 | 1.8 |
| Drainage | Overall | ND | 5.1 | 9.1 | 2.5 | 17.9 | 1.6 | 0.9 | 3.7 | 30.7 | 5.2 | 2.9 | 0.3 | | 0.9 | 0.0 | 7.4 |
| | | D | 3.1 | 2.6 | 3.4 | 9.1 | 0.4 | 1.4 | 4.0 | 8.9 | 9.2 | 0.8 | 0.0 | | 1.4 | 0.0 | 8.1 |
| | DGAB | ND | 7.0 | 9.8 | 5.1 | 21.1 | 1.0 | 1.8 | 10.0 | 35.3 | 6.9 | 1.9 | 0.0 | | 1.8 | 0.1 | 20.0 |
| | | D | 4.3 | 2.2 | 5.8 | 11.1 | 0.5 | 2.5 | 7.2 | 7.0 | 15.3 | 0.9 | 0.0 | | 2.5 | 0.0 | 14.3 |
| | ATB | ND | 3.6 | 7.1 | 1.4 | 15.8 | 0.7 | 0.5 | 0.7 | 27.2 | 4.4 | 0.6 | 0.8 | | 0.5 | 0.0 | 1.3 |
| | | D | 1.8 | 3.1 | 0.9 | 7.0 | 0.4 | 0.4 | 0.9 | 10.9 | 3.1 | 0.7 | 0.0 | | 0.4 | 0.0 | 1.8 |

**Longitudinal Cracking- WP**

The effects of the design and site factors, in terms of standard deviate, are shown in Figure 5-26. The summary of p-values corresponding to the analyses performed to study the effects of design factors on longitudinal cracking-WP is presented in Table 5-33. The mean PI corresponding to each comparison presented in Table 5-33 is shown in Table 5-34. The effects of design factors on longitudinal cracking-WP, based on this analysis, are presented below:

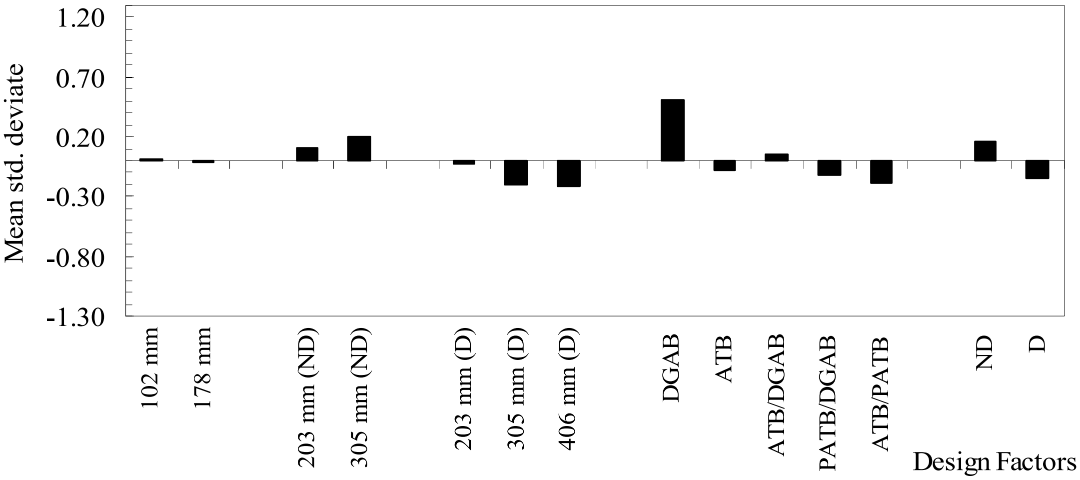
*HMA thickness*: The effect of HMA thickness on longitudinal cracking-WP is inconclusive. Sections with 102 mm HMA surface layer and sections with 178 mm HMA surface layer have shown comparable levels of longitudinal cracking-WP.

*Base thickness*: The effect of base thickness on longitudinal cracking-WP is inconclusive. In general, all sections have shown comparable performance.

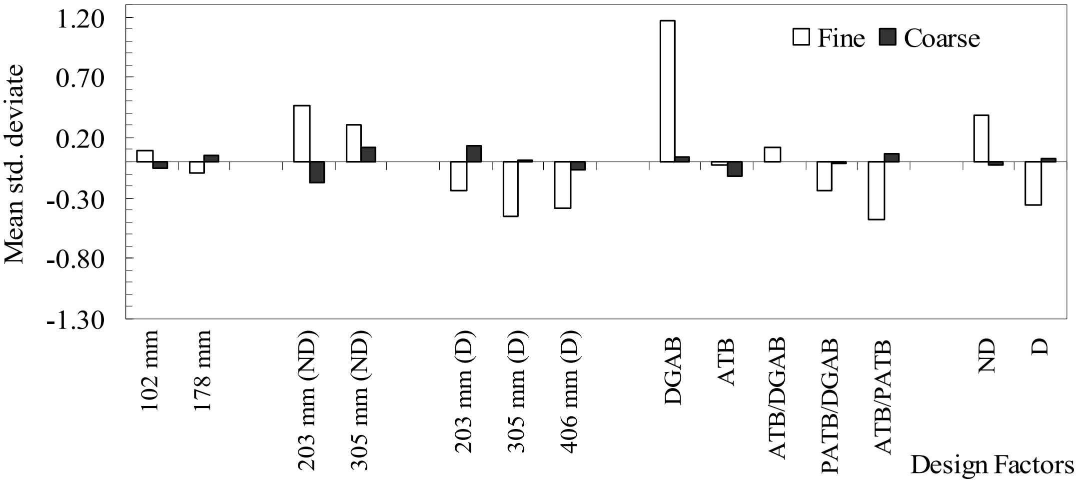
*Base Type*: The effect of base type on longitudinal cracking-WP is inconclusive. However, on average, sections built on ATB have exhibited least cracking compared to other sections, especially among sections built on fine-grained soils.

*Drainage*: In general, the effect of drainage is statistically significant with un-drained sections showing higher cracking than those with drainage. However, this effect is not operationally significant. This effect is statistically and operationally significant among sections built on fine-grained soils, especially among sections located in WF zone. In addition, drainage seems to be more effective for sections with DGAB.

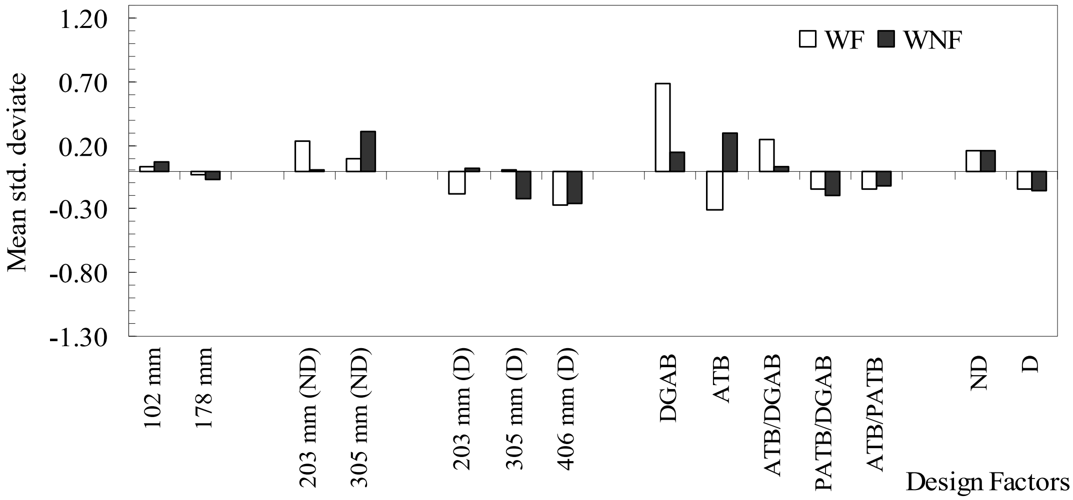
On the whole, at this point in time, sections in WF zone have exhibited much higher cracking than those in other climatic zones. Among pavements built on fine-grained soils, those built with DGAB have shown higher longitudinal cracking-WP and those built with ATB have shown the least longitudinal cracking-WP. This main effect of base type was statistically and operationally significance. Also among pavements built on fine-grained soils, drainage has a significant effect on longitudinal cracking and this effect is more pronounced (significant) among pavements built with DGAB. This effect is statistically significant and is of practical importance.



(a) Overall



(b) By subgrade type



(c) By zone type

Figure 5-26 Effect of design factors on longitudinal cracking-WP (1 inch = 25.4 mm)

Table 5-33 Summary of p-values for comparisons of standard deviates— Longitudinal cracking-WP

| Design Factor | | Comparison | Overall | By subgrade | | By climatic zone | | | | By subgrade and zone | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Fine | Coarse | WF | WNF | DF | DNF | WF | | WNF | | DF | | DNF | |
| | | | | | | | | | | F | C | F | C | F | C | F | C |
| HMA thickness | | 102 mm vs. 178 mm | 0.851 | 0.420 | 0.630 | 0.850 | 0.560 | 0.127 | 0.425 | 0.440 | 0.400 | .730 | 0.290 | | | | |
| Base thickness | Overall | 203 mm vs. 305 mm vs. 406 mm | 0.451 | 0.237 | 0.813 | 0.690 | 0.620 | 0.685 | 0.780 | 0.512 | 0.570 | 0.770 | 0.790 | | | | |
| | ND | 203 mm vs. 305 mm | 0.703 | 0.720 | 0.379 | 0.787 | 0.499 | 0.550 | 0.653 | 0.754 | 0.969 | 0.934 | 0.325 | | | | |
| | D | 203 mm vs. 305 mm vs. 406 mm | 0594 | 0.362 | 0.839 | 0.803 | 0.558 | 0.248 | 0.929 | 0.480 | 0.497 | 0.364 | 0.439 | | | | |
| Base type | Overall | DGAB vs. ATB vs. ATB/DGAB | 0.281 | 0.067 | 0.990 | 0.410 | 0.920 | 0.470 | 0.230 | 0.093 | 0.680 | 0.790 | 0.620 | | | | |
| | ND | DGAB vs. ATB vs. ATB/DGAB | 0.172 | 0.045 | 0.923 | 0.240 | 0.890 | 0.321 | 0.256 | 0.193 | 0.097 | 0.501 | 0.718 | | | | |
| | D | DGAB vs. ATB | 0.668 | 0.052 | 0.757 | 0.990 | 0.745 | 0.354 | 0.481 | 0.148 | 0.451 | 0.321 | 0.650 | | | | |
| | All Bases | DGAB vs. ATB vs. ATB/DGAB vs. DGAB/PATB vs. ATB/PATB | 0.058 | 0.000 | 0.988 | 0.305 | 0.753 | 0.085 | 0.349 | 0.030 | 0.698 | 0.181 | 0.893 | | | | |
| Drainage | Overall | Drainage vs. No-Drainage | 0.049 | 0.001 | 0.815 | 0.297 | 0.220 | 0.045 | 0.650 | 0.052 | 0.290 | 0.063 | 0.943 | | | | |
| | DGAB | Drainage vs. No-Drainage | 0.020 | 0.001 | 0.850 | 0.130 | 0.340 | 0.080 | 0.710 | 0.080 | 0.450 | 0.110 | 0.510 | | | | |
| | ATB | Drainage vs. No-Drainage | 0.650 | 0.090 | 0.630 | 0.700 | 0.360 | 0.190 | 0.180 | 0.510 | 0.480 | 0.170 | 0.950 | | | | |
| N | | | 152 | 68 | 84 | 44 | 60 | 24 | 24 | 32 | 12 | 24 | 36 | | | | |

Note: Shaded cells show statistically significant at 90% or higher level of confidence.

Table 5-34 Summary of means of PI for longitudinal cracking-WP

| Design Factors | | Comparison | Overall | By subgrade | | By climatic zone | | | | By subgrade and zone | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | WF | | WNF | | DF | | DNF | |
| | | | | Fine | Coarse | WF | WNF | DF | DNF | F | C | F | C | F | C | F | C |
| HMA thickness | | 102 mm | 13.9 | 17.3 | 11.2 | 22.3 | 2.8 | 0.9 | 39.5 | 30.7 | 1.5 | 2.8 | 2.8 | | 0.9 | 12.7 | 66.4 |
| | | 178 mm | 14.3 | 17.9 | 11.3 | 24.6 | 2.7 | 2.6 | 35.4 | 31.4 | 5.4 | 5.7 | 0.7 | | 2.6 | 4.4 | 66.4 |
| Base thickness | Overall | 203 mm | 13.8 | 18.0 | 10.5 | 23.2 | 2.5 | 1.7 | 37.9 | 32.5 | 0.8 | 3.5 | 1.9 | | 1.7 | 12.3 | 63.5 |
| | | 305 mm | 14.3 | 18.5 | 10.8 | 24.7 | 3.7 | 2.2 | 33.0 | 31.3 | 6.3 | 5.7 | 2.3 | | 2.2 | 8.2 | 57.8 |
| | | 406 mm | 14.5 | 14.7 | 14.3 | 21.3 | 1.3 | 0.6 | 47.6 | 27.5 | 2.7 | 2.7 | 0.3 | | 0.6 | 0.0 | 95.2 |
| | ND | 203 mm | 14.3 | 21.0 | 9.2 | 26.5 | 3.0 | 1.9 | 34.9 | 37.4 | 1.0 | 4.5 | 1.9 | | 1.9 | 15.9 | 54.0 |
| | | 305 mm | 15.0 | 22.9 | 8.6 | 27.8 | 5.2 | 3.7 | 27.5 | 37.8 | 1.0 | 7.6 | 3.6 | | 3.7 | 13.7 | 41.3 |
| | D | 203 mm | 12.9 | 13.6 | 12.4 | 18.5 | 1.8 | 1.4 | 42.3 | 25.7 | 0.6 | 1.9 | 1.8 | | 1.4 | 6.8 | 77.8 |
| | | 305 mm | 13.2 | 12.2 | 14.0 | 20.6 | 1.3 | 0.0 | 41.3 | 22.6 | 14.3 | 2.7 | 0.4 | | 0.0 | 0.0 | 82.6 |
| | | 406 mm | 14.5 | 14.7 | 14.3 | 21.3 | 1.3 | 0.6 | 47.6 | 27.5 | 2.7 | 2.7 | 0.3 | | 0.6 | 0.0 | 95.2 |
| Base type | Overall | DGAB | 15.3 | 19.8 | 11.7 | 25.2 | 2.1 | 2.5 | 44.1 | 35.0 | 1.6 | 3.8 | 0.9 | | 2.5 | 15.3 | 72.9 |
| | | ATB | 12.0 | 14.0 | 10.3 | 19.5 | 2.5 | 1.0 | 31.5 | 24.1 | 5.9 | 5.2 | 0.7 | | 1.0 | 1.2 | 61.7 |
| | | ATB/DGAB | 16.8 | 22.2 | 12.5 | 30.9 | 5.2 | 1.9 | 35.8 | 42.5 | 1.8 | 3.1 | 6.7 | | 1.9 | 9.8 | 61.8 |
| | ND | DGAB | 16.9 | 27.7 | 9.2 | 32.2 | 3.2 | 5.5 | 39.5 | 47.9 | 0.9 | 5.5 | 1.6 | | 5.5 | 31.5 | 47.5 |
| | | ATB | 10.7 | 17.1 | 5.2 | 20.1 | 3.9 | 1.0 | 18.3 | 26.7 | 0.3 | 9.7 | 0.1 | | 1.0 | 3.1 | 33.5 |
| | | ATB/DGAB | 16.8 | 22.2 | 12.5 | 30.9 | 5.2 | 1.9 | 35.8 | 42.5 | 1.8 | 3.1 | 6.7 | | 1.9 | 9.8 | 61.8 |
| | D | DGAB | 14.2 | 15.2 | 13.5 | 21.4 | 1.3 | 0.4 | 47.2 | 28.6 | 2.1 | 2.7 | 0.4 | | 0.4 | 4.5 | 89.9 |
| | | ATB | 12.8 | 11.9 | 13.7 | 19.1 | 1.6 | 0.9 | 40.3 | 22.3 | 9.7 | 2.1 | 1.2 | | 0.9 | 0.0 | 80.5 |
| Drainage | Overall | ND | 14.7 | 22.0 | 8.9 | 27.2 | 4.1 | 2.8 | 31.2 | 37.6 | 1.0 | 6.1 | 2.8 | | 2.8 | 14.8 | 47.6 |
| | | D | 13.5 | 13.5 | 13.6 | 20.2 | 1.5 | 0.7 | 43.7 | 25.3 | 5.9 | 2.4 | 0.8 | | 0.7 | 2.3 | 85.2 |
| | DGAB | ND | 16.9 | 27.7 | 9.2 | 32.2 | 3.2 | 5.5 | 39.5 | 47.9 | 0.9 | 5.5 | 1.6 | | 5.5 | 31.5 | 47.5 |
| | | D | 14.2 | 15.2 | 13.5 | 21.4 | 1.3 | 0.4 | 47.2 | 28.6 | 2.1 | 2.7 | 0.4 | | 0.4 | 4.5 | 89.9 |
| | ATB | ND | 10.7 | 17.1 | 5.2 | 20.1 | 3.9 | 1.0 | 18.3 | 26.7 | 0.3 | 9.7 | 0.1 | | 1.0 | 3.1 | 33.5 |
| | | D | 12.8 | 11.9 | 13.7 | 19.1 | 1.6 | 0.9 | 40.3 | 22.3 | 9.7 | 2.1 | 1.2 | | 0.9 | 0.0 | 80.5 |

**Longitudinal Cracking- NWP**

The effects of the design and site factors, in terms of standard deviate, are shown in Figure 5-27. The summary of p-values corresponding to the analyses performed to study the effects of design factors on longitudinal cracking-NWP is presented in Table 5-35. The mean PI corresponding to each comparison presented in Table 5-35 is shown in Table 5-36. The effects of design factors on longitudinal cracking-NWP, based on this analysis, are presented below:

*HMA thickness*: The effect of HMA surface thickness is not significant. Comparable amount of cracking occurred in sections with “thin” and “thick” HMA surface.

*Base thickness*: The effect of base thickness is not significant. On average, sections with 406 mm base have shown slightly lesser cracking than other sections.

*Base Type*: The effect of base type is not significant. Comparable amount of cracking occurred in all sections, irrespective of base type.

*Drainage*: In general, sections with un-drained sections showing higher cracking than those with drainage. However, this effect is not significant. Also, this effect is more apparent among sections located in WF zone.

On the whole, at this point in time, it seems that longitudinal cracking-NWP is not a “structural” distress. It may be more affected by climate. It may be noted that the amount of longitudinal cracking-NWP is higher among sections located in “freeze” climate.

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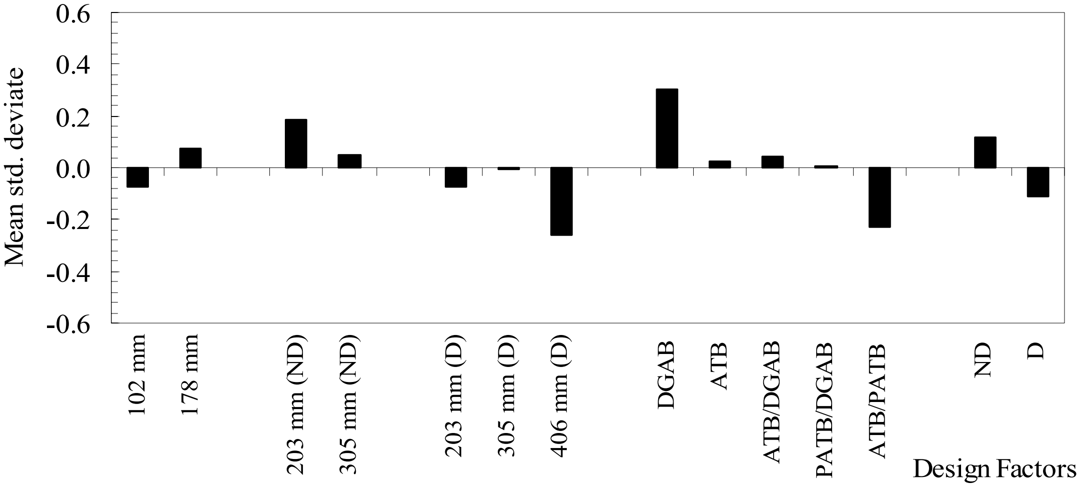
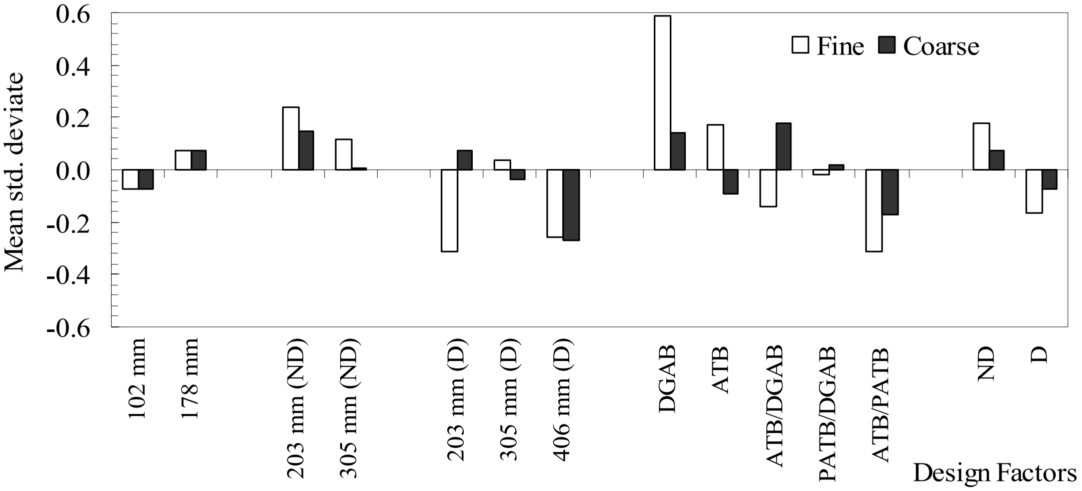
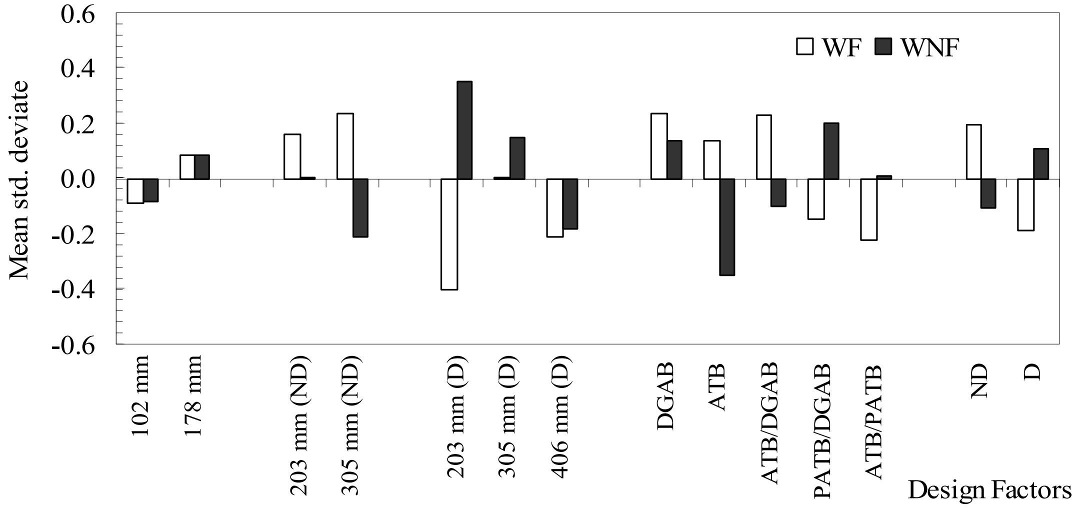


(a) Overall



(b) By subgrade type



(c) By zone type

Figure 5-27 Effect of design factors on longitudinal cracking-NWP (1 inch = 25.4 mm)

Table 5-35 Summary of p-values for comparisons of standard deviates— Longitudinal cracking-NWP

| Design Factor | | Comparison | Overall | By subgrade | | By climatic zone | | | | By subgrade and zone | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Fine | Coarse | WF | WNF | DF | DNF | WF | | WNF | | DF | | DNF | |
| | | | | | | | | | | F | C | F | C | F | C | F | C |
| HMA thickness | | 102 mm vs. 178 mm | 0.304 | 0.510 | 0.440 | 0.430 | 0.490 | 0.120 | 0.230 | 0.250 | 0.940 | 0.460 | 0.790 | | | | |
| Base thickness | Overall | 203 mm vs. 305 mm vs. 406 mm | 0.220 | 0.540 | 0.350 | 0.490 | 0.610 | 0.300 | 0.320 | 0.620 | 0.780 | 0.840 | 0.250 | | | | |
| | ND | 203 mm vs. 305 mm | 0.545 | 0.733 | 0.615 | 0.831 | 0.594 | 0.096 | 0.440 | 0.617 | 0.366 | 0.942 | 0.388 | | | | |
| | D | 203 mm vs. 305 mm vs. 406 mm | 0.467 | 0.513 | 0.513 | 0.523 | 0.377 | 0.919 | 0.584 | 0.146 | 0.988 | 0.415 | 0.090 | | | | |
| Base type | Overall | DGAB vs. ATB vs. ATB/DGAB | 0.280 | 0.390 | 0.420 | 0.620 | 0.500 | 0.760 | 0.042 | 0.960 | 0.430 | 0.630 | 0.650 | | | | |
| | ND | DGAB vs. ATB vs. ATB/DGAB | 0.524 | 0.278 | 0.702 | 0.963 | 0.621 | 0.857 | 0.014 | 0.740 | 0.650 | 0.679 | 0.327 | | | | |
| | D | DGAB vs. ATB | 0.196 | 0.268 | 0.451 | 0.792 | 0.540 | 0.569 | 0.180 | 0.840 | 0.877 | 0.456 | 0.711 | | | | |
| | All Bases | DGAB vs. ATB vs. ATB/DGAB vs. DGAB/PATB vs. ATB/PATB | 0.235 | 0.157 | 0.743 | 0.540 | 0.701 | 0.465 | 0.052 | 0.587 | 0.764 | 0.743 | 0.311 | | | | |
| Drainage | Overall | Drainage vs. No-Drainage | 0.104 | 0.120 | 0.420 | 0.082 | 0.400 | 0.077 | 0.360 | 0.150 | 0.320 | 0.540 | 0.110 | | | | |
| | DGAB | Drainage vs. No-Drainage | 0.220 | 0.190 | 0.660 | 0.330 | 0.880 | 0.380 | 0.330 | 0.280 | 0.790 | 0.580 | 0.420 | | | | |
| | ATB | Drainage vs. No-Drainage | 0.210 | 0.090 | 0.780 | 0.240 | 0.370 | 0.130 | 0.007 | 0.250 | 0.670 | 0.430 | 0.084 | | | | |
| N | | | 184 | 76 | 108 | 76 | 60 | 24 | 24 | 40 | 36 | 24 | 36 | | | | |

Note: Shaded cells show statistically significant at 90% or higher level of confidence.

Table 5-36 Summary of means of PI for longitudinal cracking-NWP

| Design Factors | | Comparison | Overall | By subgrade | | By climatic zone | | | | By subgrade and zone | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | WF | | WNF | | DF | | DNF | |
| | | | | Fine | Coarse | WF | WNF | DF | DNF | F | C | F | C | F | C | F | C |
| HMA thickness | | 102 mm | 47.7 | 35.9 | 55.8 | 78.0 | 14.9 | 77.2 | 6.7 | 59.9 | 97.2 | 13.7 | 15.7 | | 77.2 | 4.1 | 9.3 |
| | | 178 mm | 49.0 | 40.8 | 54.9 | 77.7 | 15.6 | 84.1 | 4.3 | 66.6 | 90.5 | 15.7 | 15.5 | | 84.1 | 0.8 | 7.8 |
| Base thickness | Overall | 203 mm | 48.9 | 37.4 | 56.4 | 79.9 | 16.8 | 84.2 | 4.0 | 65.2 | 93.6 | 14.9 | 18.1 | | 84.2 | 4.2 | 3.8 |
| | | 305 mm | 49.0 | 40.8 | 55.1 | 79.1 | 13.7 | 77.9 | 9.1 | 66.8 | 93.9 | 13.4 | 13.9 | | 77.9 | 1.7 | 16.6 |
| | | 406 mm | 45.4 | 35.0 | 53.5 | 70.5 | 15.1 | 78.6 | 0.0 | 52.6 | 94.3 | 17.3 | 13.6 | | 78.6 | 0.0 | 0.1 |
| | ND | 203 mm | 52.4 | 47.7 | 55.5 | 88.0 | 13.9 | 89.3 | 4.6 | 81.2 | 94.8 | 19.9 | 9.9 | | 89.3 | 3.0 | 6.3 |
| | | 305 mm | 46.9 | 35.9 | 54.6 | 77.9 | 9.8 | 78.1 | 10.1 | 61.1 | 96.6 | 10.4 | 9.4 | | 78.1 | 2.8 | 17.4 |
| | D | 203 mm | 43.6 | 20.4 | 57.7 | 66.7 | 21.2 | 76.6 | 3.1 | 36.6 | 91.8 | 7.4 | 30.3 | | 76.6 | 6.1 | 0.0 |
| | | 305 mm | 52.2 | 47.4 | 55.8 | 80.8 | 19.6 | 77.7 | 7.7 | 74.0 | 89.8 | 18.0 | 20.7 | | 77.7 | 0.0 | 15.5 |
| | | 406 mm | 45.4 | 35.0 | 53.5 | 70.5 | 15.1 | 78.6 | 0.0 | 52.6 | 94.3 | 17.3 | 13.6 | | 78.6 | 0.0 | 0.1 |
| Base type | Overall | DGAB | 47.8 | 34.2 | 56.6 | 77.0 | 16.3 | 79.5 | 10.2 | 58.5 | 94.3 | 14.9 | 17.2 | | 79.5 | 4.6 | 15.7 |
| | | ATB | 48.9 | 41.6 | 54.4 | 77.9 | 15.4 | 80.2 | 2.7 | 65.7 | 93.4 | 16.2 | 14.8 | | 80.2 | 0.7 | 4.7 |
| | | ATB/DGAB | 48.3 | 39.6 | 54.6 | 79.5 | 12.3 | 85.0 | 0.7 | 67.2 | 93.7 | 10.3 | 13.5 | | 85.0 | 1.3 | 0.0 |
| | ND | DGAB | 47.0 | 28.8 | 57.2 | 81.9 | 11.1 | 81.0 | 15.6 | 56.8 | 98.7 | 12.4 | 10.2 | | 81.0 | 5.5 | 25.7 |
| | | ATB | 53.1 | 52.7 | 53.3 | 86.6 | 12.2 | 85.2 | 5.9 | 80.5 | 94.7 | 22.7 | 5.2 | | 85.2 | 1.8 | 9.9 |
| | | ATB/DGAB | 48.3 | 39.6 | 54.6 | 79.5 | 12.3 | 85.0 | 0.7 | 67.2 | 93.7 | 10.3 | 13.5 | | 85.0 | 1.3 | 0.0 |
| | D | DGAB | 48.3 | 37.0 | 56.2 | 74.4 | 19.8 | 78.5 | 6.6 | 59.1 | 91.4 | 16.6 | 21.9 | | 78.5 | 4.1 | 9.1 |
| | | ATB | 46.1 | 33.8 | 55.1 | 71.9 | 17.5 | 76.8 | 0.6 | 55.0 | 92.6 | 11.9 | 21.2 | | 76.8 | 0.0 | 1.3 |
| Drainage | Overall | ND | 49.6 | 41.6 | 55.0 | 82.8 | 11.9 | 83.7 | 7.4 | 70.6 | 95.7 | 15.2 | 9.7 | | 83.7 | 2.9 | 11.9 |
| | | D | 47.2 | 35.4 | 55.7 | 73.1 | 18.6 | 77.6 | 3.6 | 56.9 | 92.0 | 14.2 | 21.6 | | 77.6 | 2.0 | 5.2 |
| | DGAB | ND | 47.0 | 28.8 | 57.2 | 81.9 | 11.1 | 81.0 | 15.6 | 56.8 | 98.7 | 12.4 | 10.2 | | 81.0 | 5.5 | 25.7 |
| | | D | 48.3 | 37.0 | 56.2 | 74.4 | 19.8 | 78.5 | 6.6 | 59.1 | 91.4 | 16.6 | 21.9 | | 78.5 | 4.1 | 9.1 |
| | ATB | ND | 53.1 | 52.7 | 53.3 | 86.6 | 12.2 | 85.2 | 5.9 | 80.5 | 94.7 | 22.7 | 5.2 | | 85.2 | 1.8 | 9.9 |
| | | D | 46.1 | 33.8 | 55.1 | 71.9 | 17.5 | 76.8 | 0.6 | 55.0 | 92.6 | 11.9 | 21.2 | | 76.8 | 0.0 | 1.3 |

### 5.6.4 *Effect of Experimental Factors on Pavement Response*

This section of the report is a discussion of the results from analyses of FWD data (pavement response) of the SPS-1 sections. Three parameters were chosen for analyses – peak deflection under FWD load ($d_0$), far-sensor deflection ($d_6$), and AREA. The peak deflection under FWD load is indicative of the "overall capacity" of the pavement structure while the far-sensor deflection is illustrative of the subgrade "strength". The AREA is the area under the first three feet of the deflection basin. The computational details regarding the AREA can be found in the reference "LTPP Data Analysis: Feasibility of Using FWD Deflection Data to Characterize Pavement Construction Quality", NCHRP Project 20-50 [7], by Richard N. Stubstad, October 2002. The AREA is indicative of stiffness of the upper layers of the pavement relative to the stiffness of the underlying layers. Higher the AREA higher is the stiffness of upper layers in relation to underlying layers.

An ANOVA was conducted with the peak deflection under the FWD load plate (do), the far sensor deflection at 60 inches from the FWD load (d6) and the AREA as the dependent variables. All the response parameters have been calculated using the initial deflections of the test sections.

It should be noted that the pavement surface temperature at the time of testing was taken as a covariate along with the age at the time of testing and variability in the HMA and base layer thicknesses. The natural logarithmic transformation has been applied to the three response indicators to fulfill the ANOVA assumptions. The results from ANOVA are summarized in Tables 5-37 and 5-38. The brief discussion of the results is given below:

Peak Deflection under FWD Load ($d_0$)

When only design factors were considered by blocking the site effects, interactions between HMA thickness and base type (p=0.043), base thickness and base type (p=0.000), base type and drainage (p=0.000), have shown significant effects on the peak deflection.

Among the pavement sections built on DGAB, those with 102 mm HMA thickness have shown higher peak deflection than those with 178 mm HMA thickness. Also as expected, thicker bases for each base type have helped in reducing the peak deflection. However, the reduction in peak deflection was more significant in the case of ATB and ATB/DGAB base types. Furthermore, among pavement sections built on DGAB, those with drainage have shown lesser peak deflections than those without drainage. As mentioned before, DGAB with drainage refers to PATB/DGAB with drainage. It was assumed in the experiment, to study the effect of drainage among sections with DGAB that PATB has the same structural "strength" as DGAB. This assumption appears to be invalid from above result.

When all the site and design factors were considered simultaneously along with the two-way interactions between the main factors, the interaction between subgrade soil and climatic zone (p=0.005) was found to have a very significant effect on the peak deflection.

Among the pavement sections located in "wet" climates, those built on fine-grained subgrade soils have a significantly higher peak deflection ($d_0$) as compared to those built on coarse-grained subgrade soils. This effect is more prominent on pavements located in WNF zone than those located in WF zone.

Far Sensor Deflection ($d_6$)

When only design factors were considered by blocking the site effects, the main effects of base type (p=0.000), base thickness (p=0.005) and drainage (p=0.012) have significant effects on the far-sensor deflection (60-inches away from the center of the load).

Pavement sections built on DGAB bases have shown higher far-sensor deflections than those built on other base types. Pavement sections constructed on 203 mm bases have also shown significantly higher far-sensor deflections than those built on 305 mm or 406 mm bases. Furthermore, sections built with drainage have lesser far-sensor deflections than those without drainage. This effect can be attributed to PATB as the effect of drainage and the effect of PATB cannot be separated (confounded).

When all the site and design factors were considered simultaneously along with the two-way interactions between the main factors, an interaction between subgrade type and climatic zone (p=0.000) was found to have a significant effect on the far-sensor deflections. Among pavement sections located in "wet" climate, those built on fine-grained subgrade soils have higher deflections than those built on coarse-grained soils. This effect is significant among sections located in WNF zone.

The ANOVA results also show that HMA thickness and pavement mid depth temperature do not have a significant affect on the far-sensor deflection. The results seem reasonable, as this deflection ($d_6$) represent the subgrade strength, which is independent of the HMA thickness and pavement temperature.

AREA

When only design factors are considered by blocking the site effects, the interactions between HMA thickness and base type (p=0.002), base thickness and base type (p=0.03), and, drainage and base type (p=0.000) have shown significant effects on AREA.

Among pavement sections built on DGAB, those with "thin" HMA surface layer have significantly lower AREA values compared to those with "thick" HMA surface layer, implying that the upper layers of these pavement sections are "less stiff". Also, the increase in HMA thickness from 102 to 178 mm on ATB does not significantly increase AREA.

For sections built on DGAB, increasing base thickness from 8 to 12 inches has not shown a significant effect on AREA; however a two-fold increase in base thickness (from 8 to16 inch) has shown a significant increase in AREA. Also, base thickness does not seem to have a significant effect on AREA in pavement sections with ATB bases.

Among the pavement sections constructed on DGAB, those with drainage have a significantly different AREA compared to those without drainage; test sections with drainage have higher AREA, implying higher stiffness. This indicates that the structural capacity of the PATB layer is somewhat higher than that of the DGAB.

When all the site and design factors were considered simultaneously along with the two-way interactions between the main factors, the interaction between subgrade type and climatic zone (p=0.000) was found to have a very significant effect on AREA. Among the pavement sections located in WNF zone, those built on fine-grained subgrade soils have significantly higher AREA values than those built on coarse-grained soils. However, in the case of sections located in WF zone, this effect is not significant indicating that AREA could be independent of the subgrade soil type.

Table 5-37 Summary of p-values from ANOVA for determining the effect of design factors on flexible pavement response — Overall

| Design Factor | Performance Measures | | |
|---|---|---|---|
| | Peak Deflection ($d_o$) | Far Deflection ($d_6$) | AREA |
| HMA thickness | 0.000 | 0.560 | 0.000 |
| Base type | 0.000 | 0.000 | 0.000 |
| Base thickness | 0.000 | 0.005 | 0.214 |
| Drainage | 0.590 | 0.012 | 0.000 |
| Mid depth temperature | 0.000 | 0.738 | 0.000 |
| Site (blocked) | 0.000 | 0.000 | 0.000 |
| | $R^2$=0.884<br>N=210 | $R^2$=0.864<br>N=210 | $R^2$=0.854<br>N=210 |

Table 5-38 Summary of p-values from ANOVA for determining the effect of site factors on flexible pavement response — Overall

| Design Factor | Performance Measures | | |
|---|---|---|---|
| | Peak Deflection ($d_o$) | Far Deflection ($d_6$) | AREA |
| Subgrade | 0.000 | 0.000 | 0.353 |
| Zone | 0.000 | 0.000 | 0.000 |
| Subgrade*Zone | 0.005 | 0.005 | 0.005 |
| Mid depth temperature | 0.000 | 0.495 | 0.000 |
| | $R^2$=0.865<br>N=210 | $R^2$=0.658<br>N=210 | $R^2$=0.682<br>N=210 |

## 5.7 APPARENT RELATIONSHIP BETWEEN RESPONSE AND PERFORMANCE

In this section of the report the observations regarding apparent relationships between flexible pavement response (FWD testing) and performance are presented. The usefulness of such relationships can be divided into two categories:

- Explanatory: To provide an explanatory information for a given performance trend. For example, a relationship between AC rutting and the farthest sensor deflection would indicate that rutting is related to the subgrade soil.
- Predictive: To provide a predictive capability of the future level of a given performance measure. For example, the initial high average deflection of a section may explain its future cracking and rutting (due to subgrade) performance.

Explanatory relationships were established using multiple regressions on data from all the test sections in the experiment. Predictive relationships were established based on bivariate correlation analyses at the site level, and using scatter plots on data from all sections. The DLR data were used for predictive relationships regarding the instrumented sections in Ohio.

### *5.7.1 Overall Analysis—Explanatory Relationships*

In this section, the entire population of the SPS-1 experiment was used to seek apparent explanatory relationships between response and performance. This analysis was done irrespective of the experimental design matrix layout, since pavement response should reflect the effects of the various structural designs. In other words, the analysis spans over all the SPS-1 sections, as opposed to it being restricted to individual structural designs. The spatial variability of the deflections and deflection-based indices (within a section) was considered by taking the 95th percentile within each section. As deflection on all sections was measured during different seasons and times, the impact of temperature and moisture conditions cannot be ignored. Additionally the deflection and deflection-based parameters (SCI, BDI etc.,) are influenced by variety of factors, such as:

- Asphalt temperature (at mid depth)
- Thickness of asphalt layer
- The layer moduli of various layers and overall pavement structure
- Subgrade strength
- Apparent stiff layer depth

- Pavement distresses etc.

To consider the effect of various variables on the response at the same time, the multiple linear regression technique was used. The pavement response parameters (surface deflection ($d_0$), SCI and BDI) were taken as dependent variables and all other variables (temperature, asphalt thickness, subgrade strength and pavement distresses) were considered as independent variables. As expected, the surface deflection is significantly correlated with the asphalt layer thickness, mid-depth asphalt temperature, and deflection at the outer most sensors that represents the subgrade strength. Furthermore, fatigue cracking, longitudinal cracking-WP and transverse cracking in all the sections have shown statistically significant relationships with the surface deflection. The results of multiple regression analyses within each zone have also shown that, on average, fatigue and transverse cracking has a significant positive effect on the surface deflection. An example of such multiple regression models is given by the following equation:

$$\ln(d_o) = 3.694 + 0.17T - 0.085H_{ac} - 0.031Age + 0.602\ln(d_6) + 0.001AC + 0.004TC + 0.001LCWP$$

($R^2$=0.856, *SE=0.269*)

where: *ln* is the natural logarithm
T is the mid-depth asphalt concrete temperature (C)
$H_{ac}$ is the HMA layer thickness
Age is the age of the pavement section at the time of FWD testing
AC is alligator cracking (sqm) at the time of testing
TC is transverse cracking length (m)
LCNWP is longitudinal cracking not in the wheel path (m)

The sensitivity analysis of the regression model for overall SPS-1 database was performed to observe the explanatory relationships between various independent variables with the surface deflection ($d_0$) under the FWD load plate. The following conclusions can be made from these results:

- The effect of asphalt thickness on the measured surface deflection ($d_0$) is very significant (*p=0.000*). The thicker the HMA layer, the lower the deflection will be.
- Mid-depth asphalt temperature at the time of testing has a significant positive effect on $d_0$ (*p=0.000*).
- The age of the pavement has indicated a negative effect on $d_0$ (*p=0.000*). Aging effect on HMA pavement may cause the stiffening of asphalt thus may reduce the deflections.

- The higher the "subgrade" deflection, d6 (deflection at the outer most sensor, or 60 inches in this case), the higher $d_0$ will be ($p=0.000$).
- Fatigue cracking ($p=0.000$), longitudinal cracking-WP ($p=0.006$) and longitudinal cracking-NWP ($p=0.012$) have a significant positive effect on $d_0$; i.e., higher cracking will cause an increase in $d_0$.
- Similarly, transverse cracking has a significantly positive effect on $d_0$ ($p=0.001$).

### *5.7.2 Site Level Analyses— Predictive Relationships*

This section summarizes the findings regarding predictive relationships between initial response (FWD deflection or deflection-based indices) and future pavement performance (cracking, rutting and roughness), at the site level. Various deflection-based indices [7, 8] were calculated based on the individual deflection basins for each section; these indices include:

- AREA (the area under first three feet of deflection basin),
- SCI─ Surface Curvature Index, (d0 – d12),
- BDI─ Base Damage Index, [8](d12 – d24),
- d36 ─ (d0-d36),
- do (peak deflection under the load),
- d6 (farthest deflection at 60 inches away from the load),
- ES (effective stiffness of upper (bound) layer), and
- Eg (subgrade modulus calculated from surface deflection at 36 inches from the load).

Bivariate correlation analyses between response parameters (deflections or deflection basin parameters) and performance (cracking, rutting and roughness) were conducted for all the states within SPS-1 experiment. The latest performance for each section within the SPS-1 experiment was used in these analyses. The effect of temperature on the measured deflection was taken into account by applying a temperature correction [9] . It is to be noted that for a site age, traffic, construction, material properties and environment are the same and thus this provides a good opportunity for seeking apparent relationships.

Figure 5-28 and Figure 5-29 are examples of bivariate relationships between SCI and AREA with fatigue cracking. The site in the state of Kansas (20) was chosen for this example because of high extent of cracking at the site. It can be seen that for the sections in this site, initial SCI and initial AREA have a slight association ($\rho = 0.4$) with the future fatigue cracking, in that higher the SCI or lower the AREA, higher is the cracking. Similarly, Figure 5-31 is the relationship between BDI and future rutting for the same site. In this case, BDI has a strong correlation ($\rho = 0.77$) with future rutting i.e. sections that had higher initial BDI have higher rutting at a later stage. Also, Figure 5-30 shows the variation in future roughness (IRI) as a function of BDI. In this case, BDI has a correlation ($\rho = 0.42$) with the future roughness of all the pavement sections for this site (KS (20)).

Figure 5-32 and Figure 5-33 show relationships of roughness and rut depth with BDI and AREA for the sections in the site of OH (39). Strong correlations ($\rho = 0.85$ each) were observed between future roughness and rut depth. Sections that had higher initial BDI had higher future roughness, and sections with lower AREA had higher future rutting.

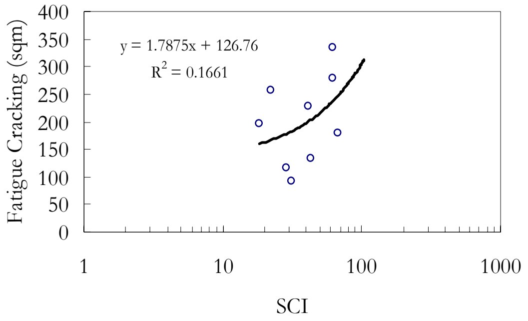


Figure 5-28 Fatigue cracking and SCI relationship— State (20) Kansas

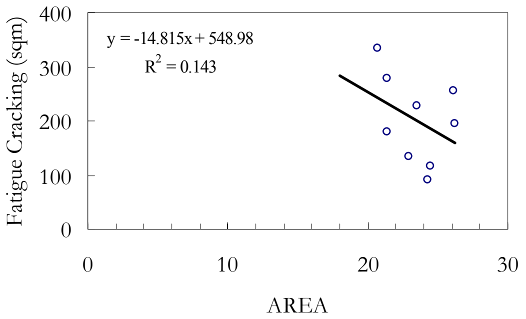


Figure 5-29 Fatigue cracking and AF relationship— State (20) Kansas

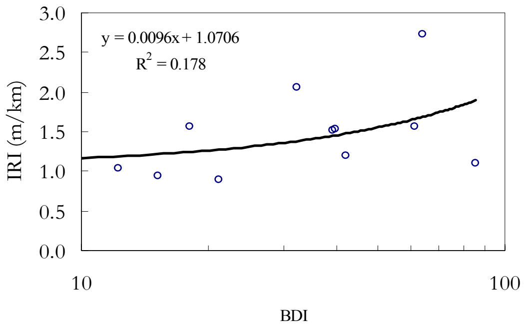


Figure 5-30 Roughness and BDI relationship— State (20) Kansas

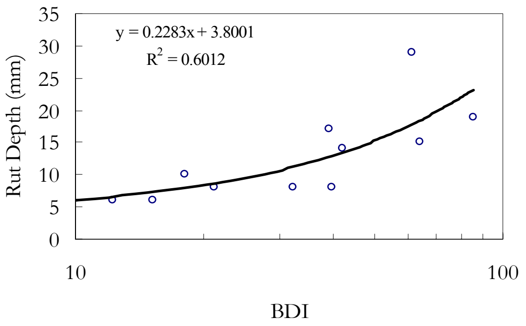


Figure 5-31 Rut depth and BDI relationship— State (20) Kansas

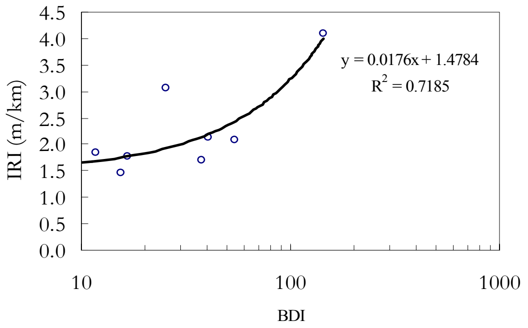


Figure 5-32 Roughness and BDI relationship— State (39) Ohio

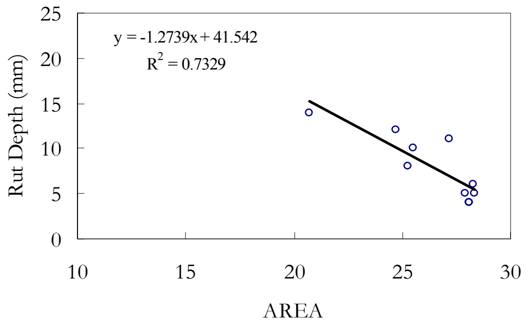


Figure 5-33 Rut depth and AF relationship— State (39) Ohio

Tables 5-39 through 5-41 are summaries of correlation coefficients from the bivariate analyses for three performances (fatigue cracking, rutting and roughness) and various deflection parameters between all the sites.

The results show that fifteen out of seventeen sites have a consistent trend of relationship between AREA, BDI, $d_o$ and future cracking. Also, fourteen out of seventeen sites have a positive association between SCI and fatigue cracking. On an average, AREA, SCI and BDI have reasonable associations with fatigue cracking for all the sites in SPS-1 experiment. Sections that have higher fatigue cracking had higher initial SCI or BDI, and lower AREA.

The deflection basin parameters do not have a consistent association with rutting across the sites (see Table 5-40). This inconsistency may be explained in light of different rutting mechanisms for flexible pavements i.e., structural or asphalt mix rutting.

Consistent trends were observed only between BDI and future roughness across most of the sites (15 out of 17 sites) in the SPS-1 experiment (see Table 5-41). Sections that had higher BDI have higher roughness.

Apparent relationships between AREA and various performance measures (fatigue cracking, rutting and roughness) were found to be significant within sites that have shown considerable distress. Higher AREA means stiffer upper layers of a pavement. Sections that had higher AREA exhibited lesser cracking, rutting and roughness. Based on the magnitude of correlation coefficients, it was also found that sections that had stiffer bound layers are more likely to exhibit cracking than (structural) rutting.

Table 5-39 Summary of correlations for deflections and DBPs with fatigue cracking

| State | | *Area* | *ES/Esg* | *ES* | *Esg* | *d0* | *d6* | *SCI* | *BDI* | Zone | SG |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 31 | Nebraska | -0.79 | -0.66 | -0.64 | -0.37 | 0.90 | 0.43 | 0.94 | 0.91 | WF | F |
| 26 | Michigan | 0.48 | 0.59 | 0.42 | 0.21 | -0.42 | -0.03 | -0.46 | -0.45 | WF | F |
| 19 | Iowa | -0.45 | -0.11 | -0.09 | 0.05 | 0.41 | 0.15 | 0.55 | 0.49 | WF | F |
| 20 | Kansas | -0.38 | -0.26 | -0.25 | -0.14 | 0.33 | -0.01 | 0.41 | 0.30 | WF | F |
| 39 | Ohio | -0.66 | -0.44 | -0.44 | -0.43 | 0.58 | 0.20 | 0.63 | 0.63 | WF | F |
| 55 | Wisconsin | -0.46 | -0.38 | -0.37 | -0.02 | 0.38 | 0.04 | 0.51 | 0.22 | WF | C |
| 10 | Delaware | -0.93 | -0.78 | -0.65 | -0.04 | 0.72 | -0.03 | 0.93 | 0.73 | WF | C |
| 5 | Arkansas | -0.07 | -0.02 | -0.19 | -0.54 | 0.34 | 0.59 | 0.17 | 0.34 | WF | C |
| 51 | Virginia | -0.72 | -0.57 | -0.58 | -0.32 | 0.75 | 0.04 | 0.79 | 0.75 | WNF | F |
| 1 | Alabama | -0.79 | -0.68 | -0.64 | -0.08 | 0.72 | -0.27 | 0.75 | 0.73 | WNF | F |
| 48 | Texas | -0.48 | -0.33 | -0.57 | -0.49 | 0.74 | 0.65 | 0.78 | 0.58 | WNF | C |
| 40 | Oklahoma | -0.47 | -0.43 | -0.59 | -0.16 | 0.25 | -0.05 | 0.28 | 0.28 | WNF | C |
| 12 | Florida | -0.40 | -0.37 | -0.40 | 0.14 | 0.50 | -0.12 | 0.46 | 0.55 | WNF | C |
| 30 | Montana | -0.36 | -0.31 | -0.58 | -0.74 | 0.53 | 0.83 | 0.34 | 0.42 | DF | C |
| 32 | Nevada | -0.49 | -0.355 | -0.31 | 0.10 | 0.38 | -0.17 | 0.41 | 0.29 | DF | C |
| 35 | New Mexico | 0.19 | 0.22 | 0.33 | -0.14 | 0.31 | -0.01 | -0.14 | 0.60 | DNF | F |
| 4 | Arizona | -0.13 | -0.22 | 0.06 | 0.53 | -0.10 | -0.55 | -0.03 | -0.03 | DNF | C |
| (-) ρ | | 15 | 15 | 14 | 12 | 2 | 9 | 3 | 2 | | |
| (+) ρ | | 2 | 2 | 3 | 5 | 15 | 8 | 14 | 15 | | |
| Mean | | -0.41 | -0.30 | -0.32 | -0.14 | 0.43 | 0.10 | 0.43 | 0.43 | | |
| Std | | 0.36 | 0.34 | 0.34 | 0.32 | 0.33 | 0.35 | 0.38 | 0.33 | | |
| CoV | | 0.89 | 1.12 | 1.03 | 2.21 | 0.76 | 3.55 | 0.89 | 0.76 | | |

Note: The SPS-1 sections in State 22 (Louisiana) are young and have not shown any significant distress therefore, are not included in this analysis.

Table 5-40 Summary of correlations for deflections and DBPs with rut depth

| State | | *Area* | *ES/Esg* | *ES* | *Esg* | *d0* | *d6* | *SCI* | *BDI* | Zone | SG |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 31 | Nebraska | -0.45 | -0.48 | -0.24 | 0.29 | 0.28 | 0.06 | 0.41 | 0.29 | WF | F |
| 26 | Michigan | 0.32 | 0.53 | 0.41 | 0.10 | -0.14 | -0.04 | -0.16 | -0.14 | WF | F |
| 19 | Iowa | -0.56 | -0.43 | -0.41 | -0.22 | 0.40 | 0.13 | 0.43 | 0.46 | WF | F |
| 20 | Kansas | -0.80 | -0.55 | -0.59 | -0.23 | 0.76 | 0.11 | 0.82 | 0.78 | WF | F |
| 39 | Ohio | -0.86 | -0.88 | -0.88 | -0.72 | 0.79 | 0.51 | 0.75 | 0.76 | WF | F |
| 55 | Wisconsin | 0.26 | 0.31 | 0.37 | 0.37 | -0.60 | -0.45 | -0.48 | -0.65 | WF | C |
| 10 | Delaware | -0.72 | -0.55 | -0.62 | -0.25 | 0.66 | 0.37 | 0.73 | 0.61 | WF | C |
| 5 | Arkansas | 0.37 | 0.51 | 0.51 | 0.03 | -0.11 | -0.02 | -0.20 | -0.03 | WF | C |
| 51 | Virginia | -0.58 | -0.40 | -0.39 | -0.22 | 0.69 | 0.02 | 0.78 | 0.68 | WNF | F |
| 1 | Alabama | -0.51 | -0.34 | -0.26 | 0.23 | 0.63 | -0.30 | 0.73 | 0.69 | WNF | F |
| 48 | Texas | 0.65 | 0.62 | 0.80 | 0.37 | -0.67 | -0.28 | -0.65 | -0.62 | WNF | C |
| 40 | Oklahoma | 0.02 | 0.23 | -0.15 | -0.43 | 0.60 | 0.67 | 0.54 | 0.55 | WNF | **C** |
| 12 | Florida | 0.56 | 0.60 | 0.40 | -0.62 | -0.33 | 0.66 | -0.44 | -0.39 | WNF | C |
| 30 | Montana | -0.62 | -0.66 | -0.70 | -0.59 | 0.68 | 0.56 | 0.60 | 0.63 | DF | C |
| 32 | Nevada | 0.05 | -0.002 | -0.03 | -0.31 | 0.03 | 0.13 | -0.10 | 0.25 | DF | C |
| 35 | New Mexico | 0.35 | 0.27 | 0.31 | -0.24 | -0.46 | 0.25 | -0.47 | -0.09 | DNF | F |
| 4 | Arizona | -0.19 | -0.31 | -0.33 | -0.20 | 0.06 | 0.02 | 0.05 | 0.04 | DNF | C |
| (-) ρ | | 9 | 10 | 11 | 11 | 6 | 5 | 7 | 6 | | |
| (+) ρ | | 8 | 7 | 6 | 6 | 11 | 12 | 10 | 11 | | |
| Mean | | -0.16 | -0.09 | -0.11 | -0.16 | 0.19 | 0.14 | 0.20 | 0.22 | | |
| Std | | 0.51 | 0.50 | 0.49 | 0.34 | 0.51 | 0.33 | 0.52 | 0.48 | | |
| CoV | | 3.22 | 5.46 | 4.65 | 2.20 | 2.61 | 2.33 | 2.66 | 2.13 | | |

Note: The SPS-1 sections in State 22 (Louisiana) are young and have not shown any significant distress therefore, are not included in this analysis.

Table 5-41 Summary of correlations for deflections and DBPs with IRI

| State | | *Area* | *ES/Esg* | *ES* | *Esg* | *d0* | *d6* | *SCI* | *BDI* | Zone | SG |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 31 | Nebraska | -0.61 | -0.44 | -0.54 | -0.43 | 0.66 | 0.49 | 0.62 | 0.72 | WF | F |
| 26 | Michigan | -0.75 | -0.71 | -0.78 | -0.82 | 0.78 | 0.74 | 0.73 | 0.76 | WF | F |
| 19 | Iowa | -0.53 | -0.31 | -0.28 | 0.04 | 0.18 | -0.12 | 0.30 | 0.25 | WF | F |
| 20 | Kansas | -0.34 | -0.31 | -0.38 | -0.38 | 0.40 | -0.16 | 0.27 | 0.42 | WF | F |
| 39 | Ohio | -0.79 | -0.65 | -0.65 | -0.58 | 0.84 | 0.37 | 0.85 | 0.85 | WF | F |
| 55 | Wisconsin | 0.37 | 0.45 | 0.50 | 0.23 | -0.54 | -0.04 | -0.46 | -0.54 | WF | C |
| 10 | Delaware | -0.71 | -0.60 | -0.68 | -0.36 | 0.73 | 0.28 | 0.68 | 0.76 | WF | C |
| 5 | Arkansas | -0.02 | -0.03 | -0.17 | -0.41 | 0.21 | 0.42 | 0.05 | 0.21 | WF | C |
| 51 | Virginia | -0.70 | -0.50 | -0.55 | -0.38 | 0.78 | 0.06 | 0.83 | 0.77 | WNF | F |
| 1 | Alabama | -0.47 | -0.32 | -0.31 | -0.31 | 0.69 | 0.23 | 0.66 | 0.69 | WNF | F |
| 48 | Texas | 0.38 | 0.44 | 0.36 | -0.17 | -0.11 | 0.15 | -0.20 | -0.09 | WNF | C |
| 40 | Oklahoma | 0.45 | 0.49 | 0.25 | -0.35 | 0.17 | 0.56 | 0.10 | 0.10 | WNF | C |
| 12 | Florida | -0.31 | -0.31 | -0.42 | 0.14 | 0.47 | -0.15 | 0.38 | 0.51 | WNF | C |
| 30 | Montana | -0.55 | -0.61 | -0.69 | -0.62 | 0.63 | 0.62 | 0.50 | 0.55 | DF | C |
| 32 | Nevada | -0.47 | -0.229 | -0.20 | -0.16 | 0.71 | 0.44 | 0.72 | 0.68 | DF | C |
| 35 | New Mexico | 0.39 | 0.50 | 0.49 | -0.31 | -0.02 | 0.33 | -0.35 | 0.29 | DNF | F |
| 4 | Arizona | -0.56 | -0.46 | -0.47 | -0.08 | 0.63 | 0.05 | 0.64 | 0.65 | DNF | C |
| (-) ρ | | 13 | 13 | 13 | 14 | 3 | 4 | 3 | 2 | | |
| (+) ρ | | 4 | 4 | 4 | 3 | 14 | 13 | 14 | 15 | | |
| Mean | | -0.31 | -0.21 | -0.27 | -0.29 | 0.43 | 0.25 | 0.37 | 0.45 | | |
| Std | | 0.44 | 0.42 | 0.42 | 0.27 | 0.39 | 0.28 | 0.41 | 0.37 | | |
| CoV | | 1.44 | 2.00 | 1.57 | 0.93 | 0.91 | 1.12 | 1.11 | 0.83 | | |

Note: The SPS-1 sections in State 22 (Louisiana) are young and have not shown any significant distress therefore, are not included in this analysis.

### *5.7.3 Overall Analyses— Predictive Relationships*

This section summarizes the findings of apparent relationships between initial response (FWD deflection or deflection base indices) and future pavement performance (cracking, rutting and roughness), based on data from all the test sections in the SPS-1 experiment. The relationships were explored using bivariate scatter plots between selected response parameters and performance measures for all the pavements in the experiment.

Though the sites differ in age, traffic, climate, and materials this analysis are intended to use the wealth of data from all the sections in the experiment. Moreover, the variation in age of the sites may not be very critical at this point in time as no definitive trends were observed between pavement age and performance (see Figure 5-34). Also, it is assumed in this analysis that deflection basin parameters (pavement response) will "characterize" the structural features such as HMA surface thickness, base type and base thickness. In other words, pavement response was assumed to be strongly correlated with the structural capacity of the pavement. In order to account for the effects of subgrade type and climate, relationships were explored for different subgrade soil types (fine- and coarse-grained soils) and climates (WF, WNF, DF and DNF).

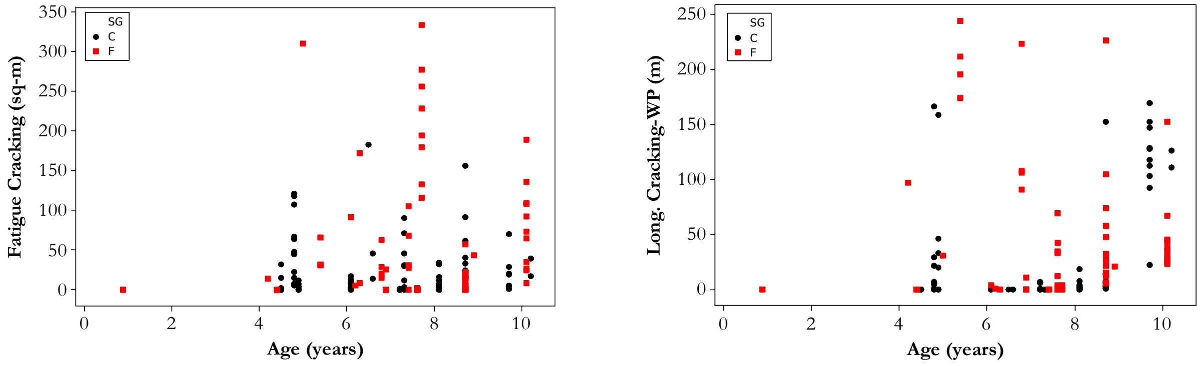
Figure 5-35 shows a scatter plot between SCI (from initial response) and fatigue cracking. Among pavements constructed on fine-grained soils, ones with higher initial SCI have more cracking, especially in WNF zone. Similarly, from Figure 5-36 it seems that stiffer pavements (higher AREA) on fine-grained soils, especially if located in WF climatic zone, have higher fatigue cracking.

Higher longitudinal cracking-WP was observed for the pavement sections with higher initial AREA, especially among pavements located in WNF climatic zone (see Figure 5-37). The observation may imply that pavements with stiffer structural layers are more likely to exhibit this distress. No apparent relation was observed between AREA and longitudinal cracking-NWP (see Figure 5-38). The distress was found to be independent of the structural capacity (AREA) of various pavements. Thus the probable cause of this distress type may be the environment and not the loading (traffic).

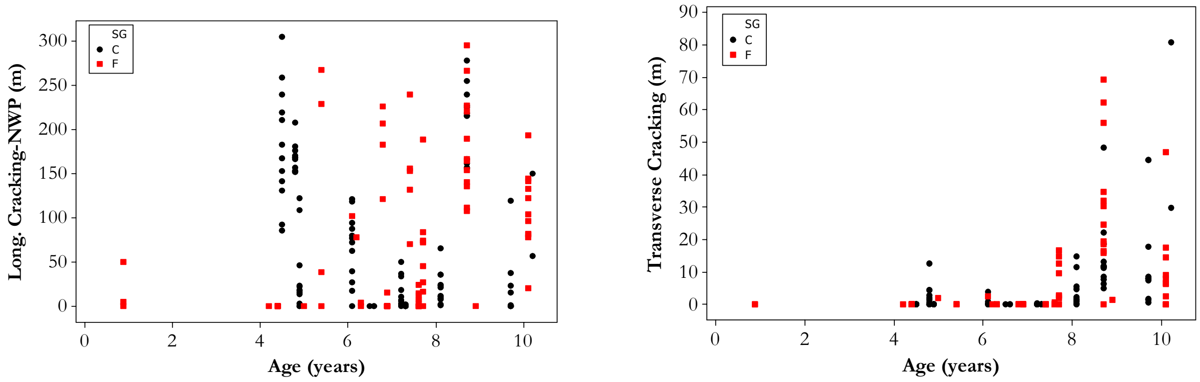
Figure 5-39 shows a scatter plot between AREA and transverse cracking. No apparent trend was observed in the plot. This could imply that this distress type is not load-related and probably caused by the environment.

The apparent relationship between initial BDI and rutting is shown in Figure 5-40. It seems that among pavements constructed on fine-grained soils and located in WF zone, those with higher BDI experienced higher rutting. It can also be observed that some pavements with less BDI (stronger structure) have experienced higher rutting as compared to pavements with high BDI. These pavements could have experienced mix-related rutting (not structural rutting).

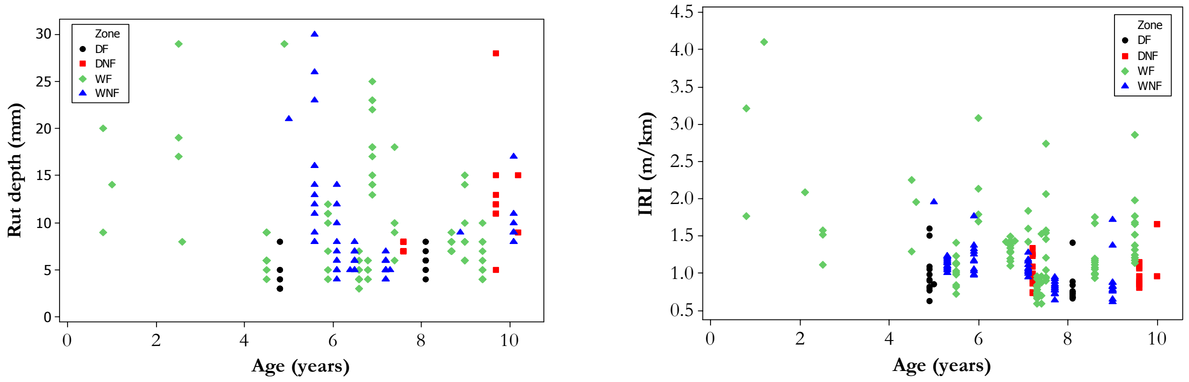
Figure 5-41 is the scatter plot between BDI and latest IRI. It seems that among pavements constructed on fine-grained soils and located in WF zone, those with higher BDI developed higher roughness.



(a) Fatigue cracking (b) Long. cracking-WP

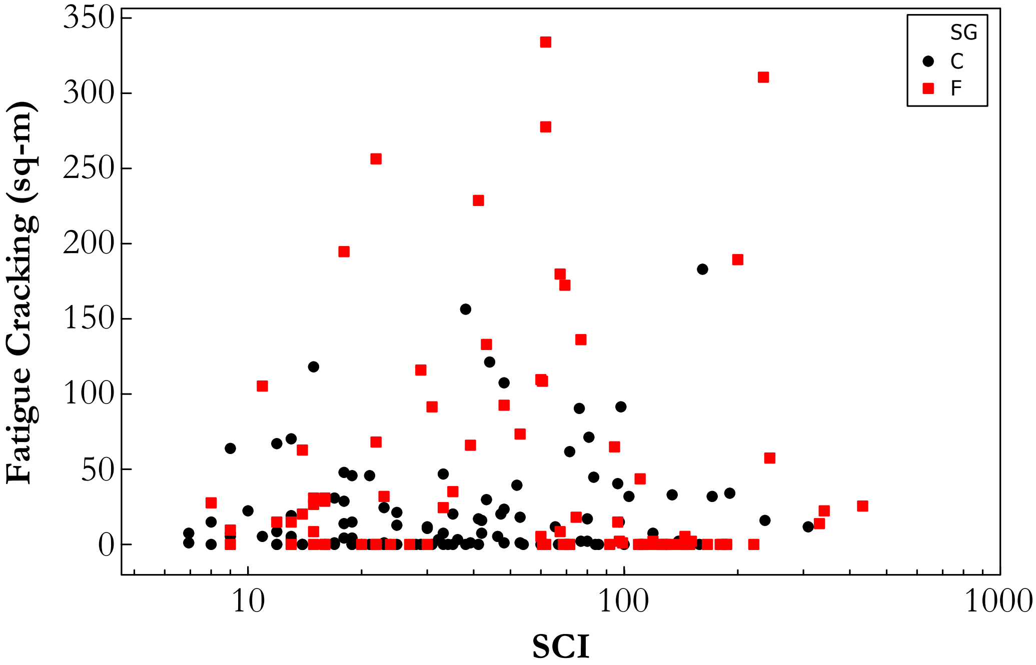


(c) Long. cracking-NWP (d) Transverse cracking

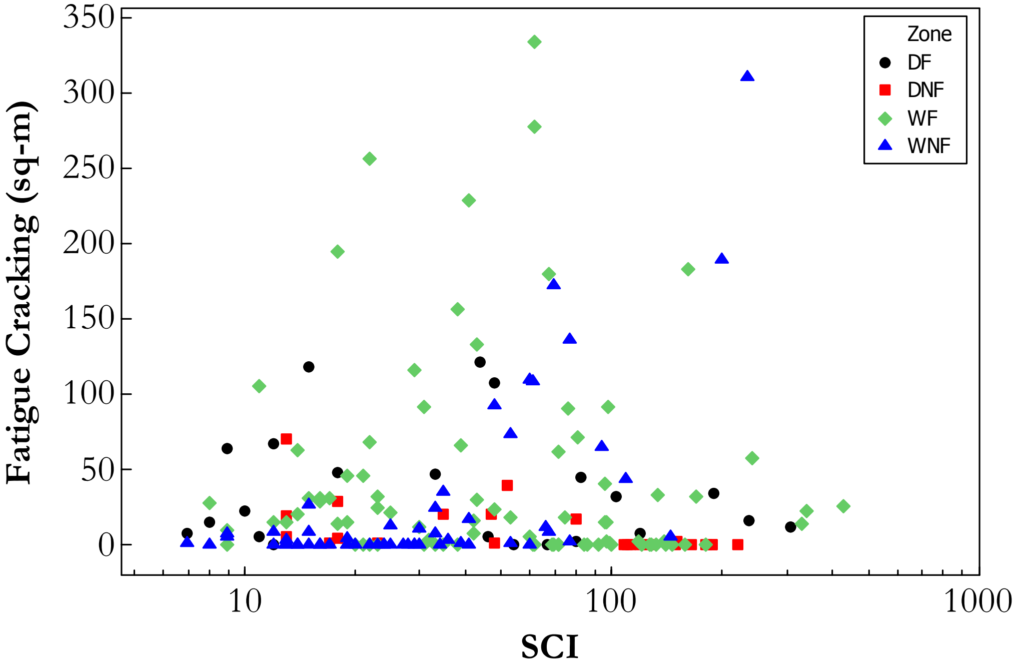


(e) Rut depth (f) Roughness

Figure 5-34 Relationships between age and different performance measures

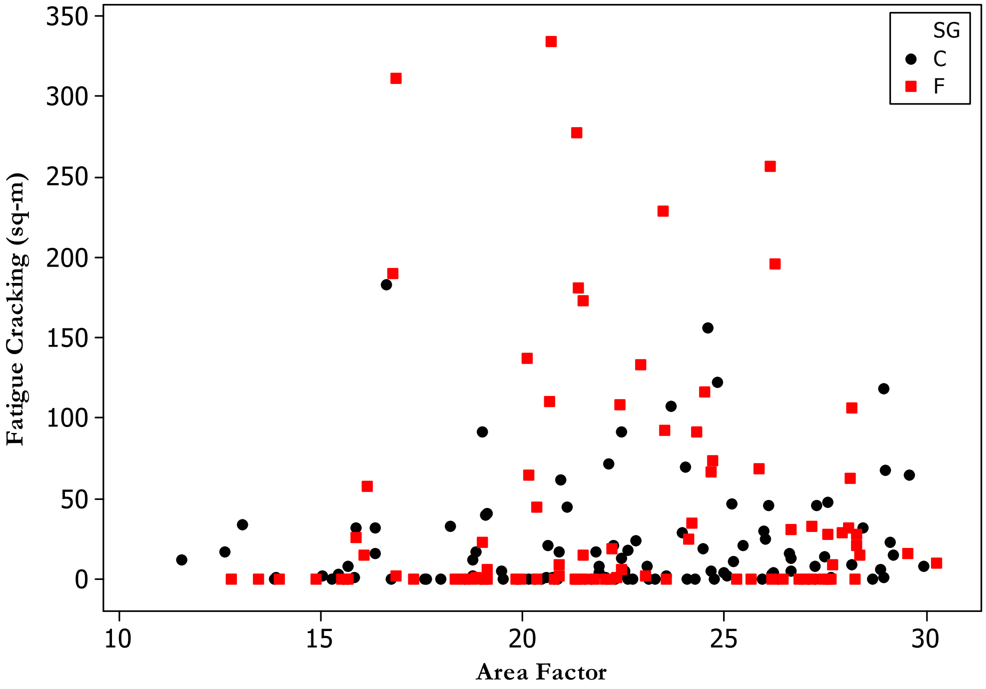


(a) Effect by subgrade soil type

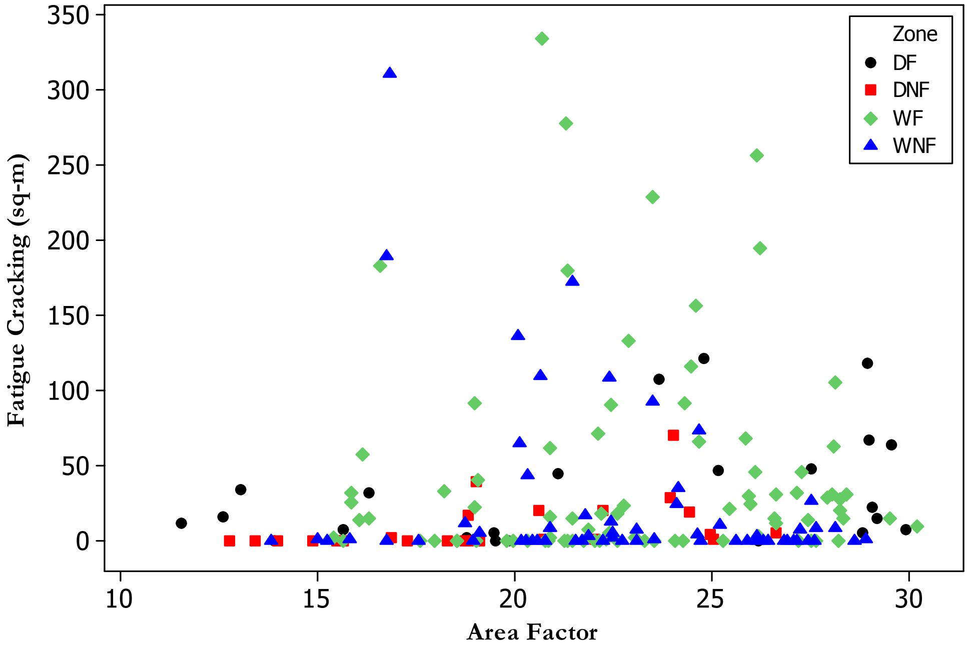


(b) Effect by climatic zone

Figure 5-35 Apparent relationships between SCI and fatigue cracking

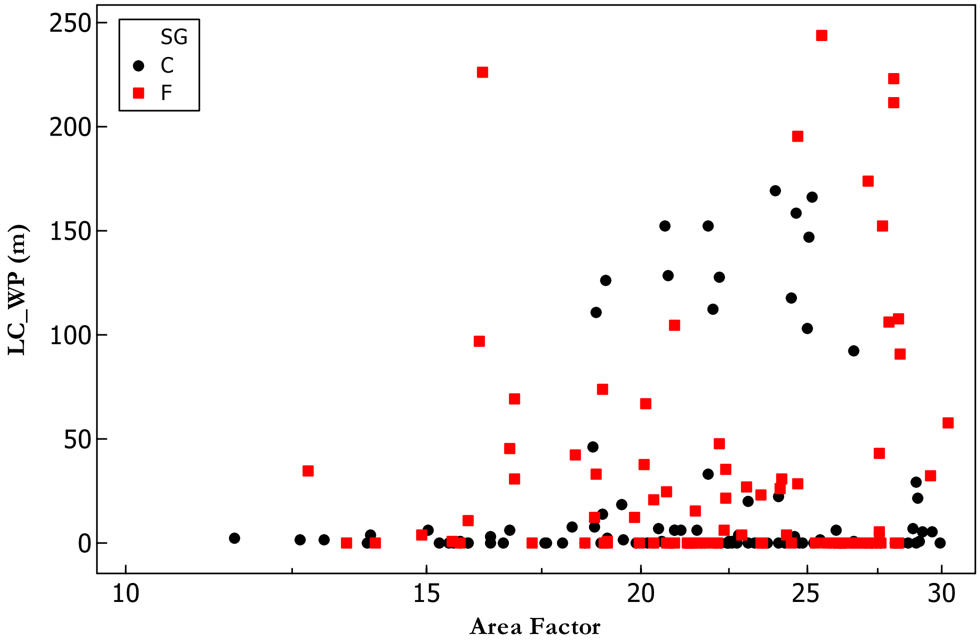


(a) Effect by subgrade soil type

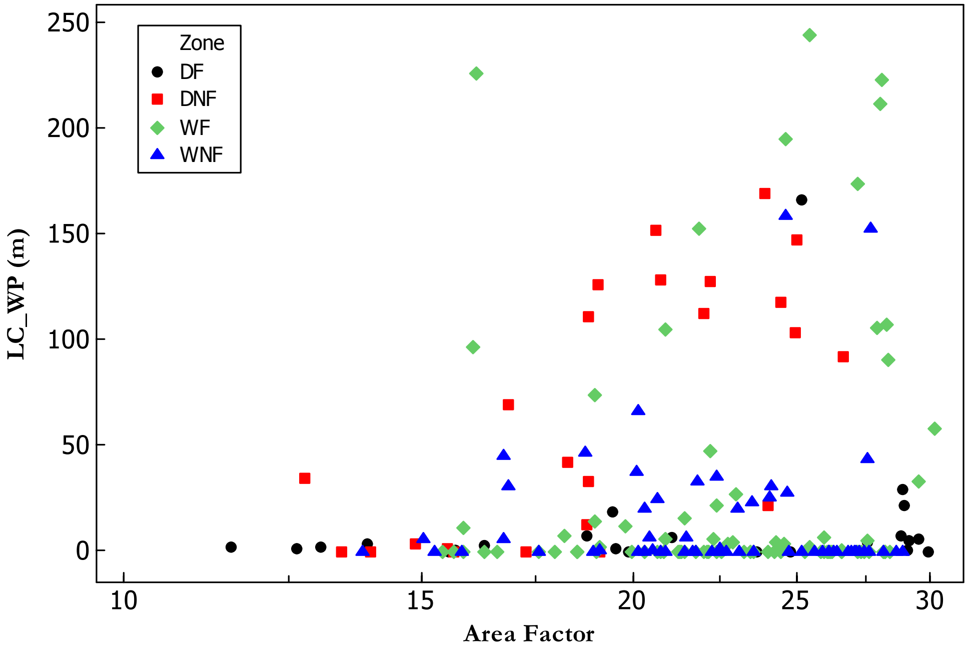


(b) Effect by climatic zone

Figure 5-36 Apparent relationships between AREA and fatigue cracking

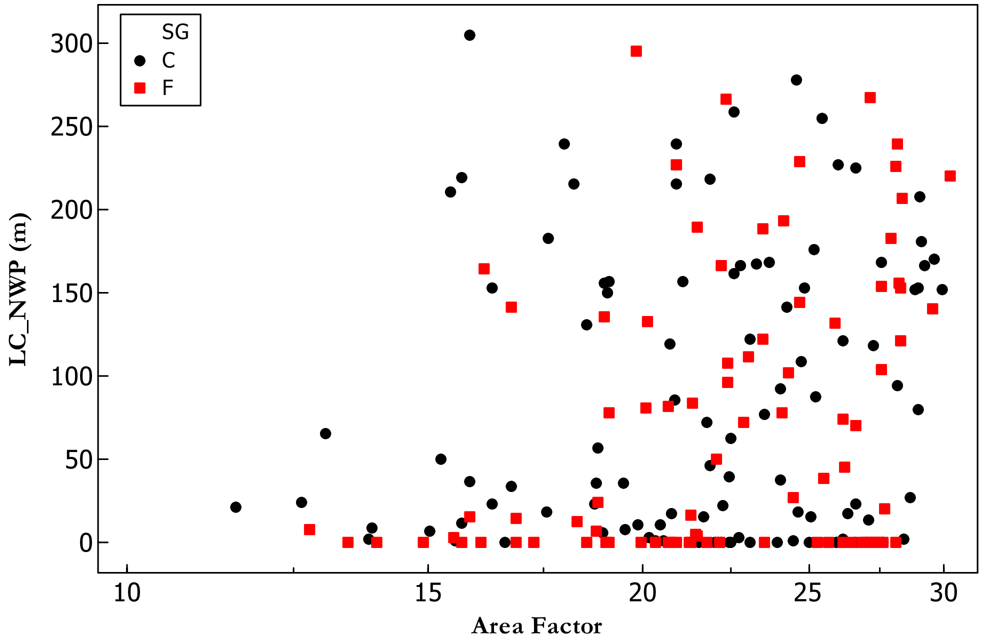


(a) Effect by subgrade soil type

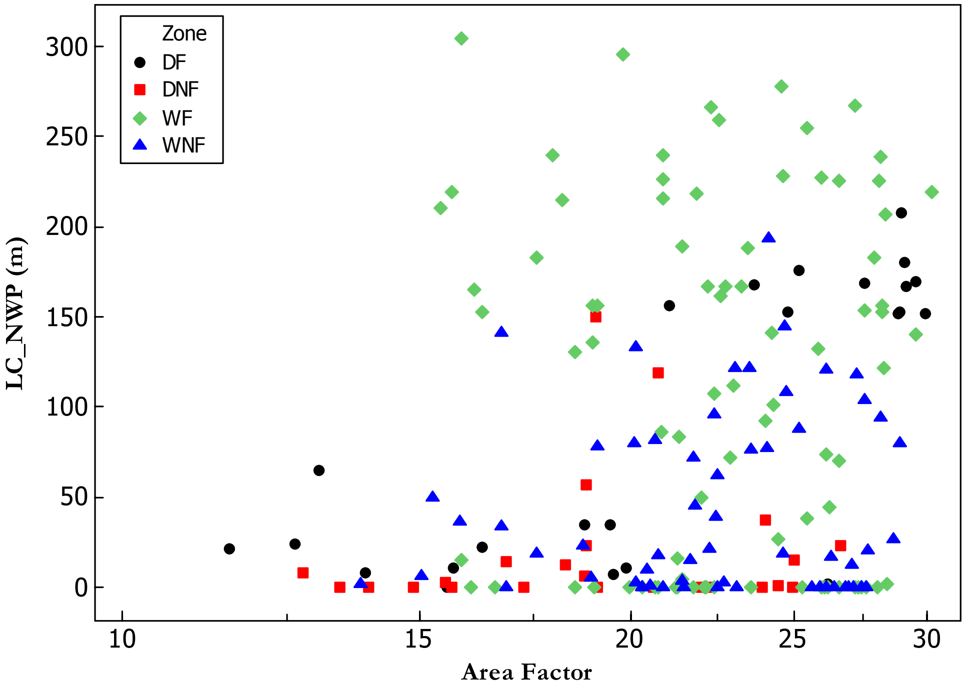


(b) Effect by climatic zone

Figure 5-37 Apparent relationships between AREA and longitudinal cracking-WP

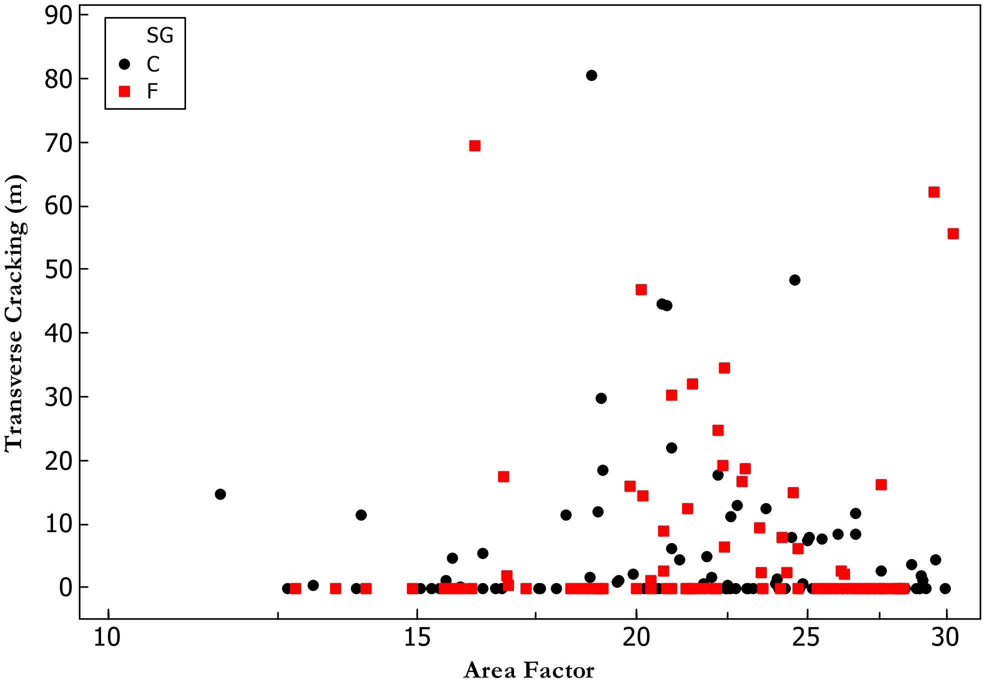


(a) Effect by subgrade soil type

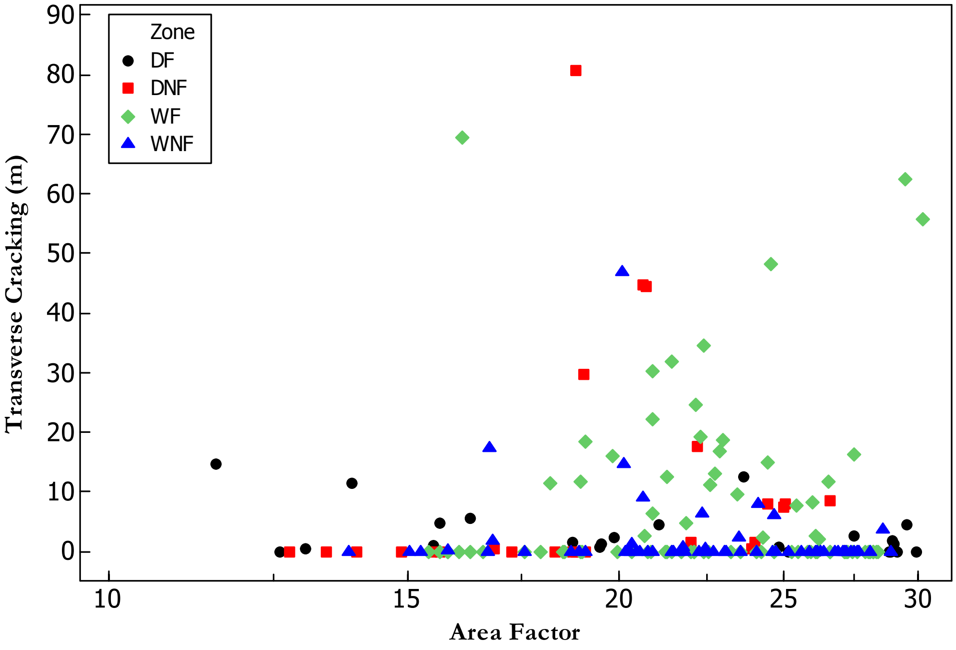


(b) Effect by climatic zone

Figure 5-38 Apparent relationships between AREA and longitudinal cracking-NWP

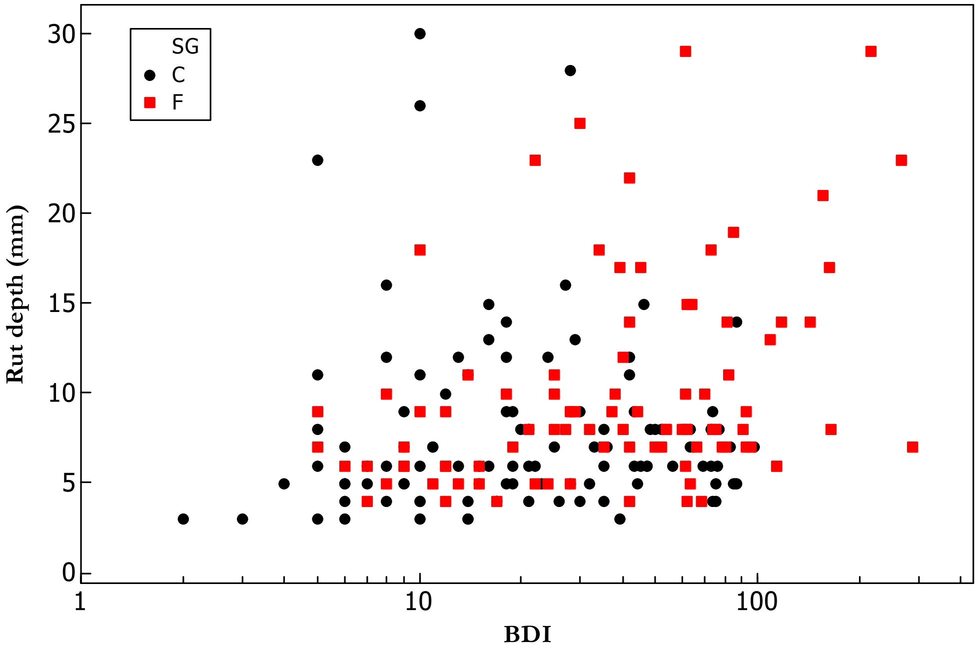


(a) Effect by subgrade soil type

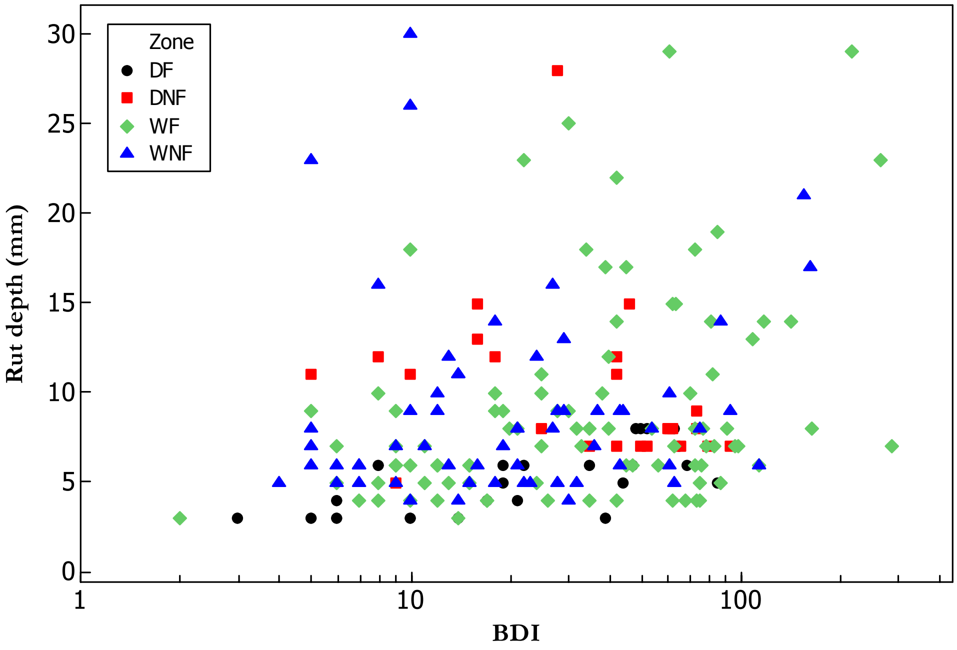


(b) Effect by climatic zone

Figure 5-39 Apparent relationships between AREA and transverse cracking

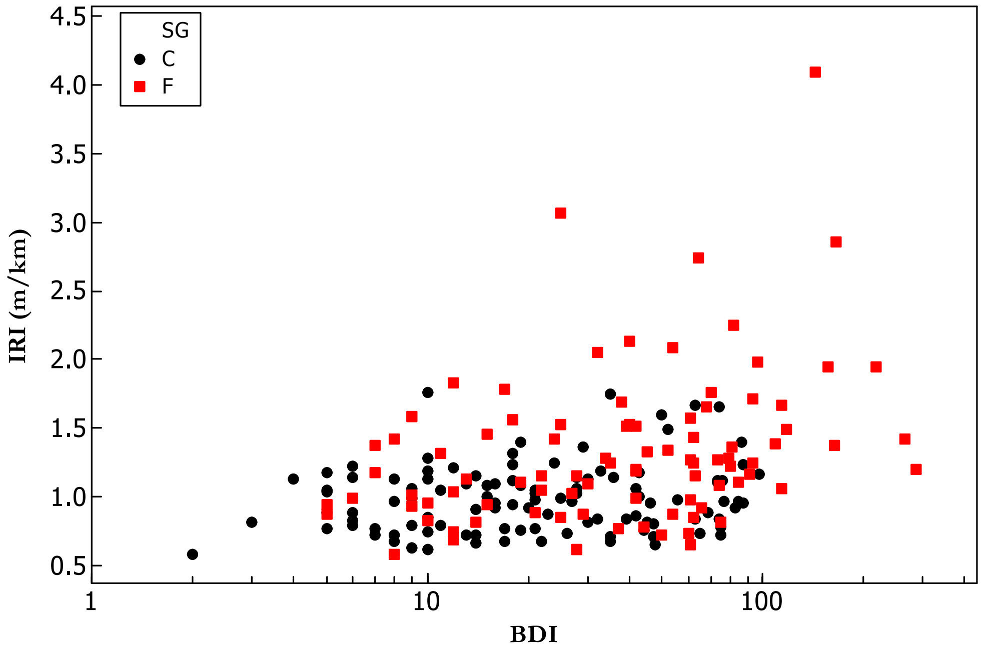


(a) Effect by subgrade soil type

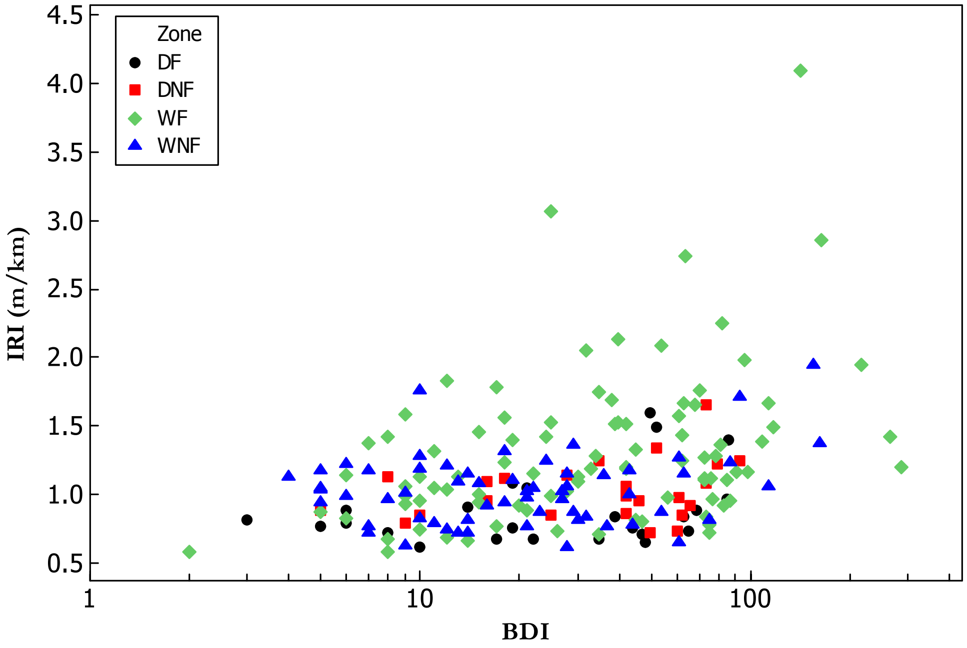


(b) Effect by climatic zone

Figure 5-40 Apparent relationships between BDI and rut depth



(a) Effect by subgrade soil type



(b) Effect by climatic zone

Figure 5-41 Apparent relationships between BDI and IRI

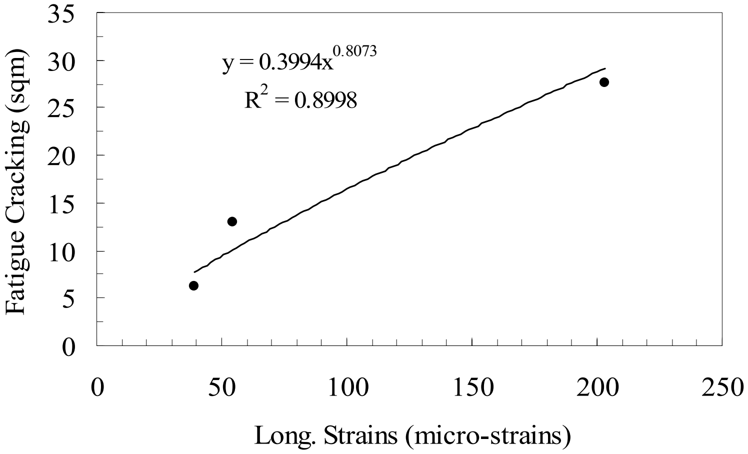
### *5.7.4 Dynamic Load Response for OH (39) test sections*

This section presents the summary of findings from the analysis of Dynamic Load Response (DLR) data from the instrumented flexible pavement sections in the state of Ohio. These sections were instrumented with strain gauges, pressure cells and LVDTs to measure the pavement “response”. The SHRP experiment in Ohio targeted four core sections (see Chapter 2) for the installation of sensors to monitor dynamic pavement response during controlled vehicle tests.

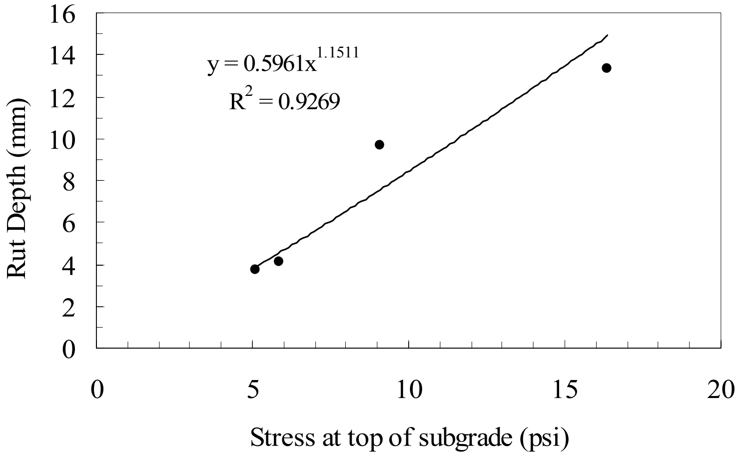
The main objective in this project was to study the response-performance relationship by using the measured dynamic load response and actual observed performance of the sections, in the SPS-1 experiment. Therefore, an attempt was made to relate the observed performance of these instrumented sections with measured responses (strains and surface deflections in HMA surface layer, and stress at top of subgrade) by means of bivariate scatter plots.

The bivariate relationships between measured responses and observed performances are shown in Figure 5-42 and Figure 5-43. However, this finding is limited to these four instrumented sections. The measured longitudinal strain (initial value) is “strongly” associated with future fatigue cracking, and the vertical stress at the top of the subgrade is “strongly” associated with future rutting. It should be noted that the pavement sections in OH (39) site exhibited premature rutting due to very wet and soft subgrade soil. Other observations regarding the dynamic load response of the instrumented test sections are summarized below:

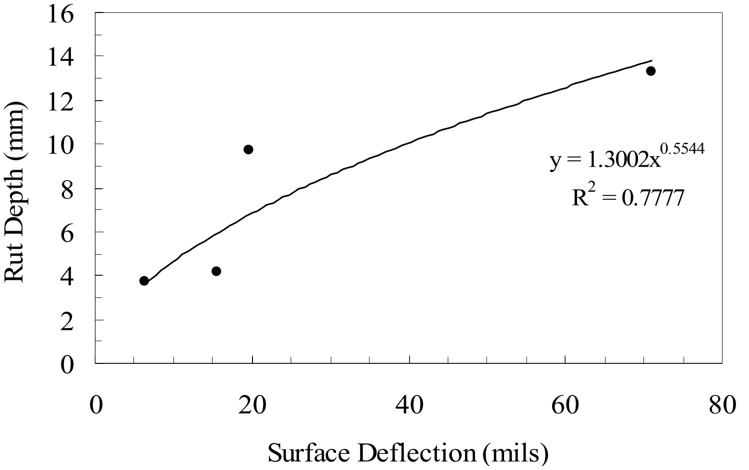
- In general, the strain in the longitudinal direction is higher than the strain in the transverse direction; this is consistent with the mechanistic analysis for flexible pavements.
- Sections with higher strain values have poor fatigue performance. These results are in agreement with the mechanistic-empirical design predictions as fatigue cracking in the flexible pavements is generally considered to be related to the initial tensile strain at the bottom of the HMA layer (bottom up cracking).
- The sections that exhibited high measured stress at the top of the subgrade and high surface deflection have shown poor rut performance.
- The sections that exhibited high measured stress and deflection have higher roughness.



(a) Relationship between strain and fatigue cracking

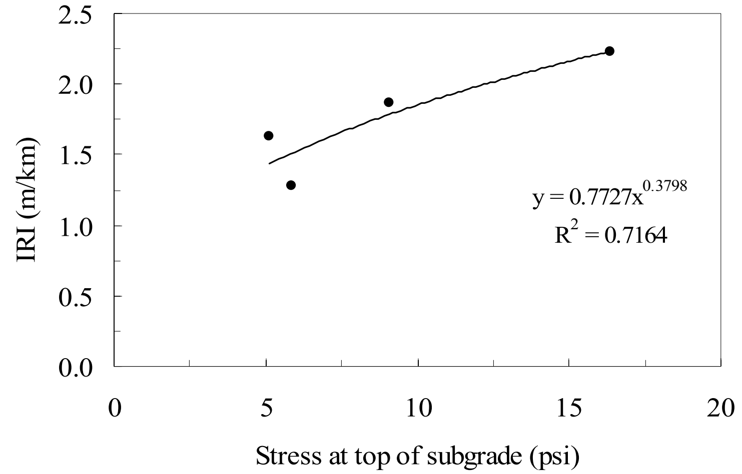


(b) Relationship between stress and rutting

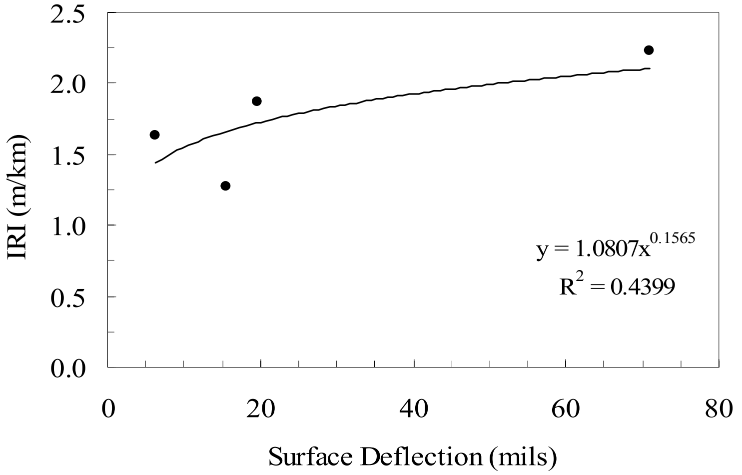


(c) Relationship between deflection and rutting

Figure 5-42 Relationship between measured responses and observed performances— Fatigue cracking and rutting



(d) Relationship between stress and roughness



(e) Relationship between deflection and roughness

Figure 5-43 Relationship between measured responses and observed performances— Roughness

## 5.8 SYNTHESIS OF RESULTS FROM ANALYSES

This section of the report summarizes the findings from various analyses performed on SPS-1 data. The methods employed in this study were explained in Chapter 4 and the results obtained from these analyses were presented above in this chapter.

Broadly two types of analyses were employed – magnitude-based and frequency-based. The magnitude-based analyses that were used are one-way (univariate) and multivariate ANOVA. These methods are used for comparison of means. The frequency-based analyses that were used are Binary Logistic Regression (BLR) and Linear Discriminant Analysis (LDA). These methods help identify the factors that significantly contribute to the occurrence of a distress based on the likelihood of occurrence or non-occurrence of distresses. In site-level analyses, the performance of pavements within each site was compared. The results from site-level analysis were used to ascertain the consistency of the effects of experimental factors across all sites.

The magnitude-based methods, though powerful, are more appropriate for analyses of distresses which have both high occurrence and magnitude (for example: fatigue cracking, roughness, and rutting). On the other hand, the frequency-based methods are more suitable when the occurrence of a distress is fairly high (for example: transverse cracking) but magnitude is low.

An attempt has been made to summarize the above said effects of design and site features on the performance and response measures. The results were interpreted in light of the type of analysis, and occurrence and extent of distress. ANOVA being the most “powerful” among the methods was given higher importance. However, the results from this analysis may not be reliable in case of limited (low occurrence of distress) or unbalanced data. Therefore, in these cases, the effects of design features, on the occurrence of distresses were investigated using BLR and LDA.

All results need to be interpreted in light of the experiment design, occurrence and extent of distresses, and analyses methods used. A “weak” effect at this point in time may become a “medium” or “strong” effect in the long term. Hence, all the conclusions are based on “mid-term” performance of the ongoing SPS-1 experiment.

The synthesis of results is presented next for each performance measure separately.

### *5.8.1 Effects of structural factors for flexible pavements — SPS-1 experiment*

This section is subdivided into three parts: (i) pavement performance, (ii) pavement response, and (iii) relationship between response and performance. The structural factors include HMA thickness, base thickness, base type, and drainage. The experiment also includes studying the secondary effects of site factors, namely subgrade type and climatic zones.

#### *5.8.1.1 Effect of Design and Site Factors on Pavement Performance*

The effects of the experimental factors on each performance measure are discussed below, one performance measure at a time.

**Fatigue Cracking**

All the experimental factors were found to be affecting fatigue cracking, though not at the same level. On the whole, pavements with “thin” 102 mm (4-inch) HMA surface layer have shown more fatigue cracking than those with “thick” 178 mm (7-inch) HMA surface layer. Also pavements constructed with only dense-graded aggregate base (DGAB) have shown more fatigue cracking than those with dense-graded asphalt treated base over unbound aggregate base (ATB/DGAB) and those with ATB base only, with the latter base type showing the best performance. The effects of HMA surface thickness and base type were found to be statistically and practically significant. The main effect of base thickness was found to be statistically insignificant. However, on average, pavements with 406 mm (16-inch) base thickness have shown slightly better fatigue performance than those with 203 mm (8-inch) or 305 mm (12-inch) base thickness. It should be noted that only pavement sections with drainage have a 406 mm (16-inch) base thickness according to the SPS-1 experiment design; therefore, it is unclear whether this effect is caused by the increased base thickness or by drainage provided with the permeable asphalt treated base (PATB). In this regard, the frequency-based analyses did show that pavements with drainage have significantly lower chances of cracking than those without drainage.

In general, pavement sections built on fine-grained soils have more fatigue cracking than those built on coarse-grained soils. Also pavements located WF zone have shown more fatigue cracking than those located in WNF zone. These effects were found to be statistically significant and are of practical significance.

Among un-drained pavements, on average, an increase in HMA surface thickness from 102 mm (4-inch) to 178 mm (7-inch) has a slightly higher effect on fatigue cracking for pavements with DGAB than for pavements with ATB.

The above effect of HMA surface thickness is more significant for sections built on coarse-grained soils. On the other hand, among pavements built on fine-grained soils, the effect of drainage is seen only in those sections with DGAB; i.e., those with drainage have less fatigue cracking than those without drainage. Also among drained pavements built on fine-grained soils, those with 203 mm (8-inch) base have more cracking than those with 305 mm (12-inch) or 406 mm (16-inch) base. These effects were found to be statistically and practically significant. Hence, for pavements built on fine-grained soils, thicker base helps improve fatigue performance for drained pavements while drainage helps improve fatigue performance for those with DGAB.

The main effect of HMA thickness, discussed above, is mainly seen among sections located in WNF zone. The effect is of practical and statistical significance. This may be an indication that an increase of HMA thickness from 102 mm (4-inch) to 178 mm (7-inch) is not sufficient in resisting fatigue cracking for pavements in WF zone as compared to WNF zone.

Among sections located in the WF zone, those with DGAB have shown the highest amount of cracking while those with ATB have the least cracking. In addition, those with 406 mm (16-inch) drained base have the least amount of fatigue cracking. These effects were found to be statistically and practically significant. This suggests that among pavements located in WF zone, “thick” 406 mm (16-inch) treated bases with drainage are less prone to cracking. The effects of HMA thickness and base thickness discussed above imply that, among sections located in WF zone, an increase in base thickness to 406 mm (with drainage) has a greater impact than an increase in HMA thickness from 102 mm (4-inch) to 178 mm (7-inch), suggesting that a thicker base and drainage helps in reducing frost effects.

**Structural Rutting**

The extent of structural rutting among the test sections in the SPS-1 experiment is 6.5 mm, on average, with a standard deviation of 2.4 mm. Their average age is about 7 years with a range between 4.5 and 10 years. The amount of rutting for the majority of these sections is within the normal range at this point in time. Therefore, the results at this point may only show initial trends and may not be of much practical significance.

Marginal main effects of drainage, HMA thickness, and base thickness on structural rutting were observed. Pavements with “thin” [102 mm (4-inch)] HMA surface layer have shown slightly more rutting than those with “thick” [178 mm (7-inch)] HMA surface layer. Also, on average, pavements with 406 mm (16-inch) drained base have shown somewhat better rut performance than those with 203 mm (8-inch) and 305 mm (12-inch) base. However, these effects of HMA surface thickness and base thickness were not found to be statistically significant. Pavements with drainage have less rutting than those without drainage. The effect of drainage on structural rutting was found to be statistically significant; however the effect is not of practical significance at this point in time.

In general, pavement sections built on fine-grained subgrade have shown more rutting than those built on coarse-grained subgrade. This effect is statistically significant and appears to be of practical significance. On the other hand, there is no apparent effect of climate (WF vs. WNF) on structural rutting.

Among the pavements built on coarse-grained soils, those with 178 mm (7-inch) HMA surface have shown slightly less rutting than those with 102 mm (4-inch) HMA surface. This effect was statistically significant; however it is not operationally meaningful at this point. The above suggests that for sections built on fine-grained soils an increase in HMA thickness from 102 mm (4-inch) to 178 mm (7-inch) may not be sufficient in reducing the amount of rutting. On the other hand, among pavements built on fine-grained soils, a marginal positive effect of drainage is seen in sections with ATB.

Among drained pavements located in WF zone, those with DGAB have shown more rutting than those with ATB. Also, among sections located in WF zone and built with ATB, those with drainage have shown significantly less rutting than those without drainage. Both of these effects were found to be statistically significant and are of operational significance. This implies that, among pavements located in WF zone, those with ATB and drainage perform better than those with other combinations of base type and drainage.

Among un-drained sections located in WNF zone, those with 305 mm (12-inch) base have less rutting than those with 203 mm (8-inch) base. This effect was found to be statistically significant and of practically significance. For sections built on DGAB and located in WNF zone, those with drainage have shown slightly less rutting than those without drainage. The effect was found to be marginally significant. These early trends imply that the importance of drainage among pavements with DGAB is considerable in improving rut performance among sections located in WNF zone. On the other hand an increase in base thickness from 203 mm (8-inch) to 305 mm (12-inch) improves rut performance for un-drained sections, irrespective of base type.

**Roughness**

All the experimental factors were found to be affecting roughness, though not at the same level. Pavements with “thin” [102 mm (4-inch)] HMA surface layer have higher change in IRI (ΔIRI) than those with “thick” [178 mm (7-inch)] HMA surface layer. This effect was found to be statistically significant but is not of practical significance at this point in time. Also, pavements constructed with DGAB have higher ΔIRI than those with ATB/DGAB and ATB, while pavements with ATB have the best performance for roughness. Pavements with thicker bases have lower ΔIRI. Also pavements with drainage have lower ΔIRI than un-drained pavements. The above main effects of base thickness, base type and drainage were found to be statistically significant and are of practical significance.

In general, pavements built on fine-grained soils have shown higher ΔIRI than those built on coarse-grained soils, especially among sections in WF zone. Also, the change in roughness among sections located in WF zone is significantly higher than those in WNF zone. These effects were found to be statistically significant and are of practical significance.

Among pavements built on fine-grained soils, an increase in HMA thickness from 102 mm (4-inch) to 178 mm (7-inch) has a significant positive effect on change in roughness. Also for un-drained pavements, those with ATB have significantly lower ΔIRI than those with DGAB. Finally the effect of drainage is significant only for sections with DGAB. The above effects were found to be statistically significant and are of practical significance. These effects suggest that, for pavements built on fine-grained soils, higher HMA thickness and/or treated base will help inhibit the increase in roughness. Also, drainage appears to be more effective in preventing an increase in roughness for sections with DGAB, especially among those located in WF zone.

For un-drained pavements built on coarse-grained soils, an increase in base thickness from 203 mm (8-inch) to 305 mm (12-inch) has a marginally significant effect, in that sections with thicker base have lower ΔIRI. However, this effect is not of practical significance at this point in time.

### Transverse Cracking

The effect of base thickness on transverse cracking is insignificant, at this point. Pavements constructed with DGAB have more transverse cracking than those with ATB/DGAB and ATB, while pavements with ATB have shown the least amount of cracking. The effect was found to be statistically significant; however it is not of practical significance at this point in time. Slightly more cracking was observed on pavements with “thin” [102 mm (4-inch)] HMA surface layer. Also, pavements with drainage have shown slightly less cracking than un-drained pavements. However, these effects were not found to be statistically significant.

In general, pavements built on fine-grained soils have shown more transverse cracking than those built on coarse-grained soils. This effect was found to be statistically significant and is of practical significance.

Pavements located in WF zone have shown significantly more transverse cracking than those located in WNF zone. This main effect of climatic zone was found to be statistically significant and is of practical significance. This confirms that transverse cracking occurs mainly in freezing environment.

Among drained pavements built on coarse-grained soils, those with ATB performed better than those with DGAB. Also, among pavements with DGAB and built on fine-grained soils, those with drainage have shown significantly less transverse cracking than those without drainage. These effects were statistically significant and appear to be of practical significance.

### Longitudinal Cracking-WP

The effects of HMA and base thickness on longitudinal cracking-WP are insignificant at this point in time. Pavements with drainage have shown less cracking than un-drained pavements. The main effect of drainage was found to be statistically significant, but is not of practical significance at this point.

In general, pavements built on fine-grained soils have shown more longitudinal cracking-WP than those built on coarse-grained soils. This effect is of statistical and practical significance. Also, on average pavements in WF zone have shown higher levels of longitudinal cracking-WP than those in WNF, especially among pavements built on fine-grained subgrade. This effect was found to be marginally significant.

Among pavements built on fine-grained soils, those built with DGAB have shown more longitudinal cracking-WP, and those built with ATB have shown the least amount of cracking. This main effect of base type was statistically and operationally significant. Also among pavements built on fine-grained soils, drainage has a significant effect on longitudinal cracking, and this effect is more pronounced among pavements built with DGAB. This effect was statistically significant and is of practical significance. This trend implies that if a pavement on fine-grained subgrade is constructed with a DGAB base, better performance (in terms of longitudinal cracking-WP) can be achieved by providing drainage. These effects are seen in both WF and. WNF zones.

**Longitudinal Cracking-NWP**

The effects of HMA thickness, base thickness, and base type on longitudinal cracking-NWP are insignificant at this point in time. Pavements with drainage have shown slightly less cracking than un-drained pavements. However, the effect of drainage was found to be only marginally significant.

The effect of subgrade type was not found to be statistically significant. In general, more longitudinal cracking-NWP was observed among sections located in “freeze” climate compared to those in “no-freeze” climate. This main effect of climatic zone is statistically significant and is of practical significance. Also, the effect of drainage is more pronounced (with marginal statistical significance) among pavements located in “freeze” climate. However, this effect is not of practical significance.

These initial trends indicate that longitudinal cracking-NWP is caused by “freeze” climate (frost effects), and that pavements without drainage may be more prone to it.

#### *5.8.1.2 Effect of Design and Site Factors on Pavement Response*

Three pavement response parameters were chosen for ANOVA – peak deflection under FWD load ($d_0$), far-sensor deflection ($d_6$), and AREA. All the response parameters have been calculated using the initial deflections of the test sections. Also, the pavement surface temperature at the time of testing was taken as a covariate along with the age at the time of testing and variability in the HMA and base layer thicknesses. The natural logarithmic transformation has been applied to the three response indicators to fulfill the ANOVA assumptions. The following discussion summarizes the effects of design and site factors on each of the response parameters.

### Peak Deflection under FWD Load ($d_0$)

The interactions between HMA thickness and base type, base thickness and base type, base type and drainage, have significant effects on the peak deflection ($d_0$).

Among the pavement sections built on DGAB, those with 102 mm (4-inch) HMA thickness have higher $d_0$ than those with 178 mm (7-inch) HMA thickness. Also as expected, thicker bases for each base type have lower $d_0$. However, this effect was more significant in the case of sections with treated bases (ATB or ATB/DGAB). Furthermore, pavement sections with PATB/DGAB have lower $d_0$ than those with DGAB.

The interaction between subgrade soil and climatic zone was found to have a very significant effect on $d_0$. Test sections built on fine-grained soils have shown significantly higher $d_0$ as compared to those built on coarse-grained soils. This effect is more prominent on pavements located in WNF zone.

### Far Sensor Deflection (d6)

The effects of base type, base thickness and drainage have significant effects on the far-sensor deflection ($d_6$). HMA thickness and pavement mid depth temperature do not have a significant effect on $d_6$.

The interaction between subgrade soil type and climatic zone was found to have a significant effect on $d_6$. Test sections built on fine-grained soils have shown significantly higher $d_6$ as compared to those built on coarse-grained soils. This effect is more prominent on pavements located in WNF zone.

Pavement sections built with DGAB have shown higher far-sensor deflections than those built on other base types. Pavements constructed on 203 mm bases have also shown significantly higher far-sensor deflections than those built on 12-inch (203 mm) or 406 mm (16-inch) bases. Furthermore, pavement sections with PATB/DGAB have lower $d_6$ than those with DGAB. These effects of the design factors on $d_6$ are based on statistical analyses only, and may or may not be of practical importance.

**AREA**

The interactions between HMA thickness and base type, base thickness and base type, and, drainage and base type have significant effects on the AREA parameter.

Among pavement sections built on DGAB, those with “thin” HMA surface layer have lower AREA values compared to those with “thick” HMA surface layer, implying that the upper layers of these pavement sections are “less stiff”. The increase in HMA thickness from 102 mm (4-inch) to 178 mm (7-inch) on ATB does not significantly increase the AREA value.

For sections built on DGAB, increasing base thickness from 203 mm (8-inch) to 305 mm (12-inch) has not shown a significant effect on AREA; however a two-fold increase in base thickness [from 8 to16 inch (203 to 406 mm)] has shown a significant increase in AREA. Also, base thickness does not seem to have a significant effect on AREA in pavement sections with ATB bases. Furthermore, pavement sections with PATB/DGAB have higher AREA values than those with DGAB. This indicates that the structural capacity of the PATB layer is somewhat higher than that of the DGAB.

Among the pavement sections located in WNF zone, those built on fine-grained subgrade soils have significantly higher AREA values than those built on coarse-grained soils. However, in the case of sections located in WF zone, this effect is not significant indicating that AREA could be independent of the subgrade soil type.

A simplified summary of results from all analyses is given in Table 5-42. The summary is only meant to give an overall assessment of the effects. The reader is strongly recommended to read the following write-up for a better understanding of all the effects. It is important to note that a “strong”, “medium” or “weak” effect should only be interpreted in terms of the difference in effects at the various levels of a factor. As an example, a “strong” effect of HMA thickness and a “strong” effect of subgrade soil type should not be interpreted as HMA thickness and subgrade type having the same strength of effect.

A black circle indicates a “strong” effect (significant); a grey circle indicates a “medium” effect, and a white circle indicates a “weak” effect. Operational significance was determined only for “strong” or “medium” effects. It should be noted that an effect can be statistically significant (meaning that it is not a coincidence) but may not be operationally/ practically significant, at this point in time.

Table 5-42 ‘Simplified’ summary of effects of design and site factors for flexible pavements

| Design Factor | Performance Measures | | | | | | Response Measures | | |
|---|---|---|---|---|---|---|---|---|---|
| | Fatigue cracking | Rutting | Roughness | Transverse cracking | Longitudinal cracking | | Peak deflection $d_o$ | Peak deflection $d_6$ | Area Factor |
| | | | | | WP | NWP | | | |
| HMA thickness | ● | ◍ | ● | ◍ | ○ | ○ | ● | ○ | ● |
| Base type | ● | ◍ | ● | ● | ◍ | ○ | ● | ● | ● |
| Base thickness | ◍ | ◍ | ● | ○ | ○ | ○ | ● | ● | ◍ |
| Drainage | ◍ | ◍ | ● | ◍ | ● | ◍ | ◍ | ● | ● |
| Climatic Zone | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| Subgrade type | ● | ● | ● | ● | ● | ○ | ● | ● | ◍ |

Note: This table is solely for the purpose of summarizing some of the effects in a ‘simple’ format. The reader is urged to read relevant text in the report for a better understanding.

| Symbol | Description |
|---|---|
| ● | Strong Effect (Main effect exists) |
| ◍ | Medium Effect (Interaction effect) |
| ○ | Weak Effect |

#### *5.8.1.3 Apparent Relationship between Response and Performance*

Two types of relations between flexible pavement response under (FWD testing) and performance were explored for the SPS-1 pavement sections—explanatory and predictive. Explanatory relationships were established using multiple regressions on data from all the test sections in the experiment. Predictive relationships were established based on bivariate correlation analyses at the site level, and using scatter plots on data from all sections. The dynamic load response (DLR) data from instrumented sections in Ohio were used for predictive relationships. The salient findings are briefly presented below:

**Overall Analysis— Explanatory Relationship**

A regression model was developed considering the peak deflection ($d_0$) as the dependent variable and variables such as temperature, asphalt thickness, subgrade strength and performance measures as independent variables. The observations based on the regression model are as follows:

- Pavements with "thick" [178 mm (7-inch)] HMA surface layer were observed (with statistical significance) to have significantly lower deflections than those with "thin" [102 mm (4-inch)] HMA surface layer.
- Mid-depth temperature of the HMA layer, at the time of testing, has a statistically significant effect on $d_{0.}$ Irrespective of design features, pavement deflections ($d_0$) measured at higher temperatures is greater than those at lower temperatures.
- Older pavements have slightly lower deflections ($d_0$) compared to younger pavements, which could be due to stiffening (aging) of the asphalt.
- Pavements with "weaker" subgrade (higher $d_6$) have significantly higher $d_0$ (with statistical significance).
- Pavements with more cracking (fatigue cracking or longitudinal cracking) have a significantly higher $d_0$ (with statistical significance), compared to those with less cracking.

**Site Level Analysis— Predictive Relationships**

This section summarizes the findings regarding the predictive relationships between initial response (FWD deflection or deflection basin indices) and future pavement performance (fatigue cracking, rutting and roughness) at the site level. The data for sections from LA (22) were excluded from these analyses, as performance data for the sections are available for just one year.

- On average, AREA, SCI and BDI have shown reasonable correlations with fatigue cracking for sections in most of the sites in the SPS-1 experiment. In most of the sites, pavements with higher initial SCI or BDI, or lower initial AREA were found to have higher fatigue cracking.
- Consistent trends were observed between BDI and future IRI for the various sites in the SPS-1 experiment. In most of the sites, pavements with higher initial BDI were found to have higher IRI.
- The deflection basin parameters have not shown a consistent relationship with rut depth for the various sites in the SPS-1 experiment.

### Overall Analysis— Predictive Relationships

Relationships were explored between initial response (FWD deflection basin indices) and pavement performance (cracking, rutting and roughness), using bivariate scatter plots between selected response parameters and performance measures for all pavement sections in the experiment. The main observations based on these relationships are listed below:

- Among pavements constructed on fine-grained soils, ones with higher SCI have shown more fatigue cracking, especially in WNF zone. Also, stiffer pavements (higher AREA) on fine-grained soils have shown more fatigue cracking, especially if located in WF climatic zone.
- Higher longitudinal cracking-WP was observed for the pavement sections with higher AREA especially among pavements located in WNF climatic zone.
- No apparent relation was observed between AREA and longitudinal cracking-NWP, implying that this distress could be independent of the pavement structural capacity.
- No apparent trend was observed between AREA and transverse cracking. This could imply that this distress type is not load-related.
- Among pavements constructed on fine-grained soils and located in WF zone, those with higher BDI experienced slightly higher rutting. It was also observed that some pavements with lower BDI (stronger structure) have experienced higher rutting as

compared to pavements with high BDI. These pavements could have experienced mix-related rutting (not structural rutting).

- Among pavements constructed on fine-grained soils and located in WF zone, those with higher BDI developed slightly higher roughness over time.

**Dynamic Load Response for OH (39) test sections**

This section of the report presents the summary of findings from the analysis of measured Dynamic Load Response (DLR) data from the instrumented flexible pavement sections in the state of Ohio. The observations from the analysis of these instrumented sections are summarized below:

- In general, the strains in the longitudinal direction are higher than the strains in the transverse direction; this is consistent with the results from mechanistic analysis of flexible pavements.
- The sections that were observed to have higher initial strain values have shown worse fatigue performance. These results are in agreement with the mechanistic-empirical design predictions that fatigue cracking in flexible pavements is related to the initial tensile strain at the bottom of the HMA layer (bottom up cracking).
- The sections that were observed to have high initial stress at the top of the subgrade layer and those that were observed to have high initial surface deflection under the load have shown poor rut performance.

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# CHAPTER 6 - ANALYSIS RESULTS FOR SPS-2 EXPERIMENT

## 6.1 INTRODUCTION

A summary of findings from all analyses conducted for the SPS-2 experiment is presented in this chapter. The relevant statistical methods and analysis procedures were explained in Chapter 4. Analyses were performed both on performance and response (FWD) data. The performance measures that were analyzed include transverse and longitudinal cracking, faulting, and roughness (initial roughness and change in roughness). The structural response parameters that were analyzed include deflection parameters from mid-slab FWD testing (J1 testing). In this chapter, results from site-level analysis will be followed by results from overall analysis, and results from apparent relationship between response and performance, leading to the summary of findings. In addition, a narrative on the effect of construction on performance of SPS-2 sections and performance of each test section at each site is also presented. A list of all analyses conducted on the SPS-2 data is below:

- Site-level analyses (on performance measures): Evaluation of the consistency of the effects of design factors across sites.

- Overall analyses (on the performance and response measures):
  a) Extent of distress by experimental factors
  b) Analysis of Variance (ANOVA)
  c) Linear Discriminant Analysis (LDA)
  d) Binary Logistic Regression (BLR)

- An investigation of apparent relationships between response and performance at the site level and for the overall population.

## 6.2 PREVIOUS FINDINGS

A review was performed on LTPP studies that have identified factors affecting rigid pavement response and performance. A brief summary of findings from these studies and reports relevant to SPS-2 is presented here.

*Factors Affecting Rigid Pavement Performance*

**PCC slab thickness**

- Thicker (279 mm) slabs experience reduced faulting, transverse cracking, spalling, and edge and corner deflections and hence reduced pumping [1-4].

**Subgrade type [5-7]**

- Uniformity of support was identified as a dominant factor in the published literature. It was also concluded that weak subgrade provide non-uniform support that can lead to corner cracking and increased potential for voids.
- Pavements resting on very stiff subgrade experience excessive curling and warping. Studies conducted in Chile have shown that pavements resting on stiff subgrade have resulted in cracking of 23% of slabs, on average. The subgrade fineness also has an impact on pavement performance. The finer subgrade is susceptible to pumping, erosion, frost heave and swells.

**Climate [5-8]**

- Moisture in LTPP is characterized by the number of wet days and location of site (wet or dry). Temperature in LTPP is characterized by location of site (non-freeze versus freeze), # of freeze -thaw cycles, annual mean temperature and number of days above 32$^{o}$C. Pavements located in regions with high annual number of freeze thaw cycles, high number of wet days exhibited higher levels of spalling and faulting compared to others. An increase in the number of wet days from 80-130 significantly increased faulting levels. Pavements with un-doweled joints exposed to freeze-thaw cycles less than 70 experienced less faulting than un-doweled pavements exposed to freeze thaw cycles grater than 70.
- Curling stresses in combination with heavy axles can increase the potential for occurrence of transverse cracking. These stresses have a substantial influence on performance of slabs

resting on stiff bases. Pavement sections located in freeze zones exhibited more roughness than pavements located in non-freeze zones.

Another study [9] was conducted using SPS-2 data to identify the factors affecting pavement smoothness. A summary of main findings from this research is given below:

- No statistical difference was found between initial roughness of the sections constructed with 200 mm (8”) thick and sections constructed with 275 mm (11”) thick PCC slab.
- The highest early-age IRI was obtained for PCC surfaces placed on LCB while the lowest early-age IRI values were obtained for those placed on PATB.
- The change in roughness that had occurred over the monitored period at the SPS-2 sections indicated different patterns. Some sections showed very high increase, while some showed a reduction in roughness.
- The change in roughness, based on the profile data, could be related to changes in curvature of the PCC slabs. Both temperature-related (curling) and moisture-related (warping) curvatures were identified among the sections.
- The time of day (temperature during profiling) is a cause for variation (increase or decrease) in roughness for some sections.
- The section (or design) with 200 mm (8”) thick slab with PCC of 3.8 MPa (550-psi) 14-day flexural strength and built on DGAB is more susceptible to changes in curvature than the rest of the designs in SPS-2.

Two studies[10, 11] were conducted to investigate the effects of sub-drainage on the performance of asphalt and concrete pavements. The following is a summary of observations from this research based on analysis of the SPS-2 data, for concrete pavements:

- Un-drained pavement sections built on DGAB or on LCB may develop roughness, transverse and longitudinal cracking more rapidly than drained sections built on PATB.
- The SPS-2 faulting data available through mid-June 2001 were too erratic to support meaningful statistical analysis.

- With respect to IRI change, larger mean differences were detected for the PATB sections with “poor” drainage than for PATB sections with “good” drainage, when un-drained and drained sections were compared. The quality of drainage is not a significant factor in the differences observed in IRI increase.
- In the analyses of transverse and longitudinal cracking in drained versus un-drained SPS-2 sections, larger mean differences were detected for PATB sections with “good” drainage than for those with “poor” drainage.

## 6.3 EFFECT OF CONSTRUCTION ON PAVEMENT PERFORMANCE

As mentioned in section 5.3 in Chapter 5, any abnormality in early performance was used as an indicator to identify sections exhibiting premature “failure”. The performance of all the sections, over time, was observed for this purpose and those sections that had premature “failure” (in first few years of service life) were identified.

In order to further investigate the construction-related performance issues, the performance, with respect to each performance measure, for all pavement sections in the SPS-2 experiment was examined over time. This analysis helped minimize the bias, if any, in the results. The analysis is discussed next with illustrations.

A brief discussion of construction-related performance issues, for each performance measure is presented in this portion of the report. Based on the time-series plots for all distress measures it was found that cracking (transverse and/or longitudinal) was the predominant premature “failure” for most of the pavement sections.

### Transverse and Longitudinal Cracking

Figure 6-1 and Figure 6 - 3 show cracking in all the SPS-2 test sections, over time. It can be observed that some sections have conspicuously high initial cracking. It was found that most of the sections with this abnormal performance are from NV (32). A wide range of construction issues (material-related) that were reported in the construction report for the site is believed to be the cause (see site summary of NV in Appendix B1 for details). Figure 6 - 2 and Figure 6 - 4 show transverse and longitudinal cracking in all sections except those from NV (32).

In light of the unusual behavior of test sections at NV (32), data from these sections was excluded from all statistical analyses.

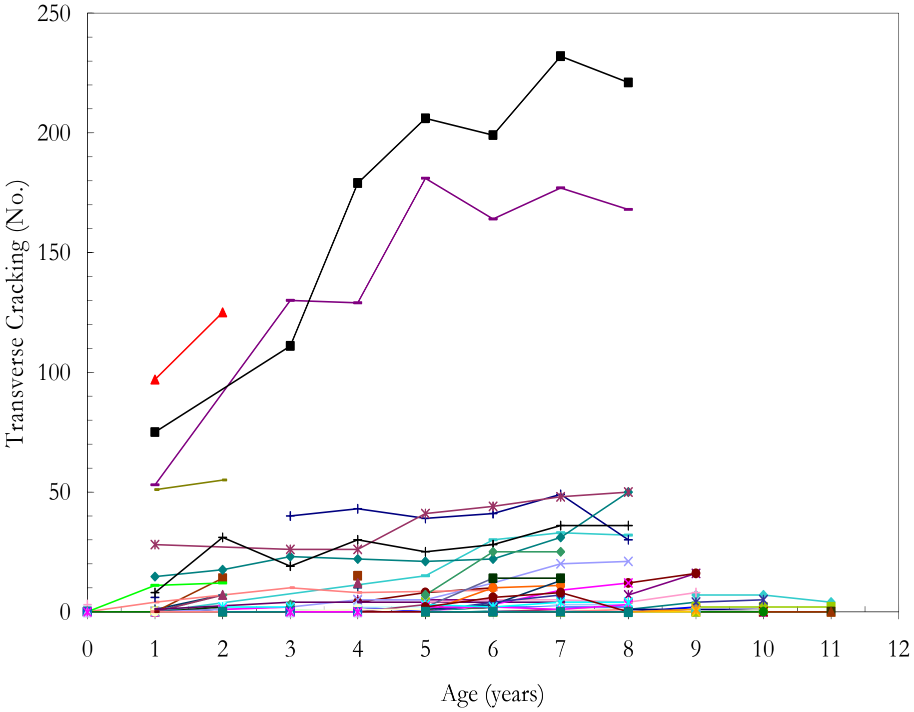


Figure 6 - 1 Transverse cracking with time - All sections

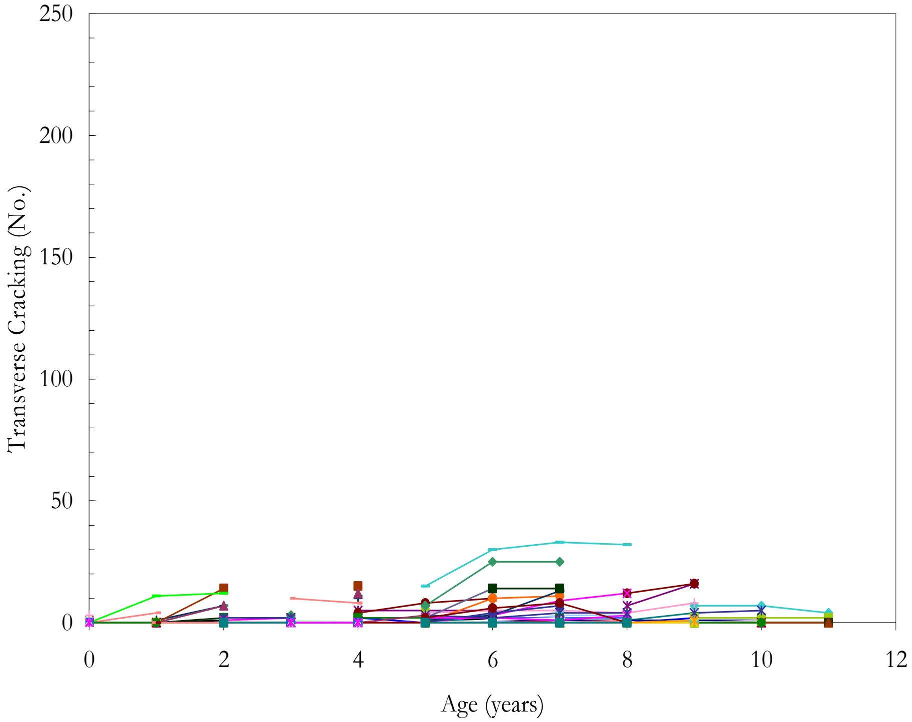


Figure 6 - 2 Transverse cracking with time - Selected sections (without Nevada)

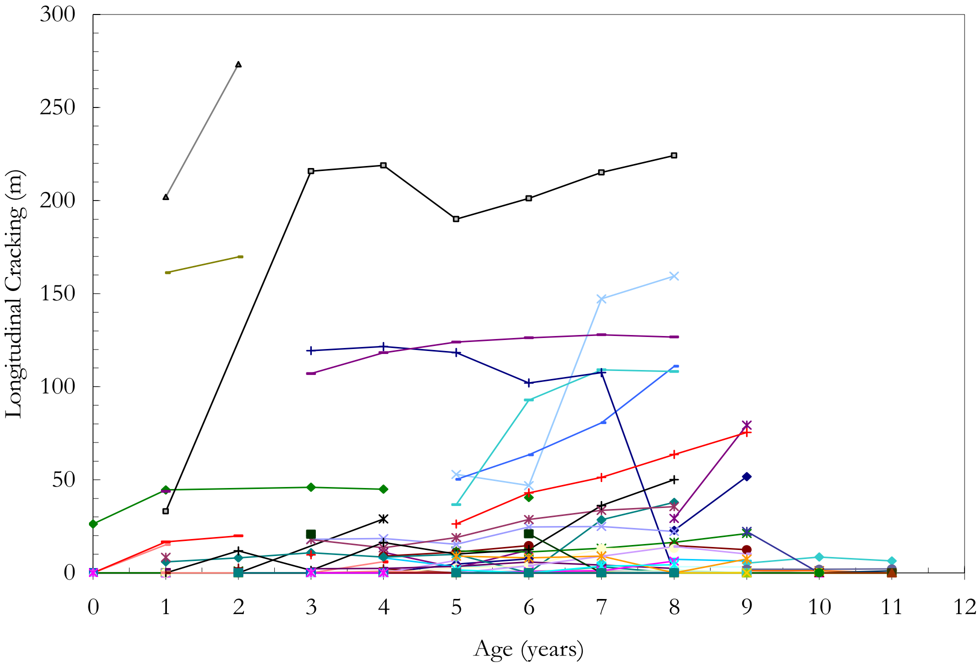


Figure 6 - 3 Longitudinal cracking with time - All sections

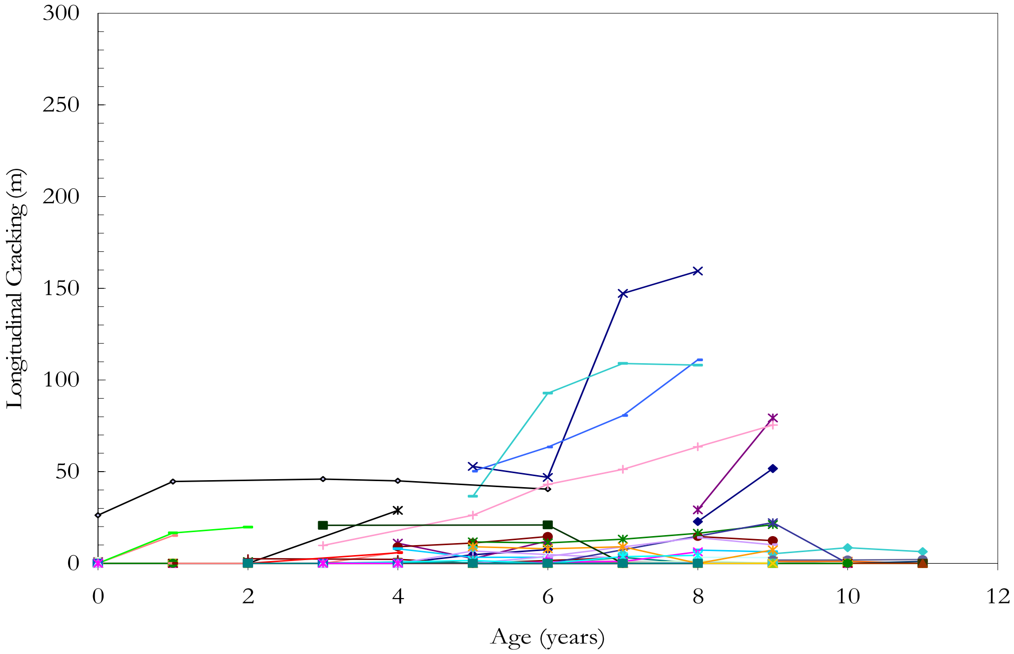


Figure 6 - 4 Longitudinal cracking with time - Selected sections (without Nevada)

### Roughness and Joint Faulting

Figure 6 - 5 shows the progression of roughness over time in all the SPS-2 sections except NV (32). It can be observed that only a few sections have exhibited an unusual performance. Exclusion of data from these sections was not considered necessary, as their inclusion will not impact the results considerably. Therefore, all the pavement sections [except those from NV (32)] were included in analyses regarding roughness.

Figure 6 - 6 shows faulting growth over time in selected SPS-2 sections (i.e. without NV). As in the case of roughness, only a few sections have exhibited abnormal performance and exclusion of data from these sections was not considered necessary. Hence, all the pavement sections [except those from NV (32)] were included in analyses regarding faulting.

In the above section of the report, issues related to the performance of the pavement sections were highlighted. Some construction and/or maintenance related issues with respect to the in-pavement drainage were identified in previous research [10, 11]. The in-pavement drainage for the rigid pavement sections was found to have some deviations from design.

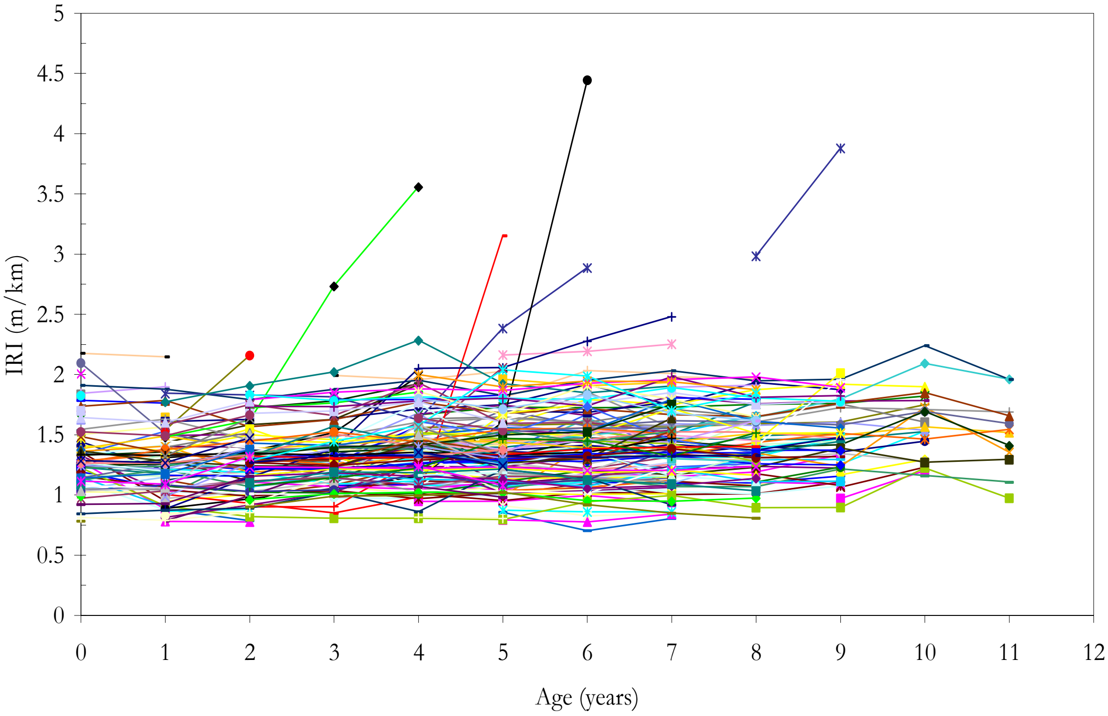


Figure 6 - 5 IRI with time - Selected sections (without Nevada)

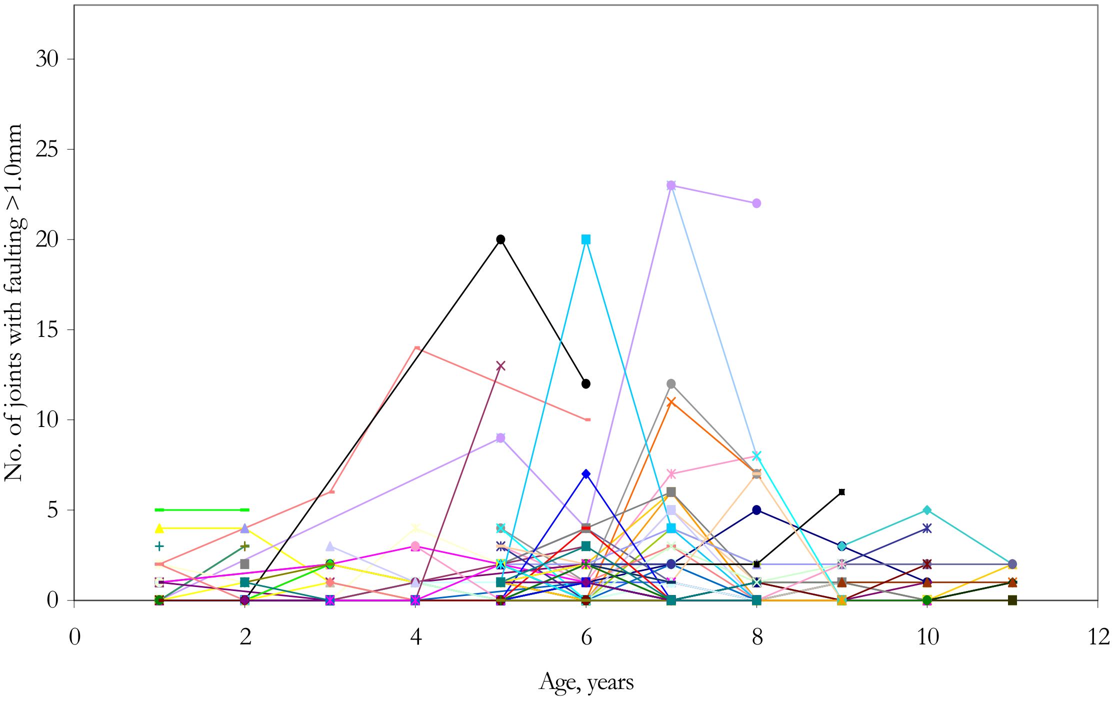


Figure 6 - 6 Joint Faulting with time - Selected sections (without Nevada)

## Drainage Issues

All the drained sections of the SPS-2 experiment were video taped to assess the condition of the drainage in the project NCHRP 1-34C [11]. A subjective assessment of the quality of the drainage functioning as "good" or "poor" was reported for each section. The ratings assigned to each section of the experiment in Table 6-1. As shown in the table, some of the sections that were supposed to be un-drained, according to the experiment design, were constructed with drainage. A "poor" rating is an indication of; (i) buried lateral outlet, (ii) outlet fully blocked with silt, gravel or other debris (iii) longitudinal drains being fully blocked, or (iv) a considerable amount of standing water in the longitudinal drain. A "good" rating was given to drainage if a reasonably sufficient flow of water was evident even if some amount material was present in the drains. Hall et al [11] conducted preliminary analysis of the performance of SPS-2 test sections in light of their assessment of drainage, and a brief (paraphrased) summary of their findings are presented below:

- Undrained pavement sections built on DGAB or on LCB may develop roughness, transverse and longitudinal cracking more rapidly than drained sections built on PATB.
- The SPS-2 faulting data available through mid-June 2001 were too erratic to support meaningful statistical analysis.
- With respect to IRI change, larger mean differences were detected for the PATB sections with "poor" drainage than for PATB sections with "good" drainage, when un-drained and drained sections were compared. The quality of drainage is not a significant factor in the differences observed in IRI increase.
- In the analyses of transverse and longitudinal cracking in drained versus un-drained SPS-2 sections, larger mean differences were detected for PATB sections with "good" drainage functioning than for those with "poor" drainage functioning.

However, the above trends were based only on the average performance and in no case, were the differences detected statistically significant. These findings regarding the functioning of drainage and the effect of drainage may be helpful during the interpretation of the results (from this study), regarding the effect of drainage.

Table 6- 1 Subjective ratings of drainage functioning for SPS-2 test sections based on video inspection results (Hall et al [11])

| State | Test Section ID | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0201<br>0213 | 0202<br>0214 | 0203<br>0215 | 0204<br>0216 | 0205<br>0217 | 0206<br>0218 | 0207<br>0219 | 0208<br>0220 | 0209<br>0221 | 0210<br>0222 | 0211<br>0223 | 0212<br>0224 |
| | Base Type | | | | | | | | | | | |
| | Dense-graded aggregate base | | | | Lean concrete base | | | | Permeable asphalt-treated base over aggregate | | | |
| | Un-drained | | | | | | | | Drained | | | |
| AZ (4) | | | | | | | | | G | G | G | G |
| AR (5) | | | | P | | P | | | P | P | P | P |
| CA (6) | | | | P | | | | | G | G | G | P |
| CO (8) | | | | | | | | | G | P | P | P |
| DE (10) | | | | | | | | | P | G | P | G |
| IA (19) | | | | | | | | | P | P | ? | ? |
| KS (20) | | | | | | | | | G | G | G | G |
| MI (26) | P | | | | | | | P | P | ? | P | ? |
| NV (32) | | | | | | | | | G | G | G | ? |
| NC (37) | | | | | P | | | | P | P | P | P |
| ND (38) | | | | | | | | | G | G | G | G |
| OH (39) | $?^*$ | $?^*$ | $?^*$ | $?^*$ | $?^*$ | $?^*$ | $?^*$ | $?^*$ | G | P | G | P |
| WA (53) | | | | | | | | | G | G | G | G |
| WI (55) | | | | | | | | | ? | ? | ? | ? |

[1] G= Drainage function rated as good

[2] ? = Drainage outlet not found

[3] P = Drainage function rated as poor

[4] $?^*$= Camera could not be inserted

## 6.4 SITE-WIDE PERFORMANCE SUMMARIES

This section summarizes the performance trends for each site within the SPS-2 experiment based on the latest available data (Release 17 of DataPave) at the time of writing this report. This is intended to help the reader gain an understanding of performance of test sections at each site. The performance measures discussed here include transverse and longitudinal cracking, wheelpath joint faulting, and roughness. Additional details about each of the sites can be found in site-level summaries presented in Appendix B1.

A summary of performance of the test sections with “noticeable” distresses is in Appendix B2. A section is said to be exhibiting “noticeable” distress when a crack (transverse or longitudinal) or a wheelpath joint faulting of 2.0 mm or more is exhibited.

### Arizona, AZ (4)

This site is located in the Dry No Freeze zone and built on coarse-grained subgrade soils. The site was opened to traffic in October 1993. The ‘proposed’ traffic volume is 1092 KESAL/ year. Any “noticeable” distress did not occur on section 214. In addition, no cracking (transverse or longitudinal) was observed in sections 215, 216 and 223.

Transverse cracking was observed in sections 217 through 220. About 45% of the slabs are cracked in sections 217 and 218, whereas, less than 12% of slabs are cracked in sections 219 and 220. About half of the transverse cracks for section 217 are of medium severity.

Longitudinal cracking of 52 m and 80 m occurred on sections 0213 and 0217, respectively, while cracking in sections 218, 221, 222 and 224 is less than 12.5 m. In section 0213, about 30% of longitudinal cracking is of medium or high severity.

More than 40% of the joints in 6 out of the 12 sections have at least 1.0 mm of wheelpath joint faulting. Less than 3 joints in sections 215 through 219 and section 223 have faulted in excess of 2.0 mm. The initial IRI of the sections ranged from 1.0 to 1.4 m/km. The latest IRI measurement indicates that after about 11 years of service the IRI ranges from 1.1 to 1.9 m/km.

### Arkansas, AR (5)

This test site is located in the Wet No Freeze zone and was opened to traffic in November 1995. All sections, except sections 222 and 223, were built on coarse-grained soils. The ‘proposed’ traffic volume is 1903 KESAL/ year. No “noticeable” distress was observed in sections 220, 221 and 223.

Cracking (transverse or longitudinal) occurred only in sections 213, 217, 218 and 219. Longitudinal cracking of range 108 m to 160 m occurred on sections 213, 217 and 218. In sections 213 and 218, 25% and 40% of cracking, respectively, is of medium severity.

About 88% of slabs have transverse cracks in section 218, and sections 213 and 217 have less than 10 % of slabs cracked. About 70% of cracking in section 218 is of medium severity.

More than 50% of the joints have measurable faulting ($\geq$ 1.0 mm) in sections 213 through 216 and sections 221, 222, and 224. In sections 213, 214, 215, 222, and 224 more than 20% of joints faulted at least 2.0 mm. The initial roughness of the sections at this site ranged from 0.9 to 1.6 m/ km. After about 9 years of service, the roughness (IRI) ranges from 1.1 to 2.3 m/ km.

**California, CA (6)**

This test site is located in Dry No Freeze zone and was built on coarse-grained soils. This is the youngest site of the experiment and was opened to traffic in October 2000. The ‘proposed’ traffic volume is 2405 KESAL/ year. No “noticeable” distress was observed in sections 204 and sections 209 through 212. No cracking (transverse or longitudinal) was observed in section 214 and in sections 209 through 212.

Transverse Cracking occurred in sections from 201 through 208 except 204. In sections 201, 202, 205, and 206, 30% to 42% of the slabs exhibited transverse cracks. Less than 3 cracks were observed in sections 203, 207, and 208. In sections 201, 202, and 206, 60 to 70% of the cracking is of medium or high severity.

Longitudinal cracking occurred only in sections 205 and 208 with about 29 m of cracking in 208 and less than 1.0 m of cracking in 205. All cracking is of low severity.

Measurable faulting occurred in less than 3 joints in sections 201, 202, 205, and 212. The initial roughness of the sections at this site ranged from 0.9 to 1.7 m/km. The latest IRI measurement indicates that after about 4 years of service, the roughness (IRI) ranges from 1.3 to 2.0 m/km.

**Colorado, CO (8)**

This test site is located in Dry Freeze zone and was opened to traffic in November 1993. Sections 214, 216, 219, 223, and 224 were built on coarse-grained soils while other sections were built on fine-grained soils. The 'proposed' traffic volume is 400 KESAL/year. No "noticeable" distress was observed in sections 214, 215, 216 and 221.

One transverse crack each occurred in sections 218 and 222. Longitudinal cracking occurred only on sections 213, 217, and 222. Longitudinal cracking of about 21.0 m was observed in section 217 whereas less than 1.5 m of cracking occurred in sections 213 and 222. In section 217, about 38% of cracking is of medium severity.

No measurable wheelpath joint faulting occurred in 215 and 222. In other sections, measurable faulting (1.0 mm or more) occurred at 9% to 42% of joints. The initial roughness of the sections at this site ranged from 1.0 to 1.8 m/ km. According to the latest data, the roughness (IRI) ranges from 1.2 to 1.8 m/ km.

**Delaware, DE (10)**

This test site is located in Wet Freeze zone and was built on coarse-grained soils. The site was opened to traffic in May 1996. The 'proposed' traffic volume is 380 KESAL/year. Transverse cracking (9 cracks) occurred only in section 205. No "noticeable" distress was observed in sections 202, 203, 204, 208 and 212.

Longitudinal cracking occurred in sections 207 and 209 with magnitudes of 41 m and 3 m, respectively. In section 207 all cracking is of medium severity.

Measurable faulting (1.0 mm and more) occurred in all sections except 203 and 208. At least 15% of the joints exhibited measurable faulting in sections 201, 202, 205, 206, and 209. Faulting more than 1.0 mm was observed at 2 to 5 joints in sections 205, 209, and 210. The initial roughness of the sections at this site ranged from 0.8 to 1.6 m/km. After about 8 years of service, the roughness (IRI) ranges from 0.8 to 1.9 m/km.

**Iowa, IA (19)**

This test site is located in Wet Freeze zone and was built on fine-grained soils. The site was opened to traffic in December 1994. The 'proposed' traffic volume is 377 KESAL/year. No "noticeable" distress was observed in sections 214, 218, 219, 220, 222 and 223.

Transverse cracking, in 6% of slabs, occurred in section 217. Longitudinal cracking, of total length less than 5.0 m, occurred on sections 213, 222 and 224. All longitudinal cracking is of medium severity.

In sections 214 through 218, and 221, more than 30% of joints have measurable (1.0 mm or more) wheelpath joint faulting. Two joints each in sections 215 and 216 have faulted in excess of 2.0 mm. The initial roughness of the sections at this site ranged from 1.0 to 2.2 m/km. The latest IRI measurement indicates that after about 8 years of service, the roughness (IRI) ranges from 1.1 to 2.0 m/km.

### Kansas, KS (20)

This test site is located in the Wet Freeze zone and was built on fine-grained soils. The sections at this site, which is the oldest site in the experiment, were opened to traffic in August 1992. The ‘proposed’ traffic volume is 757 KESAL/year. No “noticeable” distress was observed in sections 208 and 209.

Transverse cracking occurred in sections 201 and 202. 4 transverse cracks occurred in 201 and 2 cracks occurred in 202. Longitudinal cracking of length less than 7.0 m occurred in sections 201, 206 and 208.

Measurable faulting occurred at 20% to 45% of joints in all sections except 202, 204, 207, 209, and 211. Moreover, faulting of 2.0 mm or more occurred at 1 or 2 joints of all sections except 209 and 211. The initial roughness of the sections at this site ranged from 1.1 to 2.1 m/km. After about 12 years of service, the roughness (IRI) ranges from 1.0 to 2.0 m/km.

### Michigan, MI (26)

This test site is located in the Wet Freeze zone and was built on fine-grained soils. The site was opened to traffic in November 1993. The ‘proposed’ traffic volume is 1505 KESAL/ year. Sections 213, 215, 217, and 218 have been de-assigned from the experiment after rehabilitation was done to the sections. Among the sections that are in the experiment, only 214 and 218 have “noticeable” distress.

Among the sections that are in the experiment, transverse cracking (5 cracks) was observed in section 214.

Measurable faulting occurred at less than 20% of joints in all sections (in the experiment) except 216. Faulting greater than 1.0 mm occurred at less than 12% of joints in sections 223 and 214. The initial roughness of the sections at this site ranged from 0.9 to 1.8 m/km. Roughness (IRI), as per the latest data, ranges from 1.1 to 4.1 m/km.

### Nevada, NV (32)

This test site is located in Dry Freeze zone and was opened to traffic in September 1995. All sections except 201 and 205 were built on coarse-grained soils. The ‘proposed’ traffic volume is 800 KESAL/year. Section 212 had severe cracking following paving and it was replaced with nonconforming materials. Thus the section was removed from the experiment in 1995. In addition, sections 202 and 206 were de-assigned from the experiment following rehabilitation work. All the sections exhibited “noticeable” distress.

In sections 203 and 205, 168 and 221 transverse cracks occurred, of which 80 to 95 % of is medium or high severity cracking. In all sections, except 206 and 209, at least 70 % of cracking is of medium or high severity. Also, more than 125 m of longitudinal cracking occurred in the same sections. In sections 203, 205, and 207, 70 to 95% of cracking is of medium to high severity.

Except in sections 201 and 210, at least 20% of the joints have measurable faulting. Faulting greater than 1.0 mm was observed at 2 joints each in sections 205 and 207. The initial roughness of the sections at this site ranged from 0.8 to 1.6 m/km. Roughness (IRI), as per the latest data, ranges from 1.1 to 2.5 m/ km.

### North Carolina, NC (37)

This test site is located in Wet No Freeze zone and was built on fine-grained soils. Traffic was opened on the site in July 1994. The ‘proposed’ traffic volume is 715 KESAL/year. “Noticeable” distress was observed in sections 201, 202, 204, 205, and 210.

Transverse cracking was observed in sections 201 and 205. A total of 12 transverse cracks (36% of slabs) occurred in section 205 while 1 crack occurred in section 201. Longitudinal cracking occurred in 203, 205 and 210. A total of 6 m of longitudinal cracking occurred in section 205 whereas cracking of less than 1.0 m length occurred in 205 and 210. All cracking (transverse and longitudinal) is of low severity.

Measurable faulting occurred at 20% to 35% of joints in sections 201, 202, 206, and 210. The initial roughness of the sections at this site ranged from 1.1 to 1.6 m/km. Roughness (IRI), as per the latest data, ranges from 1.1 m/ km to 1.8 m/km.

**North Dakota, ND (38)**

This test site is located in Wet Freeze zone and was opened to traffic in November 1994. The site was built on fine-grained soils. The 'proposed' traffic volume is 420 KESAL/year. "Noticeable" distress did not occur in sections 213, 221, 222, and 223.

8 transverse cracks (half of high severity) in 217 and 1 crack each in sections 219, 220, and 224 were observed. No cracking occurred in other sections.

Longitudinal cracking was observed in sections 217, 218, and 224. Section 217 exhibited longitudinal cracking of total length equal to 75 m whereas 218 and 224 exhibited cracking less than 10 m. Almost all of the cracking is of medium or high severity in sections 217 and 224.

Except for sections 223 and 218, all the other sections had measurable faulting at 30% of joints or more. Among sections with "noticeable" distress, all sections except 218 have faulting greater than 1.0 mm at 1 to 6 joints. The initial roughness of the sections at this site ranged from 1.2 to 2.0 m/km. After about 10 years of service, the roughness (IRI) ranges from 1.1 to 1.9 m/km.

**Ohio, OH (39)**

This test site is located in Wet Freeze zone and was opened to traffic in October 1996. The site was built on fine-grained soils. The 'proposed' traffic volume is 608 KESAL/year. No "noticeable" distresses were observed in sections 203, 207 and 208. Longitudinal cracking did not occur on any of the test sections.

Sections 203, 207, 208, and 211 exhibited no transverse cracking. Section 205 exhibited 25 transverse cracks (in 76% of slabs) while other cracked sections exhibited less than 7 cracks. 10 cracks in 205 and 6 cracks (out of 7) in 210 are of medium or high severity.

Sections 203, 204, 207, and 208 had at least 20% of the joints that faulted 1.0 mm or more. Sections 204, 205, and 211 had one joint each with measurable faulting. The initial roughness of the sections at this site ranged from 0.9 to 1.5 m/km. After about 8 years of service, the roughness (IRI) ranges from 0.9 to 1.8 m/km.

**Washington, WA (53)**

This test site is located in Dry Freeze zone and was opened to traffic in November 1995. The site was constructed on fine-grained soils. The ‘proposed’ traffic at the site is 462 KESAL/year. “Noticeable” distress occurred only in sections 205, 206 and 212.

Transverse cracks (less than 5 cracks i.e. 15% of slabs) occurred in sections 205 and 206. Longitudinal cracking occurred in section 206 with a total length of 4 m (low severity).

Measurable faulting was recorded in all sections except 202, 209 and 210, and 211. Among the sections that have faulted joints, less than 6 joints have faulting of 1.0 mm. The initial roughness of the sections at this site ranged from 0.8 to 1.2 m/km. Roughness (IRI), as per the latest data, ranges from 0.8 to 1.8 m/km.

**Wisconsin, WI (55)**

This test site is located in Dry Freeze zone and was opened to traffic in November 1997. The site was constructed on coarse-grained soils. The ‘proposed’ traffic volume is 462 KESAL/year. “Noticeable” distress occurred in sections 216 and 222. No cracking (transverse or longitudinal) has occurred on any of the sections. While 12% to 36% joints in 213, 214, 219, 221, and 222 had measurable faulting, 15% of joints in 222 faulted more than 1 mm. The initial roughness of the sections at this site ranged from 0.8 to 1.6 m/ km. Roughness (IRI), as per the latest data, ranges from 0.8 to 1.6 m/ km.

## 6.5 SITE-LEVEL ANALYSES

This section of the report is a discussion of the results obtained from site-level analyses of the SPS-2 experiment data. The concepts of performance index (PI) and relative performance were used to perform site-level analyses (details in Chapter 4), as in the case of SPS-1 experiment. These analyses were conducted separately for each performance measure. These performance measures are:

- Transverse cracking,
- Longitudinal cracking,
- Faulting, and
- Roughness (IRI).

Site-level analyses deal with each SPS-2 project separately. For each site, the climatic conditions, subgrade type (for most of the sites) and traffic are same. Construction conditions, material sources and surveys were also considered to be same for all sections within each SPS-2 site.

As described in Chapter 4, the site-level analyses consists of two types of comparisons: (i) Level-A — In this analysis all designs (201 through 212, or 213 through 224) at a given site are compared (among themselves) such that only one factor (design feature) is held common within the sections of each group under comparison; (ii) Level-B — In this analysis, most of the factors (design features) are “controlled” for comparisons. The analysis process is summarized in Figure 6-7. The results from level-A and level-B comparisons, in terms of relative performance ratio, can be found in Appendix B4.

Non-parametric tests (Wilcoxon Signed Ranks test and Friedman test) were performed on relative performance ratio to determine the statistical significance of the difference in relative performance ratio of different levels within each design factor. For example, the relative performance ratio corresponding to transverse cracking, for sections with 203 mm (8-inch) slab and sections with 279 mm (11-inch) slab were compared to investigate the statistical significance of the consistency of the effect of PCC slab thickness on transverse cracking across sites. A p-value less than or equal to 0.05 was considered to be indicative of a statistically significant consistency of an effect.

In site-level analyses, statistical significance of an effect needs to be interpreted as the significance of the effect's consistency across sites but not necessarily as significance of its effect on the magnitude of distress.

In this chapter, the discussion of results for level-A and level-B analyses is presented separately. Some basic descriptive statistics regarding the performance of the test sections are also presented, to corroborate the results. Though these statistics are not at site-level they are meant to give the reader an insight about the extent/occurrence of distresses.

In the SPS-2 experiment, only the test sections built on PATB were provided with in-pavement drainage. As a consequence of this, the impact of drainage alone or base type alone cannot be studied. In other words, the effect of PATB and the effect of drainage cannot be separated. Therefore, an assumption was made that DGAB and PATB are structurally the "same" (as in the case of SPS-1 experiment [12]), and the analysis was performed by comparing performance of sections constructed on DGAB and sections constructed on PATB. It is important to note that the effect of drainage discussed in this report would be a result of comparison between sections on DGAB and sections on PATB. Furthermore, to study the effect of base type, the performance of sections with DGAB, sections with LCB and sections with PATB were compared. Here too the effect of PATB is fused with the effect of drainage.

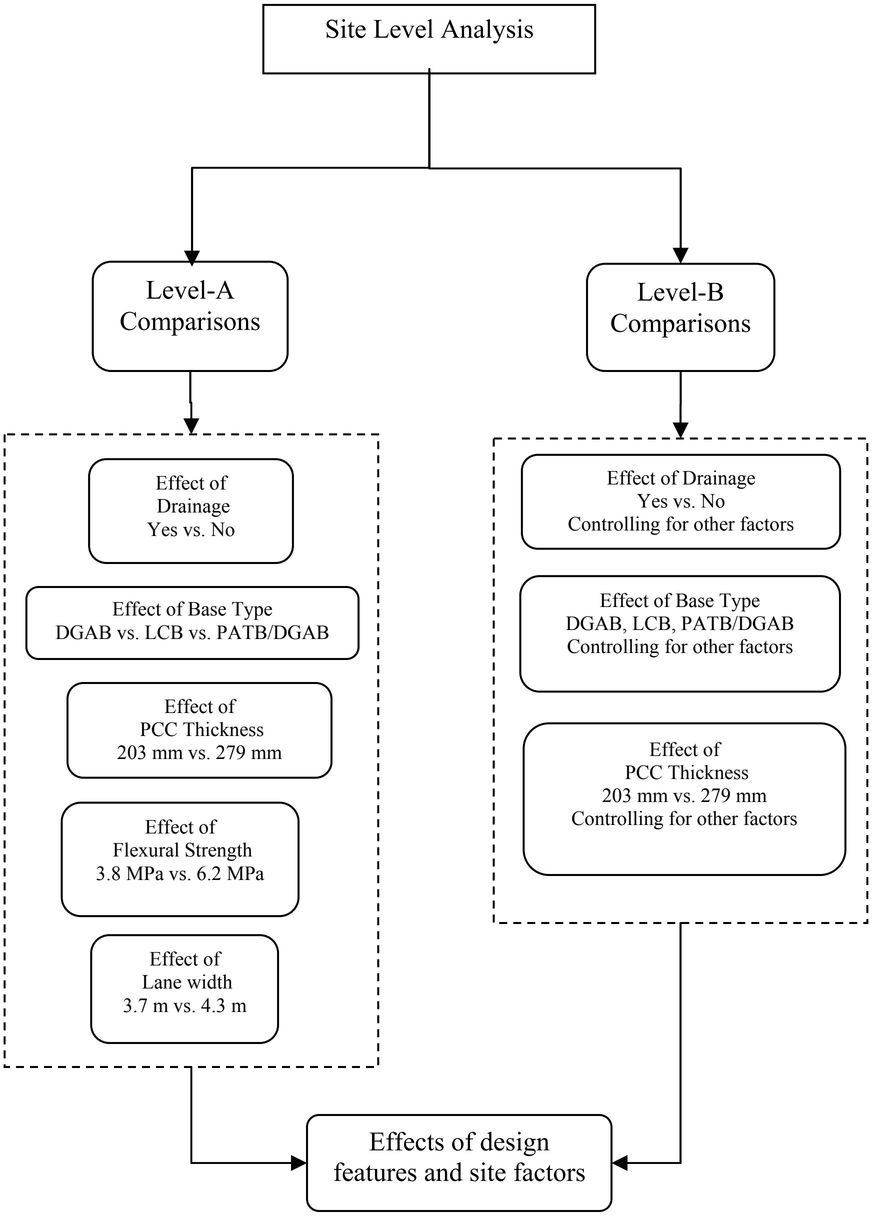


Figure 6 - 7 Methodology for site-level analyses (SPS-2)

### 6.5.1 Effect of design features on performance- Comparisons at level-A

The discussion of results from level-A analyses is presented here. These results are presented taking one design feature at a time.

#### *Drainage*

To investigate the effects of drainage, sections 201 through 204, and, 213 through 216 were considered as "without drainage" and sections 209 through 212, and, 220 through 224 were considered as "with drainage". Hence it is important to note that the effects of drainage that are discussed here are from comparisons only between sections built on DGAB and sections built on PATB.

From level-A analysis, the effects of drainage on cracking, faulting and roughness are inconclusive, at this point in time. This observation should not be interpreted as drainage not having a significant impact on pavement performance in general. All the observations and conclusions need to be interpreted keeping in view the age of the test sections and the low occurrence of distresses in the SPS-2 test sections.

Table 6- 2 is the summary of effects of drainage on cracking (transverse and longitudinal). The effect of drainage on cracking in different climates is also inconclusive. Table 6- 3 is a summary of results obtained from level-A analysis on wheelpath joint-faulting and roughness.

#### *Base Type*

Sections built on each of the three base types, DGAB, LCB and PATB, were compared at each site to study their relative impact on performance. The analysis is a comparison among 56 sections built on DGAB, 56 sections built on LCB and 55 sections built on PATB. Base type was found having a consistent effect on cracking. However, the effect is not consistent (across sites) for faulting and roughness.

Approximately 59% of sections built on LCB have exhibited cracking compared to 38% of sections built on DGAB and 25% of sections built on PATB. Though the analysis indicates higher cracking in sections built on LCB, the conclusions need to be considered in light of the construction issues (details in Appendix B1) and, the magnitude and severity of cracking.

Table 6- 4 is the summary of the effects of base type on cracking.

Table 6-5 is the summary of the effects of base type on faulting and roughness. In general, the trend of faulting suggests higher faulting in the sections built on DGAB. The effect of base type on roughness seems to be inconclusive because at most of the sites the difference in IRI of sections built on the three base types is not considerably high. As of latest distress survey, 80% of the sections in the experiment have IRI less than 1.8 m/km. The extent and magnitude of the distresses are to be considered along with the conclusions.

Table 6- 2 Effects of drainage on cracking, based on Level-A analysis

| Design Factor | Performance Measure | Effect | Comments |
|---|---|---|---|
| Drainage* | Transverse cracking | Inconclusive (p=0.299) | • In 5 of the 14 sites, no cracking occurred and the performance of sections with and without drainage is thus similar.<br>• In 6 of the 9 sites with distressed sections, sections without drainage exhibited more cracking than ones with drainage.<br>• Overall, 25% of sections without drainage and 12% of sections with drainage have exhibited cracking.<br>• 21% of sections in WF zone, 13% of sections in WNF, 35% of sections in DF zone, and 19% of sections in DNF zone have exhibited cracking. |
| | Longitudinal cracking | Inconclusive (p= 0.411) | • In 5 of the 9 sites with distressed sections, sections without drainage exhibited more cracking than ones with drainage.<br>• In 5 of the 14 sites, no cracking occurred and the performance of sections with and without drainage is thus similar.<br>• Overall, 21% of sections without drainage and 19% of sections with drainage have exhibited cracking.<br>• 9% of sections in WF zone, 19% of sections in WNF, 35% of sections in DF zone, and 25% of sections in DNF zone have exhibited cracking. |

*Effect of drainage is a result of comparison between sections built on DGAB and sections built on PATB.

Table 6- 3 Effects of drainage on faulting and roughness, based on Level-A analysis

| Design Factor | Performance Measure | Effect | Comments |
|---|---|---|---|
| Drainage* | Wheelpath joint-faulting (>1.0 mm) | Inconclusive (p= 0.699) | • In 7 of the 14 sites, sections without drainage exhibited more faulting than ones with drainage.<br>• In 5 of the 14 sites, sections with drainage performed poorer than sections without drainage.<br>• 46% of sections without drainage and 31% of sections with drainage have faulting>1.0 mm (at one joint or more).<br>• 45% of sections in WF zone, 56% of sections in WNF, 8% of sections in DF zone, and 25% of the sections in DNF zone have exhibited faulting>1.0 mm (at one joint or more). |
| | Roughness (IRI) | Inconclusive (p= 0.084) | • In 11 of the 14 sites, the performance of sections with and without drainage is comparable.<br>• Average latest roughness of sections without drainage and sections with drainage are 1.6 and 1.3 m/km. |

*Effect of drainage is a result of comparison between sections built on DGAB and sections built on PATB.

Table 6- 4 Effects of base type on cracking based on Level-A analysis

| Design Factor | Performance Measure | Effect | Comments |
|---|---|---|---|
| Base type | Transverse cracking | Consistent effect (p= 0.000) | • In all the 13 sites with distressed sections, higher cracking was observed in sections built on LCB, compared to other sections.<br>• 25%, 46% and 12% of sections on DGAB, LCB, and PATB, respectively, exhibited cracking. |
| | Longitudinal cracking | Consistent effect (p= 0.002) | • In 11 of the 13 sites with distressed sections, higher cracking was observed in sections built on LCB, compared to other sections.<br>• 21%, 42% and 19% of sections on DGAB, LCB, and PATB, respectively, exhibited cracking. |

Table 6- 5 Effects of base type faulting and roughness based on Level-A analysis

| Design Factor | Performance Measure | Effect | Comments |
|---|---|---|---|
| Base type | Wheelpath joint-faulting (>1.0 mm) | Inconclusive (p= 0.238) | • In 7 of the 14 sites, more faulting was observed in sections built on DGAB, compared to other sections. In 3 sites sections on PATB and in 2 sites sections on LCB had higher faulting.<br>• 46%, 37% and 31% of sections on DGAB, LCB, and PATB, respectively, have faulting>1.0mm, at one joint or more.<br>• 43% of sections in WF zone, 42% of sections in WNF zone, 23% of sections in DF, and 29% of sections in DNF zone exhibited faulting. |
| | Roughness (IRI) | Inconclusive (p= 0.064) | • In 10 of the 14 sites, comparable roughness was observed in all sections.<br>• In 4 of the 14 sites, more roughness was observed in sections built on DGAB, compared to other sections.<br>• Average latest roughness of sections on DGAB, LCB, and PATB are 1.6, 1.6 and 1.3 m/km, respectively. |

***PCC slab thickness***

A total of 84 sections with 203 mm (8-inch) PCC slab and 83 sections with 279 mm (11-inch) PCC slab were compared (at site-level) for this analysis. This includes all the sections in the experiment.

The effect of slab thickness is consistent in the case of transverse and longitudinal cracking. Though a deviation from target thickness was observed in considerable number of sections (details in Chapter 3), the analysis indicates a significant effect of PCC slab thickness on cracking. Table 6- 6 is the summary of effects of PCC slab thickness on cracking. It is to be noted here that 49% of cracking (transverse and/or longitudinal) has occurred in sections that were built on LCB, of which 67% of the sections are sections with 203 mm (8-inch) PCC slabs. These statistics suggest a noticeable effect of both slab thickness and base type.

The effect of PCC slab thickness on faulting and roughness is summarized in Table 6- **7**. Sections constructed with 203 mm (8-inch) PCC slab had slightly more faulting in 5 sites while a reverse trend was observed in 4 sites. In addition, the roughness of both 203 mm (8-inch) PCC slab and 279 mm (11-inch) PCC slab sections was found to be comparable at all sites, suggesting an insignificant effect of slab thickness on roughness. The effect of PCC slab thickness on faulting and IRI is thus inconclusive.

Table 6- 6 Effects of slab thickness on cracking, based on Level-A analysis

| Design Factor | Performance Measure | Effect | Comments |
|---|---|---|---|
| PCC slab thickness | Transverse cracking | Consistent effect (p= 0.001) | • In all sites that have distressed sections (13 sites), more cracking was observed in sections with 203 mm (8-inch) PCC slab, compared to sections with 279 mm (11") PCC slab.<br>• 40% of sections with 203 mm (8-inch) PCC slab and 15% of sections with 279 mm (11") PCC slab exhibited cracking. |
| | Longitudinal cracking | Consistent effect (p= 0.020) | • In 11 of the 13 sites that have distressed sections, more cracking was observed in sections with 203 mm (8-inch) PCC slab, compared to sections with 279 mm (11") PCC slab.<br>• 41% of sections with 203 mm (8-inch) PCC slab and 14% of sections with 279 mm (11") PCC slab exhibited cracking. |

Table 6- **7** Effects of slab thickness on faulting and roughness, based on Level-A analysis

| Design Factor | Performance Measure | Effect | Comments |
|---|---|---|---|
| PCC slab thickness | Wheelpath joint-faulting (>1.0 mm) | Inconclusive (p= 0.665) | • In 5 of the 14 sites, more faulting was observed in sections with 203 mm (8-inch) PCC slab, while, in 4 sites a reverse trend was observed.<br>• 36% of sections with 203 mm (8-inch) and 40% of sections with 279 mm (11") PCC slab have faulting>1.0 mm (at one joint or more). |
| | Roughness (IRI) | Inconclusive (p= 0.414) | • In all the sites, comparable performance was observed in all sections.<br>• Average latest roughness of both the sections with 203 mm (8-inch) PCC slab and sections with 279 mm (11") PCC slab is 1.5 m/km. |

***PCC flexural strength***

The performance of test sections with target 14-day PCC flexural strength of 3.8 MPa and test sections with target 14-day PCC strength of 6.2 MPa was compared to study the effect of PCC flexural strength on the performance of SPS-2 sections. A total of 84 sections with 3.8 MPa concrete and 83 sections with 6.2 MPa concrete were compared. The effect of flexural strength on cracking, faulting and roughness appears to be insignificant. Comparable performance was observed in sections with higher strength concrete (6.2 MPa) and lower strength concrete (3.8 MPa).

It is important to consider the deviations from target flexural strength in the sections. A detailed discussion of the deviations was presented in Chapter 3. The deviation from target PCC 14-day flexural strength was studied using the data that is available for 52% of the sections in the experiment. The average 14-day flexural strength of PCC of sections with target strength of 3.8 MPa was 3.6 MPa while in sections with target strength of 6.2 MPa was 5.6 MPa. Among sections with target flexural strength of 3.8 MPa, 34% of sections had PCC flexural strength (at 14-days) that exceeded the allowable range of 3.4 MPa to 4.2 MPa, while 16% failed to reach even the lower limit of the range. In the case of sections with target flexural strength of 6.2 MPa, 34% of sections had PCC flexural strength (at 14-days) below the allowable range, and none of the sections exceeded the range. In half of the sections with target strength of 6.2 MPa that failed to meet the lower limit of the range, the PCC strength reached the required limit at 28-days. These deviations from target strength could be a reason for comparable performance of all the pavements.

Table 6- 8 is the summary of effects of PCC flexural strength on cracking. At most of the sites, comparable performance (cracking) was observed for both higher strength and lower strength concrete sections. The effect is thus inconclusive.

The effect of PCC flexural strength on faulting and roughness is summarized in Table 6- 9. In light of low occurrence of faulting, the effect of PCC flexural strength is inconclusive. Similarly, the effect of PCC flexural strength on roughness appears to be insignificant.

Table 6- 8 Effects of flexural strength on cracking, based on Level-A analysis

| Design Factor | Performance Measure | Effect | Comments |
|---|---|---|---|
| PCC flexural strength | Transverse cracking | Inconclusive (p=0.400) | • In 6 of the 14 sites, lower strength concrete sections exhibited higher cracking than higher strength concrete sections.<br>• In 5 of the 14 sites, all sections have performed at comparable levels.<br>• 26% of lower strength concrete sections and 25% of higher strength concrete sections exhibited cracking. |
|  | Longitudinal cracking | Inconclusive (p=0.944) | • In 7 of the 14 sites, lower strength concrete sections exhibited higher cracking than higher strength concrete sections.<br>• In 5 of the 14 sites, higher strength concrete sections exhibited higher cracking than lower strength concrete sections.<br>• 26% of lower strength concrete sections and 25% of higher strength concrete sections exhibited cracking. |

Table 6- 9 Effects of flexural strength on faulting and roughness, based on Level-A analysis

| Design Factor | Performance Measure | Effect | Comments |
|---|---|---|---|
| PCC flexural strength | Wheelpath joint-faulting (>1.0 mm) | Inconclusive (p=0.925) | • In 12 of the 14 sites, sections with higher strength concrete and lower strength concrete exhibited comparable level of performance.<br>• 31% of lower strength concrete sections and 40% of higher strength concrete sections have faulting>1.0 mm (at one joint or more). |
|  | Roughness (IRI) | Inconclusive (p=0.102) | • In all sites of the experiment, similar performance was observed in sections with higher strength concrete and sections with lower strength.<br>• Average latest roughness of lower or higher strength concrete sections is 1.5 m/km. |

### *Lane width*

The widened lane [4.3 m (14 ft)] sections were compared to those with standard lane [3.7 m (12 ft)] to study the effect of lane width on performance of the test sections. For this, 84 sections with standard lane width and 83 sections with widened lane were compared. Some effect of lane width was observed only in the case of faulting. The effect of lane width on other distresses seems to be insignificant.

In general, the effect of lane width on transverse cracking seems to be insignificant as widened lane sections and standard lane sections have performed similarly in most of the sites. But some effect of lane width seems to exist on longitudinal cracking. In a majority of the sites (9 of 13) slightly higher longitudinal cracking was observed in widened lane sections compared to standard lane sections. This could be due to the geometry of the wider lane (4.3 m) that causes greater transverse bending stresses in widened lanes, as opposed to a standard lane (for same loading). Table 6- 10 is the summary of effects of lane width on cracking.

A consistent effect of lane width was found on wheelpath joint-faulting, in that, sections with standard lane experienced more faulting that ones with wider lane (4.3 m) at most of the sites. This could be because of the greater distance of wheelpath from edge in the case of wider lane (4.3 m) that causes less corner stresses in wider lane (4.3 m) sections. Table 6- 11 presents a summary of the lane width effect on faulting and roughness. The effect of lane width on roughness is inconclusive at this point in time.

Table 6- 10 Effects of lane width on cracking based on Level-A analysis

| Design Factor | Performance Measure | Effect | Comments |
|---|---|---|---|
| Lane Width | Transverse cracking | Inconclusive (p=0.222) | • In 6 of the 14 sites, sections with standard lane exhibited higher cracking than ones with wider lane (4.3 m).<br>• In 5 of the 14 sites, both standard lane and wider lane (4.3 m) sections have shown comparable levels of performance.<br>• 28% and 24% of sections with standard lane and wider lane (4.3 m), respectively, have exhibited cracking. |
| | Longitudinal cracking | Inconclusive (p=0.362) | • In 9 of the 14 sites, sections with wider lane (4.3 m) exhibited higher cracking than ones with wider lane (4.3 m).<br>• 25% and 26% of sections with standard lane and wider lane (4.3 m), respectively, have exhibited cracking. |

Table 6- 11 Effects of lane width on faulting and roughness based on Level-A analysis

| Design Factor | Performance Measure | Effect | Comments |
|---|---|---|---|
| Lane Width | Wheelpath joint-faulting (>1.0 mm) | Consistent effect **(p=0.003)** | • In 9 of the 14 sites, sections with standard lane exhibited higher faulting than ones with wider lane (4.3 m).<br>• 39% of standard lane sections and 32% of wider lane (4.3 m) sections have faulting>1.0 mm (at one joint or more). |
| | Roughness (IRI) | Inconclusive (p=0.096) | • In all sites of the experiment, similar performance was observed in sections with standard lane and sections with wider lane (4.3 m).<br>• Average latest roughness of standard lane sections and wider lane (4.3 m) sections are 1.6 and 1.5 m/km. |

### 6.5.2 Effect of design features- Paired Comparisons at Level-B

Level-B comparisons are those in which all possible factors other than the one of interest are controlled. The individual sections that are compared under this analysis were identified in chapter 4. The effects of drainage, base type, and PCC slab thickness on the performance measures are presented below.

***Drainage***

Sections with drainage (i.e. sections with PATB) were compared with sections without drainage (sections with DGAB) controlling the effects of all other factors, namely, PCC slab thickness, lane width, and flexural strength. The effect of drainage is consistent (across sites) on transverse cracking. Slight effect was observed on roughness, whereas no effect was apparent in the case of faulting and longitudinal cracking.

For sections with 203 mm (8") PCC slab, the effect of drainage seems to be consistent on transverse cracking. Table 6- 12 is the summary of effects of drainage on cracking. The effect of drainage on longitudinal cracking is inconclusive. Sections with drainage and without drainage performed similarly in varying conditions.

Table 6- 13 is a summary of effects of drainage on faulting and roughness. No consistent effect seems to exist on the occurrence of faulting. In general, more sections without drainage have faulted than ones with drainage. Among sections with 203 mm (8") slab, a slight effect of drainage ($p=0.076$) appears to exist on roughness in those with standard lane. Sections without drainage have slightly higher roughness than ones with drainage.

Table 6- 12 Effect of drainage on cracking, based on Level-B analysis

| Design Factor | Performance Measure | Effect | Comments |
|---|---|---|---|
| Drainage* | Transverse cracking | Consistent effect **(p=0.034)** | • At 5 of the 7 sites with distresses sections, among sections 203 mm (8") PCC slab, sections without drainage cracked more than sections with drainage.<br>• Among 203 mm (8") PCC slab, 18% and 43% of sections with drainage and without drainage have exhibited transverse cracking.<br>• Cracking was observed only at two sites in the thicker (279 mm) slab sections. |
| | Longitudinal cracking | Inconclusive | • No discernable trends were observed for longitudinal cracking.<br>• Among 203 mm (8") PCC slab, 25% of sections with drainage and 25% of sections without drainage have exhibited longitudinal cracking. |

*Effect of drainage is a result of comparison between sections built on DGAB and sections built on PATB.

Table 6- 13 Effect of drainage on faulting and roughness, based on Level B analysis

| Design Factor | Performance Measure | Effect | Comments |
|---|---|---|---|
| Drainage* | Wheelpath joint-faulting (>1.0 mm) | Inconclusive | • In most of the sites, among 203 mm (8") PCC slab, the sections without drainage faulted more than sections with drainage.<br>• Among the 203 mm (8") PCC slab, 25% of sections with drainage and 36% of sections without drainage exhibited faulting. |
| | Roughness (IRI) | Slight effect (p=0.076) | • Effect of drainage seems to be negligible as the sections with drainage and without drainage have performed similarly in most of the sites.<br>• Among the 203 mm (8") PCC slab, the average roughness of sections with drainage and without drainage are 1.3 and 1.6 m/km. |

*Effect of drainage is a result of comparison between sections built on DGAB and sections built on PATB.

### *Base Type*

Sections built on each of the three base types, DGAB, LCB and PATB, were compared at each site by controlling the effects of PCC slab thickness and lane width. A consistent effect of base type on transverse and longitudinal cracking was observed. The effect of base type on faulting and roughness is not clear.

On average, among sections built with 203 mm (8-inch) slabs, those built on LCB have exhibited higher transverse cracking than other sections (see Table 6-14). This trend was observed in a majority of sites. Among sections with 203 mm (8-inch) slab and standard lane width, the trend is consistent (p=0.001) across the sites. This effect may be an “interaction effect”, as the effect of base type was discernable among sections with 203 mm (8-inch) slab and standard lane, and not in sections with 279 mm (11-inch) slab.

The effect of base type on longitudinal cracking (see Table 6-14) is consistent among sections with 203 mm (8-inch) slab, in that sections built on LCB have higher cracking than those on other bases.

The effect of base type on faulting is inconclusive. In general, a slight effect of base type was observed on faulting, in that sections built on DGAB had higher faulting than other sections at a majority of the sites, irrespective of other design features. Table 6-15 is a summary of effects of base type on faulting and roughness. The effect of base type on roughness is inconclusive.

### *PCC slab thickness*

The performance of sections with target PCC slab thickness of 203 mm was compared with that of sections with target PCC slab thickness of 279 mm by controlling the effects of base type and PCC flexural strength. The effect of PCC slab thickness was consistent on cracking (transverse and longitudinal), whereas no noticeable effect was found on faulting and roughness. Among sections built with DGAB or LCB, sections with 8-inch (203 mm) slab had higher cracking than sections with 11-inch (279 mm) slab. Table 6-6 is the summary of effects of PCC slab thickness on cracking. In the case of longitudinal cracking, the effect was found consistent among sections built with LCB with higher cracking in sections with 8-inch (203 mm) slab. Table **6-** 17 is a summary of the effect of PCC slab thickness on faulting and roughness. The effect of PCC slab thickness on faulting and roughness is inconclusive.

Table 6- 14 Effect of base type on cracking, based on Level B analysis

| Design Factor | Performance Measure | Effect | Comments |
|---|---|---|---|
| Base type | Transverse cracking | Consistent effect **($p<0.05$)** | • In 9 sites, among thinner slab (203 mm) sections, sections built on LCB cracked more than sections on other base types.<br>• 43%, 64% and 18% of sections on DGAB, LCB and PATB have exhibited cracking among thinner (203 mm) slab sections. |
| | Longitudinal cracking | Consistent effect **($p<0.05$)** | • In 8 sites, of the 12 sites at which cracking was observed, sections built on LCB exhibited more cracking sections built on other base types.<br>• Among the thinner slab (203 mm) sections, 54% of sections built on LCB and 25% of other sections exhibited cracking. |

Table 6- 15 Effect of base type on faulting and roughness, based on Level B analysis

| Design Factor | Performance Measure | Effect | Comments |
|---|---|---|---|
| Base type | Wheelpath joint-faulting (>1.0 mm) | Inconclusive | • Those built on DGAB seem to be experiencing higher faulting than other sections, especially among sections built on fine-grained soils.<br>• 39% of sections built on DGAB, 34% of sections built on LCB and 26% of sections built on PATB have faulting >1.0 mm, at one or more joints. |
| | Roughness (IRI) | Inconclusive | Effect of base type seems to be negligible as all the sections performed similarly, in general. |

Table 6- 16 Effect of slab thickness on cracking, based on Level B analysis

| Design Factor | Performance Measure | Effect | Comments |
|---|---|---|---|
| PCC slab thickness | Transverse cracking | Consistent effect **($p<0.05$)** | Thinner slab (203 mm) sections exhibit more transverse cracking than thicker slab (279 mm) sections, among sections with DGAB or LCB. |
| | Longitudinal cracking | Consistent effect **($p<0.05$)** | Thinner slab (203 mm) sections exhibit more longitudinal cracking than thicker (279 mm) slab, among sections with LCB. |

Table 6- 17 Effect of slab thickness on faulting and roughness, based on Level B analysis

| Design Factor | Performance Measure | Effect | Comments |
|---|---|---|---|
| PCC slab thickness | Wheelpath joint-faulting (>1.0 mm) | Inconclusive | Effect of base type seems to be negligible as all the sections perform similarly |
| | Roughness (IRI) | Inconclusive | Effect of base type seems to be negligible as all the sections perform similarly |

## 6.6 OVERALL ANALYSIS

The results obtained from statistical analyses performed on the SPS-2 data are presented in this section. Both the performance and response variables were analyzed to study the effects of various design and site-factors on the pavement sections. Analyses were performed combining all data and is referred to as 'Overall' analyses. Analyses were also conducted in each climatic zone combining data from all sections within a zone as per the recommendation of the project panel. Linear Discriminant Analysis (LDA), Binary Logistic Regression (BLR), and Analysis of Variance (ANOVA) are the statistical methods that were employed for analyses.

### Analysis of Performance Measures

The performance measures that were analyzed to investigate the impact of design and site factors on rigid pavement performance are as follows:

- Transverse cracking,
- Longitudinal cracking,
- Wheel path joint-faulting, and
- Roughness (IRI)- initial roughness and change in roughness.

The significance of factors affecting occurrence of transverse cracking, longitudinal cracking, faulting and roughness were determined using LDA and BLR, which are frequency-based methods (details in Chapter 4). For analyses on cracking, the test sections were grouped into 2 categories – sections with cracking, and sections without cracking. Faulting greater than 1.0 mm was considered to be "noticeable" (distress) given the low levels of faulting in test sections. In LDA and BLR analysis on faulting, sections with at least one occurrence of noticeable faulting were categorized as one group, and the other sections were categorized as another. Analyses were then performed to identify factors that significantly discriminate the groups. In the case of IRI, a threshold of 1.5 m/km was used to separate the test sections as groups. The value corresponds to the threshold between "normal" and "poor" pavements [13] for an age of 7 years, which is the average age of SPS-2 test sections.

As mentioned in Chapter 4, ANOVA was used to determine the significance of factors impacting initial roughness (IRI), change in roughness (first survey to latest survey), and joint-faulting. The number of joints that faulted greater than 1.0 mm was taken as the performance measure for faulting. ANOVA method could not be applied to transverse and longitudinal cracking as the assumption of constant variance of residuals was violated owing to occurrence of cracking in not more than 30% of test sections. Wherever required, a natural logarithmic transformation of the variable of interest was done to satisfy the assumptions of ANOVA. Traffic volume and age of test sections were considered as covariates in all analyses to adjust for the difference in traffic loading and age among the sites in the experiment.

### Analysis of Response (FWD) Measures

The response measures that were analyzed to determine the effects of design and site factors are as follows:

- Deflection under FWD load ($d_0$): This deflection corresponds to the structural strength of the entire pavement structure.
- Deflection at the farthest sensor from FWD load ($d_6$): This deflection gives an idea about the strength of the subgrade soil.
- Effective Stiffness (ES) of the PCC slab.
- Area Factor (AF) of the PCC slab of the pavement.

Each of the above measures was derived or calculated from the midslab FWD testing (J1). FWD testing is conducted at 10 slabs on each section during a typical survey. For a section, an average of the deflections from all the tests corresponding to a survey was used for obtaining the above response measures.

Effective Stiffness (ES) of PCC slab and Area Factor (AF) were calculated based on the study by Stubstad [14]. Higher the ES or AF, stiffer the upper layer of the pavement.

Analysis was conducted on the above measures corresponding to first survey and to last survey, separately. It was assumed that the measures corresponding to first survey of the sections, gives an idea about the contribution of the design and site factors to the as-built structural condition of the test sections. Also, it was assumed that analysis of the response measures corresponding to the latest (or final) survey provides information about the contribution of the design and site factors to the “long-term” performance of the test sections.

It is known that the temperature of the PCC slab at the time of testing has considerable bearing on the deflections of the PCC slab. For this, in all the analyses on response parameters, surface and bottom temperatures at the time of testing were taken as covariates.

## RESULTS FROM ANALYSES

The following is a summary of the main findings from each method of analysis, categorized by performance measure and response indicator. Basic statistics pertaining to the extent of occurrence of distresses have been presented along with results to corroborate the results with data. It is suggested that the results be interpreted keeping in view the extent of distresses (see Chapter 3) that occurred in the test sections.

In the discussion of results, the word ‘significance’ needs to be interpreted as statistical significance, unless specified as practical significance. An asterisk in the results indicates both practical and statistical significance of an effect.

As mentioned before, all analyses were conducted without including data from the site in Nevada (32), as extensive distresses at the site are related to wide range of construction issues that occurred at the site but not to pavement performance. Inclusion of data from this site will affect results from analyses, significantly.

### 6.6.1 Extent of Distresses by Experimental Factor

This section contains a discussion on the effect of key experimental factors as in the case of the SPS-1 experiment. As stated earlier in Chapter 3, the occurrence of cracking and faulting in the SPS-2 sections was “low”. Hence, only roughness (latest or final roughness) of the test sections is presented to illustrate the effects of experimental factors on roughness (see Figure 6-8). Figure 6-8 indicates that about 60% of all test sections have shown IRI value higher than 1 m/km, with about 20% of all test sections showing IRI value higher than 1.4 m/km. The effect of specific design and site factors is discussed below. The following is a summary of inferences from analysis of roughness:

a) Drainage: The effect of drainage, in terms of higher percentage of test sections showing roughness, is more pronounced at the higher levels of roughness. This could mean that drainage is effective in reducing growth of roughness [see Figure 6-8 (a)].

b) Base Type: The difference in the percentage of test sections that have roughness, between those built on DGAB and those built on PATB are highest among all experimental factors (about 20%). Sections built on DGAB bases showed the highest percentages, while those built on LCB and those built on PATB showed comparable values [see Figure 6-8 (a)].

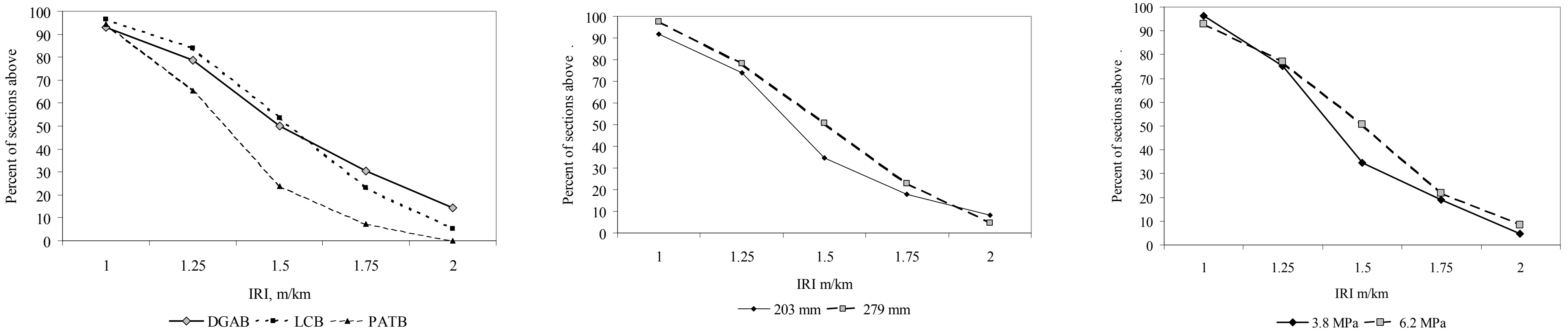
c) PCC Slab Thickness: The percentage of test sections with 203 mm (8-inch) PCC slab that have IRI of at least 1.5 m/km is about 30% as compared to about 50% for test sections with 279 mm (11-inch) PCC slab. The difference in percentage of test sections with higher roughness levels for sections with different thickness is negligible [see Figure 6-8 (b)].

d) Flexural Strength: The percentage of test sections with higher strength concrete (6.2 MPa) that have IRI of at least 1.5 m/km is about 50% as compared to about 30% for test sections with lower strength concrete (3.8 MPa). This difference is lesser at higher levels of roughness [see Figure 6-8 (c)].

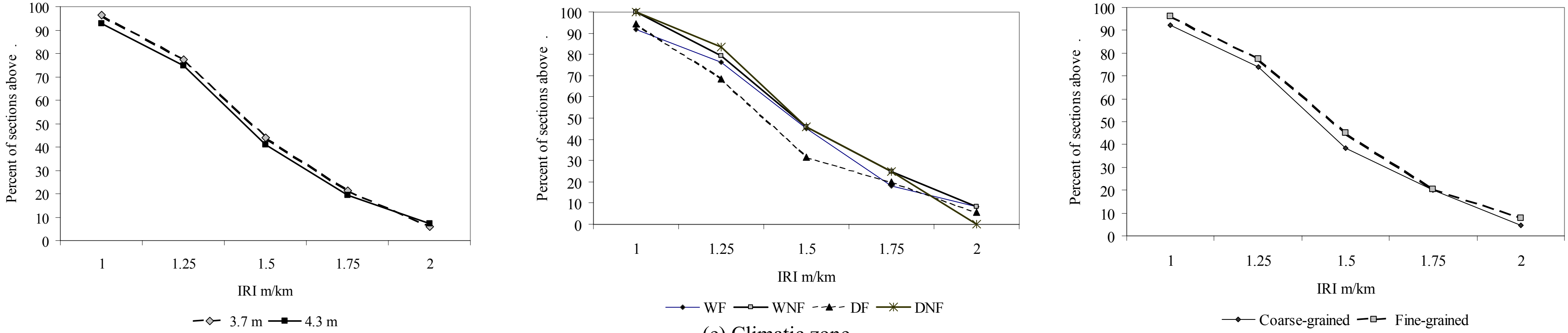
e) Lane Width: Consistently, more sections with standard lane width 3.7 m (12-feet) have exceeded (slightly) various IRI levels than sections with widened lane 4.3 m (14-feet) [see Figure 6-8 (d)].

f) Climatic Zone: The effect of climate on roughness appears to be significant; with about 5% to 10% more sections in WF zone exceeding 1.5 m/km than sections in DF zone [see Figure 6-8 (e)].

g) Subgrade Soil Type: Consistently sections built on fine-grained soils have exceeded (slightly) various IRI levels than sections built on coarse-grained soils [see Figure 6-8 (f)].



(a) Base type (b) PCC slab thickness (c) PCC flexural strength



(d) Lane Width (e) Climatic zone (f) Subgrade

Figure 6 - 8 Effect of experimental factors on roughness

### 6.6.2 Frequency-based Methods

Two frequency-based methods were used- Linear Discriminant Analysis and Binary Logistic Regression (details in Chapter 4). The results from these analyses are as follows:

*Linear Discriminant Analysis*

Based on this method all the distresses were analyzed using the following thresholds for categorization of the sections.

- Transverse or longitudinal cracking: Cracked versus non-cracked
- Wheel path joint faulting: Faulting ≤1.0 mm versus Faulting> 1.0 mm
- Roughness: IRI (final)< 1.5 m/km versus IRI (final)>1.5 m/km
  IRI (initial)<1.25 m/km versus IRI (initial)> 1.25 m/km.

This analysis is intended to identify the experimental factors that best discriminate the distresses versus non-distressed pavement sections. As the pavements in the SPS-2 experiment have not shown a "high" level of distress, this analysis will help in finding the significant design and site factors contributing to the occurrence of distresses (rather than magnitude), at this point in time. Traffic and pavement age, are considered as covariates in this analysis.

**Transverse cracking**

The design factors drainage, base type, and target PCC thickness were significant in discriminating between cracked or un-cracked sections. Table 6- 18 summarizes the effect of the design and site factors on the occurrence of transverse cracking, in general.

In the WF zone, the effects of PCC thickness (p=0.041) and subgrade soil type (p= 0.007) were statistically significant in discriminating between sections with cracking and without cracking. Table 6- 19 summarizes effects of experimental factors based on the results of LDA on transverse cracking for sections in WF zone.

It was observed that 33% of sections with 203 mm slab have exhibited transverse cracking while 14% of sections with 279 mm slab have exhibited cracking. Moreover, 14% of sections with thinner (203 mm) slab have exhibited high severity cracking where as none of the thicker (279 mm) slab sections exhibited high severity cracking. While 33% of sections built on fine-grained soils manifested transverse cracking, 4% of sections built on coarse-grained exhibited cracking. Also, about 22% (13 of the 60 sections) of sections built on fine-grained subgrade soils have exhibited high severity cracking while 4% (1 of the 24 sections) of the sections built on coarse-grained soils exhibited cracking.

Table 6- 18 Summary of results from LDA on transverse cracking- Overall

| Factor Category | Factor | Effects on transverse cracking | p-value |
|---|---|---|---|
| Design | Drainage | Presence of drainage significantly reduces the chances of occurrence of cracking | ***Yes (*0.001)** |
| | Target PCC thickness | Thicker (279 mm) PCC thickness reduces the chances of occurrence of cracking | ***Yes* (0.001)** |
| | Base type | The type of base significantly impacts the chances of the occurrence of cracking | ***Yes* (0.044)** |
| | Flexural Strength | No significant effect. In general, the 6.2 MPa mixes tend to mitigate cracking. | No (0.716) |
| | Lane Width | No significant effect. 4.3 m wide lane sections tend to inhibit cracking. | No (0.467) |
| Site | Climatic Zone | No significant effect. Designs constructed in Dry zones tend to crack more. | No (0.147) |
| | Subgrade soil type | No significant effect, however the model indicates that sections on fine subgrade soils tend to crack more than sections on coarse subgrade soils | No (0.538) |

Table 6- 19 Results from LDA on transverse cracking, WF zone

| Factor | Effects on transverse cracking | p-value |
|---|---|---|
| Drainage | No significant effect. Presence of drainage reduces the chances of occurrence of cracking | No (0.151) |
| Target PCC thickness | Sections with thicker (279 mm) PCC slabs crack significantly less | ***Yes* (0.041)** |
| Base type | No significant effect. Sections on LCB tend to crack more. | No (0.214) |
| Flexural Strength | No significant effect. In general, the 6.2 MPa mixes tend to crack more | No (1.000) |
| Lane Width | No significant effect. 4.3 m wide lane sections tend to inhibit cracking | No (0.614) |
| Subgrade soil type | Sections on fine subgrade soils tend to crack significantly more than sections on coarse subgrade soils | ***Yes* (0.007)** |

### Longitudinal cracking

The effect of target PCC thickness, base type and the climatic zone are significant in discriminating between cracked and un-cracked sections. Table 6-20 summarizes the effect of the design and site factors on the occurrence of longitudinal cracking.

The effects of PCC thickness and base type, in WF zone, were statistically significant in discriminating between sections with cracking and sections with no cracking. Table 6- 21 summarizes the effects of experimental factors based on the results from LDA on longitudinal cracking, for pavements in WF zone.

While 19% of sections with 203 mm (8-inch) PCC slab have exhibited longitudinal cracking, 10% of sections with 279 mm (11-inch) PCC slab have exhibited cracking. Also, 7%, 25%, and 11% of sections built on DGAB, LCB and PATB, respectively, have exhibited longitudinal cracking.

Table 6- 20 Summary of results from LDA on longitudinal cracking

| Factor category | Factor | Effects on longitudinal cracking | p-value |
|---|---|---|---|
| Design | Drainage | No significant effect. Presence of drainage increases the chances of occurrence of cracking. | No (0.180) |
| | Target PCC thickness | Thicker (279 mm) PCC thickness reduces the chances of occurrence of cracking | ***Yes (0.000)*** |
| | Base type | The type of base significantly impacts the chances of the occurrence of cracking | ***Yes (0.004)*** |
| | Flexural Strength | No significant effect. In general, the 6.2 MPa mixes tend to mitigate cracking. | No (0.834) |
| | Lane Width | No significant effect. 4.3 m wide lane sections tend to have more cracking. | No (0.834) |
| Site | Climatic Zone | Designs constructed in Dry zones tend to crack more. | ***Yes (0.009)*** |
| | Subgrade soil type | No significant effect, however the model indicates that sections on fine subgrade soils tend to crack more than sections on coarse subgrade soils | No (0.456) |

Table 6- 21 Results from LDA on Longitudinal cracking, in WF zone

| Factor | Effects on longitudinal cracking | p-value |
|---|---|---|
| Drainage | No significant effect. Sections with drainage have cracked more than the ones without drainage | No (0.193) |
| Target PCC thickness | Thicker (279 mm) PCC thickness significantly reduces the chances of occurrence of cracking | ***Yes (0.026)*** |
| Base type | Sections on LCB crack significantly more than other sections | ***Yes (0.023***) |
| Flexural Strength | No significant effect. In general, the 6.2 MPa 900-psi mixes tend to crack more. | No (1.000) |
| Lane Width | No significant effect. 4.3 m wide lane sections tend to inhibit cracking. | No (0.463) |
| Subgrade soil type | No significant effect, the model indicates that sections on fine subgrade soils tend to crack more than sections on coarse subgrade soils | No (0.296) |

### Faulting

None of the design or site factors are discriminating between sections with faulting and without faulting, at this point in time. Climate appears to have some effect (p-value= 0.098), in that; the pavements located in Wet zones have higher faulting than those located in Dry zones (see Table 6-22). Analysis was also conducted combining data from sections located in the WF zone and none of the factors were found to be significantly affecting the occurrence of faulting.

### Roughness

The initial and current roughness of the test sections were analyzed by categorizing the variables using the thresholds mentioned before. Table 6-23 and Table 6-24 are results from these analyses. PCC thickness was the only factor that was found to be discriminating between "smooth" and "rough" pavement sections based on the initial IRI categories. Based on LDA on current roughness, drainage, PCC thickness, and base type were found to be the significant factors.

Table 6- 22 Summary of LDA on Faulting

| Factor category | Factor | Effects on faulting | p-value |
|---|---|---|---|
| Design | Drainage | No significant effect. Presence of drainage decreases the chances of faulting. | No (0.202) |
| | Target PCC thickness | No significant effect. Thicker (279 mm) PCC thickness increases the chances of occurrence of pumping. | No (0.623) |
| | Base type | No significant effect. Lesser faulting occurs in LCB. | No (0.315) |
| | Flexural Strength | No significant effect. In general, the 6.2 MPa mixes tend to have more faulting. | No (0.251) |
| | Lane Width | No significant effect. 3.7 m wide lanes tend to have more faulting. | No (0.412) |
| Site | Climatic Zone | No significant effect. Designs constructed in Wet zones tend to have more faulting. | No (0.098) |
| | Subgrade soil type | No significant effect, however the model indicates that sections on fine subgrade soils tend to fault lesser than sections on coarse subgrade soils | No (0.846) |

Table 6- 23 Summary of results from LDA on initial roughness

| Factor category | Factor | Effects on initial roughness | p-value |
|---|---|---|---|
| Design | Drainage* | Presence of drainage decreases the chances of higher initial roughness. | No (0.090) |
| | Target PCC thickness | Sections with 279 mm PCC slab have higher chances of being built rougher than the 203 mm ones. | ***Yes (0.054)*** |
| | Base type | No significant effect. Lesser roughness was observed on sections built with PATB. | No (0.329) |
| | Flexural Strength | No significant effect. In general, the 6.2 MPa mixes tend to have more roughness. | No (0.201) |
| | Lane Width | No significant effect. 4.3 m wide lanes tend to have more roughness. | No (0.750) |
| Site | Climatic Zone | No significant effect. Designs constructed in Wet zones tend to have more roughness. | No (0.232) |
| | Subgrade soil type | No significant effect Sections on fine subgrade soils tend to have more initial roughness. | No (0.342) |

* The effect of drainage is based on comparison between sections built on PATB and sections built on DGAB.

Table 6- 24 Summary of results from LDA on initial roughness, in WF zone

| Factor | Effects on initial roughness | p-value |
|---|---|---|
| Drainage* | No significant effect. Presence of drainage decreases the chances of higher initial roughness. | No (0.356) |
| Target PCC thickness | No significant effect. Sections with 279 mm PCC slab have higher chances of being built rougher than 203 mm ones. | No (0.835) |
| Base type | No significant effect. Sections with PATB tend to be built smoother. | No (0.0.594) |
| Flexural Strength | No significant effect. In general, the 6.2 MPa mixes tend to have more roughness. | No (0.190) |
| Lane Width | No significant effect. 3.7 m wide lanes tend to have more roughness. | No (0.190) |
| Subgrade soil type | No significant effect. Sections on fine subgrade soils tend to have more initial roughness. | No (0.071) |

*The effect of drainage is based on comparison between sections built on PATB and sections built on DGAB.

Table 6- 25 Summary of results from LDA on roughness

| Factor category | Factor | Effects on final (latest) roughness | p-value |
|---|---|---|---|
| Design | Drainage | Presence of drainage inhibits increase in roughness. | ***Yes (0.000)*** |
| | Target PCC thickness | Thicker (279 mm) PCC thickness increases the chances of higher roughness. | ***Yes (0.036)*** |
| | Base type | Sections on DGAB and LCB have higher increase in roughness. | ***Yes (0.017)*** |
| | Flexural Strength | No significant effect. In general, the 6.2 MPa mixes tend to cause more roughness. | No (0.076) |
| | Lane Width | No significant effect. 12-foot wide lanes tend to have lesser roughness. | No (0.873) |
| Site | Climatic Zone | No significant effect. Designs constructed in Wet zones tend to have more roughness. | No (0.588) |
| | Subgrade soil type | No significant effect. Sections on fine subgrade soils have more roughness. | No (0.317) |

Table 6- 26 Summary of results from LDA on roughness, in WF zone

| Factor | Effects on final (latest) roughness | p-value |
|---|---|---|
| Drainage | Presence of drainage inhibits increase in roughness. | ***Yes (0.008)*** |
| Target PCC thickness | No significant effect. Thicker (279 mm) PCC thickness decreases the chances of higher roughness. | No (1.000) |
| Base type | Sections on DGAB have higher increase in roughness. | ***Yes (0.032)*** |
| Flexural Strength | No significant effect. In general, 6.2 MPa mixes tend to cause more roughness. | No (0.081) |
| Lane Width | No significant effect. 3.7 m wide lanes tend to have more roughness. | No (0.193) |
| Subgrade soil type | Sections on fine subgrade soils have more roughness. | ***Yes (0.004)*** |

### *Binary Logistic Regression (BLR)*

The BLR model was used to model the probability of occurrence for the various performance measures. Thresholds similar to the ones used for LDA were used to categorize the test sections for this analysis. The results are summarized in Table 6-27 and Table 6-28.

#### Transverse Cracking

The BLR model for transverse cracking was significant with a p-value of 0.000. Moreover, 88.5% of the times, the model correctly differentiate cracked sections from non-cracked sections. Based on this analysis, the effects of significant factors are as follows:

*PCC slab thickness*—Sections built with 203 mm (8-inch) PCC slab have significantly higher probability of cracking than the ones built with 279 mm (11-inch) PCC slab.

*Base Type*—Sections built on PATB have significantly higher likelihood of cracking than those built on LCB.

*Subgrade*—Sections built on fine subgrade soils have significantly higher probability of cracking than the ones built on coarse subgrade soils.

Based on the BLR on data from sections in WF zone, the effect subgrade soil type (0.029 in BLR) was statistically significant in discriminating between sections with cracking and sections without cracking.

#### Longitudinal Cracking

The BLR model for longitudinal cracking was significant with a p-value of 0.000. Moreover, 88.5% of the times, the model correctly differentiates cracked sections from un-cracked sections. Based on this analysis, the following conclusions can be made.

*Base Type*—Sections on LCB have significantly higher chances of cracking compared to the DGAB sections.

*PCC slab thickness*—Sections with 203 mm thick slab have significantly higher chances of cracking than the Sections with 279 mm thick slab.

*Climatic Zone*—Sections in Dry No Freeze have significantly higher chances of cracking than Wet Freeze.

From BLR on data from sections in WF zone, it was found that PCC slab thickness has a slight effect ($p = 0.084$) on cracking.

### Faulting

The BLR model for faulting was significant with a p-value of 0.010. Moreover, 69.9% of the times, the model correctly differentiates sections with faulting from sections without faulting. From the analysis the following effects were found to be significant:

*Subgrade type*—Sections on coarse-grained soils have significantly higher chances of faulting than the sections that are built on fine-grained soils.

*Climatic Zone*— The chances of occurrence of faulting are slightly higher for the non-drained sections. Also, the chances of occurrence of faulting in Wet freeze climatic zone are higher than those in Dry No Freeze zone.

Table 6- 27 Summary of p-values from BLR for determining the effect of experimental factors on pavement performance measures- Overall

| Experimental Factors | Transverse cracking | Longitudinal cracking | Faulting | Roughness | |
|---|---|---|---|---|---|
| | | | | Initial | Current |
| Drainage | 0.083 (3.4) | 0.616 (0.68) | 0.06 (2.3) | 0.28 (1.6) | 0.003 (7.5) |
| Base type | 0.073 (4.9)* | 0.099 (2.7) | 0.17 (1.4) | 0.12 (2.4) | 0.007 |
| PCC thickness | 0.019 (3.6) | 0.001 (8.7) | 0.955 (0.98) | 0.018 (0.49) | 0.381 (0.67) |
| Flexural Strength | 0.550 (1.4) | 0.825 (1.13) | 0.24 (0.65) | 0.17 (0.63) | 0.077 (0.44) |
| Lane Width | 0.389 (1.6) | 0.800 (1.15) | 0.381 (1.37) | 0.687 (0.87) | 0.876 (0.931) |
| Subgrade type | 0.003 (9.5) | 0.361 (1.98) | 0.046 (0.38) | 0.186 (1.73) | 0.283 (1.97) |
| Climatic Zone | 0.571 | 0.017 (18) | 0.104 | 0.400 | 0.262 |

Note: Values in parenthesis are odds ratios.
*LCB vs. PATB.

Table 6- 28 Summary of p-values from BLR for determining the effect of experimental factors on pavement performance measures- WF Zone

| Experimental Factors | Transverse cracking | Longitudinal cracking | Faulting | Roughness | |
|---|---|---|---|---|---|
| | | | | Initial | Current |
| Drainage | 0.736 (0.74) | 0.55 (0.35) | 0.140 (2.34) | 0.510 (1.5) | 0.004 (47.4) |
| Base type | 0.767 | 0.237 | 0.32 | 0.383 | 0.014 |
| PCC thickness | 0.650 (1.43) | 0.084 (11.3) | 0.763 (1.15) | 0.058 (.039) | 0.066 (5.05) |
| Flexural Strength | 0.643 (0.70) | 0.868 (0.84) | 0.723 (0.85) | 0.141 (0.48) | 0.222 (0.37) |
| Lane Width | 0.593 (1.49) | 0.234 (4.65) | 0.337 (1.57) | 0.147 (2.1) | 0.655 (1.39) |
| Subgrade type | 0.029 (19.5) | 0.488 (0.23) | 0.636 (0.70) | 0.066 (2.97) | 0.368 (3.009) |

Note: Values in parenthesis are odds ratios.

## Roughness

The BLR model for initial roughness was significant with a p-value of 0.023. Moreover, 61.5% of the times, the model correctly differentiates sections with “poor” roughness from other sections. Based on this analysis, base type and PCC slab thickness are significant factors that discriminate between the categories. The effects of the factors are:

> Base Type—Sections built on LCB have significantly (p-value=0.040) higher probability of roughness than the ones built on PATB.
>
> PCC slab thickness—Sections built with thinner slab (203 mm) have significantly (p-value=0.038) lesser probability of being built rougher than the ones built with thicker slab (279 mm).

The BLR model for latest roughness was significant with a p-value of 0.000. Moreover, 78.8% of the times, the model correctly differentiate sections with “poor” roughness from other sections. Based on this analysis, only base type has a significant effect on the categories and the effect is described below.

> Base Type—Sections built on DGAB or LCB have significantly (p-value=0.007) higher probability of roughness than the ones built on PATB. This may also be interpreted that sections with drainage have significantly lesser chances of becoming rougher compared to sections without drainage (sections on DGAB).

### 6.6.3 Analysis of Variance

ANOVA was performed on roughness and faulting of sections in the SPS-2 experiment. The procedure adopted for this analysis is the same as that for analysis of SPS-1 data. As mentioned before, the analyses were performed combining data from all sections (overall) in the experiment. Also ANOVA was conducted on data for sections within each zone. It should be noted that analysis within zone was presented only for the WF zone. Each of the other zones has two sites each and this sample size did not yield meaningful results because of less statistical "power". The effects of design factors and site factors on pavement performance are discussed next leading to a discussion on results from analysis of pavement response.

***Effects of design factors on pavement performance***

The results from this analysis are summarized in Table 6-29 and these results indicate that the most significant design factor is the base type, which has a significant effect on ΔIRI and $IRI_{o.}$ In addition to the effect of base type, ΔIRI is affected by drainage and PCC thickness (slight effect), $IRI_o$ is affected by PCC slab thickness, and faulting is affected by lane width.

For investigating the practical (operational) significance of the mean difference between the levels of design factors, the marginal means (predicted cell means from the model) were transformed back to the original scale of the distress, as discussed in Chapter 5. These conversions were necessary in order to find out the practical/operational mean difference.

Table 6- 30 shows the back-transformed marginal means for all levels of design factors. The following discussion summarizes significant effects of design factors on pavement performance:

- **Effect of drainage:** Pavement sections with drainage have shown significantly lower change in roughness than those without drainage. This effect was found to be practically significant (>0.10 m/km per year).
- **Effect of base type**: Pavement sections with DGAB have shown the highest change in roughness while those with PATB have shown the least change in roughness. This difference in change in roughness between sections with DGAB and sections with PATB is practically significant (>0.10 m/km per year). Sections built with LCB had the highest initial roughness while other sections had comparable initial roughness.

- **Effect of PCC thickness**: Significantly (practically and statistically) higher initial roughness was observed on sections with 279 mm (11") PCC slab compared to sections with 203 mm (8") PCC slab. However, the change in roughness was slightly higher in sections with 203 mm PCC slab compared to those with 279 mm PCC slab.
- **Effect of flexural strength**: No significant effect of PCC flexural strength was found on roughness and faulting, at this point.
- **Effect of lane width**: Pavement sections with wider lane (4.3 m) have shown significantly lower faulting than those with standard lane (3.7 m). No significant effect of lane width was found on roughness.

Table 6- 29 Summary of p-values from ANOVA for determining the effects of design factors on pavement performance – Overall

| **Factor** | **Faulting** | **Roughness (IRI)** | |
|---|---|---|---|
| | | **ΔIRI** | **$IRI_o$** |
| Drainage | 0.477 | 0.002* | 0.373 |
| PCC thickness | 0.243 | 0.094* | 0.003 |
| Base Type | 0.585 | 0.009* | 0.037 |
| PCC Flexural Strength | 0.903 | 0.544 | 0.246 |
| Lane Width | 0.050 | 0.860 | 0.313 |
| Site (blocked) | 0.000 | 0.006 | 0.000 |
| | N=110<br>$R^2$=0.411 | N=114<br>$R^2$=0.305 | N=156<br>$R^2$=0.344 |

* Also shows operational/practical significance

Table 6- 30 Summary of marginal means from ANOVA for determining the effect of main design factors on pavement performance measures—Overall

| Design Factor | | IRI | |
|---|---|---|---|
| | | ΔIRI (m/km) | $IRI_o$ (m/km) |
| Drainage | No | 0.34 | 1.33 |
| | Yes | 0.14 | 1.29 |
| PCC thickness | 203 mm | 0.32 | 1.25 |
| | 279 mm | 0.22 | 1.36 |
| Base Type | DGAB | 0.39 | 1.29 |
| | LCB | 0.30 | 1.37 |
| | PATB | 0.16 | 1.25 |
| PCC Flexural Strength | 3.8 MPa | 0.29 | 1.28 |
| | 6.2 MPa | 0.24 | 1.32 |
| Lane Width | 3.7 m | 0.26 | 1.32 |
| | 4.3 m | 0.27 | 1.28 |
| MSE | | 1.343 | 0.032 |

Similar ANOVA was performed on data from sections in the WF zone and Table 6- 31 is the summary of results from the analysis. Table 6- 32 shows the back transformed marginal means for all levels of design factors. As mentioned before, the results from analysis on data from other climatic zones are not presented, as limited amount of data is available for those zones. The following discussion summarizes significant effects of design factors on performance of sections in the WF zone:

- **Effect of drainage:** Pavement sections with drainage have shown significantly lower change in roughness than those without drainage. This effect was found to be practically significant (>0.10 m/km per year).
- **Effect of base type**: Pavement sections with LCB have shown significantly higher change in roughness compared to those with PATB and with DGAB. This difference in change in roughness between sections with LCB and sections with PATB is practically significant (>0.10 m/km per year). Sections with PATB have shown the least change in roughness. Sections built with LCB were found to have the higher initial roughness compared to other sections, which have comparable initial roughness.
- **Effect of PCC thickness**: Significantly (practically and statistically) higher initial roughness was observed on sections with 279 mm PCC slab compared to sections with 203 mm PCC slab. However, the change in roughness was significantly higher in sections with 203 mm PCC slab compared to those with 279 mm PCC slab.
- **Effect of flexural strength**: Significant effect of PCC flexural strength was found on initial roughness. Sections with higher strength concrete (6.2 MPa) had higher initial roughness compared to those with lower strength concrete (3.8 MPa).
- **Effect of lane width**: Slight effect of lane width was observed for initial roughness in that sections with standard lane (3.7 m) width were constructed with higher initial roughness.

Table 6- 31 Summary of p-values from ANOVA for determining the effects of design factors on pavement performance – WF Zone

| **Factor** | **Faulting** | **Roughness (IRI)** | |
|---|---|---|---|
| | | **ΔIRI** | **$IRI_i$** |
| Drainage | 0.420 | 0.012* | 0.688 |
| PCC thickness | 0.668 | 0.033* | 0.057 |
| Base Type | 0.701 | 0.004* | 0.557 |
| PCC Flexural Strength | 0.907 | 0.650 | 0.009 |
| Lane Width | 0.127 | 0.987 | 0.071 |
| Site (blocked) | 0.102 | 0.000 | 0.000 |
| | N=52<br>$R^2$=0.303 | N=58<br>$R^2$=0.505 | N=84<br>$R^2$=0.426 |

* Also shows operational/practical significance

Table 6- 32 Summary of marginal means from ANOVA for determining the effect of main design factors on pavement performance measures—WF Zone

| Design Factor | | IRI | |
|---|---|---|---|
| | | ΔIRI (m/km) | $IRI_o$ (m/km) |
| Drainage | No | 0.30 | 1.32 |
| | Yes | 0.13 | 1.29 |
| PCC thickness | 203 mm | 0.29 | 1.26 |
| | 279 mm | 0.16 | 1.36 |
| Base Type | DGAB | 0.26 | 1.30 |
| | LCB | 0.34 | 1.34 |
| | PATB | 0.11 | 1.27 |
| PCC Flexural Strength | 3.8 MPa | 0.20 | 1.24 |
| | 6.2 MPa | 0.23 | 1.38 |
| Lane Width | 3.7 m | 0.22 | 1.35 |
| | 4.3 m | 0.22 | 1.26 |
| MSE | | 0.947 | 0.033 |

### *Effect of Site Factors on Pavement Performance*

Given the unbalanced nature of the experimental design with respect to climatic zone, a one-way ANOVA was performed study the main effects of the subgrade soil type (fine-grained versus coarse-grained soils) and climatic zone (wet versus dry, freeze versus no-freeze), one at a time. The p-values and mean performances from these analyses are summarized in Table 6- 33 and Table 6- 34, respectively. To indicate the direction of effects, "+" and "-" signs are reported along with p-values. A "+" indicates that the first level has exhibited more distress than second level within a factor, while a "-" indicates otherwise. For example, in the case of the effect of subgrade on faulting, "+" indicates higher faulting in pavements constructed on fine-grained soils compared to those constructed on coarse-grained soils, as fine-grained soil is the first level and coarse-grained soil is the second.

The p-values indicate that subgrade type appears to be significant in affecting the initial roughness. Pavements built on fine-grained subgrade showed higher initial roughness than those constructed on coarse-grained subgrade.

Climate has a significant effect on faulting and initial roughness. Pavements located in "wet" climate have exhibited significantly higher faulting than those located in "dry" climate. A slight effect of climate was found within "dry" zones. Pavements located in DF zone exhibited higher faulting than those located in DNF zone. Pavements constructed in "wet" climate were found to have slightly higher initial roughness compared to those in "dry" climate.

Table 6- 33 Summary of p-values from one-way ANOVA for determining the effect of site factors on pavement performance measures

| Site Factor | Faulting | Roughness (IRI) | |
|---|---|---|---|
| | | $\Delta$IRI | IRI$_i$ |
| Subgrade | | | |
| Fine-grained vs. Coarse-grained | 0.184 (-) | 0.920 (+) | 0.050 (+) |
| Climate | | | |
| Wet vs. Dry | 0.006 (+) | 0.406 (-) | 0.052 (+) |
| Freeze vs. No Freeze | 0.924 (-) | 0.632 (-) | 0.317 (-) |
| Wet Freeze vs. Wet No Freeze | 0.163 (-) | 1.000 (+) | 1.000 (-) |
| Dry Freeze vs. Dry No Freeze | 0.092 (+) | 1.000 (-) | 1.000 (-) |

Table 6- 34 Summary of marginal means from one-way ANOVA for determining the effect of site factors on pavement performance measures

| Site Factor | | Faulting | Roughness (IRI) | |
|---|---|---|---|---|
| | | | $\Delta$IRI | IRI$_i$ |
| Subgrade | Fine-grained | 1.24 | 0.37 | 1.33 |
| | Coarse-grained | 1.64 | 0.38 | 1.25 |
| Climate | Wet | 1.68 | 0.35 | 1.33 |
| | Dry | 0.94 | 0.42 | 1.25 |
| | Freeze | 1.39 | 0.36 | 1.29 |
| | No Freeze | 1.41 | 0.41 | 1.33 |
| | Wet Freeze | 1.34 | 0.36 | 1.31 |
| | Wet No Freeze | 2.42 | 0.33 | 1.38 |
| | Dry Freeze | 1.18 | 0.38 | 1.21 |
| | Dry No Freeze | 0.52 | 0.50 | 1.29 |

## Effect of Design Factors on Pavement Performance based on standard deviates

As explained before in Chapter 4, the experiment design and the performance of the test sections have rendered the SPS-2 experiment unbalanced (statistical). Most of the sites, 9 of the 14, in the experiment were constructed in "wet" climate of which 7 are in the WF zone. Also, all 24 unique designs were not built in every soil-climate combination. Furthermore, non-occurrence of distresses in a considerable number of sections has also contributed to the unbalance. In light of these concerns, a simplified analysis considering one design factor at a time (univariate) was performed, as in the case of analysis of the effects of site factors.

The performance of similar designs was not found to be consistent across sites indicating a considerable influence of the site conditions at each site. The site conditions that could have contributed to this variation in performance are traffic, age, construction quality, measurement variability, and material properties, apart from site factors (i.e. subgrade and environment). In order to separate the "true" effects of the experimental factors, this "noise" should be nullified. The concept of standard deviate, as in the case of the SPS-1 experiment, was thus employed for the analyses on roughness and faulting (see Chapter 5).

This measure (standard deviate) indicates the relative performance of a design with respect to the other designs at the same site. As this measure was calculated for each section with respect to other sections in a site, it indicates the relative standing of the section compared to other sections in that site. It thus helps nullify the variation in performance (due to site conditions) across sites, as the sections are evaluated with respect to companion sections in each site. This approach of using the standard deviate is similar to blocking of the site factors performed in the multivariate analysis.

One-way analysis of variance (univariate) was performed on the standard deviates of the sections to study the effects of the design factors, by considering one design factor at a time. As the SPS-2 experiment design calls for study of the effects of design factors at different site conditions, the univariate analysis was performed accordingly. The analyses were performed on data from all sections and also on subsets of data corresponding to different subgrade types, climates and combination of these. This helped in identification of the effects of design factors under different site conditions.

To study the "pure" effect of each design factor, comparisons of standard deviates were also calculated by controlling for the other factors, as in the case of level-B analyses (site-level).

As mentioned earlier, these comparisons were performed only on roughness, and faulting. The method is not appropriate for cracking because of “low” occurrence of the distresses at this point in time. The effects of design factors, based on the above-mentioned analyses, on roughness and faulting are discussed next.

### Roughness

The effects of the design and site factors, in terms of standard deviate, are shown in Figure 6-9. The change in roughness was considered as the performance measure for analyses. The summary of p-values corresponding to these analyses is Table 6- 35. The mean change in roughness corresponding to each comparison presented in Table 6- 35 is shown in Table 6- 36. Though the univariate analyses were performed on standard deviates, these means were used to identify operational significance of the effects. The effects of the design factors on change in roughness, based on this analysis, are presented below:

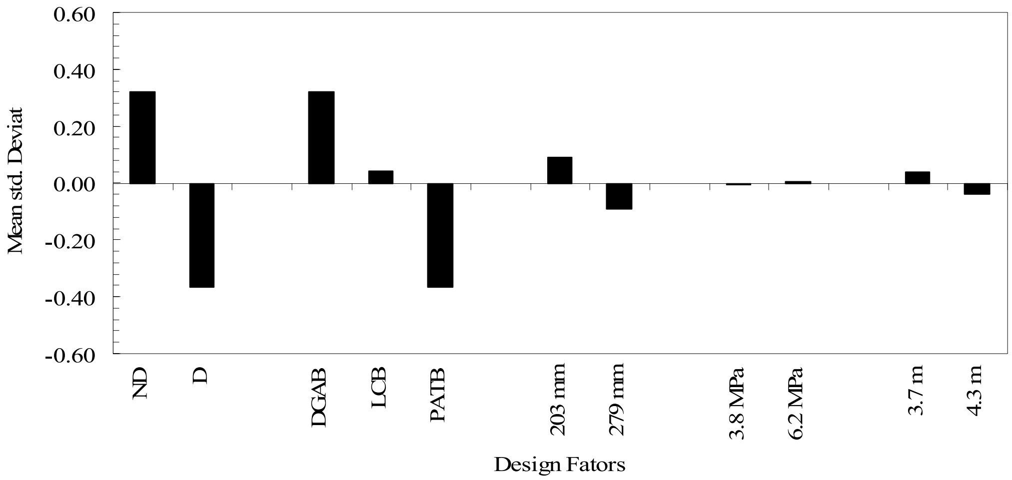
*Drainage*: On the whole, the effect of drainage is statistically and operationally significant. Un-drained sections have exhibited higher change in roughness than drained sections. This effect is consistent in all sections, irrespective of subgrade soil type. In addition, the effect is more prominent in “wet” climate. Among the sections located in WF zone, those built on fine-grained soils have shown greater change in roughness compared to those built on coarse-grained soils. This effect is marginally significant (statistical) but is of practical significance.

*Base Type*: As the effect of base type is confounded with the effect of drainage because of the SPS-2 experiment design, the results presented here are from comparisons between the performance of sections built with DGAB and sections built with LCB, which are both un-drained. On average, sections with LCB have shown lower change in roughness than sections with DGAB. This effect is not statistically significant. A significant (statistical and operational) effect of base type was observed among sections located in WNF zone, in that sections with DGAB have shown higher change in roughness than those with LCB. However, this effect should be interpreted with caution, as only two sites are located in WNF zone.

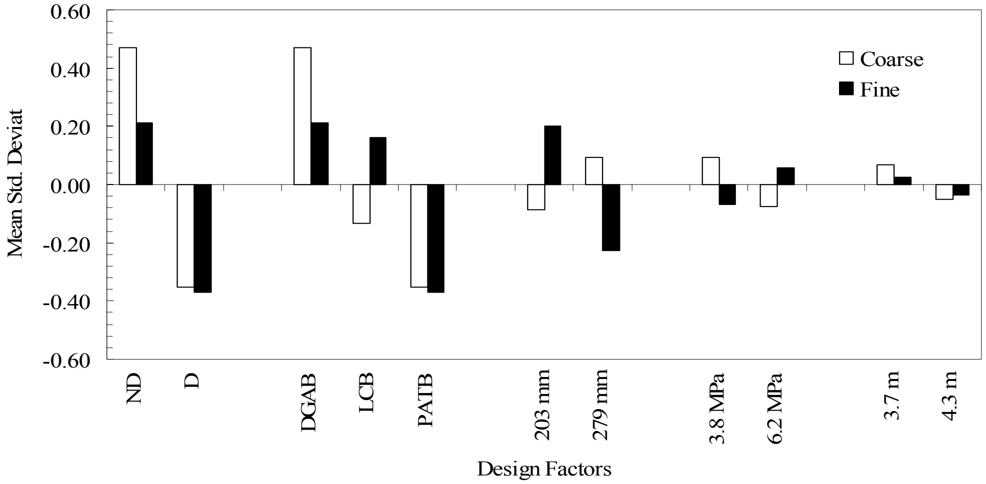
*PCC slab thickness*: The effect of PCC slab thickness is significant (statistical and operational) among sections built on fine-grained soils, especially when constructed in WF zone. Sections with 203 mm slab have shown higher change in roughness than those with 279 mm slab.

*PCC flexural strength*: The effect of PCC flexural strength was not found to be significantly affecting roughness of the SPS-2 sections, at this point in time.

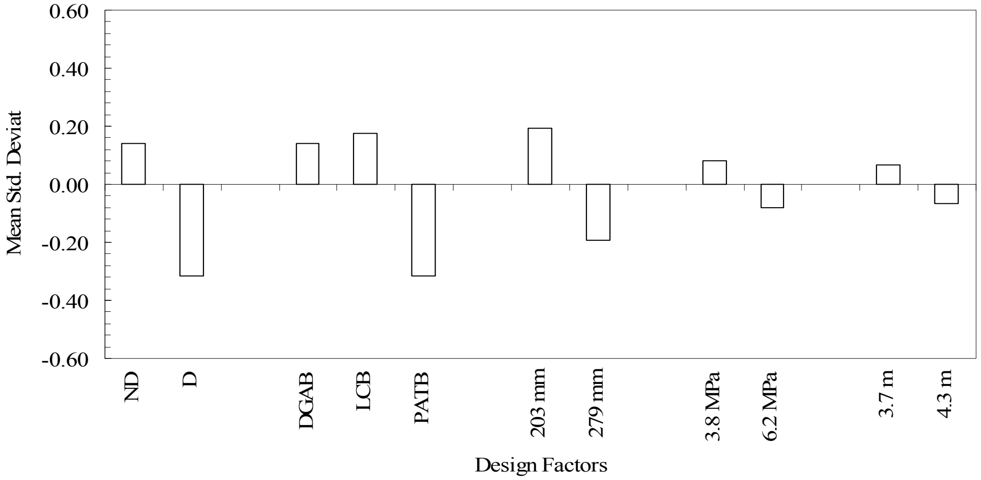
*Lane width*: The effect of lane width was not found to be significantly affecting roughness of the SPS-2 sections. On average, among sections built on fine-grained soils and located in WF zone, those with standard lane (3.7 m) have shown higher change in roughness than those with wider lane (4.3 m).



(a) Overall



(b) By subgrade type



(c) Wet Freeze (WF) zone

Figure 6 - 9 Effect of design factors on change in IRI

Table 6- 35 Summary of p-values for comparisons of standard deviates— Change in roughness

| Design Factor | Comparison | Overall | By subgrade |  | By climatic zone |  |  |  | By subgrade and zone |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | Fine | Coarse | WF | WNF | DF | DNF | WF |  | WNF |  | DF |  | DNF |  |
|  |  |  |  |  |  |  |  |  | F | C | F | C | F | C | F | C |
| Drainage | Drainage vs. No-Drainage | 0.000 | 0.009 | 0.002 | 0.052 | 0.024 | 0.004 | 0.084 | 0.071 | 0.497 | 0.297 | 0.048 | 0.051 |  |  | 0.084 |
| Base type | DGAB vs. LCB vs. PATB/DGAB | 0.001 | 0.024 | 0.016 | 0.102 | 0.003 | 0.003 | 0.123 | 0.094 | 0.852 | 0.082 | 0.017 | 0.055 |  |  | 0.123 |
| PCC thickness | 203 mm vs. 279 mm | 0.240 | 0.029 | 0.469 | 0.067 | 0.626 | 0.773 | 0.230 | 0.015 | 0.718 | 0.565 | 0.949 | 0.923 |  |  | 0.230 |
| PCC flexural Strength | 3.8 MPa vs. 6.2 MPa | 0.962 | 0.530 | 0.506 | 0.442 | 0.226 | 0.832 | 0.603 | 0.797 | 0.065 | 0.255 | 0.639 | 0.941 |  |  | 0.603 |
| Lane Width | 3.7 m vs. 4.3 m | 0.500 | 0.770 | 0.639 | 0.530 | 0.776 | 0.992 | 0.667 | 0.491 | 0.934 | 0.790 | 0.975 | 0.772 |  |  | 0.667 |

Note: Shaded cells indicate statistical significance at 90% or higher level of confidence (p<0.1).

Table 6- 36 Summary of mean change in roughness

| Design Factor | Comparison | Overall | SG |  | Zone |  |  |  | WF |  | WNF |  | DF |  | DNF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | F | C | WF | WNF | DF | DNF | F | C | F | C | F | C | C |
| Drainage | ND | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.1 | 0.4 | 0.5 | 0.1 | 0.1 | 0.5 | 0.1 | 0.1 | 0.4 |
|  | D | 0.1 | 0 | 0.1 | 0 | 0.1 | -0.1 | 0.2 | 0 | 0 | 0.1 | 0.1 | 0 | -0.2 | 0.2 |
| Base type | DGAB | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.1 | 0.4 | 0.5 | 0.1 | 0.1 | 0.5 | 0.1 | 0.1 | 0.4 |
|  | LCB | 0.2 | 0.3 | 0.1 | 0.3 | 0.1 | 0.3 | 0.2 | 0.4 | 0.1 | -0.1 | 0.2 | 0.3 | 0.3 | 0.2 |
|  | PATB | 0.1 | 0 | 0.1 | 0 | 0.1 | -0.1 | 0.2 | 0 | 0 | 0.1 | 0.1 | 0 | -0.2 | 0.2 |
| PCC slab thickness | 203 mm | 0.2 | 0.3 | 0.2 | 0.3 | 0.2 | 0.1 | 0.2 | 0.4 | 0.1 | 0.1 | 0.3 | 0.1 | 0.1 | 0.2 |
|  | 279 mm | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.3 | 0.2 | 0.1 | 0 | 0.3 | 0.1 | 0 | 0.3 |
| PCC flexural strength | 3.8 MPa | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.2 | 0.3 | 0.1 | 0 | 0.3 | 0.1 | 0.1 | 0.2 |
|  | 6.2 MPa | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 | 0.2 | 0.3 | 0 | 0.1 | 0.3 | 0.1 | 0 | 0.2 |
| Lane width | 3.7 m | 0.2 | 0.3 | 0.2 | 0.3 | 0.1 | 0.1 | 0.3 | 0.4 | 0.1 | 0.1 | 0.3 | 0.1 | 0.1 | 0.3 |
|  | 4.3 m | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 | 0.2 | 0.2 | 0.1 | 0.1 | 0.3 | 0.1 | 0 | 0.2 |

**Faulting**

The effects of the design and site factors on faulting, in terms of standard deviate, are shown in Figure 6-10. The number of joints that faulted more than 1.0 mm was considered as the performance measure for PI, and the standard deviate is based on PI. The summary of p-values corresponding to analyses on faulting is Table 6- 37. The mean PI corresponding to each comparison presented in Table 6- 37 is shown in Table 6- 38. Though the univariate analyses were performed on standard deviates, these mean PIs were used to identify operationally significant effects. The effects of the design factors on faulting, based on this analysis, are presented below. It is to be noted that the magnitude of faulting in most of the sections is "low" at this point in time (details in Chapter 3).

*Drainage*: The effect of drainage is not conclusive. However, on average, un-drained sections have exhibited more faulting than drained sections.

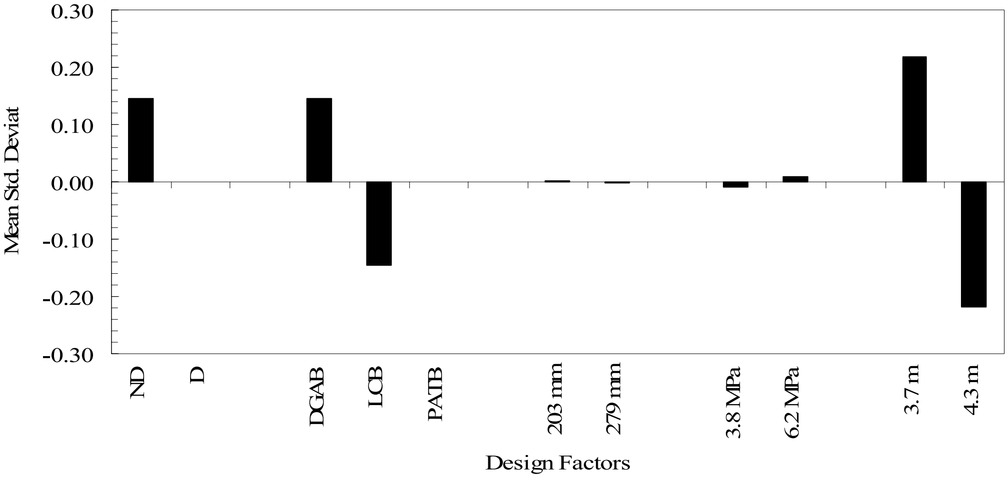
*Base Type*: As the effect of base type is confounded with the effect of drainage because of the SPS-2 experiment design, the results presented here are from comparisons between the performance of sections built with DGAB and sections built with LCB, which are both un-drained. On average, sections with LCB have shown lesser faulting than sections with DGAB. This effect is inconclusive. Also, among sections located in WF zone and built on fine-grained soils, this effect is more prominent.

*PCC slab thickness*: On average, among pavements located in WF zone sections, those with 203 mm (8") PCC slab have sown higher faulting than those with 279 mm (11") slab. However, the effect of PCC slab thickness is inconclusive at this point.

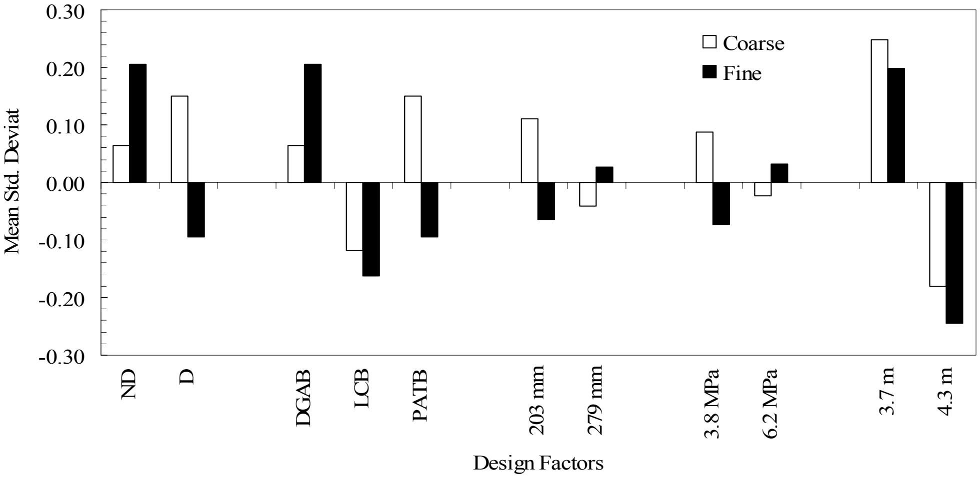
*PCC flexural strength*: The effect of PCC flexural strength is not significantly affecting faulting. However, on average, sections with 3.8 MPa (550-psi) concrete have shown slightly higher faulting than those with 6.2 MPa (900-psi) concrete.

*Lane width*: The effect of PCC flexural strength was found to be significantly affecting faulting in the SPS-2 sections. On the whole, sections built with standard lane (3.7 m) have shown lesser faulting than those with wider lane (4.3 m). This effect is more prominent among sections located in WF zone and built on fine-grained soils.

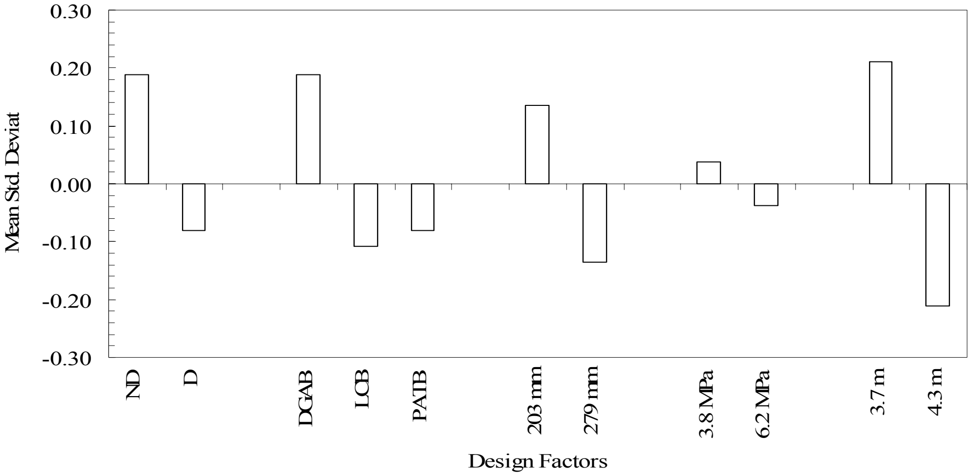
In general, higher faulting was observed in sections located in WNF zone compared to those located in other zones. However, it is to be noted that only two sites are located in WNF zone.



(a) Overall



(b) By subgrade type



(c) Wet Freeze (WF) zone

Figure 6 - 10 Effect of design factors on wheelpath joint faulting

Table 6- 37 Summary of p-values for comparisons of standard deviates— Faulting

| Design Factor | Comparison | Overall | By subgrade | | By climatic zone | | | | By subgrade and zone | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Fine | Coarse | WF | WNF | DF | DNF | WF | | WNF | | DF | | DNF | |
| | | | | | | | | | F | C | F | C | F | C | F | C |
| Drainage | Drainage vs. No-Drainage | 0.459 | 0.228 | 0.796 | 0.297 | 0.780 | 0.296 | 0.49 | 0.057 | 0.315 | 0.561 | 0.407 | 0.989 | | | 0.469 |
| Base type | DGAB vs. LCB vs. PATB/DGAB | 0.307 | 0.277 | 0.677 | 0.451 | 0.169 | 0.528 | 0.719 | 0.134 | 0.588 | 0.516 | 0.159 | 0.979 | | | 0.719 |
| PCC thickness | 203 mm vs. 279 mm | 0.974 | 0.646 | 0.545 | 0.197 | 0.282 | 0.394 | 0.750 | 0.942 | 0.009 | 0.429 | 0.525 | 0.889 | | | 0.750 |
| PCC flexural Strength | 3.8 MPa vs. 6.2 MPa | 0.899 | 0.593 | 0.663 | 0.724 | 0.994 | 0.360 | 0.965 | 0.570 | 0.816 | 0.423 | 0.414 | 0.137 | | | 0.965 |
| Lane Width | 3.7 m vs. 4.3 m | 0.009 | 0.023 | 0.085 | 0.045 | 0.448 | 0.130 | 0.276 | 0.133 | 0.190 | 0.589 | 0.597 | 0.075 | | | 0.276 |

Note: Shaded cells indicate statistical significance at 90% or higher level of confidence (p<0.1).

Table 6- 38 Summary of mean PIs for faulting

| Design Factor | Comparison | Overall | SG | | Zone | | | | WF | | WNF | | DF | | DNF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | F | C | WF | WNF | DF | DNF | F | C | F | C | F | C | C |
| Drainage | ND | 1.5 | 1.3 | 1.8 | 1.3 | 4.4 | 0.3 | 0.2 | 1.6 | 0.7 | 0.8 | 8.1 | 0.4 | 0.1 | 0.2 |
| | D | 1 | 0.8 | 1.2 | 0.7 | 2.7 | 0.9 | 0.2 | 0.4 | 1.4 | 2.3 | 3.7 | 0.5 | 2.3 | 0.2 |
| Base type | DGAB | 1.5 | 1.3 | 1.8 | 1.3 | 4.4 | 0.3 | 0.2 | 1.6 | 0.7 | 0.8 | 8.1 | 0.4 | 0.1 | 0.2 |
| | LCB | 0.7 | 0.6 | 0.8 | 0.7 | 1 | 0.9 | 0.2 | 0.6 | 0.9 | 0.4 | 1.6 | 0.8 | 1.5 | 0.2 |
| | PATB | 1 | 0.8 | 1.2 | 0.7 | 2.7 | 0.9 | 0.2 | 0.4 | 1.4 | 2.3 | 3.7 | 0.5 | 2.3 | 0.2 |
| PCC slab thickness | 203 mm | 1 | 0.8 | 1.4 | 1.1 | 2.2 | 0.6 | 0.2 | 0.8 | 1.7 | 1.2 | 3.6 | 0.6 | 0 | 0.2 |
| | 279 mm | 1.1 | 0.9 | 1.2 | 0.7 | 3.2 | 0.8 | 0.3 | 0.9 | 0.2 | 1.5 | 5.7 | 0.5 | 1.6 | 0.3 |
| PCC flexural strength | 3.8 MPa | 1.2 | 0.9 | 1.5 | 1.1 | 3 | 0.6 | 0.2 | 1.1 | 0.9 | 0.8 | 6 | 0.4 | 1.8 | 0.2 |
| | 6.2 MPa | 0.9 | 0.8 | 1.1 | 0.7 | 2.4 | 0.8 | 0.2 | 0.6 | 1 | 1.8 | 3.3 | 0.8 | 0.9 | 0.2 |
| Lane width | 3.7 m | 1.3 | 1.2 | 1.5 | 1.3 | 3.1 | 0.9 | 0.3 | 1.2 | 1.4 | 1.8 | 5.7 | 0.7 | 1.2 | 0.3 |
| | 4.3 m | 0.8 | 0.5 | 1.1 | 0.6 | 2.3 | 0.6 | 0.2 | 0.6 | 0.6 | 0.7 | 3.9 | 0.4 | 1.3 | 0.2 |

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### 6.6.4 Effect of Experimental Factors on Pavement Response

As mentioned earlier, the dependent variables that were considered for the ANOVA on pavement response include deflections $d_o$, $d_6$, Area Factor (AF) and Effective Stiffness (ES), based on deflections from the J1 location (midslab). ANOVA was performed on initial values and final (or latest) values of these deflection parameters, separately. The computational details regarding the AF and the ES can be found in the report by Stubstad [9].

A natural logarithmic transformation was applied to the deflection parameters, for the data to be used for ANOVA without any violation of statistical assumptions. The surface and bottom temperatures of the PCC slab at the time of testing were included as covariates in ANOVA along with age of the sections at the time of testing and variability in the PCC slab thickness. The results (see Table 6- 39 and Table 6- 40) from ANOVA are discussed next.

*Peak Deflection under FWD load ($d_o$)*

When the effects of design features on $d_o$-initial were studied by blocking the site factors, the main effects of base type (p=0.000) and PCC thickness (p=0.000) were found to be significant.

The pavements constructed on DGAB have shown significantly higher deflections than those constructed on PATB. The sections constructed on LCB have the least amount of deflections. Also the sections with 203 mm (8") PCC slab deflected significantly more than 279 mm (11") PCC slab.

When effects of both the design and site factors $d_o$-initial were studied, it was found that interaction between subgrade soil type and climatic zone is significant (p =0.000). Among the sections located in WF zone, those built on fine-grained subgrade soils have significantly higher deflections than those built on coarse-grained subgrade soils.

Based on analyses on final survey $d_0$, the interaction effects between base type and lane width (p=0.014), base type and subgrade soil type (p=0.014), and climate and PCC thickness (p=0.020) were found significant. Among sections with LCB, those built with standard lane (3.7 m) [3.7m (12')] have shown significantly higher $d_0$ than those with widened lane [4.3 m (14')]. Also among the sections with LCB, those built on fine-grained soils have shown significantly higher deflections than those built on coarse-grained soils. It is to be noted that, in general, sections with DGAB have significantly higher $d_0$ values than sections with LCB. For sections located in WF zone, those with 203 mm PCC slab have shown significantly higher deflections than those with 279 mm PCC slab thickness.

These results imply that the design factors significantly interact over time to affect $d_0$, unlike in the initial conditions where only the main effects of design factors were important.

*Far Sensor Deflection ($d_6$)*

The effects of design factors on $d_6$-initial were studied blocking the site factors. The main effects of base type (p=0.000) and PCC thickness (p=0.000) were found to be significant.

The pavements constructed on DGAB have shown significantly higher deflections than those constructed on PATB or LCB. The sections constructed on LCB experienced the least amount of deflections. Also the sections with 203 mm PCC slab deflected more than those with 279 mm PCC slab.

When the effects of both design and site factors were studied, the effects of site factors were not found to be important. The effect of drainage (p=0.002), PCC slab thickness (p=0.002), and base type (p=0.006) are significantly affecting $d_6$ of final year for the test sections. The sections with PATB (with drainage) have significantly lesser $d_6$ than sections with DGAB or LCB. The effect of PCC slab thickness remained the same as for initial year $d_6$.

It was also found that the main effect of subgrade is marginally significant (p =0.069) when effects of both the design and site factors were studied for final survey $d_6$. Sections built with fine-grained soils have slightly higher $d_6$ than those built on coarse-grained soils.

*Area Factor (AF)*

When the effects of design factors on $AF_{initial}$ were studied by blocking the site factors, the main effect of PCC thickness (p=0.000) was found to be significant. The sections with 279 mm thick slab have higher AF than those with 203 mm thick slab.

The main effect of climate (p=0.000) was significant when the effects of both the design and site factors were studied $AF_{initial}$. Sections located in “wet” climate have higher AF than those located in “dry” climate. An interaction between base type and subgrade (p=0.041) was also found significant, in that among sections with LCB, those constructed on coarse-grained subgrade have higher AF than those constructed on fine-grained subgrade soils. These effects were not found on final survey AF.

When the effects of design features on final survey AF were studied by blocking the site factors, the main effects of PCC slab thickness (p=0.001), and PCC flexural strength (p=0.024) were found to be significant. The effect of PCC slab thickness is similar to that for initial AF. Sections with higher strength concrete (target 14-day strength of 6.2 MPa (900-psi)) have significantly higher AF than those with lower strength concrete (target 14-day strength of 3.8 MPa (550-psi)).

*Effective Stiffness (ES)*

The effects of design features were studied by blocking the site factors. The interaction effects between base type and PCC thickness (p-value=0.053), and base type and flexural strength (p-value=0.012) were significant.

The effect of PCC thickness on ES is more, among sections with DGAB or PATB than among sections with LCB. Also, the effect of PCC flexural strength on ES is more, in the case of sections built on DGAB or PATB than in the case of sections built on LCB.

When effects of both the design and site factors were studied, it was found that the main effects of climatic zone (p=0.000) and subgrade (p=0.018) were significant. Pavements located in “wet” climate have significantly higher ES compared to those located in “dry” climate. Also, the upper layers of sections built on coarse-grained subgrade soil were significantly stiffer than those built on fine-grained soil.

Drainage (p=0.05), PCC slab thickness (p=0.000), base type (p=0.016) and flexural strength (p=0.020) were found to have significant main effects when the effects of design features on final survey ES were studied by blocking the site factors (see Table 6- 39). The effects of PCC thickness and base type were similar as in the case of initial ES. However, sections built with drainage have higher ES than those without drainage. Also, sections with higher strength concrete have higher ES than those with lower strength concrete.

Table 6- 39 Summary of p-values for the effects of design factors on rigid pavement response

| Design Factor | $d_o$ | | $d_6$ | | Area Factor | | Effective stiffness of PCC slab | |
|---|---|---|---|---|---|---|---|---|
| | Initial | Final | Initial | Final | Initial | Final | Initial | Final |
| Drainage | 0.000 | 0.000 | 0.002 | 0.002 | 0.352 | 0.922 | 0.234 | 0.050 |
| PCC thickness | 0.000 | 0.000 | 0.000 | 0.002 | 0.000 | 0.001 | 0.000 | 0.000 |
| Base Type | 0.000 | 0.000 | 0.000 | 0.006 | 0.387 | 0.863 | 0.000 | 0.016 |
| PCC Flexural Strength | 0.948 | 0.550 | 0.746 | 0. 602 | 0.300 | 0.024 | 0.586 | 0.021 |
| Lane Width | 0.425 | 0.327 | 0.186 | 0.941 | 0.673 | 0.609 | 0.570 | 0.366 |
| Site (blocked) | 0.000 | 0.012 | 0.000 | 0.000 | 0.000 | 0.003 | 0.000 | 0.006 |
| | N=156<br>$R^2$=0.816 | N=156<br>$R^2$=0.701 | N=156<br>$R^2$=0.772 | N=156<br>$R^2$=0.716 | N=156<br>$R^2$=0.604 | N=156<br>$R^2$=0.427 | N=156<br>$R^2$=0.630 | N=156<br>$R^2$=0.450 |

Table 6- 40 Summary of p-values for the effects of design factors on rigid pavement response

| Design Factor | $d_o$ | | $d_6$ | | Area Factor | | Effective stiffness of PCC slab | |
|---|---|---|---|---|---|---|---|---|
| | Initial | Final | Initial | Final | Initial | Final | Initial | Final |
| Subgrade | 0.001 | 0.014 | 0.707 | 0.069 | 0.687 | 0.207 | 0.018 | 0.792 |
| Zone | 0.210 | 0.570 | 0.000 | 0.025 | 0.000 | 0.569 | 0.000 | 0.173 |
| Subgrade*Zone | 0.000 | 0.360 | 0.003 | 0.211 | 0.087 | 0.187 | 0.306 | 0.207 |
| | N=156<br>$R^2$=0.783 | N=156<br>$R^2$=0.665 | N=156<br>$R^2$=0.55 | N=156<br>$R^2$=0.55 | N=156<br>$R^2$=0.254 | N=156<br>$R^2$=0.314 | N=156<br>$R^2$=0.465 | N=156<br>$R^2$=0.357 |

## 6.7 APPARENT RELATIONSHIP BETWEEN RESPONSE AND PERFORMANCE

In this section of the report the observations regarding apparent relationships between rigid pavement response (FWD testing) and performance are presented. The usefulness of such relationships can be of two kinds— explanatory and predictive (see Chapter 5).

Relationships could not be established based on data for all the sections in SPS-2 experiment because of “low” occurrence of distresses (see Chapter 3). Predictive relationships were established based on bivariate correlation analyses and scatter plots, at the site level, for sections in those sites that exhibited some distress at this point in time. The DLR data were used for predictive relationships regarding the instrumented sections in Ohio and North Carolina.

### 6.7.1 Site Level Analyses— Predictive Relationships

This section summarizes the findings regarding predictive relationships between initial response (FWD deflection or deflection-based indices) and future pavement performance (cracking), at the site level. Various deflection-based indices were calculated based on the individual deflection basins for each section. These indices include:

- do (peak deflection under the load),
- d6 [farthest deflection at 1.5 m (60 in.) away from the load],
- AF (Area Factor), and
- ES (effective stiffness of upper (bound) layer.

Bivariate correlation analyses between response parameters (deflections or deflection basin parameters (DBPs)) and transverse cracking were conducted for AZ (4), OH (39) and MI (26) of the SPS-2 experiment. These sites were selected based on the extent of occurrence of the distress. Relationships between roughness and deflection parameters were explored within each site. The latest performance for each section within the SPS-2 experiment was used in these analyses. It is to be noted that for a site, age, traffic, construction, material properties and environment are the same and thus this provides a good opportunity for seeking apparent relationships.

Figure 6-11 through Figure 6-16 are examples of bivariate relationships between Effective Stiffness (ES), Area Factor (AF), and $d_0$ with transverse cracking and roughness. Among sections in AZ (4), a negative correlation was observed between ES and IRI. Sections with higher stiffness (i.e. higher ES) showed higher roughness (see Figure 6-11). Sections with higher stiffness also showed potential for transverse cracking (see Figure 6-12). Sections with lower stiffness (i.e. lower AF or lower ES) have shown higher transverse cracking in MI (26) (see Figures 6-13 and 6-14). Among the sections in OH (39), higher roughness was observed for those with higher peak deflection and sections with higher stiffness had higher transverse cracking (see Figures 6-15 and 6-16).

Table 6-41 is a summary of correlation coefficients from the bivariate analyses for roughness and various deflection parameters within each site. The deflection basin parameters do not have a consistent association with roughness. This inconsistency may be explained in light of "low" magnitude of roughness for SPS-2 sections at this point in time.

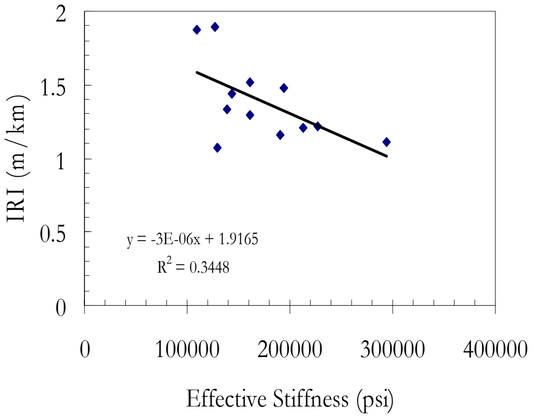

Figure 6 - 11 Roughness and ES relationship — State (4) Arizona

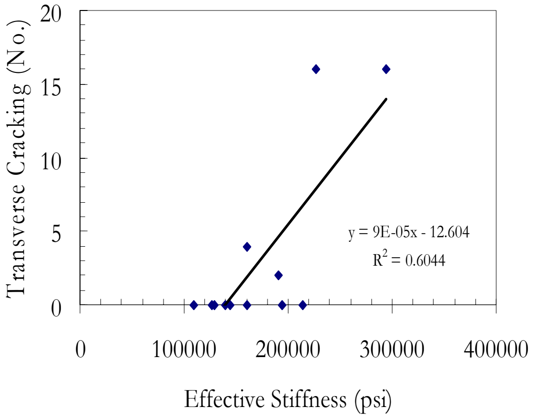

Figure 6 - 12 Transverse cracking and ES relationship— State (4) Arizona

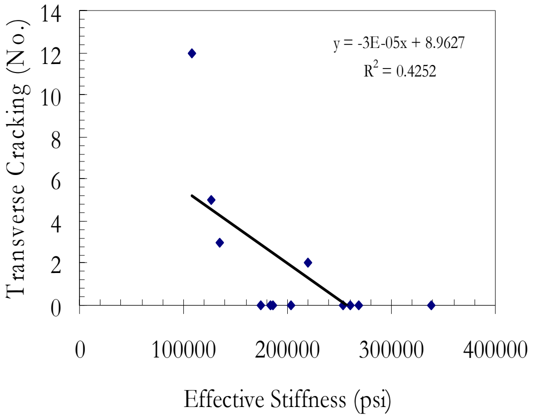

Figure 6 - 13 Transverse cracking and ES relationship — State (26) Michigan

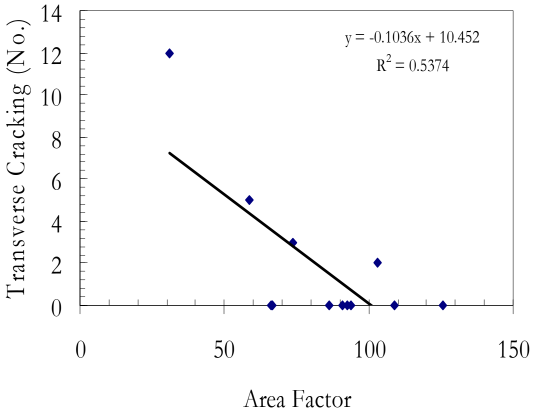

Figure 6 - 14 Roughness and ES relationship — State (4) Arizona

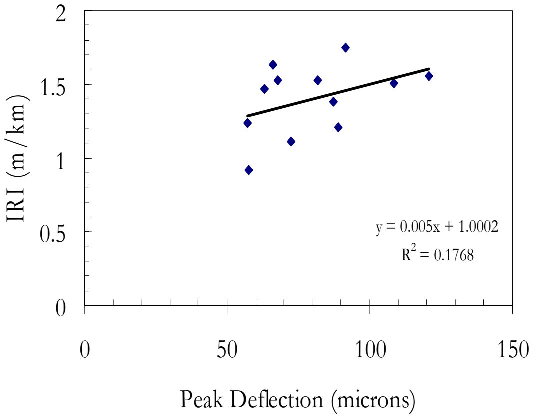

Figure 6 - 15 Roughness and $D_o$ relationship — State (39) Ohio

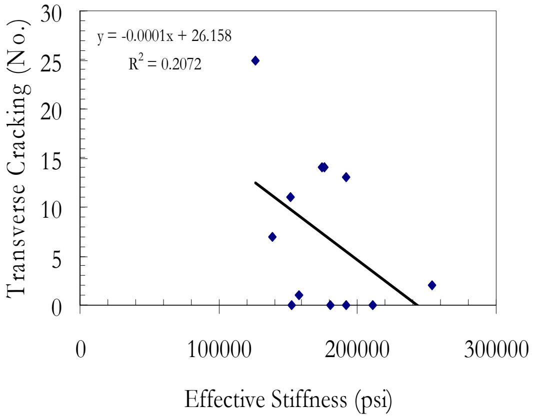

Figure 6 - 16 Transverse cracking and ES relationship — State (39) Ohio

Table 6- 41 Summary of correlations for deflections and DBPs with IRI

| State ID | State | Do | AF | ES | Zone | SG |
|---|---|---|---|---|---|---|
| 10 | DE | -0.29 | 0.53 | 0.36 | WF | C |
| 19 | IA | 0.26 | 0.18 | -0.09 | WF | F |
| 20 | KS | -0.38 | -0.36 | 0.24 | WF | F |
| 26 | MI | -0.05 | -0.38 | -0.27 | WF | F |
| 38 | ND | -0.44 | 0.30 | 0.23 | WF | F |
| 39 | OH | 0.41 | -0.03 | -0.32 | WF | F |
| 55 | WI | 0.31 | -0.25 | -0.42 | WF | C |
| 5 | AR | 0.37 | 0.31 | 0.00 | WNF | C |
| 37 | NC | -0.19 | 0.53 | 0.66 | WNF | F |
| 8 | CO | -0.37 | -0.27 | 0.02 | DF | F |
| 53 | WA | -0.42 | -0.55 | -0.44 | DF | F |
| 4 | AZ | 0.22 | -0.43 | -0.58 | DNF | C |
| 6 | CA | -0.56 | 0.04 | 0.04 | DNF | C |
| (-) ρ | | 8 | 7 | 6 | | |
| (+) ρ | | 5 | 6 | 7 | | |
| Mean | | -0.09 | -0.03 | -0.04 | | |
| Std | | 0.36 | 0.37 | 0.36 | | |
| CoV | | 4.1 | 13.0 | 8.3 | | |

### 6.7.2 Relationship between strain and performance

This section is regarding the Dynamic Load Response (DLR) of the instrumented rigid pavement sections in the states of Ohio and North Carolina. Four sections were instrumented with strain gauges and LVDTs to measure the pavement “response”, at each site (details in Chapter 2).

An attempt was made to relate the observed performance of the instrumented sections with measured responses (strains and deflections of PCC slab). The attempt was limited by low distresses for the instrumented pavement sections, especially among sections in NC. Consequently, no significant findings could be made, at this point in time. However, some observations regarding the dynamic load response of the instrumented test sections are summarized below:

- Higher deflections and strains occurred in the section with DGAB compared to the sections with LCB.
- Strains and deflections were higher in the sections with LCB compared to the section with PATB.
- Higher strains and deflections were observed in the section with 8”-thick [203 mm] PCC slab compared to the section with 11”-thick [279 mm] PCC slab

## 6.8 SYNTHESIS OF ANALYSES RESULTS FOR RIGID PAVEMENTS

This section of the report summarizes all the findings from various analyses performed on SPS-2 data. The methods employed in this study were explained in Chapter 4 and the results obtained from these analyses were presented in this chapter. The synthesis of results from analyses is similar to that of flexible pavements of the SPS-1 experiment (see Chapter 5).

As mentioned before, broadly two types of analyses (overall) were performed – magnitude-based and frequency-based. ANOVA, which is a method for comparing means, is the magnitude-based analysis. Binary Logistic Regression (BLR) and Linear Discriminant Analysis (LDA) are frequency-based analyses, which give the likelihood of occurrence and non-occurrence of distresses. The site-level analyses were used to compare the performance of pavements within each site. The results from site-level analysis were used to ascertain the consistency of the effects (of experimental factors) across all sites.

The magnitude-based methods, though powerful, are more appropriate for analyses of distresses, which have “fairly high” occurrence (for example, roughness, and faulting). On the other hand, the frequency-based methods are more suitable when magnitude of a distress is low but the occurrence of the distress is considerable (for example, transverse cracking, and longitudinal cracking).

An attempt has been made to ‘summarize’ the above said effects of design and site features on the performance and response measures. The results were interpreted in light of the type of analysis, and occurrence and extent of distress. ANOVA being the most “powerful” among the methods was given higher importance for distresses with “good” occurrence and/or extent (roughness and faulting). However, the results from this analysis suffer seriously in case of limited (low occurrence of distress) and unbalanced data. Therefore, in these cases, the effects of experimental features, mainly on occurrence of distresses, were investigated using BLR and LDA. The results from site-level analyses (paired comparisons and comparison of designs) and data exploration (extent of distresses) were then considered to confirm the findings. Based on the site-level analyses the consistency of effects was ascertained.

All results need to be interpreted in light of the experiment design, occurrence and extent of distresses, and analyses methods used. A “weak” effect at this point in time may become a “medium” or “strong” effect in the long term. Hence, all the conclusions are based on “mid-term” performance of the ongoing SPS-2 experiment.

The synthesis of results is presented next, separately for each performance measure. A ‘simple’ summary of results from all analyses is

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Table 6- 42. The summary is only meant to give the reader an idea about the effects. The reader is strongly recommended to read the following write-up for a better understanding of all the effects. It is important to note that a “strong”, “medium” or “weak” effect of a factor should only be interpreted as “strong”, “medium”, or “weak” difference in effects of different levels of a factor, respectively. In other words, a “strong” effect of PCC slab thickness and a “strong” effect of subgrade soil type should not be interpreted as PCC slab thickness and subgrade type having the same strength of effect.

In this summary of effects of design and site factors, a black circle was used to indicate “strong” effect (significant), a grey circle was used to indicate a “medium” effect, and a white circle was used to indicate a “weak” effect. Operational significance was determined only for “strong” or “medium” effects. It should be noted that an effect can be statistically significant (meaning that it is not a happenstance) but may not be operationally/ practically significant, at this point in time.

The SPS-2 experiment, entitled *Strategic Study of Structural Factors for Rigid Pavements*, is one of nine special pavement studies in the LTPP program. The main objectives of this experiment are to determine the relative influence and long-term effectiveness of the structural factors affecting performance of jointed plain concrete pavements (JPCP). These factors include PCC slab thickness, base type, in-pavement drainage, PCC flexural strength and lane width. The key conclusions from this study are summarized below.

### 6.8.1 Effects of experimental factors for SPS-2 experiment

This section is subdivided into three parts: (i) pavement performance, (ii) pavement response, and (iii) relationship between response and performance. The structural/design factors include PCC slab thickness, base type, drainage, PCC flexural strength and lane width. The experiment also includes studying the secondary effects of site factors, namely subgrade type and climatic zones.

#### *6.8.1.1 Effect of Design and Site Factors on Pavement Performance*

The effects of the experimental factors on each performance measure are discussed below, one performance measure at a time.

PCC slab thickness and base type seem to be the most important factors affecting the occurrence of transverse cracking, whereas, drainage seems to have a marginal effect.

The occurrence of transverse cracking among pavements with 203 mm (8-inch) PCC slab thickness is higher than that among those with 279 mm (11-inch) PCC slab thickness. Also, the occurrence of transverse cracking among pavements constructed with LCB is higher than that among those with PATB/DGAB or with DGAB. Pavements with PATB/DGAB have shown the "best" performance (least occurrence of cracking). These effects of PCC thickness and base type are statistically significant, as suggested by the frequency-based analyses. The analyses indicate a marginal effect of drainage on the occurrence of transverse cracking. Sections without drainage have slightly higher likelihood of cracking than sections with drainage.

On average, among sections built with LCB, those with 203 mm PCC slab have higher occurrence of cracking than those with 279 mm PCC slab. It is important to interpret these results in light of the construction issues, i.e. shrinkage cracking in LCB.

Pavements built on fine-grained soils have slightly higher chances for the occurrence of transverse cracking than those built on coarse-grained soils. This effect was found to be marginally significant.

### Longitudinal Cracking

PCC slab thickness and base type seem to be the most important factors affecting the occurrence of longitudinal cracking.

The occurrence of longitudinal cracking among pavements with 203 mm PCC slab is higher than among those with 279 mm. Also, the occurrence of longitudinal cracking among pavements constructed with LCB is higher than among those with PATB/DGAB or with DGAB. Pavements with PATB/DGAB have shown the "best" performance (least occurrence of cracking). These effects of PCC thickness and base type are statistically significant, as suggested by the frequency-based analyses.

On average, the above effect of PCC slab thickness is more prominent among sections built with LCB. However, it is important to interpret these results in light of the construction issues i.e. shrinkage cracking in LCB.

## Faulting

The extent of faulting among the test sections is “low”, with 62% of the sections having no joints with faulting greater than 1 mm. Only 33% of the sections have 0 to 20% of the joints that faulted more than 1.0 mm, and just 5% of the sections have more than 20% of the joints that faulted more than 1.0 mm. A majority of SPS-2 sections seem to be exhibiting “good” performance with respect to joint faulting, at this point in time. This performance seems to be reasonable as the test sections are “young” and have doweled joints at 4.6 m (15 ft) spacing. Therefore, the results at this point may only indicate the initial trends/observations that may not be of much practical significance.

Among all the design factors, lane width seems to be most important for faulting of PCC joints. In general, pavements with standard lane [3.7 m (12 ft) wide lane] have shown higher faulting than those with widened lane [4.3 m (14 ft) wide lane]. This effect of lane width is statistically significant, as suggested by magnitude-based methods. However, the effect may not be of practical significance because of the low occurrence of faulting.

The effect of lane width is more prominent among sections built on fine-grained soils than among those built on coarse-grained soils. Also, the effect is more pronounced among sections located in WF zone. Among sections located in WF zone and built on fine-grained soils, those with drainage have slightly lower (with marginal statistical significance) faulting than those without drainage. These effects are of statistical significance, and may not be practically significant, at this point in time.

Among sections located in WF zone and built on coarse-grained soils, sections with 8” (203 mm) PCC slab have slightly higher faulting than those with 279 mm PCC slab. This effect is statistically significant but not of practical significance. It is important to note that according to the experiment design of SPS-2, sections with 203 mm PCC slabs are built with dowels of 32 mm (1.25-inch) diameter, whereas sections with 279 mm PCC slabs are built with dowels of 38 mm (1.5-inch) diameter. Hence, the effect of dowel diameter and the effect of PCC slab thickness on faulting are not separable.

**Roughness**

The initial roughness (smoothness) of the pavement sections in the experiment seems to be affected by the PCC slab thickness. Pavements with thicker slab (279 mm) were found to have more initial roughness compared to those with thinner slab (203 mm).

Drainage and base type seem to be the most important factors affecting the growth in roughness, whereas, slab thickness seems to have a marginal effect.

Pavements without drainage have shown higher change in roughness than those with drainage. Also, pavements constructed with PATB have shown lower change in IRI (ΔIRI) compared to those with DGAB or LCB, while pavements with DGAB have the highest change in roughness. These effects of drainage and base type are of statistical and practical significance, as suggested by magnitude-based methods.

Among pavements constructed with standard lane (3.7 m), sections with DGAB have shown higher ΔIRI than those with LCB or PATB. This effect is of practical significance but is only marginally significant, statistically. Among pavements built on fine-grained soils, those with 203 mm PCC slab have higher ΔIRI than those with 279 mm PCC slab. This effect is more prominent among sections located in WF zone. Also, the effect of drainage (i.e. sections with PATB) is more prominent among sections located in WF zone and built on fine-grained soils. Among sections located in WF zone and built on fine-grained soils, those with drainage (i.e. sections with PATB) have shown lower ΔIRI compared to those without drainage. These marginally significant effects of drainage and PCC slab thickness are of practical significance.

The above results suggest that the change in roughness can be inhibited by constructing pavements with PATB and drainage as compared to sections with DGAB or LCB, especially in the case of pavements built on fine-grained soils. Also, among pavements built on fine-grained soils, an increase in PCC slab thickness from 203 mm to 279 mm seems to help prevent an increase in pavement roughness.

#### *6.8.1.2 Effect of Design and Site Factors on Pavement Response*

An ANOVA was conducted with the peak deflection under the FWD load plate (do), the far sensor deflection at 60 inches (1524 mm) from the FWD load (d6), the "Area Factor" (AF), and Effective Stiffness (ES) of the PCC slab as the dependent variables. All the response parameters have been calculated using the midslab deflections.

### Peak Deflection under FWD load ($d_o$)

The sections constructed on DGAB have shown significantly higher deflections than the ones constructed on PATB. The sections constructed on LCB experienced the least amount of deflections. Also the 203 mm (8-inch) thick slab sections deflected more than the 279 mm (11-inch) thick slabs.

In the Wet Freeze zone, the sections with fine subgrade soils were found to have significantly higher deflections than the sections that were built on coarse subgrade soils. Similar results were obtained from the analysis of the latest (or final) $d_o$ values.

### Far Sensor Deflection ($d_6$)

The sections constructed on DGAB have shown significantly higher deflections than the ones constructed on PATB. The sections constructed on LCB exhibited the lowest deflections. Also the sections with 203 mm (8-inch) PCC slabs deflected more than those with 11-inch (279 mm) PCC slabs. Similar results were obtained from the analysis of the latest (or final) $d_o$ values.

In the Wet Freeze zones, the sections with fine subgrade soils were found to have significantly higher deflections than the sections that were built on coarse subgrade soils. Sections located in “freeze” climate have shown significantly higher deflections than the ones located in “no freeze” climate.

### Area Factor (AF)

The sections with 11-inch (279 mm) slab have higher AF than those with 203 mm (8-inch) slab. Sections located in “wet” climate have higher AF than those in “dry” climate. An interaction between base type and subgrade was found to be significant, in that, among sections with LCB, those constructed on coarse-grained subgrade have higher AF than those constructed on fine-grained subgrade soils. These effects were not statistically significant on final survey AF values. Sections with higher strength concrete have significantly higher AF than those with lower strength concrete.

### Effective Stiffness (ES)

The effect of PCC thickness on ES is more significant among sections with DGAB than among those with LCB. The effect of PCC flexural strength on ES is more apparent for sections with DGAB or PATB than for sections with LCB. Pavements located in “wet” climate have significantly higher ES values compared to those located in "dry" climate. The sections built on coarse-grained subgrade soil were significantly stiffer than those built on fine-grained soil. The effects of PCC thickness and base type on ES from final survey were similar as in the case of initial ES. However, sections built with drainage have higher ES than those without drainage. Also, sections with higher strength concrete have higher ES than those with lower strength concrete.

A simplified summary of results from all analyses is given in Table 6-42. The summary is only meant to give an overall assessment of the effects. The reader is strongly recommended to read the following write-up for a better understanding of all the effects. It is important to note that a "strong", "medium" or "weak" effect should only be interpreted in terms of the difference in effects at the various levels of a factor. As an example, a "strong" effect of PCC slab thickness and a "strong" effect of subgrade soil type should not be interpreted as PCC slab thickness and subgrade type having the same strength of effect.

A black circle indicates a "strong" effect (significant); a grey circle indicates a "medium" effect, and a white circle indicates a "weak" effect. Operational significance was determined only for "strong" or "medium" effects. It should be noted that an effect can be statistically significant (meaning that it is not a coincidence) but may not be operationally/ practically significant, at this point in time.

Table 6- 42 Summary of effects of design and site factors for rigid pavements

| Design Factor | Performance Measures | | | | Response Measures (initial) | | | |
|---|---|---|---|---|---|---|---|---|
| | Transverse cracking | Longitudinal cracking | Faulting | Roughness | $d_o$ | $d_6$ | AF | ES |
| Drainage | ◍ | ○ | ○ | ● | ○ | ○ | ○ | ○ |
| PCC thickness | ● | ● | ○ | ◍ | ● | ● | ● | ● |
| Base type | ● | ● | ○ | ● | ● | ● | ◍ | ● |
| Flexural Strength | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ◍ |
| Lane Width | ○ | ○ | ● | ◍ | ○ | ○ | ○ | ○ |
| Climatic Zone | ○ | ● | ○ | ◍ | ◍ | ◍ | ◍ | ◍ |
| Subgrade type | ◍ | ○ | ○ | ◍ | ● | ● | ◍ | ● |

Note: This table is solely for the purpose of summarizing some of the effects in a ‘simple’ format. The reader is urged to read relevant text in the report for a better understanding.

| Symbol | Description |
|---|---|
| ● | Strong Effect (Main effect exists) |
| ◍ | Medium Effect (Interaction effect) |
| ○ | Weak Effect |

# CHAPTER 7 - ANALYSIS RESULTS FOR THE SPS-8 EXPERIMENT

## 7.1 INTRODUCTION

The purpose of this chapter is to provide a summary of the results of the analyses conducted for the SPS-8 experiment on flexible and rigid pavements. The performance measures used in the analysis include fatigue cracking, rutting, longitudinal cracking (in the wheel path and outside the wheel path), transverse cracking, faulting and IRI. The results are summarized according to individual design and site factors.

As mentioned in Chapter 3 under sections 3.5 and 3.6, all the pavement sections (flexible & rigid) in SPS-8 experiment are aged between 3 and 10 years, with an average age of 6 and 7 years for flexible and rigid pavements, respectively. Thus a majority of pavement sections of both pavement types are relatively “young” to exhibit any environment-related distresses. Only a few of SPS-8 pavements have shown some distresses as of Release 17.0. It is to be noted that the current status for SPS-8 experiment for rigid pavements shows that there is no site located in the DNF zone. The extent of various distresses exhibited by the pavements is presented in Chapter 3. Site-wise summaries of inventory data, construction issues and performance of flexible and rigid pavements can be found in Appendix C. Keeping in view the number of sections constructed for SPS-8 experiment (32 flexible pavements in 15 sites and 14 rigid pavements in 6 sites) and the extent distresses at present, statistical analysis as in the case of SPS-1 and SPS-2 experiments may not be applicable. Therefore, simple mean comparisons (only for sections that exhibited distresses) were performed to identify the effects of experimental factors on various performance measures. Some initial trends obtained from these comparisons are reported below.

## 7.2 EFFECTS OF ENVIRONMENTAL FACTORS IN SPS-8 EXPERIMENT FOR FLEXIBLE PAVEMENTS

The objective of the SPS-8 experiment is to develop conclusions concerning environmentally induced serviceability loss and the contribution of environment and subgrade to the distress of pavements. The experiment will also develop conclusions concerning the effects of base and surface thickness variations on retarding environmentally driven distress.

### *7.2.1 Site-Level Analysis*

The analysis of the data from SPS-8 sections was done based on the concepts of PI and relative performance concepts (see Chapter 4) as in SPS-1 experiment. At the site-level, various performance measures (fatigue cracking, longitudinal cracking (WP and NWP), transverse cracking, raveling, rutting and roughness) were analyzed to investigate the effects of the main site factors (climatic zone and subgrade type) on performance. The summary of results from this analysis is given below:

- The results of the available data indicate that WF zones have shown relatively higher potential for fatigue cracking; however as expected, the magnitude of distress is not significant.
- Results for longitudinal cracking-NWP were inconclusive.
- Transverse cracking occurred mainly in freeze zones.
- There was higher amount of raveling observed in WNF zone.
- Rutting performance was similar in all environments and for different subgrade types; this is to be expected since rutting is essentially a load-related distress.
- The results of roughness in terms of IRI show that sections built in WF zones appear to have higher roughness, followed by those built in WNF zones.

### *7.2.2 Overall Analysis*

The overall initial trends which show the effect of SPS-8 experimental factors on various performance measures will be discussed in this section. These comparisons were carried out only for the performance measures which have shown some extent in the SPS-8 flexible pavements.

**Fatigue Cracking:** Fatigue cracking was observed in only 12 out of 32 pavement sections. Among the cracked sections, the area of fatigue cracking varies from 0.2% to about 19% with an average of 3%. Excluding section 36-0801, where 19% of area has fatigue cracking, the average cracking area of cracked sections is about 1% with a range of 0.2% to 4.5%. The average fatigue cracking by experimental factors is shown in Figure 7-1. Pavements located in WF zones have a higher potential for cracking. On average, flexible pavements constructed on active subgrade (frost susceptible or expansive) soils and pavements with thin [102 mm (4-inch)] asphalt layer have exhibited more cracking on average than those built on other subgrade types and with thick [178 mm (7-inch)] HMA surface layer. In order to show the effect of active subgrade within fine and coarse soil types, the average performance is presented in Figure 7-2. It was observed that flexible pavements constructed on the active coarse-grained subgrade soils have shown higher potential for fatigue cracking.

**Longitudinal Cracking (WP and NWP):** Longitudinal cracking-WP was observed in only 13 out of 32 pavement sections, while longitudinal cracking-NWP occurred in 20 pavement sections. Among the cracked sections, longitudinal cracking-WP length varies from 1 to 97 m with an average of 18 m, while longitudinal cracking-NWP length varies from 1 to 305 m with an average of 115 m. Excluding both sections from MT (30) site, where 78 m and 97 m of longitudinal cracking-WP occurred in sections 0805 and 0806, among cracked sections, the average crack length is 5 m with a range of 1 to 22 m. The average longitudinal cracking in the wheel path (WP) and non-wheel path (NWP) by experimental factors are shown in Figure 7-3 and Figure 7-5. More longitudinal cracking-WP was observed on sections located in DF zone. This cracking is mainly contributed by sections in site MT (30), which are constructed on coarse subgrade type. More cracking-NWP was observed in all pavements constructed on active subgrade soils and located in WF zone. Also more cracking-NWP was observed in sections located in DNF, which is contributed by sections in NM (35) site only, these sections were constructed on fine-grained subgrade soils. The flexible pavements constructed on active fine-grained soils have shown slightly more cracking-WP; the opposite trend was observed for pavements constructed on coarse-grained soil due to contribution of only sections at site MT (30) (see Figure 7-4). More cracking-NWP is observed for flexible pavements constructed on active soils (see Figure 7-6).

**Transverse Cracking:** Transverse cracking was observed in only 10 out of 32 pavement sections. Among the cracked sections, transverse cracking length varies from 1 to 44 m with an average of 11 m. On average, pavements located in "freeze" climate and constructed on active soils have exhibit more transverse cracking. The average transverse cracking by experimental factors is shown in Figure 7-7. Pavements with "thick" [178 mm (7-inch)] HMA surface layer have shown less transverse cracking than those with “thin” [102 mm (4-inch)] HMA surface layer. On an average more transverse cracking was exhibited by flexible pavements constructed on active soils and pavements located in “freeze” climates. The pavements with thicker asphalt layer have shown lower transverse cracking than pavements with thinner asphalt surface layer. The flexible pavements constructed on active subgrade have exhibited more transverse cracking than those constructed on non-active subgrade soils especially within fine subgrades (see Figure 7-7).

**Roughness:** The average roughness, in terms of IRI, by experimental factors is presented in Figure 7-9. The average initial IRI of the SPS-8 flexible pavement sections is 1.1 m/km, with a range of 0.8 to 3.2 m/km. The average change in IRI (□IRI) for pavements is 0.32 m/km with a range of 0.0 to 2.4 m/km. Excluding both sections from OH (39) site, where 2.2 m/km and 1.7 m/km of □IRI occurred in sections 0803 and 0804, the average □IRI is 0.2 m/km with a range of 0 to 1 m/km. On average, pavements located in “wet” climate have higher change in IRI than those in “dry” climate. Furthermore, pavements located in WF zone and those built on active soils have the higher changes in IRI. Also pavements constructed on active subgrade soils have exhibited more roughness than other pavements (see Figure 7-10).

**Rut Depth:** The average rut depth for flexible pavements by experimental factors is shown in Figure 7-11. The average latest rut depth of the sections is 5 mm with a range of 1 to 24 mm. Excluding section 39-0803, where 24 mm of rut depth was observed, the average rutting is about 4 mm with a range of 1 to 9 mm. On average, the magnitude of rutting observed is “low” for the sections. Slightly higher average rut depths were observed for the pavements located in WF zone. Also pavement sections with “thin” [102 mm (4-inch)] HMA surface layer have exhibited higher rutting than pavements with “thick” [178 mm (7-inch)] HMA surface layer. Furthermore, active subgrade seems to contribute towards more rutting (Figure 7-12). The magnitude of rutting was observed to be “low” for all sections in the experiment, which is expected since rutting is essentially a load-related distress.

### *7.2.3 Comparison between Similar Designs of SPS-8 and SPS-1 Experiments*

To investigate the effect of traffic loading, similar designs in SPS-8 and SPS-1 experiments can be compared for various performance measures. This comparison may help in identifying load-related and environment-related distresses.

Median comparisons (non-parametric) were performed on similar sections in both experiments. From the experiment design matrix for SPS-1, sections 113 & 114 in all sites were identified to be similar to the structural design of SPS-8 flexible pavement sections. To investigate the median difference between the performances of these sections, the sections were analyzed in two groups [102 mm (4-inch) and 178 mm (7-inch) HMA thickness].

It was found that fatigue cracking is essentially a load-related distress whereas; transverse cracking and longitudinal cracking-NWP may be attributed to environment. However, because of the apparent differences in the traffic levels between SPS-8 and SPS-1 experiment, the project panel recommended that such comparisons should not be considered.

## 7.3 EFFECTS OF ENVIRONMENTAL FACTORS IN SPS-8 EXPERIMENT FOR RIGID PAVEMENTS

The objective of the SPS-8 experiment is to develop conclusions concerning environmentally induced serviceability loss and the contribution of environment and subgrade to the distress of pavements. The experiment will also develop conclusions concerning the effects of base and surface thickness variations on retarding environmentally driven distress.

### *7.3.1 Site-Level Analysis*

The analysis of the SPS-8 rigid pavements was done based on the PI and the relative performance concepts (see Chapter 4) similar to SPS-2 experiment. At the site-level, roughness and transverse joint sealant damage were analyzed to investigate the effects of the main site factors (climatic zone and subgrade type) on performance. The summary of results from this analysis is given below:

- The ride quality for sections constructed in the Dry Freeze zone was better than those constructed in the Wet zones. Furthermore, it can be concluded that the sections in the Wet Freeze zone exhibit a better ride than the ones in the Wet No Freeze zone.
- Transverse joint sealant damage appeared to be more prevalent in the Wet zones as compared to the Dry Freeze zone.

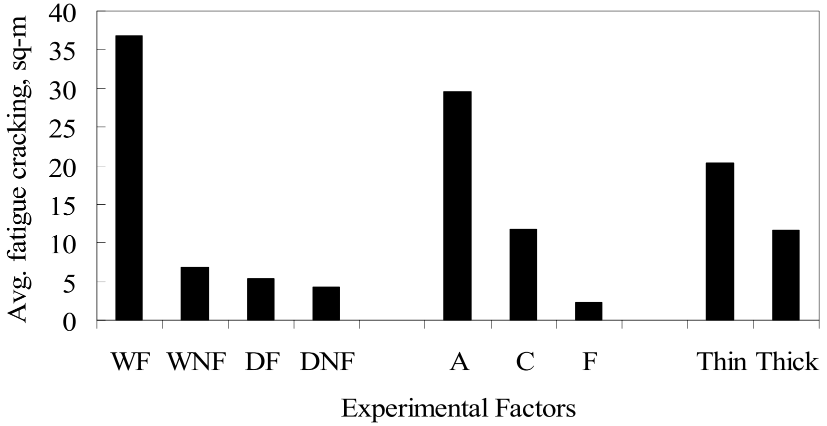

Figure 7-1 Average fatigue cracking by experimental factors— SPS-8 flexible pavements

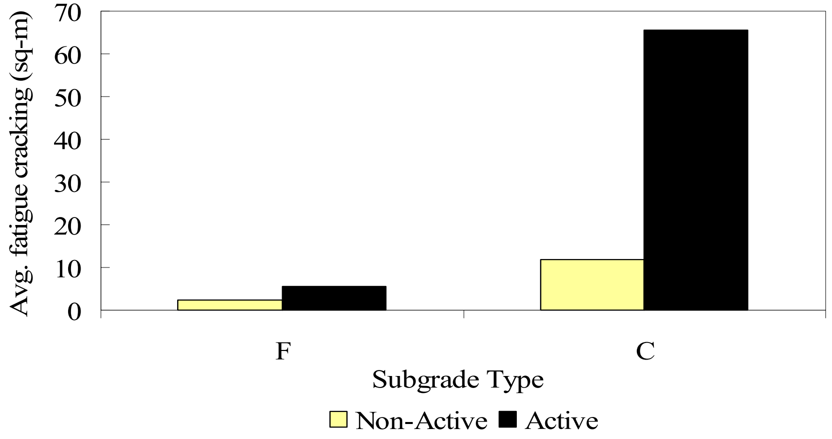

Figure 7-2 Average fatigue cracking by subgrade type— SPS-8 flexible pavements

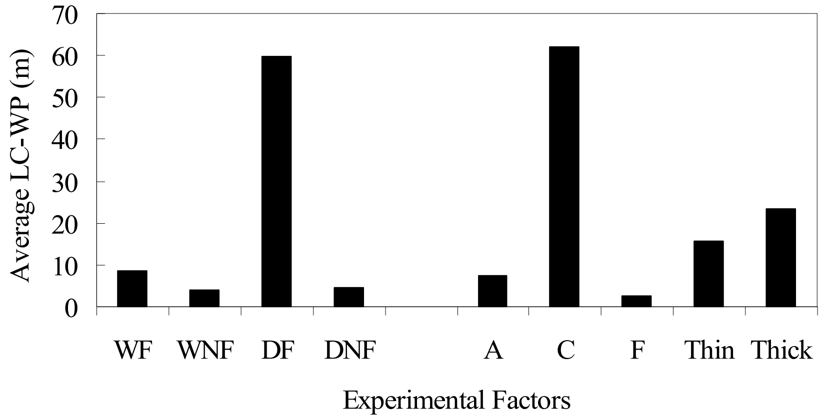

Figure 7-3 Average LC-WP by experimental factors— SPS-8 flexible pavements

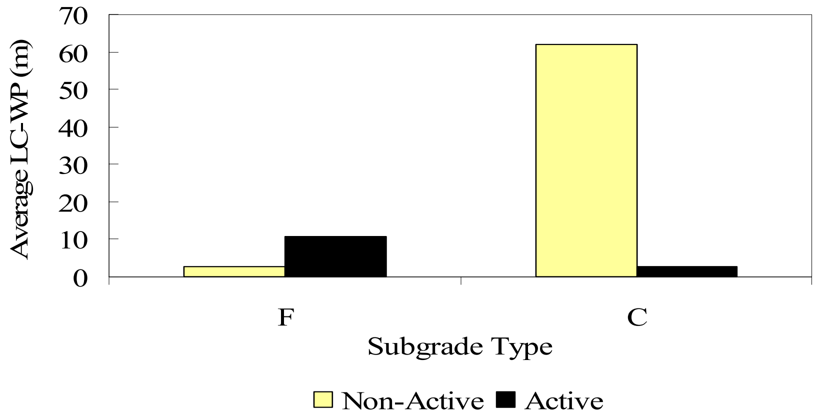

Figure 7-4 Average LC-WP by subgrade type— SPS-8 flexible pavements

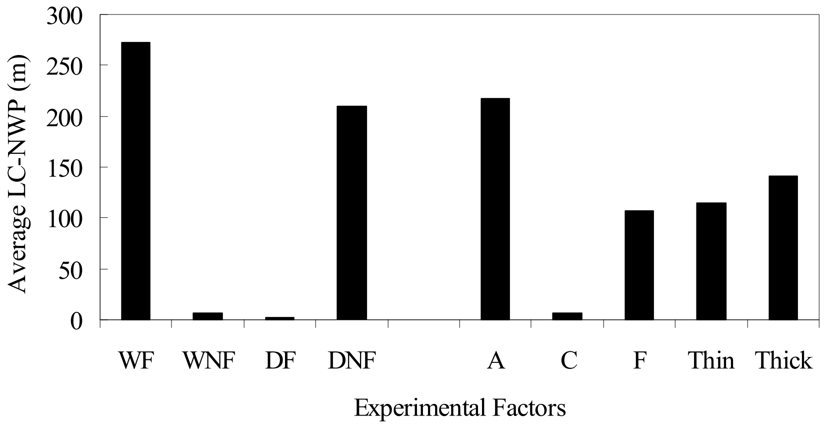

Figure 7-5 Average LC-NWP by experimental factors— SPS-8 flexible pavements

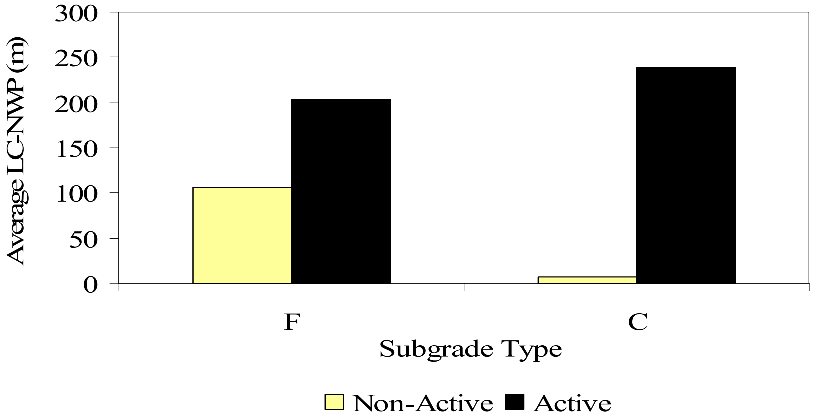

Figure 7-6 Average LC-NWP by subgrade type— SPS-8 flexible pavements

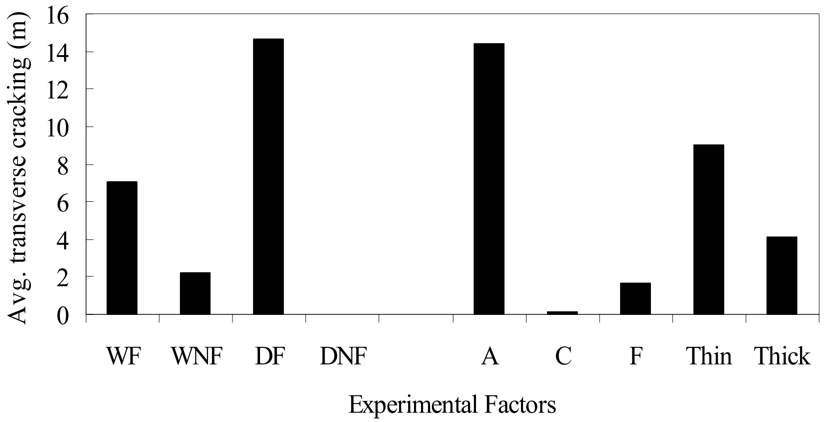

Figure 7-7 Average transverse cracking by experimental factors— SPS-8 flexible pavements

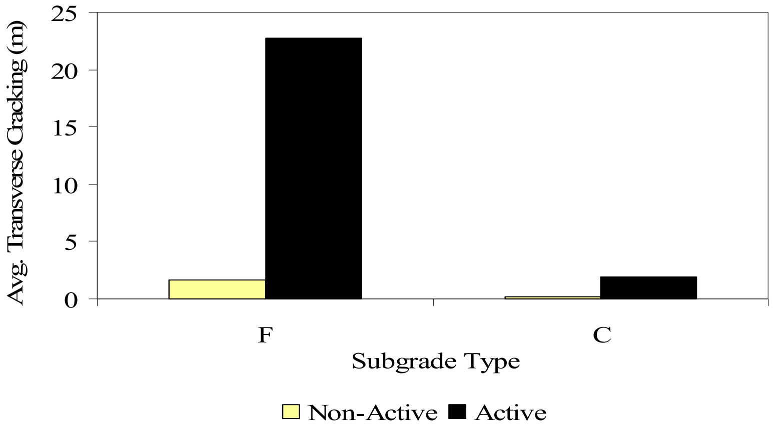

Figure 7-8 Average transverse cracking by subgrade type— SPS-8 flexible pavements

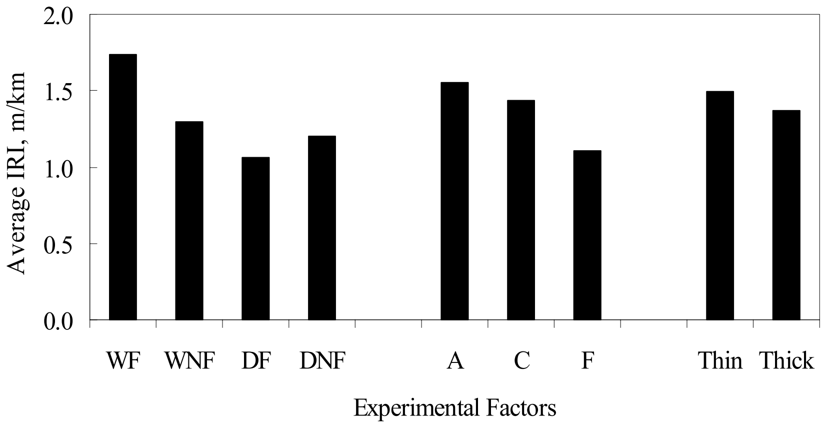

Figure 7-9 Average roughness by experimental factors— SPS-8 flexible pavements

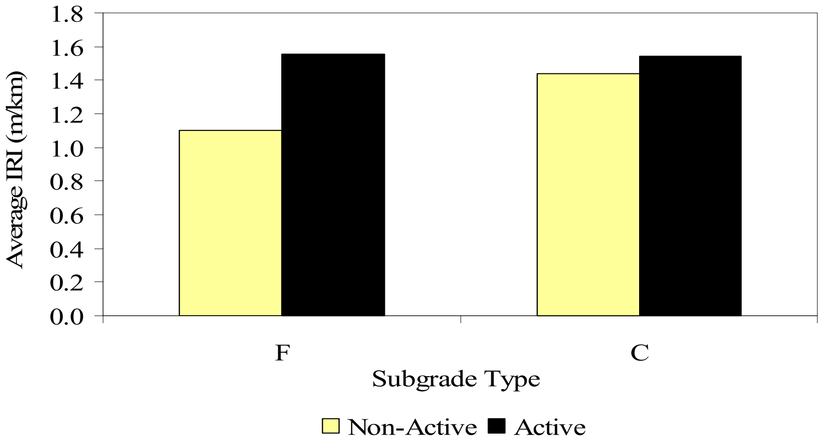

Figure 7-10 Average roughness by subgrade type— SPS-8 flexible pavements

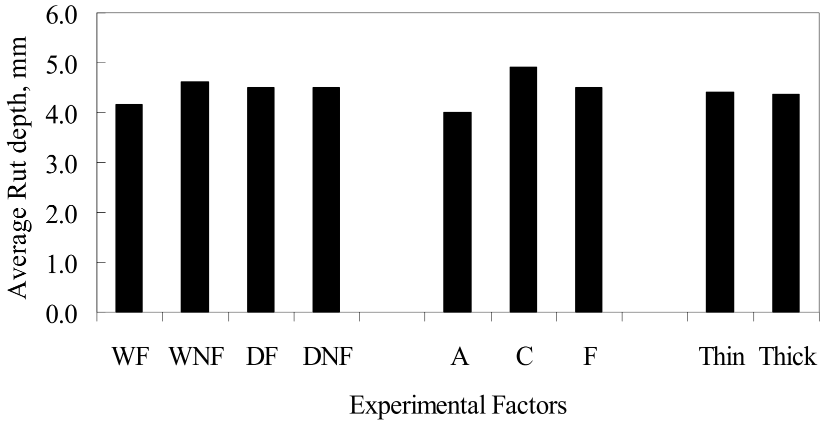

Figure 7-11 Average rut depth by experimental factors— SPS-8 flexible pavements

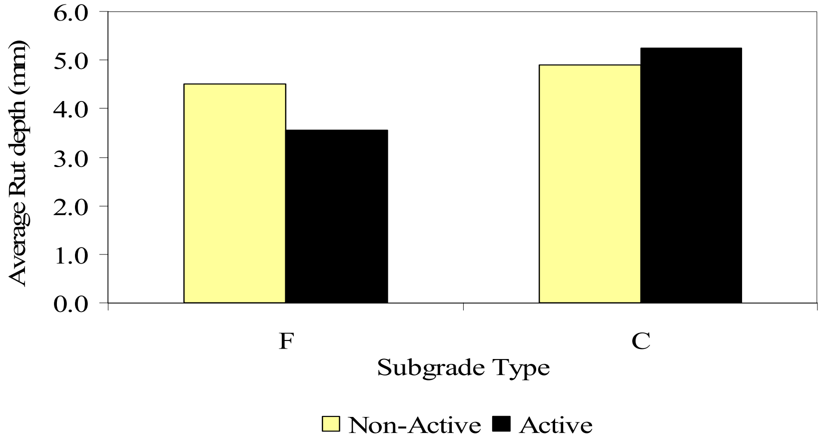

Figure 7-12 Average rut depth by subgrade type— SPS-8 flexible pavements

### *7.3.2 Overall Analysis*

The overall initial trends which show the effect of SPS-8 experimental factors on various performance measures will be discussed in this section. These comparisons were carried out only for those performance measures that were exhibited to some extent in the rigid pavements sections.

**Transverse Cracking**: Figure 7-13 shows the average transverse cracking length by experimental factors, for rigid pavements. Only three of the fourteen sections have transverse cracking, ranging from 1 to 5 cracks. Cracking was not observed in any of the pavements constructed with thicker PCC slab and in any of the pavements constructed on coarse-grained subgrade soil. Average transverse cracking was found to be higher on section located in DF zone, which was contributed by section 0811 of site CO (8). This site is the oldest (10 years) in the experiment and "very poor" climatic conditions prevailed during the construction that caused construction to happen at faster rate. Among the pavements built on fine-grained soils, those built on active soils have exhibited slightly lesser cracking than those built on non-active subgrades (see Figure 7-14).

**Longitudinal Spalling**: Figure 7-15 shows the average longitudinal spalling length by experimental factors, for rigid pavements. Six of the fourteen sections have longitudinal spalling ranging from 1 to 79 m with an average of 34 m. Spalling was not observed in any of the pavements located in the DF zone and in any of the pavements constructed on coarse-grained subgrade soil. Average spalling was found to be higher on section located in WNF zone. Also pavements with thicker PCC slab have shown slightly higher spalling than those with thinner PCC slab. Among the pavements built on fine-grained soils, those built on active soils have exhibited slightly higher spalling than those built on non-active subgrades (see Figure 7-16).

**Wheel Path Joint Faulting**: Average percent of joints that faulted more than 1 mm, by experimental factors, is shown in Figure 7-17. Seven sections have faulting of more than 1.0 mm at one or more joints. Among these sections, on average, 8% of the joints faulted more than 1 mm, with a range of 3 to 21% of joints. Average percentage of joints that faulted more than 1 mm was found to be higher on sections located in WNF zone. Also pavements constructed on active subgrade soil have shown slightly higher faulting than those constructed on others. Among the pavements built on coarse-grained soils, those built on active soils have exhibited higher faulting than those built on non-active subgrades (see Figure 7-18).

**Roughness**: Average roughness by experimental factors, is shown in Figure 7-19. The average initial IRI of the SPS-8 rigid pavement sections is 1.8 m/km, with a range of 1.0 to 3.6 m/km. The average change in IRI for rigid pavements is 0.1 m/km with a range of 0.0 to 0.7 m/km. Average roughness was found to be higher on sections located in WNF zone. Also pavements constructed on active subgrade soil have shown slightly higher IRI than those constructed on others. Among the pavements built on coarse-grained soils, those built on active soils have exhibited higher IRI than those built on non-active subgrades (see Figure 7-20). It may be noted that similar trends were observed for faulting and roughness, which may suggest a cause-effect relation among these performance measure.

### *7.3.3 Comparison between Similar Designs of SPS-8 and SPS-2 Experiments*

As in the case of analysis of flexible pavements of the experiment, comparisons were performed between the similar designs of SPS-8 and SPS-2 experiments. SPS-8 rigid pavements exhibited insignificant amount of distresses, whereas the companion SPS-2 states exhibit a wide variety of distresses (see Chapter 3). These distresses may be attributed to traffic-loading.

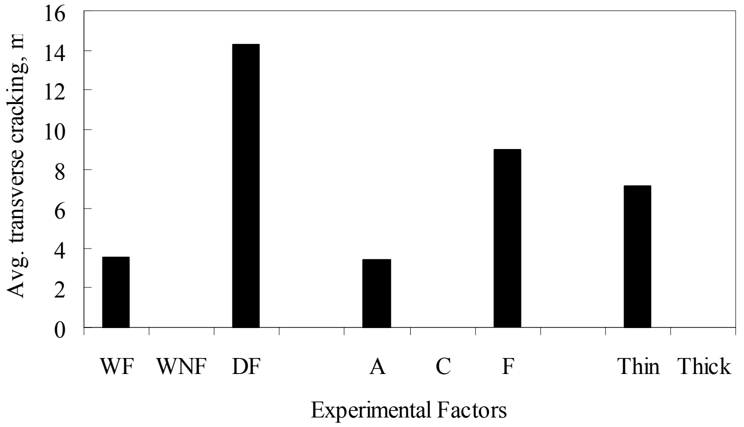

Figure 7-13 Average transverse cracking by experimental factors— SPS-8 rigid pavements

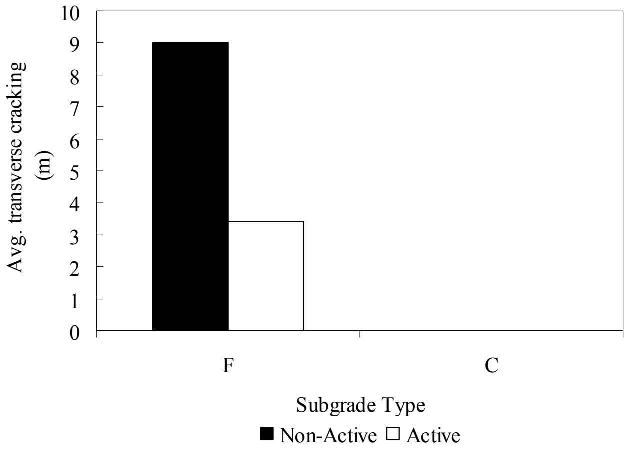

Figure 7-14 Average transverse cracking by subgrade type— SPS-8 rigid pavements

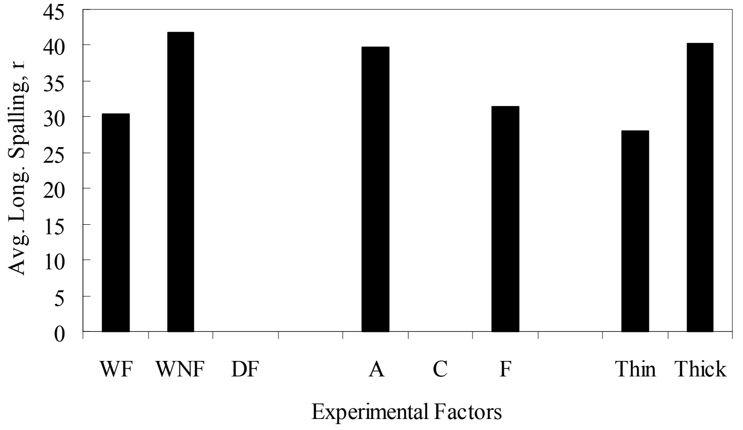

Figure 7-15 Average long. spalling by experimental factors— SPS-8 rigid pavements

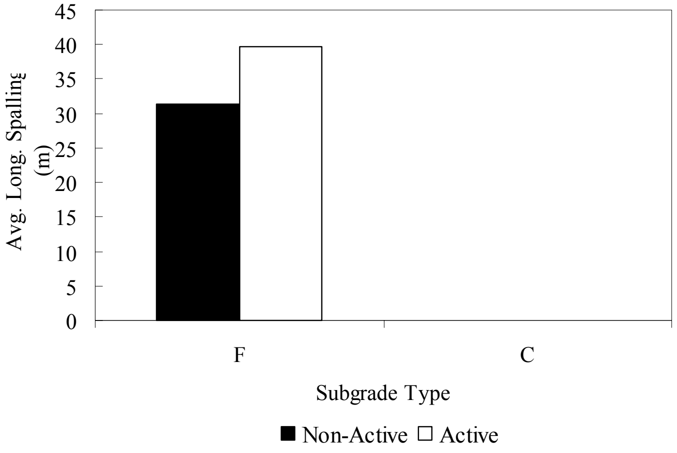

Figure 7-16 Average long. spalling by subgrade type— SPS-8 rigid pavements

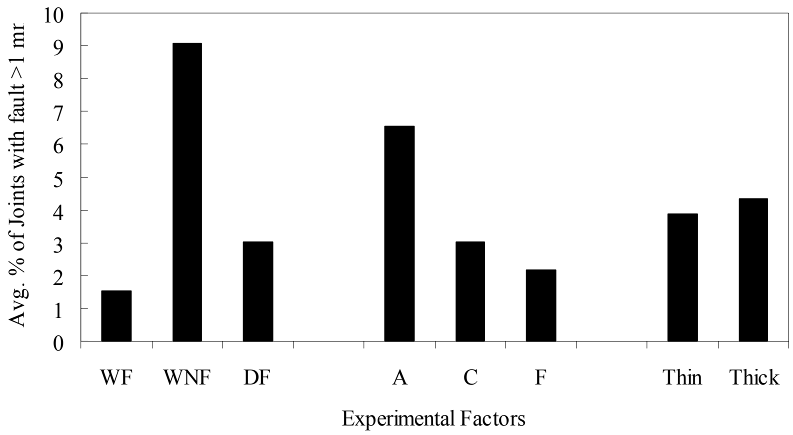

Figure 7-17 Average no. of joints having faulting > 2% by experimental factors—SPS-8 rigid pavements

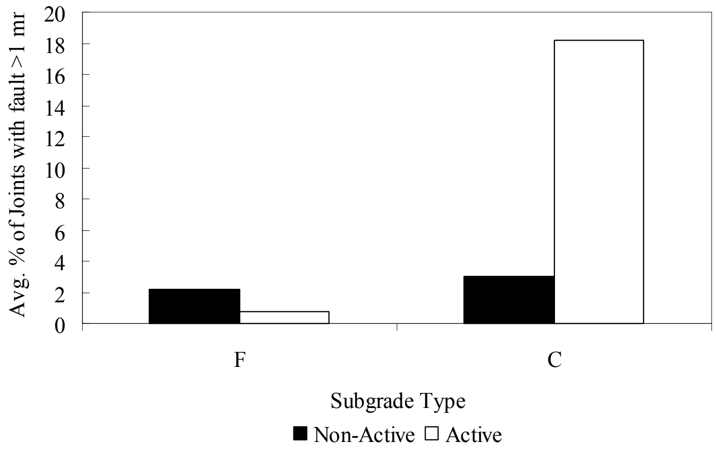

Figure 7-18 No. of joints having faulting > 2% by subgrade type— SPS-8 rigid pavements

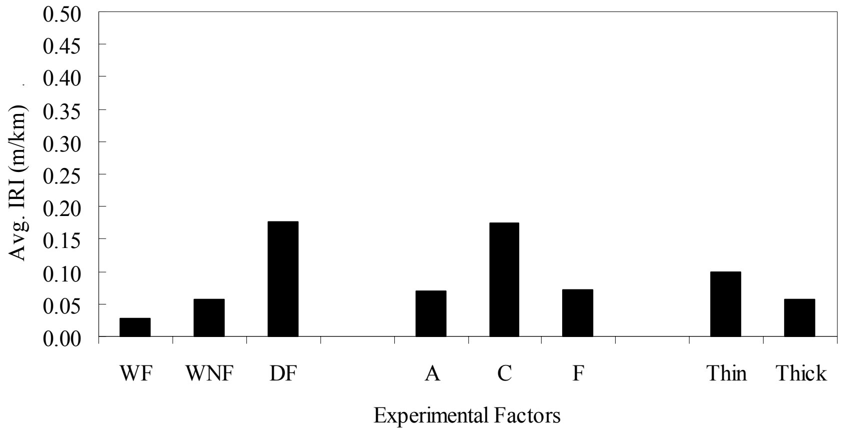

Figure 7-19 Average IRI by experimental factors— SPS-8 rigid pavements

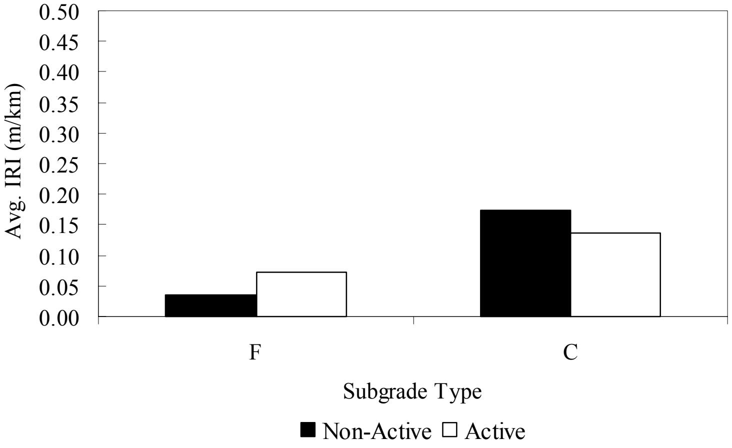

Figure 7-20 Average IRI by subgrade type— SPS-8 rigid pavements

## 7.4 SUMMARY OF RESULTS

The SPS-8 experiment is entitled *Strategic Study of Environmental Effects in Absence of Heavy Loads for Flexible and Rigid Pavements*. The study examines the effect of climate and subgrade type (active, fine, and coarse) on pavement sections incorporating different flexible and rigid pavements, which are subjected to very limited traffic as measured by ESAL accumulation. The effects of the experimental factors on flexible and rigid pavements, based on the initial trends, are summarized below.

### *7.4.1 Effect of SPS-8 Experimental Factors on Performance of Flexible Pavements*

Currently a total of 32 flexible pavement sections, in 15 sites, are present in the experiment. There are 14, 8, 6 and 4 pavement sections in WF, WNF, DF and DNF climatic zones, respectively. A total of 14 pavement sections were constructed on coarse-grained soils among which 4 sections are on "active" soils and 10 sections are on "non-active" soils. Also, 18 pavement sections were built on fine-grained soils, among which 12 sections are on "active" soils and 6 sections are on "non-active" soils. These test sections have an average age of about 6 years with a range of 3 to 10 years. The effects of the design and site factors based on initial trends, as of Release 17.0, on key performance measures are presented below:

On average, pavements in WF zone have more fatigue cracking, longitudinal cracking-NWP, and roughness than pavements in other climates. Also, in general, pavements constructed on "active" subgrade (frost susceptible or expansive) soils have higher longitudinal cracking-NWP, transverse cracking, and fatigue cracking than pavements on "non-active" soils.

Pavements located in "wet" climate, on average, have higher change in IRI than those in "dry" climate. Furthermore, pavements located in WF zone and those built on active soils have the higher changes in IRI.

### *7.4.2 Effect of SPS-8 Experimental Factors on Performance of Rigid Pavements*

Currently a total of 14 rigid pavement sections, in 5 sites, are present in the experiment. There are 8, 4 and 2 pavement sections in WF, WNF, and DF climatic zones, respectively. Three pavement sections were constructed on coarse-grained soils among which 2 sections are on “active” and one section is on “non-active” soil. Also, 11 pavement sections were built on fine-grained soil, among which 4 sections are on “active” soils and 7 sections are on “non-active” soils. These test sections have an average age of about 6.5 years with a range of 4 to 10 years. The distresses are too “low” for any meaningful conclusions to be made, at this point in time. Some observations based on initial trends, as of Release 17.0, on key performance measures are presented below:

Longitudinal spalling, on average, was higher in sections located in “wet” climate. Spalling was not observed in any of the pavements located in the DF zone and in any of the pavements constructed on coarse-grained subgrade soil. Transverse cracking was not observed in any of the pavements constructed with thicker PCC slabs and in any of the pavements constructed on coarse-grained subgrade soils.

# CHAPTER 8 - CONCLUSIONS AND RECOMMENDATIONS

## 8.1 INTRODUCTION

This chapter presents a summary of findings from a comprehensive evaluation of SPS-1, SPS-2 and SPS-8 experiments, based on mid-term performance trends [Release 17 (Level-E) of DataPave]. The current status of the experiment, construction quality, and data availability are also briefly discussed in this chapter for each experiment. Finally, the limitations of the findings from this research and recommendations for future data collection and research are presented.

A detailed description of the experiment designs and the current status of SPS-1, SPS-2 and SPS-8 experiments were presented in Chapter 2. The SPS-1 and SPS-2 experiments are fractional factorial experiments that were aimed at finding the relative influence of design and construction features on performance of new flexible and rigid pavements, respectively.

Each site within the SPS-1 and SPS-2 experiments has twelve pavement test sections with each section representing a different structural design. There are eighteen sites in the SPS-1 experiment and fourteen sites in the SPS-2 experiment; these sites are distributed throughout the United States by climatic zones (wet-freeze, wet-no-freeze, dry-freeze and dry-no-freeze) and subgrade type (fine and coarse-grained). The SPS-1 experiment is designed to investigate the effects of HMA layer thickness, base type, base thickness, and drainage on flexible pavement performance, while the SPS-2 experiment is aimed at studying the effect of PCC slab thickness, base type, PCC flexural strength, drainage, and lane width on rigid pavement performance. The current status (details in Chapter 2) of the experiments indicates some deviations from the intended experiment design for both SPS-1 and SPS-2 experiments. The most important deviation from the experiment design is the distribution of sites by climatic zone, which caused an unbalance in the number of sites per climatic zone.

The average age of test sections in the SPS-1 experiment is 7 years with a range of 3 to 11 years, while the average age of sections in the SPS-2 experiment is 7 years with a range of 5 to 12 years. It may thus be said that the pavements are “fairly young”, and high occurrence and levels of distresses may not be expected at this point in time. Thus, all conclusions from the analyses presented in this report should only be interpreted as “mid-term” performance findings.

The SPS-8 experiment was designed to study the effects of the environment on pavement performance, in the absence of heavy traffic. The experimental factors include climate and subgrade soil type. A total of 32 flexible pavement sections in 15 sites and 14 rigid pavement sections in 5 sites were constructed for the experiment. The average age of the flexible pavement sections in SPS-8 is 6 years with a range of 3 to 10 years. In the case of rigid pavements, the average age is 6 years with a range of 4 to 10 years.

A summary of data availability was presented for SPS-1, SPS-2 and SPS-8 experiments in Chapter 3. The extent and occurrence of distresses in the test sections within each of the experiments were also presented in Chapter 3. Experimental factors (design features and site factors) were compared to the as-constructed details obtained from the LTPP database and from construction reports. The deviations observed were reported in the chapter.

Based on the extent and occurrence of distresses, different methods of analysis were employed. A brief description of each of the methods used for this research is in Chapter 4. The majority of results from these analyses should be interpreted with caution in light of the “low” occurrence of distresses in the test sections within the SPS-1, SPS-2, and SPS-8 experiments. This is especially true for the SPS-2 and SPS-8 experiments. Also, it is suggested that the conclusions be considered while keeping in view the other limitations of the data, as explained later in this chapter.

A synopsis of the salient findings from all the analyses presented in previous chapters (Chapters 5, 6, and 7), for each experiment, is presented in this chapter. This summary is intended to give the reader a brief overview of the effects of design and construction features on pavement performance and response.

The findings are presented by each performance or response measure, and not by design factor, as most of the experimental factors (design and site factors) are interacting among each other.

## 8.2 EFFECTS OF STRUCTURAL FACTORS FOR FLEXIBLE PAVEMENTS — SPS-1 EXPERIMENT

The SPS-1 experiment, entitled *Strategic Study of Structural Factors for Flexible Pavements*, is one of the nine special pavement studies in the LTPP program. The effects of the experimental factors on fatigue cracking, structural rutting, roughness, transverse cracking, and longitudinal cracking (WP and NWP) are discussed below.

*It should be noted that the effects presented herein are statistically significant and of practical significance unless mentioned otherwise.*

### *8.2.1 Effect of Design and Site Factors on Pavement Performance*

The effects of the experimental factors on each performance measure are discussed below, one performance measure at a time.

**Fatigue Cracking**

- All the experimental factors were found to be affecting fatigue cracking, though not at the same level. On the whole, pavements with “thin” 102 mm (4-inch) HMA surface layer have shown more fatigue cracking than those with “thick” 178 mm (7-inch) HMA surface layer. Also pavements constructed with only DGAB have shown more fatigue cracking than those with ATB-over-DGAB, and those with ATB base only, with the latter base type showing the best performance. The main effect of base thickness is not statistically significant. However, on average, pavements with 16-inch (406 mm) base thickness have shown slightly better fatigue performance than those with 203 mm (8-inch) or 305 mm (12-inch) base thickness. It should be noted that only pavement sections with drainage have a 406 mm (16-inch) base thickness according to the SPS-1 experiment design; therefore, it is unclear whether this effect is caused by the increased base thickness or by drainage provided with PATB. In this regard, the frequency-based analyses did show that pavements with drainage have significantly lower chances of cracking than those without drainage.
- In general, pavement sections built on fine-grained soils have more fatigue cracking than those built on coarse-grained soils. Also pavements located WF zone have shown more fatigue cracking than those located in WNF zone.

- Among un-drained pavements, on average, an increase in HMA surface thickness from 102 mm (4-inch) to 178 mm (7-inch) has a slightly higher effect on fatigue cracking for pavements with DGAB than for pavements with ATB. However, this effect is not statistically significant.
- The main effect of HMA surface thickness is more significant for sections built on coarse-grained soils.
- Among pavements built on fine-grained soils, the effect of drainage is seen only in those sections with DGAB; i.e., those with drainage have less fatigue cracking than those without drainage. For drained pavements built on fine-grained soils, those with 203 mm (8-inch) base have more cracking than those with 305 mm (12-inch) and 406 mm (16-inch) base. Hence, for pavements built on fine-grained soils, drainage helps improve fatigue performance for those with DGAB while thicker base helps improve fatigue performance for drained pavements (irrespective of base type).
- The main effect of HMA thickness, discussed above, is mainly seen among sections located in WNF zone. This may be an indication that an increase of HMA thickness from 102 mm (4-inch) to 178 mm (7-inch) is not sufficient in resisting fatigue cracking for pavements in WF zone as compared to WNF zone.
- Among sections located in the WF zone, those with DGAB have shown the highest amount of cracking while those with ATB have the least cracking. In addition, those with 406 mm (16-inch) drained base have the least amount of fatigue cracking. This suggests that among pavements located in WF zone, “thick” 406 mm (16-inch) treated bases with drainage are less prone to cracking. The effects of HMA thickness and base thickness discussed above imply that, among sections located in WF zone, an increase in base thickness to 16-inch (with drainage) has a greater impact than an increase in HMA thickness from 102 mm (4-inch) to 178 mm (7-inch), suggesting that a thicker base and drainage helps in reducing frost effects.

### Structural Rutting

The extent of structural rutting among the test sections in the SPS-1 experiment is 6.5 mm, on average, with a standard deviation of 2.4 mm. Their average age is about 7 years with a range between 4.5 and 10 years. The amount of rutting for the majority of these sections is within the normal range at this point in time. Therefore, the results at this point may only show initial trends and may not be of much practical significance.

- Marginal main effects of drainage, HMA thickness, and base thickness on structural rutting were observed. Pavements with "thin" [102 mm (4-inch)] HMA surface layer have shown slightly more rutting than those with "thick" [178 mm (7-inch)] HMA surface layer. Also, on average, pavements with 406 mm (16-inch) drained base have shown somewhat better rut performance than those with 203 mm (8-inch) and 305 mm (12-inch) base. However, these effects of HMA surface thickness and base thickness were not found to be statistically significant. Pavements with drainage have less rutting than those without drainage. The effect is not of practical significance, at this point in time.
- In general, pavement sections built on fine-grained subgrade have shown more rutting than those built on coarse-grained subgrade. On the other hand, there is no apparent effect of climate (WF vs. WNF) on structural rutting.
- Among the pavements built on coarse-grained soils, those with 178 mm (7-inch) HMA surface have shown slightly less rutting than those with 102 mm (4-inch) HMA surface. However, this effect is not operationally significant at this point.
- The above suggests that for sections built on fine-grained soils an increase in HMA thickness from 102 mm (4-inch) to 178 mm (7-inch) may not be sufficient in reducing the amount of rutting. Among pavements built on fine-grained soils, a marginal positive effect of drainage is seen in sections with ATB.
- Among drained pavements located in WF zone, those with DGAB have shown more rutting than those with ATB. Also, among sections located in WF zone and built with ATB, those with drainage have shown significantly less rutting than those without drainage. This implies that, among pavements located in WF zone, those with ATB and drainage perform better than those with other combinations of base type and drainage.

- Among un-drained sections located in WNF zone, those with 305 mm (12-inch) base have less rutting than those with 203 mm (8-inch) base. For sections built on DGAB and located in WNF zone, those with drainage have shown slightly less rutting than those without drainage. This effect was found to be marginally significant. These early trends imply that the importance of drainage among pavements with DGAB is considerable in improving rut performance among sections located in WNF zone. On the other hand an increase in base thickness from 203 mm (8-inch) to 305 mm (12-inch) improves rut performance for un-drained sections, irrespective of base type.

**Roughness**

- All the experimental factors were found to be affecting roughness, though not at the same level. Pavements with “thin” [102 mm (4-inch)] HMA surface layer have higher change in IRI (ΔIRI) than those with “thick” [178 mm (7-inch)] HMA surface layer. This effect is not of practical significance at this point in time. Also, pavements constructed with DGAB have higher ΔIRI than those with ATB/DGAB and ATB, while pavements with ATB have the best performance for roughness. Pavements with thicker bases have lower ΔIRI. Also pavements with drainage have lower ΔIRI than un-drained pavements.
- In general, pavements built on fine-grained soils have shown higher ΔIRI than those built on coarse-grained soils, especially among sections in WF zone. Also, the change in roughness among sections located in WF zone is significantly higher than those in WNF zone.
- Among pavements built on fine-grained soils, an increase in HMA thickness from 102 mm (4-inch) to 178 mm (7-inch) has a significant positive effect on change in roughness. Also for un-drained pavements, those with ATB have significantly lower ΔIRI than those with DGAB. Finally the effect of drainage is significant only for sections with DGAB. These effects suggest that, for pavements built on fine-grained soils, higher HMA thickness and/or treated base will help inhibit the increase in roughness. Also, drainage appears to be more effective in preventing an increase in roughness for sections with DGAB, especially among those located in WF zone.

- For un-drained pavements built on coarse-grained soils, an increase in base thickness from 203 mm (8-inch) to 305 mm (12-inch) causes lower ΔIRI. However, this effect is marginally significant and is not of practical significance at this point in time.

### Transverse Cracking

- The effect of base thickness on transverse cracking is insignificant, at this point. Pavements constructed with DGAB have more transverse cracking than those with ATB/DGAB and ATB, while pavements with ATB have shown the least amount of cracking. However the effect is not of practical significance at this point in time. Slightly more cracking was observed on pavements with “thin” [102 mm (4-inch)] HMA surface layer. Also, pavements with drainage have shown slightly less cracking than un-drained pavements. However, these effects were not found to be statistically significant.
- In general, pavements built on fine-grained soils have shown more transverse cracking than those built on coarse-grained soils.
- Pavements located in WF zone have shown significantly more transverse cracking than those located in WNF zone. This confirms that transverse cracking occurs mainly in freezing environment.
- Among drained pavements built on coarse-grained soils, those with ATB performed better than those with DGAB.
- Among pavements with DGAB and built on fine-grained soils, those with drainage have shown significantly less transverse cracking than those without drainage.

### Longitudinal Cracking-WP

- The effects of HMA and base thickness on longitudinal cracking-WP are insignificant at this point in time. Pavements with drainage have shown less cracking than un-drained pavements. The main effect of drainage is not of practical significance at this point.
- In general, pavements built on fine-grained soils have shown more longitudinal cracking-WP than those built on coarse-grained soils.

- On average pavements in WF zone have shown higher levels of longitudinal cracking-WP than those in WNF, especially among pavements built on fine-grained subgrade. This effect was found to be only marginally significant.
- Among pavements built on fine-grained soils, those built with DGAB have shown more longitudinal cracking-WP, and those built with ATB have shown the least amount of cracking. Also, drainage has a significant effect on longitudinal cracking, and this effect is more pronounced in pavements built with DGAB. This trend implies that if a pavement on fine-grained subgrade is constructed with a DGAB base, better performance (in terms of longitudinal cracking-WP) can be achieved by providing drainage. These effects are seen in both WF and. WNF zones.

### Longitudinal Cracking-NWP

- The effects of HMA thickness, base thickness, and base type on longitudinal cracking-NWP are insignificant at this point in time. Pavements with drainage have shown slightly less cracking than un-drained pavements. However, the effect of drainage was found to be only marginally significant.
- The effect of subgrade type was not found to be statistically significant.
- In general, more longitudinal cracking-NWP was observed among sections located in “freeze” climate compared to those in “no-freeze” climate.
- The effect of drainage is more pronounced (with marginal statistical significance) among pavements located in “freeze” climate. However, this effect is not of practical significance.

These initial trends indicate that longitudinal cracking-NWP is caused by “freeze” climate (frost effects), and that pavements without drainage may be more prone to it.

In summary, based on the above discussion for SPS-1 experiment, base type seems to be the most critical design factor for fatigue cracking, roughness (IRI), and longitudinal cracking-WP. This is not to say that the effect of HMA surface thickness is not significant. In fact, the effect of base type should be interpreted in light of the fact that a dense graded asphalt treated base effectively means thicker HMA layer. Drainage and base type, when combined also play an important role in improving flexible pavement performance, especially in terms of fatigue and longitudinal cracking. Base thickness has secondary effects on performance, especially in the case of roughness and rutting.

Subgrade soil type seems to be playing an important role in flexible pavement performance. In general, pavements built on fine-grained soils have shown worst performance, especially in the case of roughness. Also, climate is a critical factor in determining flexible pavement performance. Longitudinal cracking-NWP, transverse cracking, and longitudinal cracking-WP appear to be affected by climate. Longitudinal cracking-WP and transverse cracking seems to be associated with Wet Freeze environment, while longitudinal cracking-NWP seems to be the dominant in “freeze” climate.

### *8.2.2 Effect of Design and Site Factors on Pavement Response*

Three pavement response parameters were chosen for ANOVA – peak deflection under FWD load ($d_0$), far-sensor deflection ($d_6$), and AREA. A summary of the effects of design and site factors on each of the response parameters follows.

**Peak Deflection under FWD Load ($d_0$):** For pavement sections built on DGAB, those with 102 mm (4-inch) HMA surface thickness have higher $d_0$ than those with 178 mm (7-inch) HMA surface thickness. Also pavements with thicker bases, irrespective of base type, have lower $d_0$. This effect is more prominent in the case of sections with treated bases (ATB or ATB/DGAB). Also, pavement sections with PATB/DGAB have lower $d_0$ than those with DGAB.

In general, pavements built on fine-grained soils have shown significantly higher $d_0$ as compared to those built on coarse-grained soils. This effect is more prominent on pavements located in WNF zone.

**Far Sensor Deflection (d6):** Pavements built on fine-grained soils have higher $d_6$ values as compared to those built on coarse-grained soils. This effect is more prominent on pavements located in WNF zone.

Pavements built with DGAB have shown higher $d_6$ values than those built on other base types. Pavements constructed on 203 mm (8-inch) bases have also shown significantly higher $d_6$ values than those built on 305 mm (12-inch) or 406 mm (16-inch) bases. Furthermore, pavements with PATB/DGAB have smaller $d_6$ values than those with DGAB. These effects of the design factors on $d_6$ are based on statistical analyses only, and may or may not be of practical importance.

**AREA:** For pavements built on DGAB, those with “thin” HMA surface layer have lower AREA values compared to those with “thick” HMA surface layer, implying that the upper layers of these pavements are “less stiff”.

For pavements built on DGAB, increasing base thickness from 203 mm (8-inch) to 305 mm (12-inch) has not shown a significant effect on AREA; however a two-fold increase in base thickness [from 8 to16 inch (203 to 406 mm)] has shown a significant increase in AREA. Furthermore, pavements with PATB/DGAB have higher AREA values than those with DGAB. This may be an indication that the structural capacity of the PATB layer is somewhat higher than that of the DGAB.

### *8.2.3 Apparent Relationship between Response and Performance*

Two types of relations between flexible pavement response (FWD) and performance were explored for the SPS-1 pavements— explanatory and predictive. The salient findings are briefly presented below:

**Overall Analysis— Explanatory Relationship**

Following are findings regarding relationship between response and performance based on regression analysis, after adjusting for HMA surface thickness and pavement mid-depth temperature at the time of testing:

- Older pavements have slightly lower deflections ($d_0$) compared to younger pavements, which could be due to stiffening (aging) of the asphalt.
- Pavements with "weaker" subgrade (higher $d_6$) have higher $d_0$ values.
- Pavements with more cracking (fatigue cracking or longitudinal cracking) have a higher $d_0$ values, compared to those with less cracking.

**Site Level Analysis— Predictive Relationships**

This section summarizes the observations regarding the predictive relationships between initial response and future pavement performance, based on site-level analysis.

- In most of the sites, pavements with higher initial SCI or BDI, or lower initial AREA have higher fatigue cracking.
- In most of the sites, pavements with higher initial BDI have higher IRI.
- The deflection basin parameters have not shown a consistent relationship with rut depth for the various sites in the SPS-1 experiment.

**Overall Analysis— Predictive Relationships**

The main observations based on the analyses are as follows:

- For pavements constructed on fine-grained soils, ones with higher SCI have shown more fatigue cracking, especially in WNF zone.
- Stiffer pavements (higher AREA) built on fine-grained soils have shown more fatigue cracking, especially if located in WF climatic zone.
- Higher longitudinal cracking-WP was observed for the pavement sections with higher AREA, especially among pavements located in WNF climatic zone.

- No apparent relation was observed between AREA and longitudinal cracking-NWP or transverse cracking, implying that these distresses could be independent of the pavement structural capacity.

**Dynamic Load Response for OH (39) test sections**

The observations based on analysis of DLR data from instrumented sections are:

- In general, the strains in the longitudinal direction are higher than the strains in the transverse direction.
- The sections that were observed to have higher initial strain values have shown worse fatigue performance.
- The sections that were observed to have high initial stress at the top of the subgrade layer and those that were observed to have high initial surface deflection under the load have shown poor rut performance.

## 8.3 EFFECTS OF STRUCTURAL FACTORS FOR RIGID PAVEMENTS — SPS-2 EXPERIMENT

The SPS-2 experiment, entitled *Strategic Study of Structural Factors for Rigid Pavements*, is one of nine special pavement studies in the LTPP program. The key conclusions regarding the influence of the experimental factors, based on this study, are summarized below.

*It should be noted that the effects presented herein are statistically significant unless mentioned otherwise; however, they may not be of practical significance at this point in time.*

### *8.3.1 Effect of Design and Site Factors on Pavement Performance*

**Transverse cracking:** PCC slab thickness and base type seem to be the most important factors affecting the occurrence of transverse cracking, whereas, drainage seems to have a marginal effect. The effects of design and site features on transverse cracking are as follows:

- The occurrence of transverse cracking among pavements with 203 mm (8-inch) PCC slab thickness is higher than that among those with 279 mm (11-inch) PCC slab thickness.

- The occurrence of transverse cracking among pavements constructed with LCB is higher than that among those with PATB/DGAB or with DGAB. Pavements with PATB/DGAB have shown the "best" performance (least occurrence of cracking).
- Sections without drainage have slightly higher likelihood of cracking than sections with drainage.
- On average, among sections built with LCB, those with 203 mm (8-inch) PCC slab have higher occurrence of cracking than those with 279 mm (11-inch) PCC slab. It is important to interpret these results in light of the construction issues, i.e. shrinkage cracking in LCB.
- Pavements built on fine-grained soils have slightly higher chances for the occurrence of transverse cracking than those built on coarse-grained soils.

**Longitudinal Cracking:** PCC slab thickness and base type seem to be the most important factors affecting the occurrence of longitudinal cracking. The effects of design and site features on longitudinal cracking are as follows:

- The occurrence of longitudinal cracking among pavements with 203 mm (8-inch) PCC slab thickness is higher than among those with 279 mm (11-inch) PCC slab thickness.
- The occurrence of longitudinal cracking among pavements constructed with LCB is higher than among those with PATB/DGAB or with DGAB. Pavements with PATB/DGAB have shown the "best" performance (least occurrence of cracking).
- On average, among sections built with LCB, those with 203 mm (8-inch) PCC slab have higher occurrence of cracking than those with 279 mm (11-inch) PCC slab. It is important to interpret these results in light of the construction issues i.e. shrinkage cracking in LCB.

**Faulting:** A majority of SPS-2 sections are exhibiting "good" performance with respect to joint faulting, at this point in time. Only 33% of the sections have 0 to 20% of the joints that faulted more than 1.0 mm, and just 5% of the sections have more than 20% of the joints that faulted more than 1.0 mm. Therefore, the results at this point may only indicate the initial trends/observations that may not be of much practical significance. Among all the design factors, lane width seems to be most important for faulting of PCC joints.

In general, pavements with standard lane [3.7 m (12 ft) wide lane] have shown higher faulting than those with widened lane [4.3 m (14 ft) wide lane]. The effect of lane width is more prominent among sections built on fine-grained soils than among those built on coarse-grained soils. Also, the effect is more pronounced among sections located in WF zone.

**Roughness:** The initial roughness (smoothness) of the pavement sections in the experiment seems to be affected by the PCC slab thickness. Pavements with thicker slab (279 mm) were found to have more initial roughness compared to those with thinner slab (203 mm). Drainage and base type seem to be the most important factors affecting the growth in roughness, whereas, slab thickness seems to have a marginal effect. The effects of design and site features on change in IRI are as follows:

- Pavements constructed with PATB have shown lower change in IRI (ΔIRI) compared to those with DGAB or LCB, while pavements with DGAB have the highest change in roughness
- Among pavements constructed with standard lane [3.7 m (12 ft) wide lane], sections with DGAB have shown higher ΔIRI than those with LCB or PATB.
- Among pavements built on fine-grained soils, those with 203 mm (8-inch) PCC slab have higher ΔIRI than those with 279 mm (11-inch) PCC slab. This effect is more prominent among sections located in WF zone.
- Among sections located in WF zone and built on fine-grained soils, those with drainage (i.e. sections with PATB) have shown lower ΔIRI compared to those without drainage.

The above results suggest that the change in roughness can be inhibited by constructing pavements with PATB and drainage as compared to sections with DGAB or LCB, especially in the case of pavements built on fine-grained soils. Also, among pavements built on fine-grained soils, an increase in PCC slab thickness from 8” (203 mm) to 11” (279 mm) seems to help prevent an increase in pavement roughness.

### *8.3.2 Effect of Design and Site Factors on Pavement Response*

Analyses were performed on the peak deflection under the FWD load plate (do), the far sensor deflection at 60 inches (1524 mm) from the FWD load (d6), the “Area Factor” (AF), and

Effective Stiffness (ES) of the PCC slab. All the response parameters have been calculated using the midslab deflections.

**Peak Deflection under FWD load ($d_o$):** Pavements constructed with DGAB have higher $d_o$ values than the ones constructed with PATB. Also, pavements constructed on LCB have the least $d_o$ values. Pavements with 203 mm (8-inch) thick slab have higher $d_o$ values than the 279 mm (11-inch) thick slabs.

In the Wet Freeze zone, the pavements built on fine subgrade soils have higher $d_o$ values than those built on coarse subgrade soils. Similar results were obtained from the analysis of the latest (or final) $d_o$ values.

**Far Sensor Deflection ($d_6$):** The pavements constructed on DGAB have higher $d_6$ values than the ones constructed on PATB. The pavements constructed on LCB have the least $d_6$ values. Also the pavements with 203 mm (8-inch) PCC slabs have higher $d_6$ values than those with 279 mm (11-inch) PCC slabs. Similar results were obtained from the analysis of the latest (or final) $d_o$ values.

In the Wet Freeze zones, pavements built on fine subgrade soils have higher $d_6$ values than those built on coarse subgrade soils.

**Area Factor (AF):** Pavements with 279 mm (11-inch) PCC slab have higher AF than those with 203 mm (8-inch) slab. Among pavements with LCB, those constructed on coarse-grained subgrade have higher AF than those constructed on fine-grained subgrade soils. These effects were not significant for final survey AF values. Pavements with 6.2 MPa (900 psi) concrete have higher AF than those with 3.8 MPa (550 psi) concrete. Sections located in “wet” climate have higher AF than those in “dry” climate.

**Effective Stiffness (ES):** The effect of PCC thickness on ES is more prominent among pavements with DGAB than among those with LCB. The effect of PCC flexural strength on ES is more apparent for pavements with DGAB or PATB than for sections with LCB. Also, pavements built on coarse-grained subgrade soil were stiffer than those built on fine-grained soil.

The effects of PCC thickness and base type on ES from final survey were similar as in the case of initial ES. However, pavements built with drainage have higher ES than those without drainage. Also, pavements with 6.2 MPa (900 psi) concrete have higher ES than those with 3.8 MPa (550 psi) concrete.

## 8.4 EFFECTS OF THE ENVIRONMENT IN THE ABSENCE OF HEAVY TRAFFIC FOR FLEXIBLE & RIGID PAVEMENTS — SPS-8 EXPERIMENT

The SPS-8 experiment is entitled *Strategic Study of Environmental Effects in the Absence of Heavy Loads for Flexible and Rigid Pavements*. The study examines the effect of climate and subgrade type (active, fine, and coarse) on pavement sections incorporating different flexible and rigid pavements, which are subjected to very limited traffic as measured by ESAL accumulation.

The SPS-8 pavements have “low” occurrence and extent of distresses, at this point. Most of the pavements in the experiment are performing at comparable levels. No formal statistical methods can be employed due to this. Therefore the observations presented here are just based on average performance of the distressed pavements. The observations, presented below, need to be considered as initial trends in light of these limitations.

### Flexible Pavements

On average, pavements in WF zone have more fatigue cracking, longitudinal cracking-NWP, and roughness than pavements in other climates. Also, in general, pavements constructed on “active” subgrade (frost susceptible or expansive) soils have higher longitudinal cracking-NWP, transverse cracking, and fatigue cracking than pavements on “non-active” soils.

Pavements located in “wet” climate, on average, have higher change in IRI than those in “dry” climate. Furthermore, pavements located in WF zone and those built on active soils have the higher changes in IRI.

### Rigid Pavements

Longitudinal spalling, on average, was higher in sections located in “wet” climate. Spalling was not observed in any of the pavements located in the DF zone and in any of the pavements constructed on coarse-grained subgrade soil. Transverse cracking was not observed in any of the pavements constructed with thicker PCC slabs and in any of the pavements constructed on coarse-grained subgrade soils.

## 8.5 LIMITATIONS OF THE EXPERIMENTS AND ANALYSES

All the above findings/observations on the effects of design and construction features on pavement performance and response should be considered in light of the limitations discussed herein. These limitations can be broadly classified under two categories— experiment-related and data-related.

### *8.5.1 Experiment-related issues*

- The SPS-1, SPS-2 and SPS-8 experiments, which are fractional-factorial designs, were rendered unbalanced because unequal numbers of sites were constructed in each zone-subgrade combination. This unbalanced design limits the "power" of the experiments. In the SPS-1 experiment only 2 sites each are located in DF and DNF zones, compared to 8 and 6 sites in WF and WNF zones. Moreover, both the sites of SPS-1 in the DF zone are located on coarse-grained soils. In the SPS-2 experiment, 7 are located in the WF zone compared to 2, 3 and 2 in WNF, DF, and DNF zones, respectively. Furthermore, in some of the sites not all sections were constructed on the same subgrade soil type [for example, KS (20), NV (32)].
- Initially, the SPS-1 and SPS-2 experiments were designed to have all 24 designs at a site. But later due to some implementation issues, 12 designs were constructed per site. Hence, the experiments do not have any "true" (statistical) replication of designs. In other words, though two sites (with 12 designs at each site) are located in a climate-subgrade soil combination, the traffic, age, and material-related properties vary between the sites.
- The variation in age of the sites is considerably high for the experiments. If the sites were reasonably similar in age, the findings would be more reliable. It should be noted that age of the test sections was included as a covariate in all statistical analyses to address the above issue to some extent.
- In both SPS-1 and SPS-2 experiments, in-pavement drainage was provided only for sections built with PATB. Moreover, all sections with PATB were provided with drainage. As a result of this, the effect of PATB and the effect of drainage are inseparable (confounded).
- In the SPS-1 experiment, a 406 mm (16-inch) thick base was only provided for sections with drainage. In other words, none of the sections without drainage have a 406 mm (16-

inch) base thickness. Hence, the effect of a 406 mm (16-inch) thick base and the effect of drainage are also inseparable.

- Among flexible pavement sections of SPS-1, all sections built with ATB-over-DGAB were not provided with drainage. Hence, any interaction effects of drainage and ATB-over-DGAB cannot be studied.
- The sections with 203 mm (8-inch) thick PCC slabs have dowels of 32 mm (1.25-inch) diameter and sections with 279 mm (11-inch) thick PCC slabs have dowels of 38 mm (1.5-inch) diameter. The effect of PCC slab thickness, especially on faulting, is thus not "pure".
- Only the lower limit for traffic volume was specified for the SPS-1 and SPS-2 experiments. This resulted in considerable variability in traffic across sites.
- In the SPS-8 experiment, the effects of HMA surface thickness and base thickness are confounded. Therefore, the "pure" effects of any of these factors cannot be studied.

### *8.5.2 Data-related issues*

- Reasonably accurate monitored traffic data is not available for all the sites in the experiments. This has further complicated the issue of controlling for traffic.
- Large measurement variability was observed, over time, for some of the distresses (for example, longitudinal cracking in SPS-1 and faulting in SPS-2). This variability has made the time-series trends unclear for some of the performance measures.
- The measurement variability discussed above is believed to be due to maintenance activity at some sites, which is a deviation from the experiment design. These activities tamper with the actual long-term field performance of the pavement sections.
- The frequency of distress surveys is not uniform across sites, especially for SPS-1 and SPS-2 experiments. Wide gaps in distress surveys necessitate interpolation of performance, which may not always be accurate.
- Pumping distress, in the case of rigid pavements (SPS-2), was not considered for analyses based on the recommendations by the project panel, as "the validity of related data is questionable".
- Though thorough construction guidelines were developed by the LTPP to minimize construction variability across sites, some deviations occurred. These deviations along with the material variability have added to the variability in performance across sites. If

material-related information were available for all the sections, the issues caused by performance variability could be better addressed.

- Backcalculated layer moduli are unavailable for most of the sections in the SPS-1 and SPS-2 experiments. Some of the material-related issues could be dealt with if the data were present.
- The data regarding the coefficient of thermal expansion (CTE) of concrete is not available in the DataPave IMS database (Release 17.0). Therefore, CTE of concrete could not be considered in the analyses.

## 8.6 RECOMMENDATIONS FOR FUTURE DATA COLLECTION AND RESEARCH

Based on the above issues and the experience of the authors with the LTPP data, recommendations for future data collection and research are given below.

1) Reasonably accurate monitored traffic data should be made available for all the sites to allow for better adjustment of traffic loading variation across sites.
2) All the core sections of the experiments, especially SPS-1 and SPS-2, should be closely monitored until failure or to a stage when the long-term performance (at least 15-20 years) has been captured.
3) The core sections of both SPS-1 and SPS-2 experiments should be strictly supervised to prevent any maintenance activity, as per the experiment designs. This will ensure that the actual long-term performance of the pavements is observed.
4) Most of the test sections will soon enter a critical stage in their service life; in light of this, to reap maximum benefits from the experiments, the sections should be monitored at regular intervals and with greater accuracy.
5) Hall et al [1] have identified issues regarding in-pavement drainage for sections in SPS-1 and SPS-2 experiments. The findings from this study should be considered for inclusion in the DataPave IMS database. This may help study the effect of in-pavement drainage more accurately.
6) Some of the sections in the SPS-1 and SPS-2 experiments have shown premature “failure”. These sections should be considered for exclusion from DataPave, as they do not contribute to the study of long-term pavement performance.

7) Some of the sites in both SPS-1 and SPS-2 experiments are very close to the thresholds (regarding average annual precipitation and freeze index) defined for delineation of climatic zones. The definitions of the climatic zones may need reconsideration in light of this.
8) The definition of pumping, in the case of the SPS-2 experiment, should be revisited to allow for its inclusion in future studies.
9) Accurate material data should be made available for all the sections of the experiments to allow for addressing the variability in material quality across sites. Also, backcalculated layer moduli data should be made available for all sections in DataPave to help perform mechanistic analyses.
10) Most of the construction-related issues are available only from construction reports. These issues and/or deviations should be better highlighted well within the DataPave database.
11) The spatial location of some distresses (such as cracking) is sometimes important for research. It is practically cumbersome for the users to obtain distress maps and interpret the spatial location of the distresses. It is therefore recommended that each section be "discretized" (segmented) for data collection and the related data be made available in DataPave. This would greatly decrease the level of subjectivity in the data.
12) In general, the extent of distresses on the SPS-8 test sections is "low", at this point in time. The performance data should thus be collected for sufficiently long time (15 to 20 years for all the sections in the experiment) to capture the effects of environment. A meaningful statistical analysis may then be performed to study the effects of environment.
13) The DLR instrumentation location (spatial location), alignment and designation details should be made more accurate in DataPave.
14) It is recommended that the complete actual traces of data from the instrumented DLR sections be considered for inclusion in the DataPave database (in addition to the "peak" and "valley" data) after proper quality checks. Also more data (i.e. more test series results) should be included in the DataPave. This data could be stored separately as in the case of profiles and FWD time histories.

When the long-term performance data is available for most of the sections of the SPS-1 and SPS-2 experiments, the methods employed in this research would be more “powerful” to study the effect of design and construction features. Methods that analyze the time-series data (such as survival analysis and ANOVA with repeated measures) can also be employed when the performance data for most of the sections is available for about 15 years.

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# APPENDIX A1

## Site Summaries for SPS-1 experiment
## (Inventory/construction details, status and data availability)

# ALABAMA (1)

## Site Description

The LTPP sections of Alabama were built on U.S. 280 east of Opelika, AL, in 1992. U.S. 280 is a four lane road with an AC shoulder. Table A- 1 summarizes the inventory data for SPS-1 Alabama sections. The sections in the experiment design are 01-0101 through 01-0112 and three additional sections.

Table A- 1 Inventory data for SPS-1 Alabama sections

| | |
|---|---|
| Site code | 01 |
| Climate | Wet-No-Freeze |
| Average annual precipitation (mm) | 1,340 |
| Average annual freezing index (˚C·days) | 9 |
| Estimated Traffic (ESAL) | 237,000 |
| Subgrade soil | Fine-grained |
| Shoulder | AC |

## Construction Issues

The subgrade preparation for this site began in September 1991 and upon the completion the Alabama Highway Department allowed the subgrade to sit undisturbed for approximately one year. Pavement layer placement began in June 1992. Mechanical problems of the track paver and rain at the site delayed the paving operations. Due to this delay, some of the materials were not compacted at the optimum compaction temperature range. Later, because the paver encountered further mechanical problems it was replaced by a rubber-tired paver, leaving a construction joint at section 01-0111. In addition, some deformation was noticed on the PATB layer.

## Site Status

Several sections did not meet the thickness requirements set by FHWA and deviated from the requirements for more than 6 mm. In addition, the DGAB contained more material passing the No. 200 sieve than allowed. Table A-2 summarizes the design features for the sections.

Table A- 2 Design features for SPS-1 Alabama sections

| Section ID | AC Thickness, in | | Base Thickness, in | | Base Type | Drainage |
|---|---|---|---|---|---|---|
| | Design | Actual | Design | Actual | | |
| 0101 | 7 | 7.5 | 8 | 7.9 | DGAB | No |
| 0102 | 4 | 4.2 | 12 | 11.9 | DGAB | No |
| 0103 | 4 | 4.6 | 8 | 7.4 | ATB | No |
| 0104 | 7 | 6.5 | 12 | 11.7 | ATB | No |
| 0105 | 4 | 4.2 | 8 | 11.9 | ATB/DGAB | No |
| 0106 | 7 | 7.2 | 12 | 12.1 | ATB/DGAB | No |
| 0107 | 4 | 4.6 | 8 | 7.7 | PATB/DGAB | Yes |
| 0108 | 7 | 7.3 | 12 | 12.1 | PATB/DGAB | Yes |
| 0109 | 7 | 7.6 | 16 | 16.1 | PATB/DGAB | Yes |
| 0110 | 7 | 7.9 | 8 | 7.7 | ATB/PATB | Yes |
| 0111 | 4 | 4.4 | 12 | 11.6 | ATB/PATB | Yes |
| 0112 | 4 | 3.4 | 16 | 15.7 | ATB/PATB | Yes |

## Data Availability

Table A- 3 summarizes the available data for sections in Alabama. Sections 01-0101 and 01-0102 had more data available than other sections in all fields.

Table A- 3 Data availability (No. of surveys) for SPS-1 Alabama sections

| SHRP ID | Distress | | IRI | FWD |
|---|---|---|---|---|
| | Cracking | Rutting | | |
| 0101 | 12 | 12 | 14 | 34 |
| 0102 | 12 | 12 | 15 | 33 |
| 0103 | 7 | 9 | 6 | 6 |
| 0104 | 7 | 9 | 8 | 7 |
| 0105 | 7 | 9 | 6 | 6 |
| 0106 | 7 | 9 | 7 | 6 |
| 0107 | 6 | 8 | 7 | 5 |
| 0108 | 7 | 9 | 8 | 7 |
| 0109 | 7 | 9 | 6 | 6 |
| 0110 | 7 | 9 | 7 | 7 |
| 0111 | 7 | 9 | 6 | 6 |
| 0112 | 7 | 9 | 7 | 6 |

## ARIZONA (4)

### Site Description

The LTPP sections of Arizona were built on U.S. 93 north of Kingman, AZ, in 1993. U.S. 280 is a four lane road with the inventory data summarized in Table A- 4. The sections in the experiment design are 04-0113 through 04-0124 and four additional sections.

Table A- 4 Inventory data for SPS-1 Arizona sections

| | |
|---|---|
| Site code | 04 |
| Climate | Dry-No-Freeze |
| Average annual precipitation (mm) | 241 |
| Average annual freezing index (˚C-days) | 1 |
| Estimated Traffic (ESAL) | 185,000 |
| Subgrade soil | Coarse-grained |
| Shoulder | N/A |

### Construction Issues

The majority of the test sections were constructed on fill material. The cut sections include all of test sections 04-0113, 04-0161 and half of 04-0162. These sections were later scarified to a depth of 18 inches and reprocessed to simulate fill sections.

Heavy rain occurred during several days of the subgrade placement. The rainfall for this (1992-93) period was much higher than normal. Due to the rain, the subgrade material began to pump.

### Site Status

The gradation for the AC mix did not meet the requirements. In addition, the DGAB on sections 04-0119 and 04-0122 did not meet the gradation requirements. Table A-5 summarizes the design features for the sections.

Table A- 5 Design features for SPS-1 Arizona sections

| Section ID | AC Thickness, in | | Base Thickness, in | | Base Type | Drainage |
|---|---|---|---|---|---|---|
| | Design | Actual | Design | Actual | | |
| 0113 | 4 | 4.5 | 8 | 7.5 | DGAB | No |
| 0114 | 7 | 6.8 | 12 | 12 | DGAB | No |
| 0115 | 7 | 6.6 | 8 | 8.5 | ATB | No |
| 0116 | 4 | 4.1 | 12 | 12.1 | ATB | No |
| 0117 | 7 | 7.6 | 8 | 8.4 | ATB/DGAB | No |
| 0118 | 4 | 4 | 12 | 11.8 | ATB/DGAB | No |
| 0119 | 7 | 6.3 | 8 | 8.7 | PATB/DGAB | Yes |
| 0120 | 4 | 4 | 12 | 11.9 | PATB/DGAB | Yes |
| 0121 | 4 | 4.1 | 16 | 16 | PATB/DGAB | Yes |
| 0122 | 4 | 4.2 | 8 | 8.6 | ATB/PATB | Yes |
| 0123 | 7 | 6.8 | 12 | 11.7 | ATB/PATB | Yes |
| 0124 | 7 | 6.7 | 16 | 15.8 | ATB/PATB | Yes |

## Data Availability

Table A- 6 summarizes the available data for sections in Arizona. Sections 04-0113 and 04-0114 had more data available than other sections.

Table A- 6 Data availability (No. of surveys) for SPS-1 Arizona sections

| SHRP ID | Distress | | IRI | FWD |
|---|---|---|---|---|
| | Cracking | Rutting | | |
| 0113 | 20 | 20 | 24 | 37 |
| 0114 | 19 | 20 | 24 | 36 |
| 0115 | 7 | 11 | 10 | 6 |
| 0116 | 7 | 10 | 10 | 6 |
| 0117 | 7 | 10 | 10 | 6 |
| 0118 | 7 | 10 | 10 | 6 |
| 0119 | 7 | 11 | 10 | 6 |
| 0120 | 7 | 10 | 10 | 6 |
| 0121 | 7 | 10 | 10 | 6 |
| 0122 | 7 | 10 | 10 | 6 |
| 0123 | 7 | 10 | 10 | 6 |
| 0124 | 7 | 10 | 10 | 6 |

## ARKANSAS (5)

### Site Description

The LTPP sections of Arkansas were built on U.S. 63 southeast of Jonesboro, AR, in 1992. U.S. 63 is a four lane road with an AC shoulder. Table A- 7 summarizes the inventory data. The sections in the experiment design are 050113 through 050124 and do not have any additional sections.

Table A- 7 Inventory data for SPS-1 Arkansas sections

| | |
|---|---|
| Site code | 05 |
| Climate | Wet-Freeze |
| Average annual precipitation (mm) | 1,224 |
| Average annual freezing index (˚C-days) | 47 |
| Estimated Traffic (ESAL) | 170,000 |
| Subgrade soil | Coarse-grained |
| Shoulder | AC |

### Construction Issues

During the placement of edge drains, observations revealed that the contractor had failed to leave sufficient fabric to overlap the pavement as per specifications; to remedy this, the contractor used a trencher to remove the edge drain and it was replaced in accordance with the project and LTPP specifications.

During October, there were significant delays in paving over the exposed DGAB surface due to rain. The rain delays were also encountered during asphalt paving operations.

### Site Status

The AC mix did not meet the design criteria. The requirements were a minimum stability of 8 KN and a flow between 2 to 4 mm, where the mix had 7.9 KN of stability and 1.8 mm of flow. In addition, none of the sections met the thickness requirements. Table A-8 summarizes the design features for the sections.

Table A- 8 Design features for SPS-1 Arkansas Sections

| Section ID | AC Thickness, in | | Base Thickness, in | | Base Type | Drainage |
|---|---|---|---|---|---|---|
| | Design | Actual | Design | Actual | | |
| 0113 | 4 | 4.1 | 8 | 8.2 | DGAB | No |
| 0114 | 7 | 6.9 | 12 | 11.3 | DGAB | No |
| 0115 | 7 | 7 | 8 | 7.4 | ATB | No |
| 0116 | 4 | 4.1 | 12 | 11.8 | ATB | No |
| 0117 | 7 | 6.9 | 8 | 8 | ATB/DGAB | No |
| 0118 | 4 | 4.1 | 12 | 11.4 | ATB/DGAB | No |
| 0119 | 7 | 6.8 | 8 | 7.6 | PATB/DGAB | Yes |
| 0120 | 4 | 4.2 | 12 | 11.4 | PATB/DGAB | Yes |
| 0121 | 4 | 4.5 | 16 | 15.5 | PATB/DGAB | Yes |
| 0122 | 4 | 4.6 | 8 | 7.8 | ATB/PATB | Yes |
| 0123 | 7 | 7 | 12 | 11.7 | ATB/PATB | Yes |
| 0124 | 7 | 6.9 | 16 | 14.8 | ATB/PATB | Yes |

## Data Availability

Table A- 9 summarizes the available data for sections in Arkansas. The data availability is uniform over the sections in all fields.

Table A- 9 Data availability (No. of surveys) for SPS-1 Arkansas sections

| SHRP ID | Distress | | IRI | FWD |
|---|---|---|---|---|
| | Cracking | Rutting | | |
| 0113 | 5 | 8 | 5 | 5 |
| 0114 | 5 | 8 | 5 | 5 |
| 0115 | 5 | 8 | 5 | 5 |
| 0116 | 5 | 8 | 5 | 5 |
| 0117 | 5 | 9 | 5 | 5 |
| 0118 | 5 | 9 | 5 | 5 |
| 0119 | 5 | 9 | 5 | 5 |
| 0120 | 5 | 9 | 5 | 5 |
| 0121 | 5 | 9 | 4 | 5 |
| 0122 | 5 | 9 | 5 | 5 |
| 0123 | 5 | 9 | 5 | 5 |
| 0124 | 5 | 9 | 5 | 5 |

## DELAWARE (10)

### Site Description

The LTPP Sections of Delaware were built on U.S. 113 close to Ellendale, DE, in 1995. U.S. 113 is a four lane road with an AC shoulder. The inventory data is summarized in Table A- 10. The Sections in the experiment design are 10-0101 through 10-0112 with two additional Sections.

Table A- 10 Inventory data for SPS-1 Delaware Sections

| | |
|---|---|
| Site code | 10 |
| Climate | Wet-Freeze |
| Average annual precipitation (mm) | 1,145 |
| Average annual freezing index (˚C-ays) | 58 |
| Estimated Traffic (ESAL) | 203,200 |
| Subgrade soil | Coarse-grained |
| Shoulder | AC |

### Construction Issues

There was one deviation of the contract drawings from the SPS-1 construction guidelines (inside shoulder): The pavement structure of the test sections did not carry out through the shoulder, and the edge drains were placed at the edge of the passing lane instead of a minimum of 3 ft o/s. The 6” DGAB on the shoulder was replaced with 3” of type ‘A’ borrow and 3” of deep strength asphalt. These conditions were not considered serious deviations since they will not affect the performance of the driving lane. The transverse under drains were not installed because the longitudinal grade was considered to be too flat. In addition, one of the sections (10-0102) showed early signs of distress (rutting and alligator cracking).

### Site Status

The aggregate gradation of the HMA mix did not meet the criteria for the No. 4 sieve. The average thickness of at least one layer did not meet the criteria except for sections 10-0101 and 10-0102. Table A- 11 summarizes the design features for the sections.

Table A- 11 Design features for SPS-1 Delaware Sections

| Section ID | AC Thickness, in | | Base Thickness, in | | Base Type | Drainage |
|---|---|---|---|---|---|---|
| | Design | Actual | Design | Actual | | |
| 0101 | 7 | 8.1 | 8 | 8.1 | DGAB | No |
| 0102 | 4 | 5.1 | 12 | 11.8 | DGAB | No |
| 0103 | 4 | 5.8 | 8 | 8 | ATB | No |
| 0104 | 7 | 7.7 | 12 | 12 | ATB | No |
| 0105 | 4 | 5.4 | 8 | 7.8 | ATB/DGAB | No |
| 0106 | 7 | 7.7 | 12 | 12.4 | ATB/DGAB | No |
| 0107 | 4 | 5.8 | 8 | 7.7 | PATB/DGAB | Yes |
| 0108 | 7 | 8 | 12 | 11 | PATB/DGAB | Yes |
| 0109 | 7 | 8.3 | 16 | 16.3 | PATB/DGAB | Yes |
| 0110 | 7 | 8.2 | 8 | 7.7 | ATB/PATB | Yes |
| 0111 | 4 | 4.7 | 12 | 12.6 | ATB/PATB | Yes |
| 0112 | 4 | 5.5 | 16 | 15.7 | ATB/PATB | Yes |

## Data Availability

Table A- 12 summarizes the available data for sections in Delaware. The number of data over the sections is distributed uniformly except for section 10-0102 which had the most number of data available.

Table A- 12 Data availability (No. of surveys) for SPS-1 Delaware sections

| SHRP ID | Distress | | IRI | FWD |
|---|---|---|---|---|
| | Cracking | Rutting | | |
| 0101 | 7 | 8 | 11 | 3 |
| 0102 | 10 | 12 | 13 | 21 |
| 0103 | 7 | 8 | 11 | 3 |
| 0104 | 7 | 8 | 11 | 3 |
| 0105 | 8 | 9 | 11 | 4 |
| 0106 | 7 | 8 | 11 | 3 |
| 0107 | 7 | 8 | 11 | 3 |
| 0108 | 7 | 8 | 11 | 3 |
| 0109 | 7 | 8 | 11 | 3 |
| 0110 | 7 | 8 | 11 | 3 |
| 0111 | 6 | 8 | 11 | 3 |
| 0112 | 6 | 8 | 11 | 3 |

## FLORIDA (12)

### Site Description

The LTPP sections of Florida were built on U.S. 27 south of South Bay, FL, in 1995. U.S. 27 is a four lane road with an AC shoulder. The inventory data is summarized in Table A- 13. The sections in the experiment design are 12-0101 through 12-0112 with one additional section.

Table A- 13 Inventory data for SPS-1 Florida sections

| | |
|---|---|
| Site code | 12 |
| Climate | Wet-No-Freeze |
| Average annual precipitation (mm) | 1,325 |
| Average annual freezing index (˚C-days) | 0 |
| Estimated Traffic (ESAL) | 1,463,200 |
| Subgrade soil | Coarse-grained |
| Shoulder | AC |

### Construction Issues

Rain slowed or stopped construction progress periodically throughout the winter, requiring the exposed DGAB surface to be reworked to meet density and moisture content specifications.

### Site Status

The HMA mix did not meet the requirement for No. 4 sieve. The mix contained about 60 percent passing the No. 4 sieve which is 20 percent more than the requirement.

For all sections the maximum and minimum thicknesses deviated from the design requirements by more than 6 mm. Table A-14 summarizes the design features for the sections.

Table A- 14 Design features for SPS-1 Florida Sections

| Section ID | AC Thickness, in | | Base Thickness, in | | Base Type | Drainage |
|---|---|---|---|---|---|---|
| | Design | Actual | Design | Actual | | |
| 0101 | 7 | 6.8 | 8 | 8.1 | DGAB | No |
| 0102 | 4 | 3.9 | 12 | 12.1 | DGAB | No |
| 0103 | 4 | 4.1 | 8 | 8 | ATB | No |
| 0104 | 7 | 6.8 | 12 | 12.1 | ATB | No |
| 0105 | 4 | 4 | 8 | 8 | ATB/DGAB | No |
| 0106 | 7 | 7.2 | 12 | 12.2 | ATB/DGAB | No |
| 0107 | 4 | 3.9 | 8 | 8.2 | PATB/DGAB | Yes |
| 0108 | 7 | 6.4 | 12 | 11.9 | PATB/DGAB | Yes |
| 0109 | 7 | 7.1 | 16 | 15.8 | PATB/DGAB | Yes |
| 0110 | 7 | 7.3 | 8 | 8.2 | ATB/PATB | Yes |
| 0111 | 4 | 3.9 | 12 | 12.2 | ATB/PATB | Yes |
| 0112 | 4 | 3.9 | 16 | 16.2 | ATB/PATB | Yes |

## Data Availability

Table A- 15 summarizes the available data for sections in Florida. The distribution is uniform for all fields except for the IRI. Sections 12-0102, 12-0104, 12-0108 and 12-0110 had more data points available in IRI than other sections.

Table A- 15 Data availability (No. of surveys) for SPS-1 Florida sections

| SHRP ID | Distress | | IRI | FWD |
|---|---|---|---|---|
| | Cracking | Rutting | | |
| 0101 | 4 | 6 | 4 | 4 |
| 0102 | 5 | 6 | 7 | 4 |
| 0103 | 5 | 6 | 4 | 4 |
| 0104 | 5 | 6 | 7 | 4 |
| 0105 | 5 | 6 | 4 | 4 |
| 0106 | 5 | 6 | 4 | 4 |
| 0107 | 5 | 6 | 4 | 4 |
| 0108 | 5 | 6 | 7 | 4 |
| 0109 | 5 | 6 | 4 | 4 |
| 0110 | 5 | 6 | 7 | 4 |
| 0111 | 5 | 6 | 4 | 4 |
| 0112 | 5 | 6 | 4 | 4 |

## IOWA (19)

### Site Description

The LTPP sections of Iowa were built on U.S. 61 near Fort Madison, IA, in 1992. U.S. 61 is a four lane road with an AC shoulder. The inventory data is summarized in Table A- 16. The sections in the experiment design are 19-0101 through 19-0112 with one additional section.

Table A- 16 Inventory data for SPS-1 Iowa sections

| | |
|---|---|
| Site code | 19 |
| Climate | Wet-Freeze |
| Average annual precipitation (mm) | 982 |
| Average annual freezing index (˚C-days) | 235 |
| Estimated Traffic (ESAL) | 130,000 |
| Subgrade soil | Fine-grained |
| Shoulder | AC |

### Construction Issues

Construction was delayed due to an especially rainy season. The work was suspended for 20 days (in July) because the subgrade was too soft to support the paver. The consequence of the construction problems may reflect in the performance as indicated in the construction report.

The contractor had some difficulties in placing the PATB layer. Some areas were compacted at very high temperature. This caused some of the material to move to the sides.

### Site Status

Several sections had at least one layer whose average thickness deviated from design by more than 6 mm. According to the construction report, sections 19-0107 and 19-0108 had 19 mm to 25 mm thicker PATB than design. The HMA mix did not meet the requirement for No. 4 sieve. Table A-17 summarizes the design features for the sections.

Table A- 17 Design features for SPS-1 Iowa Sections

| Section ID | AC Thickness, in | | Base Thickness, in | | Base Type | Drainage |
|---|---|---|---|---|---|---|
| | Design | Actual | Design | Actual | | |
| 0101 | 7 | 8 | 8 | 8 | DGAB | No |
| 0102 | 4 | 5.1 | 12 | 12 | DGAB | No |
| 0103 | 4 | 3.8 | 8 | 8.4 | ATB | No |
| 0104 | 7 | 7 | 12 | 12.4 | ATB | No |
| 0105 | 4 | 3.5 | 8 | 8.7 | ATB/DGAB | No |
| 0106 | 7 | 6.8 | 12 | 13 | ATB/DGAB | No |
| 0107 | 4 | 3.4 | 8 | 8.2 | PATB/DGAB | Yes |
| 0108 | 7 | 5.9 | 12 | 12.6 | PATB/DGAB | Yes |
| 0109 | 7 | 7.5 | 16 | 16.9 | PATB/DGAB | Yes |
| 0110 | 7 | 7.9 | 8 | 7.6 | ATB/PATB | Yes |
| 0111 | 4 | 4.4 | 12 | 11.8 | ATB/PATB | Yes |
| 0112 | 4 | 4.6 | 16 | 16.5 | ATB/PATB | Yes |

## Data Availability

Table A- 18 summarizes the available data for sections in Iowa. The data distribution is uniform for cracking data. However, small variability in the number of data is observed in other fields.

Table A- 18 Data availability (No. of surveys) for SPS-1 Iowa sections

| SHRP ID | Distress | | IRI | FWD |
|---|---|---|---|---|
| | Cracking | Rutting | | |
| 0101 | 5 | 9 | 8 | 5 |
| 0102 | 4 | 9 | 10 | 5 |
| 0103 | 4 | 9 | 8 | 6 |
| 0104 | 4 | 10 | 8 | 6 |
| 0105 | 4 | 7 | 8 | 5 |
| 0106 | 4 | 8 | 10 | 6 |
| 0107 | 5 | 11 | 9 | 7 |
| 0108 | 4 | 9 | 10 | 5 |
| 0109 | 4 | 10 | 10 | 4 |
| 0110 | 4 | 8 | 9 | 4 |
| 0111 | 4 | 8 | 9 | 4 |
| 0112 | 4 | 8 | 9 | 4 |

# KANSAS (20)

## Site Description

The LTPP sections of Iowa were built on U.S. 54. For these sections, the construction reports were not available. The inventory data is summarized in Table A- 19. The sections in the experiment design are 20-0101 through 20-0112 with one additional section.

Table A- 19 Inventory data for SPS-1 Kansas sections

| | |
|---|---|
| Site code | 20 |
| Climate | Wet-Freeze |
| Average annual precipitation (mm) | 672 |
| Average annual freezing index (˚C-days) | 136 |
| Estimated Traffic (ESAL) | N/A |
| Subgrade soil | Fine-grained |
| Shoulder | N/A |

## Construction Issues

The contractor experienced several problems during construction, many of which were caused by the weather. The area experienced much higher than average precipitation during spring 1993, resulting in delays and a wet subgrade. To dry out the subgrade, the contractor was allowed to incorporate fly ash.

During FWD testing, high deflections were measured in the base in some areas. There was also segregation in the mix; these problems were 'corrected' with adjustments in construction methods.

## Site Status

The thickness for each layer deviates more than 6 mm from the requirements for all sections except 20-0104, 20-0105 and 20-0110. No other deviations are noted from the data. Table A-20 summarizes the design features for the sections.

Table A- 20 Design features for SPS-1 Kansas Sections

| Section ID | AC Thickness, in | | Base Thickness, in | | Base Type | Drainage |
|---|---|---|---|---|---|---|
| | Design | Actual | Design | Actual | | |
| 0101 | 7 | 7.6 | 8 | 8.5 | DGAB | No |
| 0102 | 4 | 4 | 12 | 12.3 | DGAB | No |
| 0103 | 4 | 3.6 | 8 | 7.7 | ATB | No |
| 0104 | 7 | 6.8 | 12 | 12.1 | ATB | No |
| 0105 | 4 | 3.9 | 8 | 7.9 | ATB/DGAB | No |
| 0106 | 7 | 7.3 | 12 | 11.3 | ATB/DGAB | No |
| 0107 | 4 | 4.1 | 8 | 7.8 | PATB/DGAB | Yes |
| 0108 | 7 | 7.6 | 12 | 11.5 | PATB/DGAB | Yes |
| 0109 | 7 | 7 | 16 | 15.5 | PATB/DGAB | Yes |
| 0110 | 7 | 7 | 8 | 7.7 | ATB/PATB | Yes |
| 0111 | 4 | 4 | 12 | 12.1 | ATB/PATB | Yes |
| 0112 | 4 | 5 | 16 | 15.6 | ATB/PATB | Yes |

## Data Availability

Table A- 21 summarizes the available data for sections in Kansas. The number of available data shows variability over the sections and over the fields.

Table A- 21 Data availability (No. of surveys) for SPS-1 Kansas sections

| SHRP ID | Distress | | IRI | FWD |
|---|---|---|---|---|
| | Cracking | Rutting | | |
| 0101 | 3 | 9 | 3 | 3 |
| 0102 | 3 | 7 | 3 | 3 |
| 0103 | 6 | 12 | 8 | 6 |
| 0104 | 5 | 12 | 8 | 6 |
| 0105 | 6 | 10 | 8 | 6 |
| 0106 | 6 | 11 | 7 | 6 |
| 0107 | 3 | 7 | 3 | 3 |
| 0108 | 6 | 12 | 7 | 5 |
| 0109 | 6 | 13 | 8 | 6 |
| 0110 | 6 | 11 | 8 | 6 |
| 0111 | 6 | 12 | 8 | 6 |
| 0112 | 6 | 12 | 8 | 6 |

## LOUISIANA (22)

### Site Description

The LTPP sections of Louisiana were built on U.S. 171 between Moss Bluff and Gillis, LA, in 1997. U.S. 171 is a four lane road with an AC shoulder. The inventory data is summarized in Table A- 22. The sections in the experiment design are 22-0101 through 22-0112 without any additional sections.

Table A- 22 Inventory data for SPS-1 Louisiana sections

| | |
|---|---|
| Site code | 22 |
| Climate | Wet-No-Freeze |
| Average annual precipitation (mm) | 1,538 |
| Average annual freezing index (˚C-days) | 2 |
| Estimated Traffic (ESAL) | 523,920 |
| Subgrade soil | Fine-grained |
| Shoulder | AC |

### Construction Issues

The contractors encountered difficulties constructing on the clayey silt material found throughout the project site. Therefore, stabilizing of subgrade was considered as an alternate. Twelve percent cement was used throughout the length of the project. Rain delays were also encountered during the construction of the test sections.

### Site Status

Every section had at least one layer with the thickness deviating more than 6 mm from the design thickness. Maximum and minimum thickness values for some of the sections deviated by a large amount. Table A-23 summarizes the design features for the sections.

Table A- 23 Design features for SPS-1 Louisiana Sections

| Section ID | AC Thickness, in | | Base Thickness, in | | Base Type | Drainage |
|---|---|---|---|---|---|---|
| | Design | Actual | Design | Actual | | |
| 0113 | 4 | 4.9 | 8 | 8.1 | DGAB | No |
| 0114 | 7 | 9.5 | 12 | 11.4 | DGAB | No |
| 0115 | 7 | 7 | 8 | 9 | ATB | No |
| 0116 | 4 | 4.7 | 12 | 11.3 | ATB | No |
| 0117 | 7 | 7 | 8 | 9.2 | ATB/DGAB | No |
| 0118 | 4 | 4.4 | 12 | 11.1 | ATB/DGAB | No |
| 0119 | 7 | 7.1 | 8 | 8.1 | PATB/DGAB | Yes |
| 0120 | 4 | 3.9 | 12 | 12 | PATB/DGAB | Yes |
| 0121 | 4 | 4.1 | 16 | 17.1 | PATB/DGAB | Yes |
| 0122 | 4 | 4.6 | 8 | 7.1 | ATB/PATB | Yes |
| 0123 | 7 | 6.8 | 12 | 11.5 | ATB/PATB | Yes |
| 0124 | 7 | 7.2 | 16 | 14.2 | ATB/PATB | Yes |

## Data Availability

Table A- 24 summarizes the available data for sections in Louisiana. It shows that enough data is not present for research purposes.

Table A- 24 Data availability (No. of surveys) for SPS-1 Louisiana sections

| SHRP ID | Distress | | IRI | FWD |
|---|---|---|---|---|
| | Cracking | Rutting | | |
| 0113 | 2 | 5 | 1 | 1 |
| 0114 | 2 | 5 | 1 | 1 |
| 0115 | 2 | 5 | 1 | 1 |
| 0116 | 2 | 5 | 1 | 1 |
| 0117 | 2 | 5 | 1 | 1 |
| 0118 | 2 | 5 | 1 | 1 |
| 0119 | 2 | 5 | 1 | 1 |
| 0120 | 2 | 4 | 1 | 1 |
| 0121 | 2 | 5 | 1 | 1 |
| 0122 | 2 | 5 | 1 | 1 |
| 0123 | 2 | 5 | 1 | 1 |
| 0124 | 2 | 5 | 1 | 1 |

## MICHIGAN (26)

### Site Description

The LTPP sections of Michigan were built on U.S. 27 near St. Johns, MI, in 1995. The sections were constructed with AC shoulders. The final construction report was not available for this state. The inventory data is summarized in Table A- 25. The sections in the experiment design are 26-0113 through 26-0124 with one additional section.

Table A- 25 Inventory data for SPS-1 Michigan sections

| | |
|---|---|
| Site code | 26 |
| Climate | Wet-Freeze |
| Average annual precipitation (mm) | 870 |
| Average annual freezing index (˚C-days) | 283 |
| Estimated Traffic (ESAL) | N/A |
| Subgrade soil | Fine-grained |
| Shoulder | AC |

### Construction Issues

There was no construction report available. Four of the sections failed two months after the project was completed (Sections 0113, 0114, 0119 and 0122). No monitoring data was collected for these four sections.

### Site Status

The thickness for each layer deviates more than 6 mm from the requirements for all sections except 26-0116, 26-0122 and 26-0123. No other deviations are noted from the data. Table A- 26 summarizes the design features for the sections.

Table A- 26 Design features for SPS-1 Michigan sections

| Section ID | AC Thickness, in | | Base Thickness, in | | Base Type | Drainage |
|---|---|---|---|---|---|---|
| | Design | Actual | Design | Actual | | |
| 0115 | 7 | 5.9 | 8 | 9.6 | ATB | No |
| 0116 | 4 | 3.9 | 12 | 12 | ATB | No |
| 0117 | 7 | 6.4 | 8 | 9.2 | ATB/DGAB | No |
| 0118 | 4 | 3.5 | 12 | 12.3 | ATB/DGAB | No |
| 0120 | 4 | 3.6 | 12 | 12 | PATB/DGAB | Yes |
| 0121 | 4 | 3.9 | 16 | 16 | PATB/DGAB | Yes |
| 0123 | 7 | 6.2 | 12 | 12 | ATB/PATB | Yes |
| 0124 | 7 | 6.3 | 16 | 16.2 | ATB/PATB | Yes |

### Data Availability

Table A- 27 summarizes the available data for sections in Michigan. Some sections did not have any data available while available data had a little variability.

Table A- 27 Data availability (No. of surveys) for SPS-1 Michigan sections

| SHRP ID | Distress | | IRI | FWD |
|---|---|---|---|---|
| | Cracking | Rutting | | |
| 0115 | 8 | 8 | 8 | 5 |
| 0116 | 8 | 8 | 8 | 6 |
| 0117 | 8 | 8 | 8 | 5 |
| 0118 | 2 | 3 | 7 | 3 |
| 0120 | 2 | 3 | 6 | 3 |
| 0121 | 2 | 3 | 7 | 3 |
| 0123 | 8 | 9 | 8 | 6 |
| 0124 | 8 | 9 | 8 | 6 |

## MONTANA (30)

### Site Description

The LTPP sections of Montana were built on U.S. 15 in 1998. The sections were constructed with AC shoulders. The inventory data is summarized in Table A- 28. The sections in the experiment design are 30-0113 through 30-0124 without any additional sections.

Table A- 28 Inventory data for SPS-1 Montana sections

| | |
|---|---|
| Site code | 30 |
| Climate | Dry-Freeze |
| Average annual precipitation (mm) | 317 |
| Average annual freezing index (˚C-days) | 200 |
| Estimated Traffic (ESAL) | N/A |
| Subgrade soil | Coarse-grained |
| Shoulder | AC |

### Construction Issues

During the placement of subgrade, rain interrupted construction several times and caused the subgrade to become saturated. Some water logging was developed in few sections. One particular section, 30-0116 required the use of class-2 geo-fabric to stabilize the subgrade. There were minor localized problems with DGAB constructions on sections 30-0113 and 30-0118 respectively. Section 30-0113 had a soft spot beginning at station 1+75 to 4+50, 0.91 m (3 ft) right of the center line extending to 4.88 m right of the center line about 8 in deep due to some clay and excessive moisture in subgrade. Similarly, section 30-0118 had soft spots beginning at 0+75 to 1+00, from center line extending up to 2.44 m right of the center line about 6 to 8 inches deep due to some clay and excessive moisture in the subgrade.

### Site Status

Every section had at least one layer with the thickness deviating more than 6 mm from the design thickness. Table A-29 summarizes the design features for the sections.

Table A- 29 Design features for SPS-1 Montana sections

| Section ID | AC Thickness, in | | Base Thickness, in | | Base Type | Drainage |
|---|---|---|---|---|---|---|
| | Design | Actual | Design | Actual | | |
| 0113 | 4 | 4.8 | 8 | 8.4 | DGAB | No |
| 0114 | 7 | 7.2 | 12 | 12.4 | DGAB | No |
| 0115 | 7 | 7.4 | 8 | 9.1 | ATB | No |
| 0116 | 4 | 4.6 | 12 | 12.6 | ATB | No |
| 0117 | 7 | 7.2 | 8 | 9.2 | ATB/DGAB | No |
| 0118 | 4 | 4.6 | 12 | 12.9 | ATB/DGAB | No |
| 0119 | 7 | 7.3 | 8 | 8.9 | PATB/DGAB | Yes |
| 0120 | 4 | 4.2 | 12 | 12.5 | PATB/DGAB | Yes |
| 0121 | 4 | 4.3 | 16 | 16.5 | PATB/DGAB | Yes |
| 0122 | 4 | 4.5 | 8 | 8.3 | ATB/PATB | Yes |
| 0123 | 7 | 7.5 | 12 | 12.4 | ATB/PATB | Yes |
| 0124 | 7 | 7.2 | 16 | 17.9 | ATB/PATB | Yes |

## Data Availability

Table A- 30 summarizes the available data for sections in Montana. The distribution of data is uniform over the sections except for section 30-0114 which has the more frequency of data collection.

Table A- 30 Data availability (No. of surveys) for SPS-1 Montana sections

| SHRP ID | Distress | | IRI | FWD |
|---|---|---|---|---|
| | Cracking | Rutting | | |
| 0113 | 6 | 7 | 6 | 3 |
| 0114 | 11 | 12 | 21 | 19 |
| 0115 | 6 | 7 | 6 | 3 |
| 0116 | 6 | 7 | 6 | 3 |
| 0117 | 6 | 7 | 6 | 3 |
| 0118 | 6 | 7 | 6 | 3 |
| 0119 | 6 | 7 | 6 | 3 |
| 0120 | 6 | 7 | 6 | 3 |
| 0121 | 6 | 7 | 6 | 3 |
| 0122 | 6 | 7 | 6 | 3 |
| 0123 | 6 | 7 | 6 | 3 |
| 0124 | 6 | 7 | 6 | 3 |

# NEBRASKA (31)

## Site Description

The LTPP sections of Nebraska were built on U.S. 81 southwest of Lincoln, NE, in 1995. The sections were constructed with AC shoulders. The inventory data is summarized in Table A- 31. The sections in the experiment design are 31-0113 through 31-0124 without any additional sections.

Table A- 31 Inventory data for SPS-1 Nebraska sections

| | |
|---|---|
| Site code | 31 |
| Climate | Wet-Freeze |
| Average annual precipitation (mm) | 785 |
| Average annual freezing index (˚C-days) | 228 |
| Estimated Traffic (ESAL) | 119,000 |
| Subgrade soil | Fine-grained |
| Shoulder | AC |

## Construction Issues

There was two-way traffic on the new pavement until the existing original road had been reconstructed. Also, three of the test sections are located over culverts. However, the fill depths are greater than 10 feet at these locations. Rain caused several delays during the construction.

## Site Status

The thickness for each layer deviates more than 6 mm from the requirements for all sections except 31-0113 and 31-0121. No other deviations are noted from the data. Table A- 32 summarizes the design features for the sections.

Table A- 32 Design features for SPS-1 Nebraska sections

| Section ID | AC Thickness, in | | Base Thickness, in | | Base Type | Drainage |
|---|---|---|---|---|---|---|
| | Design | Actual | Design | Actual | | |
| 0113 | 4 | 5.1 | 8 | 8 | DGAB | No |
| 0114 | 7 | 6.7 | 12 | 12 | DGAB | No |
| 0115 | 7 | 4.4 | 8 | 12.7 | ATB | No |
| 0116 | 4 | 4.4 | 12 | 12.7 | ATB | No |
| 0117 | 7 | 7.9 | 8 | 7.8 | ATB/DGAB | No |
| 0118 | 4 | 4.3 | 12 | 12.4 | ATB/DGAB | No |
| 0119 | 7 | 7.9 | 8 | 8 | PATB/DGAB | Yes |
| 0120 | 4 | 4.7 | 12 | 12 | PATB/DGAB | Yes |
| 0121 | 4 | 5.3 | 16 | 16 | PATB/DGAB | Yes |
| 0122 | 4 | 3.8 | 8 | 8.4 | ATB/PATB | Yes |
| 0123 | 7 | 7.5 | 12 | 12.1 | ATB/PATB | Yes |
| 0124 | 7 | 7.5 | 16 | 16.3 | ATB/PATB | Yes |

## Data Availability

Table A- 33 summarizes the available data for sections in Nebraska. The distribution of data is uniform over the sections except for section 31-0114 which had the most amount of data.

Table A- 33 Data availability (No. of surveys) for SPS-1 Nebraska sections

| SHRP ID | Distress | | IRI | FWD |
|---|---|---|---|---|
| | Cracking | Rutting | | |
| 0113 | 2 | 5 | 7 | 3 |
| 0114 | 13 | 16 | 22 | 33 |
| 0115 | 3 | 7 | 9 | 4 |
| 0116 | 3 | 6 | 9 | 4 |
| 0117 | 3 | 7 | 9 | 3 |
| 0118 | 3 | 6 | 9 | 4 |
| 0119 | 3 | 7 | 9 | 4 |
| 0120 | 3 | 6 | 9 | 4 |
| 0121 | 3 | 7 | 9 | 4 |
| 0122 | 3 | 6 | 9 | 4 |
| 0123 | 3 | 7 | 9 | 4 |
| 0124 | 3 | 7 | 9 | 4 |

## NEVADA (32)

### Site Description

The LTPP sections of Nevada were built on U.S. 80 west of Battle Mountain, NV, in 1995. The sections were constructed with AC shoulders. The inventory data is summarized in Table A- 34. The sections in the experiment design are 32-0101 through 32-0112 without any additional sections.

Table A- 34 Inventory data for SPS-1 Nevada sections

| | |
|---|---|
| Site code | 32 |
| Climate | Dry-Freeze |
| Average annual precipitation (mm) | 223 |
| Average annual freezing index (˚C-days) | 156 |
| Estimated Traffic (ESAL) | 799,000 |
| Subgrade soil | Coarse-grained |
| Shoulder | AC |

### Construction Issues

The original subgrade was stabilized with lime and the embankment was replaced. In addition, during the placement of the PATB in section 32-0110 the contractor experienced a plant breakdown which delayed the paving for about 1 hour.

### Site Status

The thickness for each layer deviates more than 6 mm from the requirements for all sections except 32-0109. The DGAB did not meet the gradation requirements for materials passing No. 200 sieve. Table A- 35 summarizes the design features for the sections.

Table A- 35 Design features for SPS-1 Nevada sections

| Section ID | AC Thickness, in | | Base Thickness, in | | Base Type | Drainage |
|---|---|---|---|---|---|---|
| | Design | Actual | Design | Actual | | |
| 0101 | 7 | 7.2 | 8 | 8.5 | DGAB | No |
| 0102 | 4 | 4.3 | 12 | 11.7 | DGAB | No |
| 0103 | 4 | 4.1 | 8 | 8.8 | ATB | No |
| 0104 | 7 | 7.3 | 12 | 12.4 | ATB | No |
| 0105 | 4 | 4.2 | 8 | 8.4 | ATB/DGAB | No |
| 0106 | 7 | 7.2 | 12 | 12.5 | ATB/DGAB | No |
| 0107 | 4 | 4.4 | 8 | 7.9 | PATB/DGAB | Yes |
| 0108 | 7 | 7 | 12 | 12.2 | PATB/DGAB | Yes |
| 0109 | 7 | 7 | 16 | 16.1 | PATB/DGAB | Yes |
| 0110 | 7 | 6.6 | 8 | 8.6 | ATB/PATB | Yes |
| 0111 | 4 | 4.1 | 12 | 12.8 | ATB/PATB | Yes |
| 0112 | 4 | 4.5 | 16 | 16.6 | ATB/PATB | Yes |

## Data Availability

Table A- 36 summarizes the available data for sections in Nevada. The distribution of data is uniform over the sections except for section 32-0101, which has the highest data frequency.

Table A- 36 Data availability (No. of surveys) for SPS-1 Nevada sections

| SHRP ID | Distress | | IRI | FWD |
|---|---|---|---|---|
| | Cracking | Rutting | | |
| 0101 | 22 | 27 | 26 | 40 |
| 0102 | 7 | 11 | 9 | 6 |
| 0103 | 7 | 11 | 9 | 5 |
| 0104 | 7 | 11 | 9 | 5 |
| 0105 | 7 | 11 | 9 | 5 |
| 0106 | 7 | 11 | 9 | 5 |
| 0107 | 7 | 11 | 9 | 5 |
| 0108 | 7 | 12 | 9 | 5 |
| 0109 | 7 | 11 | 9 | 5 |
| 0110 | 7 | 11 | 9 | 4 |
| 0111 | 7 | 11 | 9 | 4 |
| 0112 | 7 | 11 | 9 | 5 |

# NEW MEXICO (35)

## Site Description

The LTPP sections of New Mexico were built on U.S. 25 north of Las Cruces, NM, in 1995. The sections were constructed with AC shoulders. The inventory data is summarized in Table A- 37. The sections in the experiment design are 35-0101 through 35-0112 without any additional sections.

Table A- 37 Inventory data for SPS-1 New Mexico sections

| | |
|---|---|
| Site code | 35 |
| Climate | Dry-No-Freeze |
| Average annual precipitation (mm) | 290 |
| Average annual freezing index (˚C-days) | 5 |
| Estimated Traffic (ESAL) | 393,000 |
| Subgrade soil | Fine-grained |
| Shoulder | AC |

## Construction Issues

It was necessary to stabilize the top 8 inches of subgrade with 4% lime for all test sections, to facilitate construction. Upon completion of the stabilization, approximately 12-18 inches of the silty-clay subgrade material was used on top of the stabilized layer to bring the subgrade back to grade elevation.

## Site Status

The thickness for each layer deviates more than 6 mm from the requirements for all sections except 35-0102 and 35-0108. The ATB mix did not meet the minimum requirements for stability and flow. The HMA did not meet the requirements for passing No. 4 sieve. Table A-38 summarizes the design features for the sections.

Table A- 38 Design features for SPS-1 New Mexico sections

| Section ID | AC Thickness, in | | Base Thickness, in | | Base Type | Drainage |
|---|---|---|---|---|---|---|
| | Design | Actual | Design | Actual | | |
| 0101 | 7 | 7.2 | 8 | 8.6 | DGAB | No |
| 0102 | 4 | 4.8 | 12 | 12.2 | DGAB | No |
| 0103 | 4 | 5.3 | 8 | 7.2 | ATB | No |
| 0104 | 7 | 8.1 | 12 | 11.1 | ATB | No |
| 0105 | 4 | 5.9 | 8 | 7.7 | ATB/DGAB | No |
| 0106 | 7 | 7.6 | 12 | 10.9 | ATB/DGAB | No |
| 0107 | 4 | 5.9 | 8 | 7.7 | PATB/DGAB | Yes |
| 0108 | 7 | 7.8 | 12 | 12.2 | PATB/DGAB | Yes |
| 0109 | 7 | 8 | 16 | 16.4 | PATB/DGAB | Yes |
| 0110 | 7 | 7.9 | 8 | 8.3 | ATB/PATB | Yes |
| 0111 | 4 | 4.9 | 12 | 11.3 | ATB/PATB | Yes |
| 0112 | 4 | 5 | 16 | 14.8 | ATB/PATB | Yes |

## Data Availability

Table A- 39 summarizes the available data for sections in New Mexico. The distribution of data is uniform over the sections.

Table A- 39 Data availability (No. of surveys) for SPS-1 New Mexico sections

| SHRP ID | Distress | | IRI | FWD |
|---|---|---|---|---|
| | Cracking | Rutting | | |
| 0101 | 6 | 9 | 4 | 3 |
| 0102 | 6 | 9 | 4 | 3 |
| 0103 | 6 | 9 | 4 | 3 |
| 0104 | 6 | 9 | 4 | 3 |
| 0105 | 6 | 9 | 4 | 3 |
| 0106 | 6 | 9 | 4 | 3 |
| 0107 | 6 | 9 | 4 | 3 |
| 0108 | 6 | 9 | 4 | 3 |
| 0109 | 6 | 9 | 4 | 3 |
| 0110 | 6 | 9 | 4 | 3 |
| 0111 | 6 | 9 | 4 | 3 |
| 0112 | 6 | 9 | 4 | 3 |

## OHIO (39)

### Site Description

The LTPP sections of Ohio were built on U.S. 23 south of Waldo, OH, in 1995. The sections were constructed with AC shoulders. The inventory data is summarized in Table A- 40. The sections in the experiment design are 39-0101 through 39-0112 with two additional sections.

Table A- 40 Inventory data for SPS-1 Ohio sections

| | |
|---|---|
| Site code | 39 |
| Climate | Wet-Freeze |
| Average annual precipitation (mm) | 972 |
| Average annual freezing index (˚C-days) | 208 |
| Estimated Traffic (ESAL) | N/A |
| Subgrade soil | Fine-grained |
| Shoulder | AC |

### Construction Issues

In sections 39-0105 and 39-0108, the original embankment material placed was unsuitable. Embankment was removed and a new 4 feet fill was placed.

### Site Status

The average HMA thickness for section 39-0110 and the ATB thicknesses for sections 39-0111 and 39-0112 deviate from the design by more than 6 mm. The HMA did not meet the gradation requirements for the No. 4 sieve. Table A- 41 summarizes the design features for the sections.

Table A- 41 Design features for SPS-1 Ohio sections

| Section ID | AC Thickness, in | | Base Thickness, in | | Base Type | Drainage |
|---|---|---|---|---|---|---|
| | Design | Actual | Design | Actual | | |
| 0101 | 7 | 6.9 | 8 | 8 | DGAB | No |
| 0102 | 4 | 3.9 | 12 | 11.8 | DGAB | No |
| 0103 | 4 | 4.1 | 8 | 8 | ATB | No |
| 0104 | 7 | 7.2 | 12 | 11.8 | ATB | No |
| 0105 | 4 | 3.7 | 8 | 7.7 | ATB/DGAB | No |
| 0106 | 7 | 6.8 | 12 | 11.8 | ATB/DGAB | No |
| 0107 | 4 | 3.8 | 8 | 8 | PATB/DGAB | Yes |
| 0108 | 7 | 6.6 | 12 | 12 | PATB/DGAB | Yes |
| 0109 | 7 | 7 | 16 | 15.9 | PATB/DGAB | Yes |
| 0110 | 7 | 7.3 | 8 | 7.6 | ATB/PATB | Yes |
| 0111 | 4 | 4 | 12 | 12.1 | ATB/PATB | Yes |
| 0112 | 4 | 4 | 16 | 15.8 | ATB/PATB | Yes |

## Data Availability

Table A- 42 summarizes the available data for sections in Ohio. In general, the number of available data is not enough, with some variation over the sections.

Table A- 42 Data availability (No. of surveys) for SPS-1 Ohio sections

| SHRP ID | Distress | | IRI | FWD |
|---|---|---|---|---|
| | Cracking | Rutting | | |
| 0101 | 1 | 2 | 2 | 2 |
| 0102 | 2 | 3 | 2 | N/A |
| 0103 | 4 | 6 | 6 | 5 |
| 0104 | 4 | 7 | 8 | 4 |
| 0105 | 3 | 4 | 3 | 4 |
| 0106 | 5 | 8 | 8 | 5 |
| 0107 | 2 | 3 | 2 | N/A |
| 0108 | 4 | 7 | 7 | 4 |
| 0109 | 4 | 7 | 7 | 4 |
| 0110 | 4 | 7 | 7 | 4 |
| 0111 | 4 | 7 | 9 | 3 |
| 0112 | 4 | 7 | 8 | 3 |

## OKLAHOMA (40)

### Site Description

The LTPP sections of Oklahoma were built on U.S. 62 west of Lawton, OK, in 1997. The sections were constructed with AC shoulders. The inventory data is summarized in Table A- 43. The sections in the experiment design are 40-0113 through 40-0124 with two additional sections.

Table A- 43 Inventory data for SPS-1 Oklahoma sections

| | |
|---|---|
| Site code | 40 |
| Climate | Wet-No-Freeze |
| Average annual precipitation (mm) | 869 |
| Average annual freezing index (˚C-days) | 90 |
| Estimated Traffic (ESAL) | 280,000 |
| Subgrade soil | Fine-grained |
| Shoulder | AC |

### Construction Issues

The projects were constructed on a site where the earthwork had been done 10 years earlier. Most of the settlement of the earthwork may have occurred before the construction.

The WIM equipment was installed at about 8 km (5 miles) from the sections. There are entrance and exit ramps between the WIM equipment and the actual sections. However, these ramps are not expected to significantly affect the truck traffic.

### Site Status

The thickness for each layer deviates more than 6 mm from the requirements for all sections except 40-0116 and 40-0123. No The HMA had too much aggregate passing the No. 4 sieve. Table A- 44 summarizes the design features for the sections.

Table A- 44 Design features for SPS-1 Oklahoma sections

| Section ID | AC Thickness, in | | Base Thickness, in | | Base Type | Drainage |
|---|---|---|---|---|---|---|
| | Design | Actual | Design | Actual | | |
| 0113 | 4 | 4.5 | 8 | 7.9 | DGAB | No |
| 0114 | 7 | 7.7 | 12 | 11.3 | DGAB | No |
| 0115 | 7 | 7.5 | 8 | 9 | ATB | No |
| 0116 | 4 | 4.2 | 12 | 11.7 | ATB | No |
| 0117 | 7 | 7.8 | 8 | 8 | ATB/DGAB | No |
| 0118 | 4 | 4.6 | 12 | 11.9 | ATB/DGAB | No |
| 0119 | 7 | 7.5 | 8 | 8.3 | PATB/DGAB | Yes |
| 0120 | 4 | 4.8 | 12 | 12.7 | PATB/DGAB | Yes |
| 0121 | 4 | 4.2 | 16 | 16 | PATB/DGAB | Yes |
| 0122 | 4 | 4.3 | 8 | 8.7 | ATB/PATB | Yes |
| 0123 | 7 | 7.3 | 12 | 13.1 | ATB/PATB | Yes |
| 0124 | 7 | 6.8 | 16 | 16 | ATB/PATB | Yes |

## Data Availability

Table A- 45 summarizes the available data for sections in Oklahoma. The distribution of data is uniform over the sections.

Table A- 45 Data availability (No. of surveys) for SPS-1 Oklahoma sections

| SHRP ID | Distress | | IRI | FWD |
|---|---|---|---|---|
| | Cracking | Rutting | | |
| 0113 | 7 | 11 | 5 | 4 |
| 0114 | 7 | 11 | 5 | 4 |
| 0115 | 7 | 10 | 5 | 4 |
| 0116 | 7 | 10 | 5 | 4 |
| 0117 | 7 | 10 | 5 | 4 |
| 0118 | 7 | 10 | 5 | 4 |
| 0119 | 7 | 10 | 5 | 4 |
| 0120 | 7 | 10 | 5 | 4 |
| 0121 | 7 | 10 | 5 | 4 |
| 0122 | 7 | 11 | 5 | 4 |
| 0123 | 7 | 10 | 5 | 4 |
| 0124 | 7 | 10 | 5 | 4 |

# TEXAS (48)

## Site Description

The LTPP sections of Texas were built on U.S. 281 north of McAllen, TX, in 1997. The sections were constructed with AC shoulders. The inventory data is summarized in Table A- 46. The sections in the experiment design are 48-0113 through 48-0124 with eight additional sections.

Table A- 46 Inventory data for SPS-1 Texas sections

| | |
|---|---|
| Site code | 48 |
| Climate | Wet-No-Freeze |
| Average annual precipitation (mm) | 561 |
| Average annual freezing index (˚C-days) | 1 |
| Estimated Traffic (ESAL) | 10,000 |
| Subgrade soil | Coarse-grained |
| Shoulder | AC |

## Construction Issues

Lime treatment was used in the subbase material for the first 10 sections. In addition, transverse drains were not installed for these sections.

## Site Status

Table A- 47 summarizes the design features for the sections.

Table A- 47 Design features for SPS-1 Texas sections

| Section ID | AC Thickness, in | | Base Thickness, in | | Base Type | Drainage |
|---|---|---|---|---|---|---|
| | Design | Actual | Design | Actual | | |
| 0113 | 4 | 4.6 | 8 | 7.8 | DGAB | No |
| 0114 | 7 | 6.8 | 12 | 12.2 | DGAB | No |
| 0115 | 7 | 7.4 | 8 | 7.6 | ATB | No |
| 0116 | 4 | 5.9 | 12 | 10.9 | ATB | No |
| 0117 | 7 | 7.4 | 8 | 7.3 | ATB/DGAB | No |
| 0118 | 4 | 4.8 | 12 | 10.3 | ATB/DGAB | No |
| 0119 | 7 | 7.4 | 8 | 7.5 | PATB/DGAB | Yes |
| 0120 | 4 | 4.7 | 12 | 11.4 | PATB/DGAB | Yes |
| 0121 | 4 | 4.3 | 16 | 15.5 | PATB/DGAB | Yes |
| 0122 | 4 | 4.6 | 8 | 8.8 | ATB/PATB | Yes |
| 0123 | 7 | 5.3 | 12 | 12.2 | ATB/PATB | Yes |
| 0124 | 7 | 6.4 | 16 | 15 | ATB/PATB | Yes |

## Data Availability

Table A- 48 summarizes the available data for sections in Texas. The distribution of data is uniform over the sections.

Table A- 48 Data availability (No. of surveys) for SPS-1 Texas sections

| SHRP ID | Distress | | IRI | FWD |
|---|---|---|---|---|
| | Cracking | Rutting | | |
| 0113 | 7 | 9 | 8 | 5 |
| 0114 | 7 | 9 | 8 | 5 |
| 0115 | 7 | 9 | 8 | 5 |
| 0116 | 7 | 9 | 8 | 5 |
| 0117 | 7 | 9 | 8 | 5 |
| 0118 | 7 | 9 | 8 | 5 |
| 0119 | 7 | 9 | 8 | 5 |
| 0120 | 7 | 9 | 8 | 5 |
| 0121 | 7 | 9 | 8 | 5 |
| 0122 | 7 | 9 | 8 | 5 |
| 0123 | 7 | 9 | 8 | 5 |
| 0124 | 7 | 9 | 8 | 5 |

## VIRGINIA (51)

### Site Description

The LTPP sections of Virginia were built on State Route (S.R.) 265 in Danville, VA, in 1995. The sections were constructed with AC shoulders. The inventory data is summarized in Table A-49. The sections in the experiment design are 51-0113 through 51-0124 with one additional section.

Table A- 49 Inventory data for SPS-1 Virginia sections

| | |
|---|---|
| Site code | 51 |
| Climate | Wet-No-Freeze |
| Average annual precipitation (mm) | 1,142 |
| Average annual freezing index (˚C-days) | 38 |
| Estimated Traffic (ESAL) | N/A |
| Subgrade soil | Fine-grained |
| Shoulder | AC |

### Construction Issues

Hydraulic cement stabilization was used for the top 152 mm of the subgrade for all the sections. The SPS-1 guidelines required that the entire length of a test section be located in a cut or rill section, however, two sections, 51-0122 and 51-0113 had cut-fill transitions located inside them.

### Site Status

Table A- 50 summarizes the design features for the sections.

Table A- 50 Design features for SPS-1 Virginia sections

| Section ID | AC Thickness, in | | Base Thickness, in | | Base Type | Drainage |
|---|---|---|---|---|---|---|
| | Design | Actual | Design | Actual | | |
| 0113 | 4 | 4 | 8 | 7.9 | DGAB | No |
| 0114 | 7 | 7.2 | 12 | 11.9 | DGAB | No |
| 0115 | 7 | 6.4 | 8 | 8.6 | ATB | No |
| 0116 | 4 | 4.5 | 12 | 12.4 | ATB | No |
| 0117 | 7 | 6.6 | 8 | 7.9 | ATB/DGAB | No |
| 0118 | 4 | 4.1 | 12 | 11.4 | ATB/DGAB | No |
| 0119 | 7 | 6.4 | 8 | 8.3 | PATB/DGAB | Yes |
| 0120 | 4 | 4.1 | 12 | 12.1 | PATB/DGAB | Yes |
| 0121 | 4 | 3.7 | 16 | 16.8 | PATB/DGAB | Yes |
| 0122 | 4 | 3.9 | 8 | 7.8 | ATB/PATB | Yes |
| 0123 | 7 | 6.5 | 12 | 12.2 | ATB/PATB | Yes |
| 0124 | 7 | 6.3 | 16 | 15.9 | ATB/PATB | Yes |

### Data Availability

Table A- 51 summarizes the available data for sections in Virginia. The IRI data has the highest frequency; whereas other performance measures the data collection frequency is lower except for section 51-0113 and section 51-0114.

Table A- 51 Data availability (No. of surveys) for SPS-1 Virginia sections

| SHRP ID | Distress | | IRI | FWD |
|---|---|---|---|---|
| | Cracking | Rutting | | |
| 0113 | 12 | 13 | 15 | 37 |
| 0114 | 14 | 17 | 23 | 45 |
| 0115 | 4 | 8 | 16 | 4 |
| 0116 | 4 | 8 | 16 | 4 |
| 0117 | 4 | 8 | 16 | 4 |
| 0118 | 4 | 8 | 16 | 4 |
| 0119 | 4 | 8 | 16 | 4 |
| 0120 | 5 | 8 | 16 | 4 |
| 0121 | 7 | 10 | 16 | 6 |
| 0122 | 4 | 8 | 16 | 4 |
| 0123 | 4 | 8 | 16 | 4 |
| 0124 | 4 | 8 | 15 | 4 |

# WISCONSIN (55)

## Site Description

The LTPP sections of Wisconsin were built on S.R. 29 in 1997. The sections were constructed with AC shoulders. The inventory data is summarized in Table A- 52. The sections in the experiment design are 55-0113 through 55-0124 without any additional sections.

Table A- 52 Inventory data for SPS-1 Wisconsin sections

| | |
|---|---|
| Site code | 55 |
| Climate | Wet-Freeze |
| Average annual precipitation (mm) | N/A |
| Average annual freezing index (˚C-days) | N/A |
| Estimated Traffic (ESAL) | N/A |
| Subgrade soil | Coarse-grained |
| Shoulder | AC |

## Construction Issues

The construction report does not indicate any difficulties during construction.

## Site Status

Table A- 53 summarizes the design features for the sections.

Table A- 53 Design features for SPS-1 Wisconsin sections

| Section ID | AC Thickness, in | | Base Thickness, in | | Base Type | Drainage |
|---|---|---|---|---|---|---|
| | Design | Actual | Design | Actual | | |
| 0113 | 4 | 5.5 | 8 | 8 | DGAB | No |
| 0114 | 7 | 8.1 | 12 | 11 | DGAB | No |
| 0115 | 7 | 7.3 | 8 | 7.5 | ATB | No |
| 0116 | 4 | 4.1 | 12 | 12 | ATB | No |
| 0117 | 7 | 6.4 | 8 | 9.6 | ATB/DGAB | No |
| 0118 | 4 | 4 | 12 | 14.1 | ATB/DGAB | No |
| 0119 | 7 | 6.6 | 8 | 9.2 | PATB/DGAB | Yes |
| 0120 | 4 | 3.9 | 12 | 13.5 | PATB/DGAB | Yes |
| 0121 | 4 | 4.2 | 16 | 17.5 | PATB/DGAB | Yes |
| 0122 | 4 | 4.5 | 8 | 9.7 | ATB/PATB | Yes |
| 0123 | 7 | 6.8 | 12 | 15.9 | ATB/PATB | Yes |
| 0124 | 7 | 7.1 | 16 | 11.7 | ATB/PATB | Yes |

## Data Availability

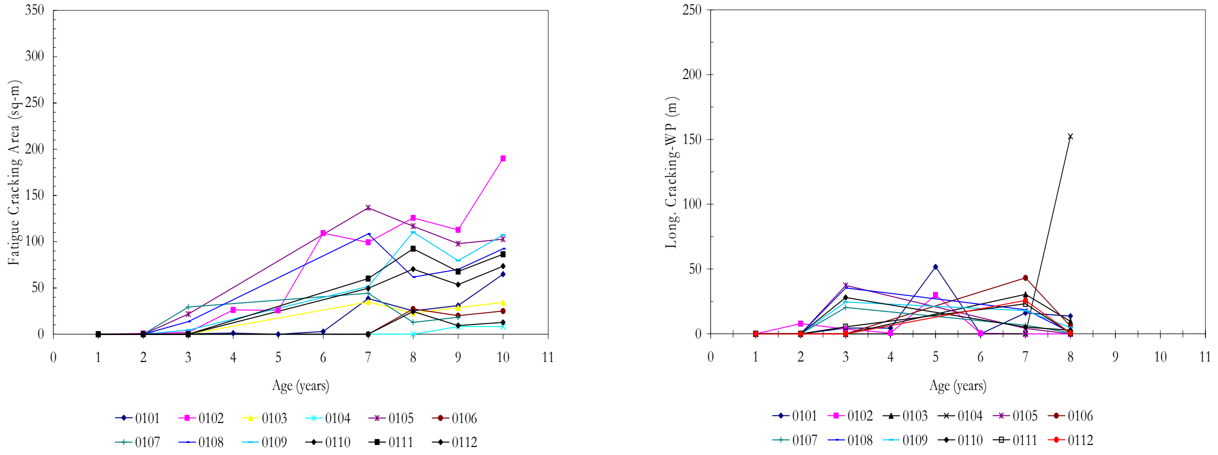
Table A- 54 summarizes the available data for sections in Wisconsin. The distribution of data is uniform over the sections but in general, not plenty.

Table A- 54 Data availability (No. of surveys) for SPS-1 Wisconsin sections

| SHRP ID | Distress | | IRI | FWD |
|---|---|---|---|---|
| | Cracking | Rutting | | |
| 0113 | 3 | 5 | 7 | 2 |
| 0114 | 4 | 4 | 7 | 3 |
| 0115 | 3 | 4 | 6 | 3 |
| 0116 | 3 | 4 | 7 | 3 |
| 0117 | 3 | 4 | 7 | 3 |
| 0118 | 3 | 4 | 7 | 3 |
| 0119 | 3 | 3 | 7 | 3 |
| 0120 | 3 | 4 | 7 | 3 |
| 0121 | 3 | 4 | 7 | 3 |
| 0122 | 3 | 4 | 7 | 3 |
| 0123 | 3 | 4 | 7 | 3 |
| 0124 | 3 | 4 | 7 | 3 |

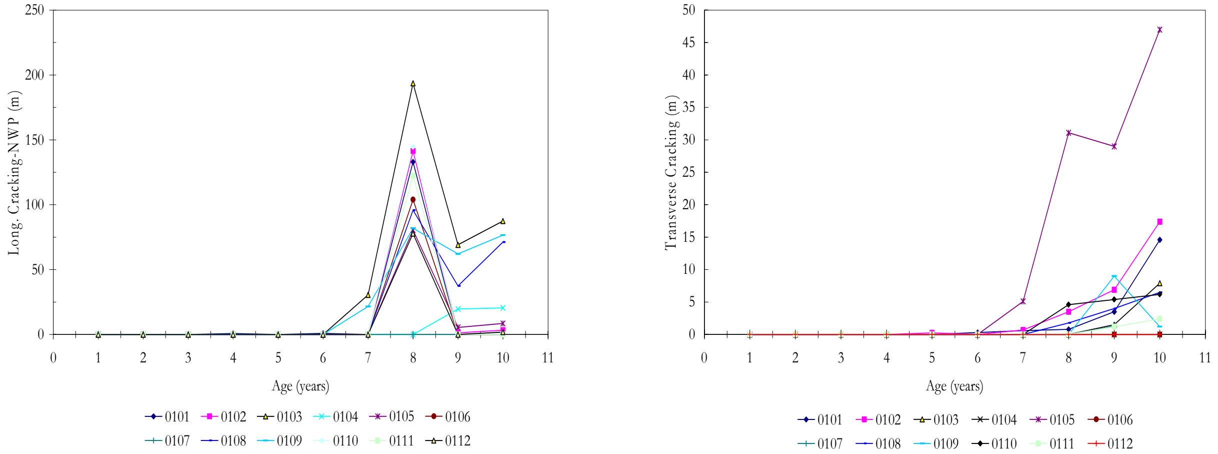
# APPENDIX A2

Site-wide Performance Data for SPS-1 experiment
(Time series plots and tables)



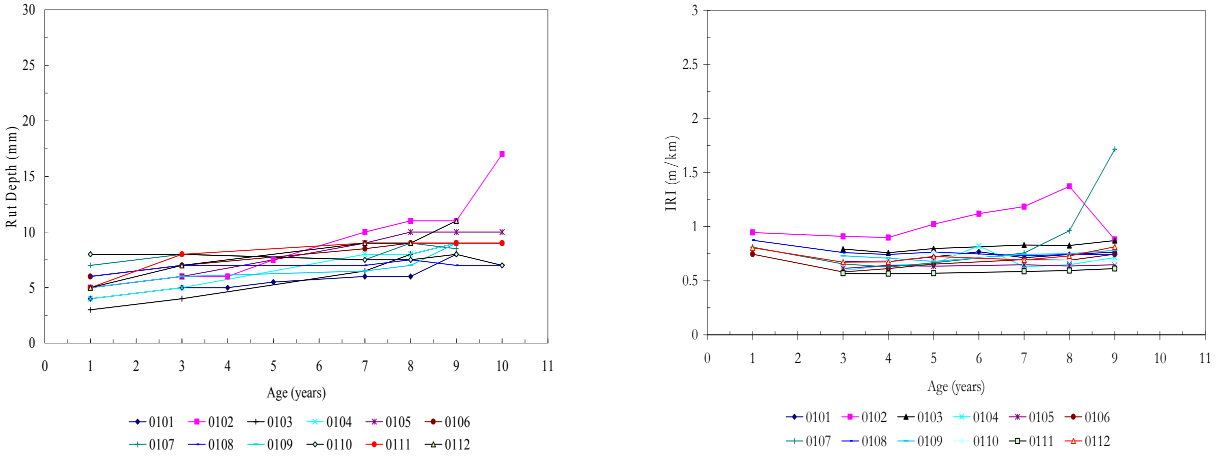
(a) Fatigue cracking

(b) longitudinal cracking-WP



(c) longitudinal cracking-NWP

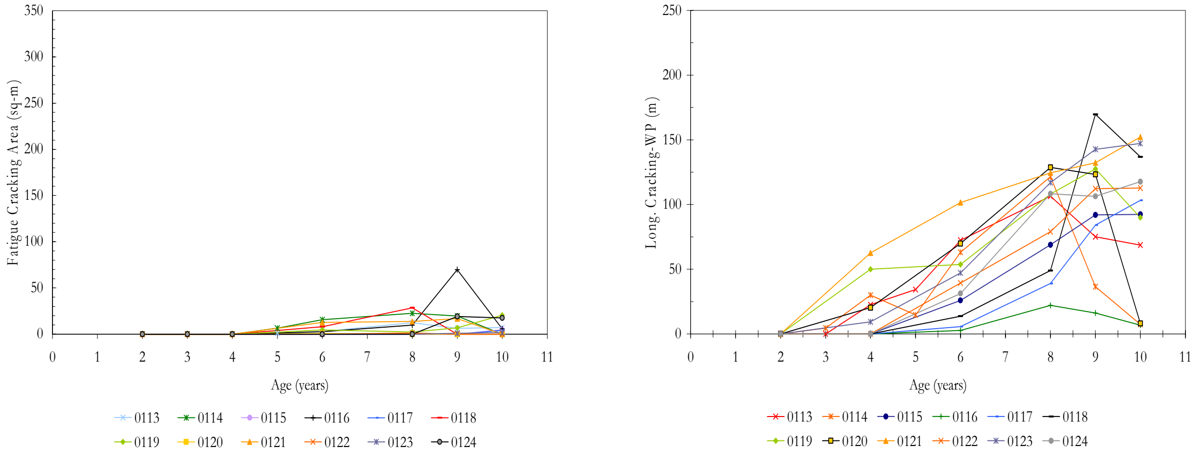
(d) Transverse cracking



(e) Rut depth

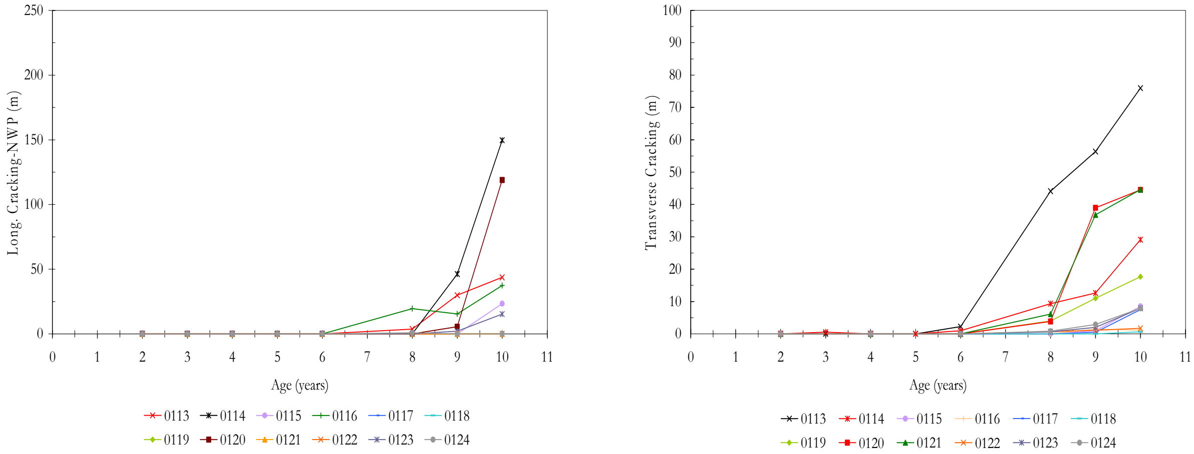
(f) Roughness (IRI)

**Figure A2- 1 Time series trend for various performance measures at the Alabama (1) site**



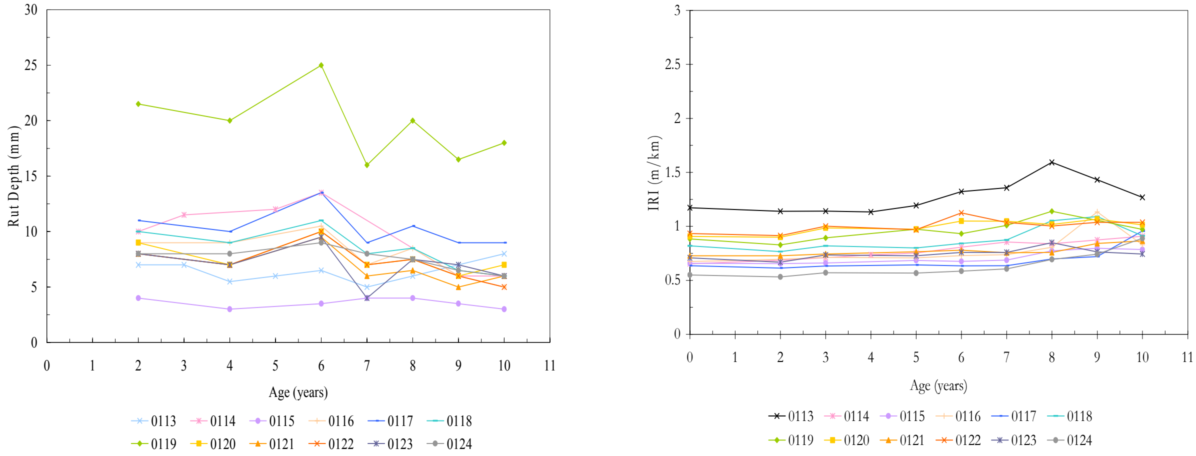
(a) Fatigue cracking

(b) longitudinal cracking-WP



(c) longitudinal cracking-NWP

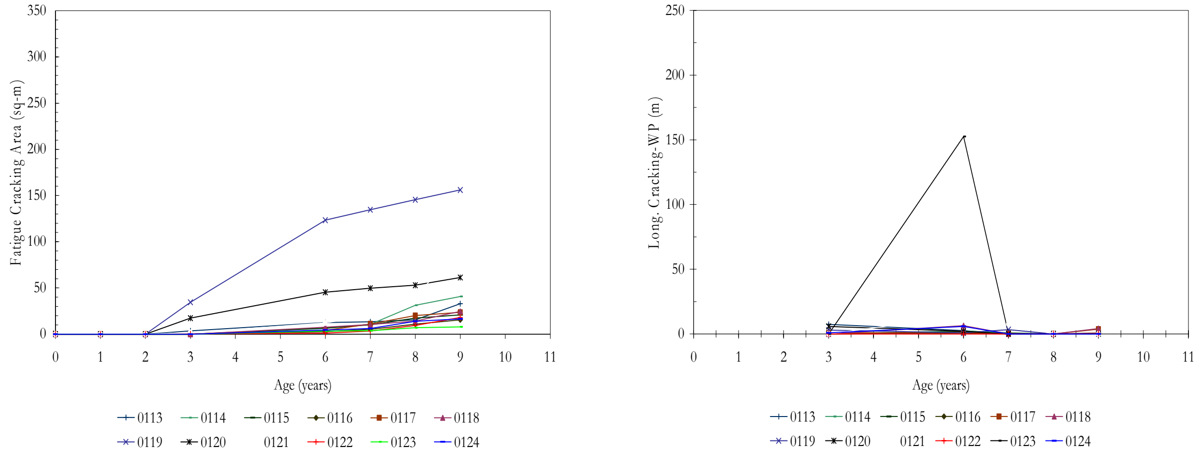
(d) Transverse cracking



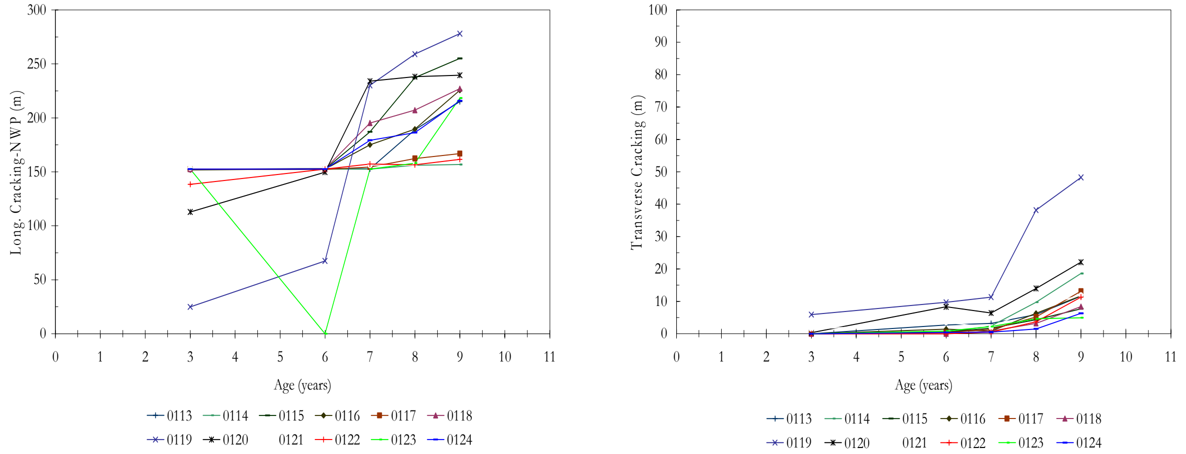
(e) Rut depth

(f) Roughness (IRI)

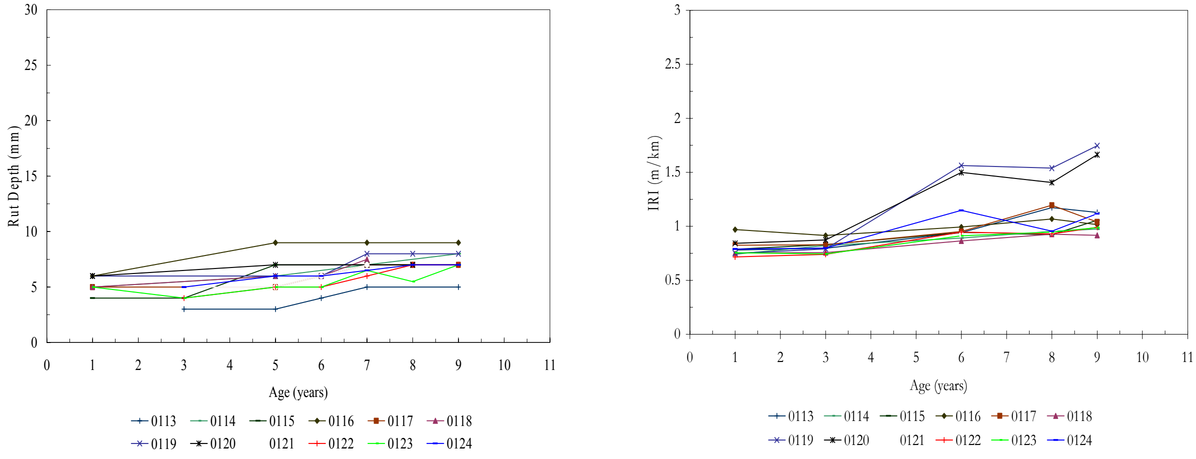
**Figure A2- 2 Time series trend for various performance measures at the Arizona (4) site**



(a) Fatigue cracking (b) longitudinal cracking-WP

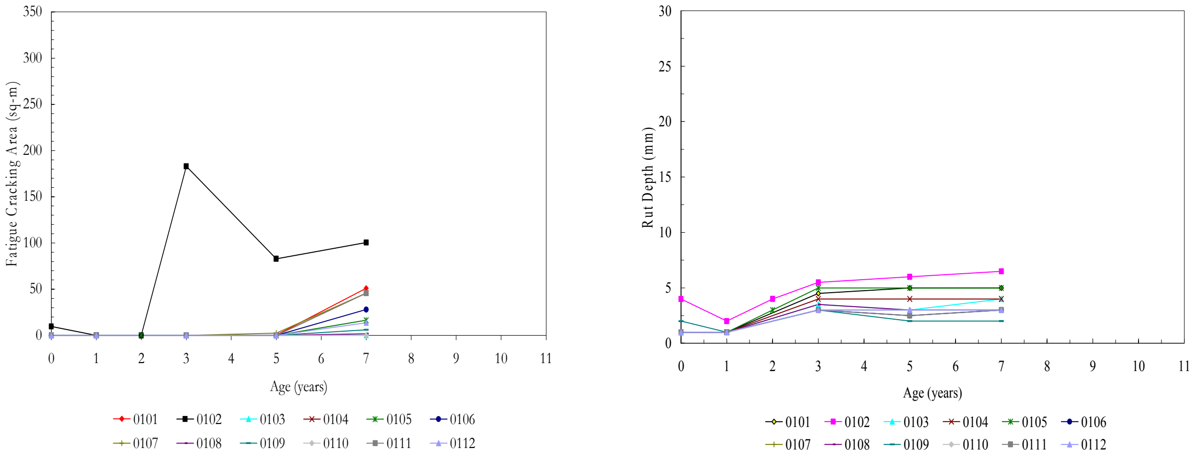


(c) longitudinal cracking-NWP (d) Transverse cracking



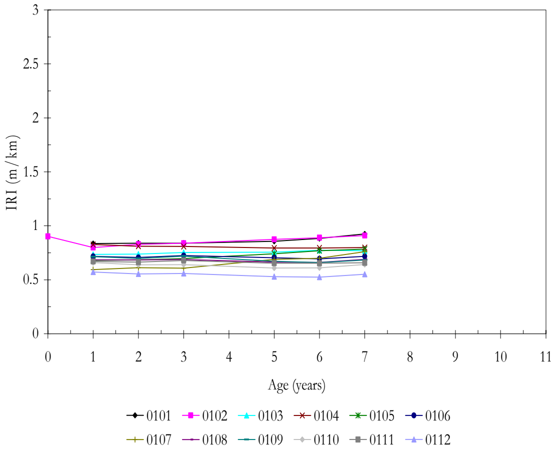
(e) Rut depth (f) Roughness (IRI)

**Figure A2- 3 Time series trend for various performance measures at the Arkansas (5) site**



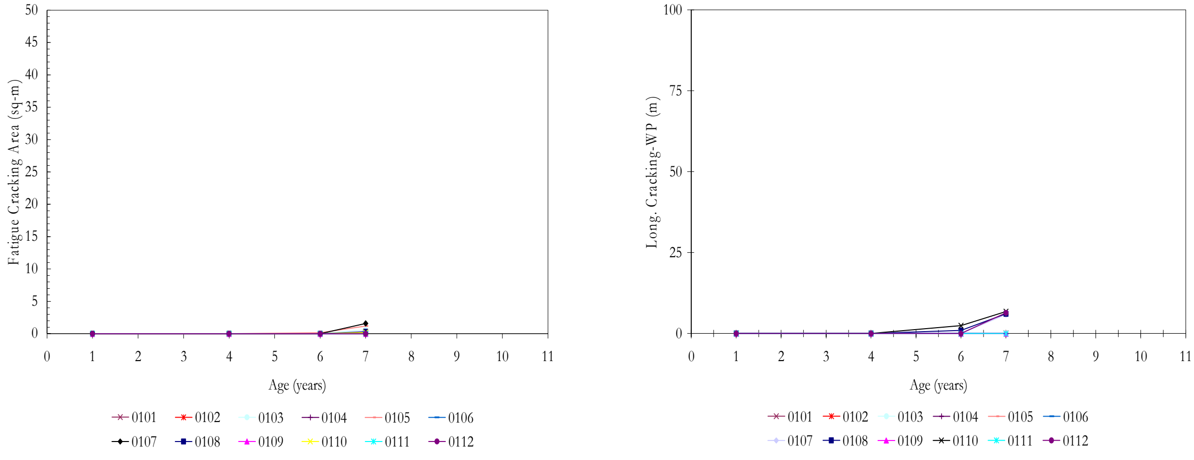
(a) Fatigue cracking

(b) Rut depth



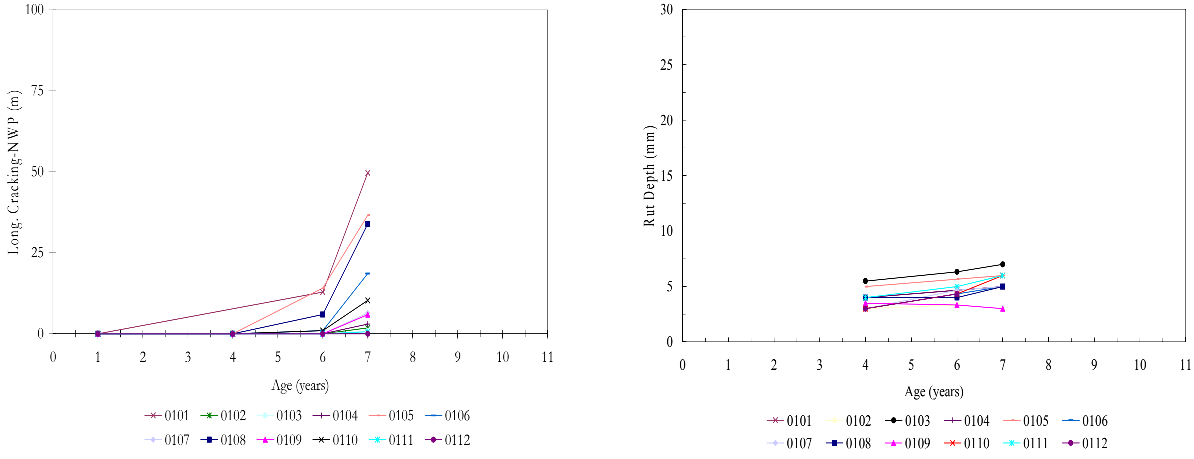
(c) Roughness (IRI)

**Figure A2- 4 Time series trend for various performance measures at Delaware (10) site**



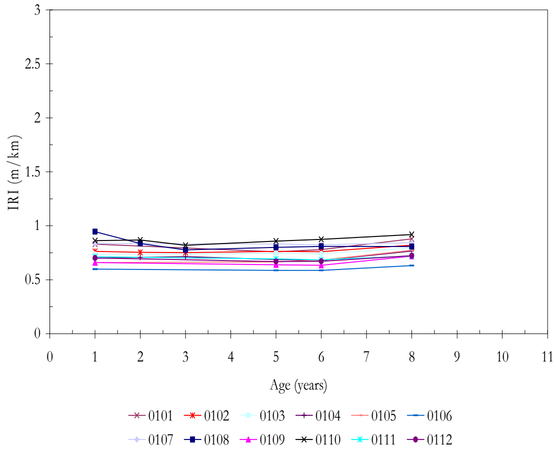
(a) Fatigue cracking

(b) longitudinal cracking-WP



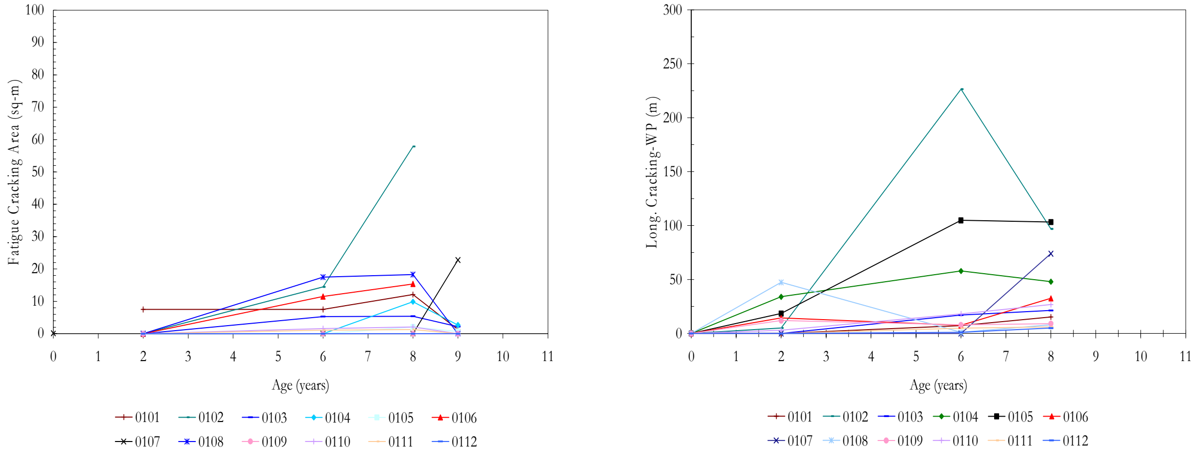
(c) longitudinal cracking-NWP

(d) Rut depth



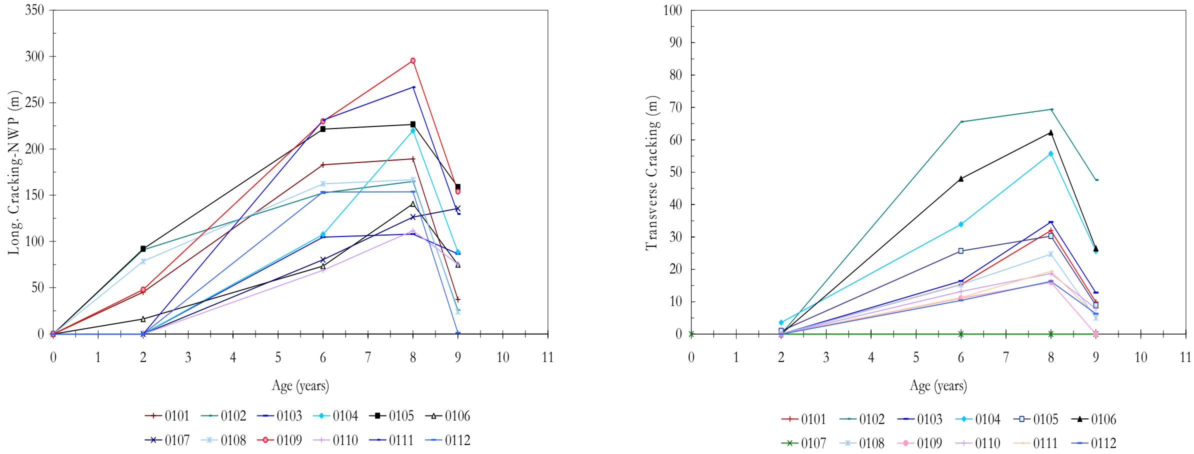
(e) Roughness (IRI)

**Figure A2- 5 Time series trend for various performance measures at Florida (12) site**



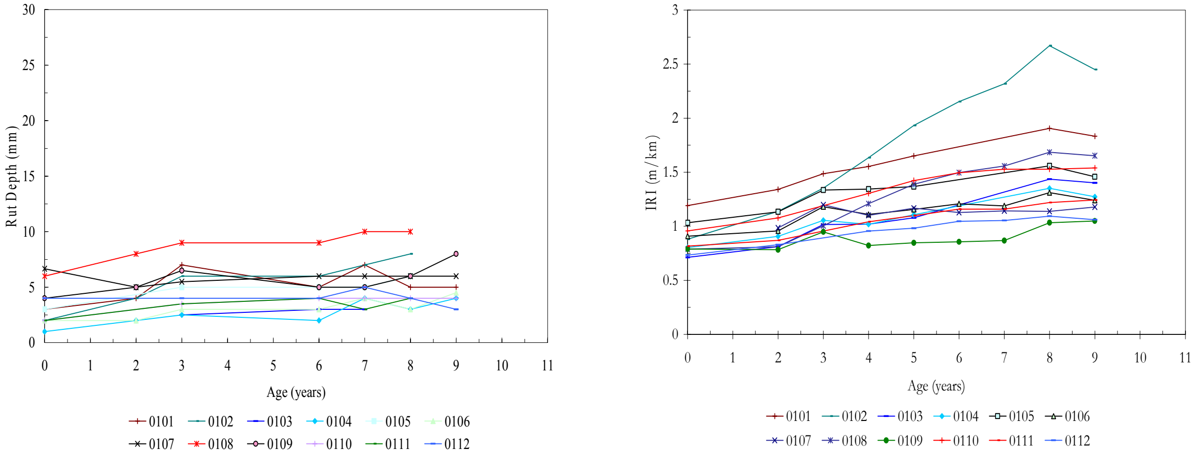
(a) Fatigue cracking

(b) longitudinal cracking-WP



(c) longitudinal cracking-NWP

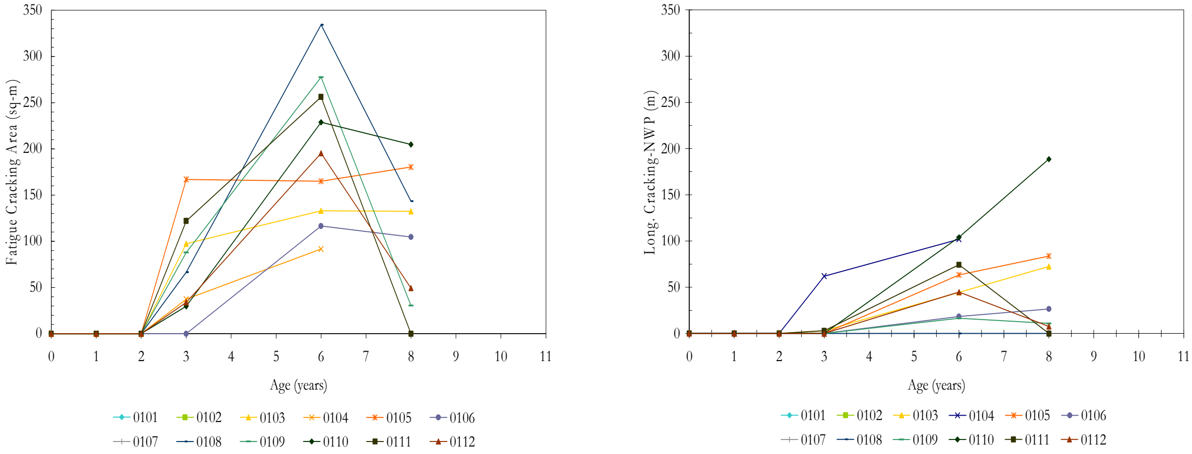
(d) Transverse cracking



(e) Rut depth

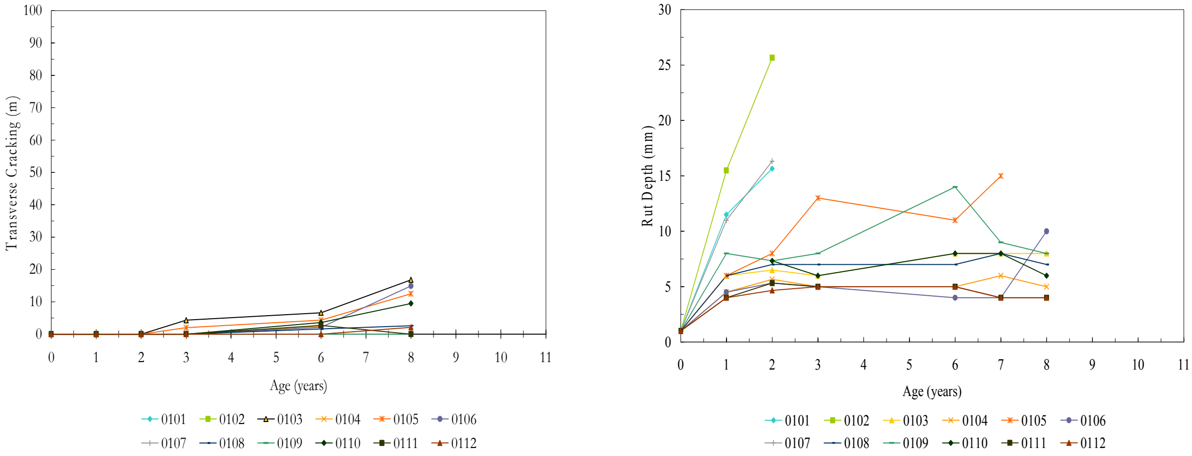
(f) Roughness (IRI)

**Figure A2- 6 Time series trend for various performance measures at Iowa (19) site**



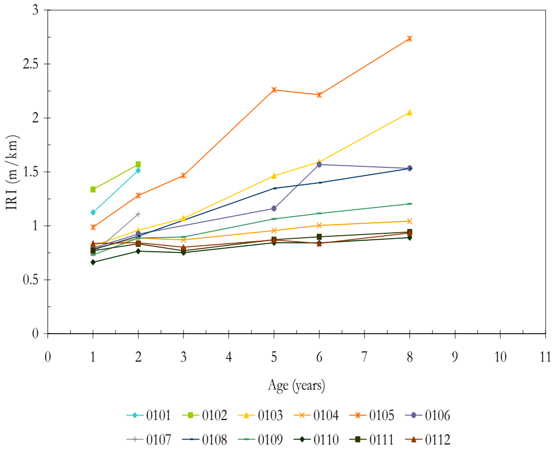
(a) Fatigue cracking

(b) longitudinal cracking-NWP



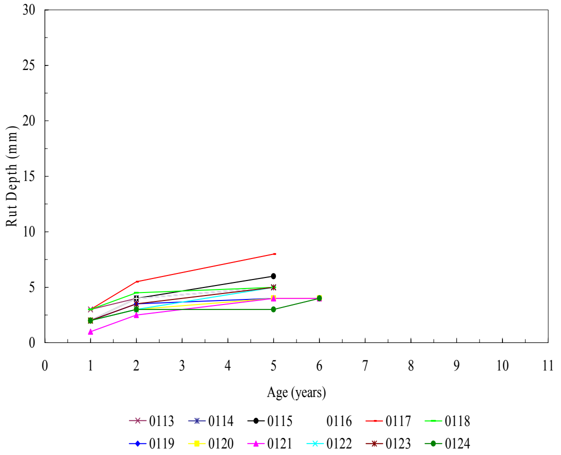
(c) Transverse cracking

(d) Rut depth



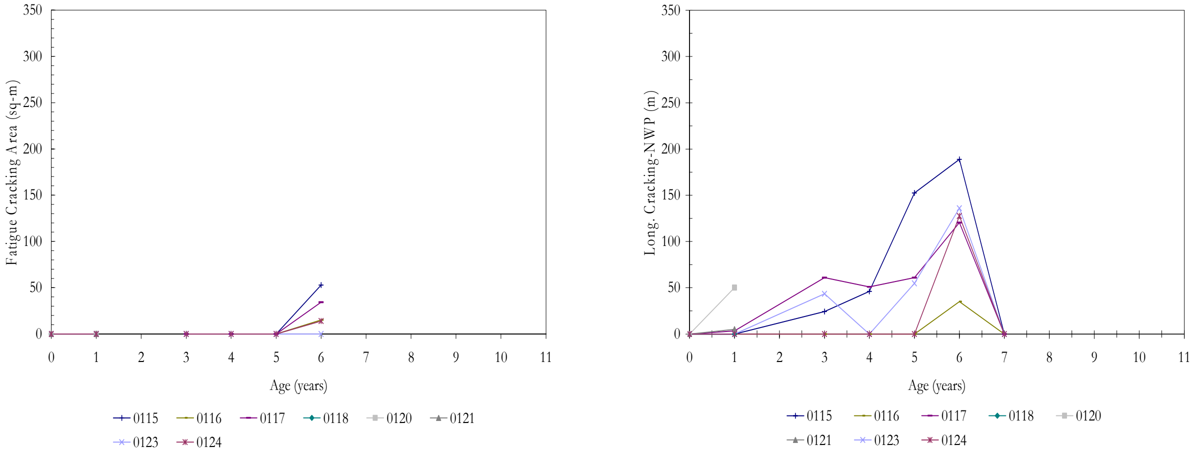
(e) Roughness (IRI)

**Figure A2- 7 Time series trend for various performance measures at Kansas (20) site**

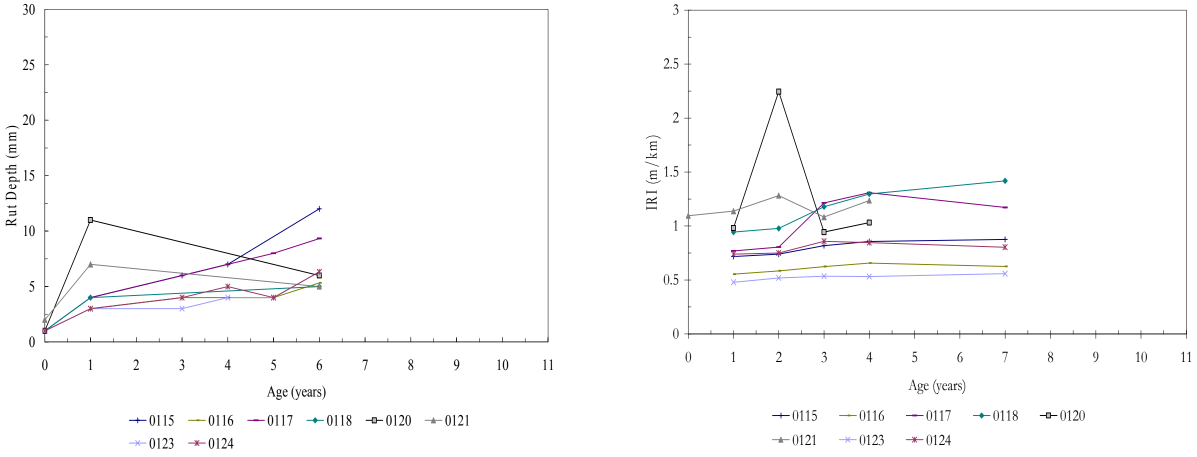


(a) Rut depth

**Time series trend for various performance measures at site Louisiana (22)**

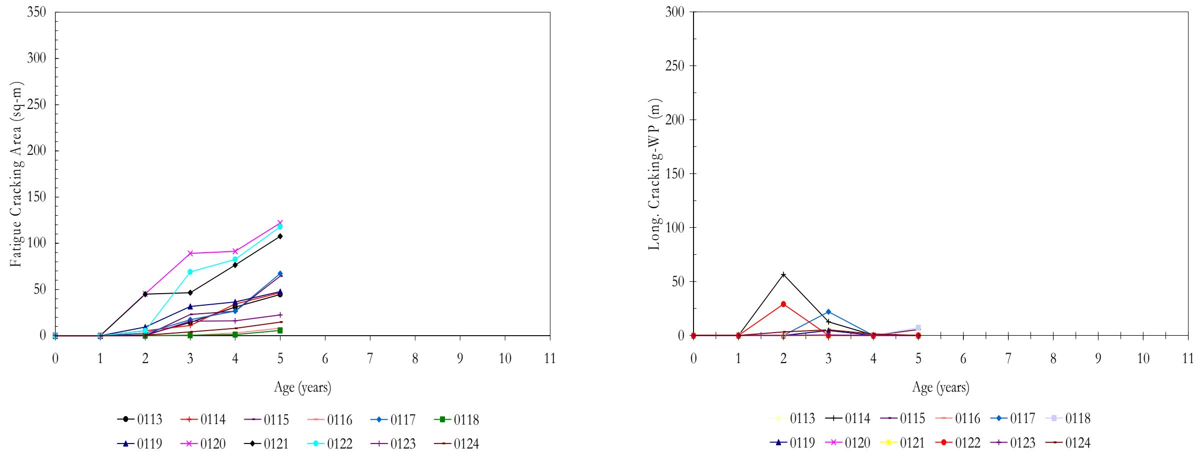


(a) Fatigue cracking (b) longitudinal cracking-NWP



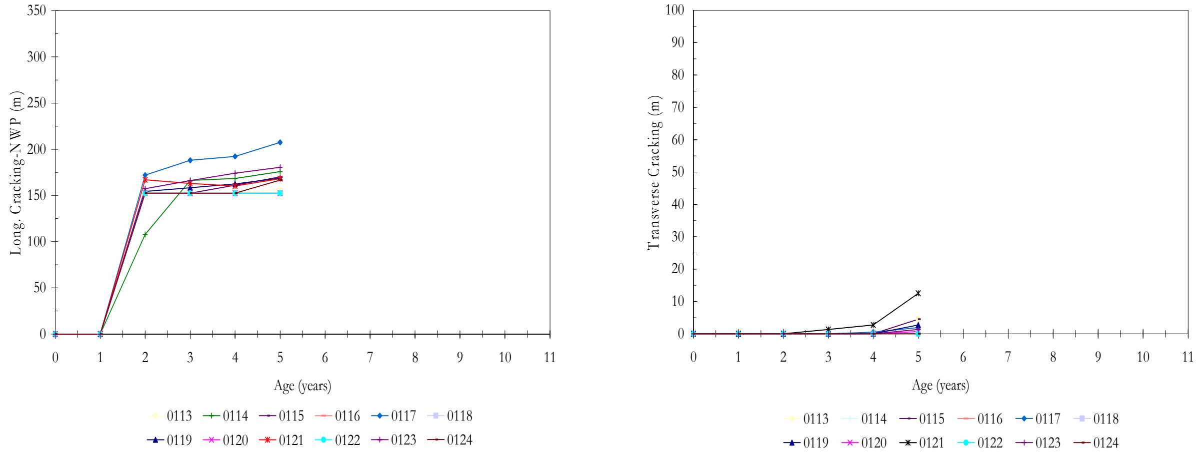
(c) Rut depth (d) Roughness (IRI)

**Figure A2- 8 Time series trend for various performance measures at Michigan (26) site**



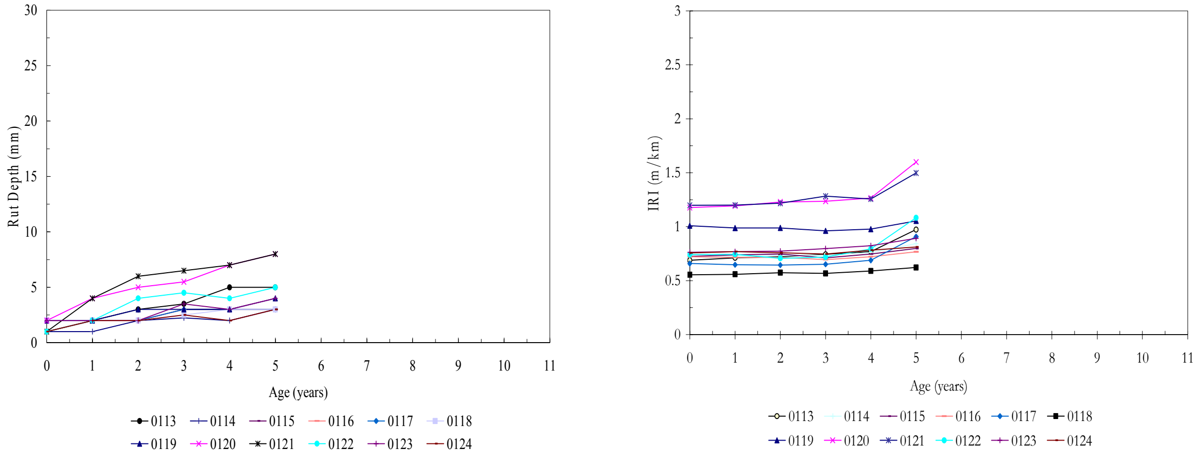
(a) Fatigue cracking

(b) longitudinal cracking-WP



(c) longitudinal cracking-NWP

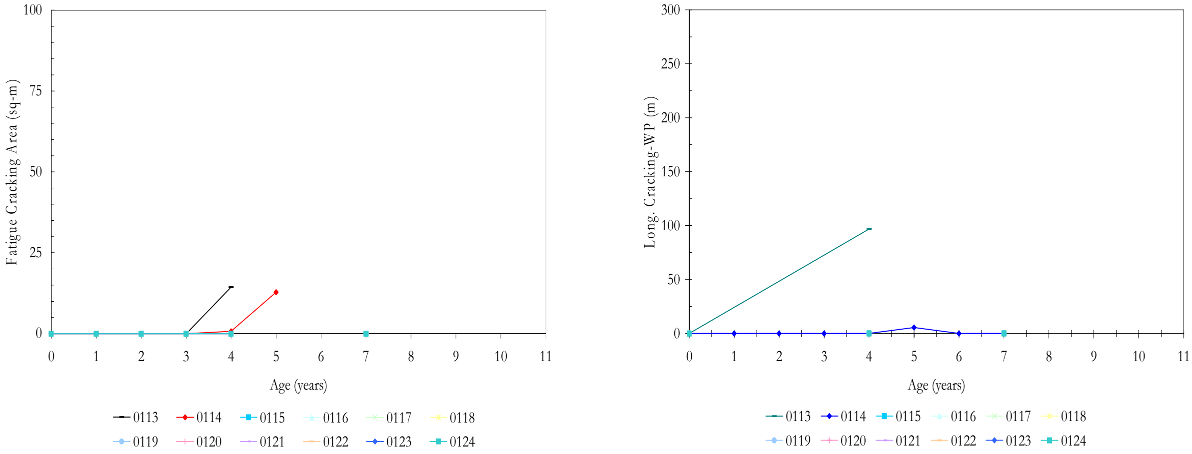
(d) Transverse cracking



(e) Rut depth

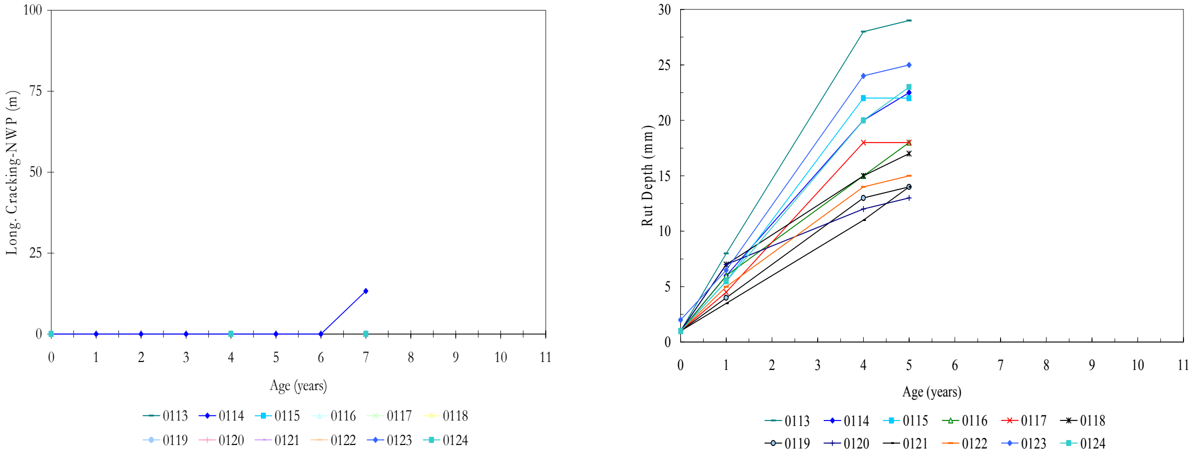
(f) Roughness (IRI)

**Figure A2- 9 Time series trend for various performance measures at Montana (30) site**



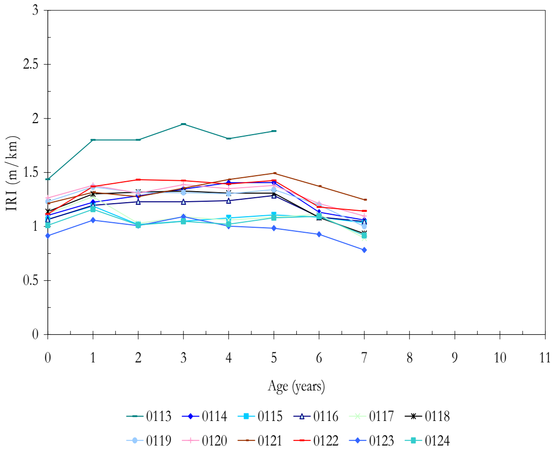
(a) Fatigue cracking

(b) longitudinal cracking-WP



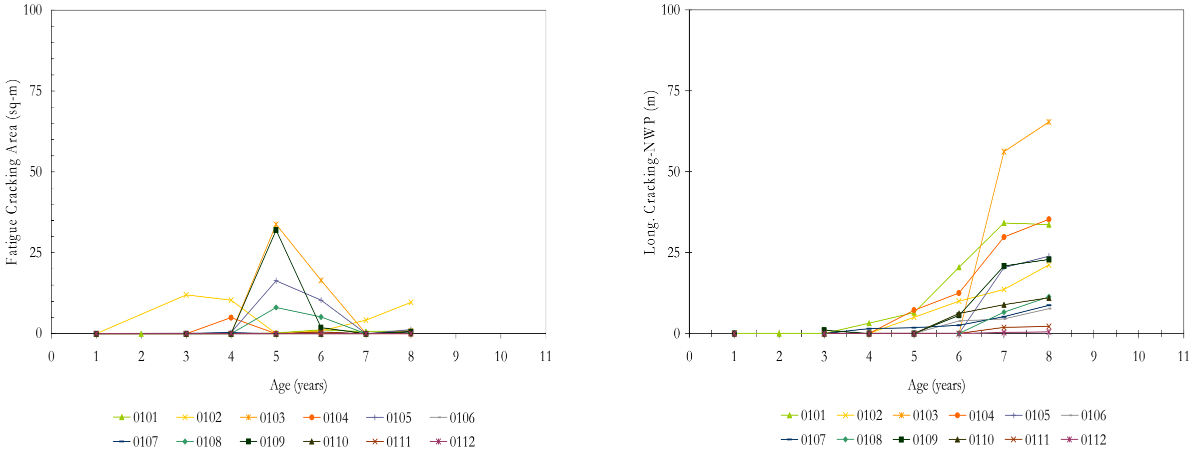
(c) longitudinal cracking-NWP

(d) Rut depth



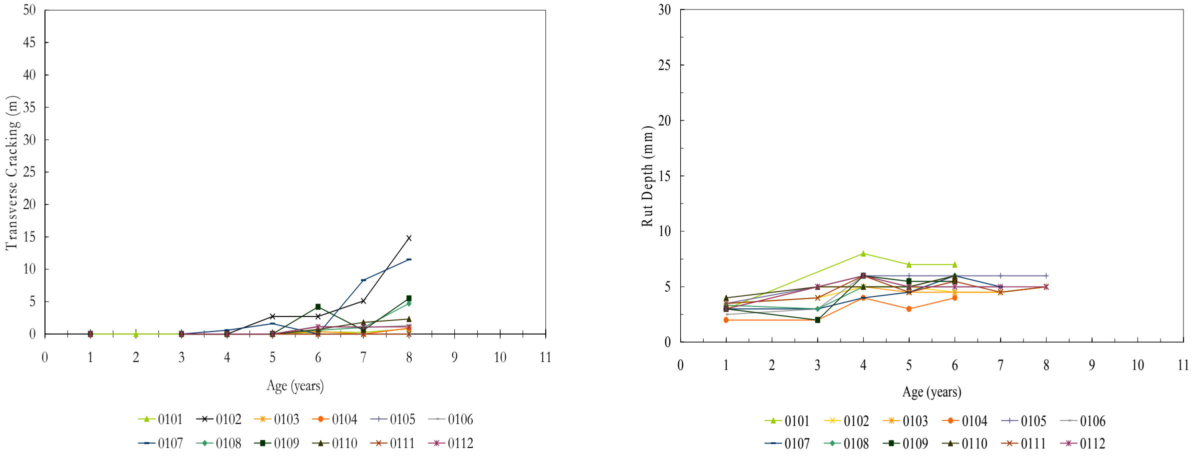
(e) Roughness (IRI)

**Figure A2- 10 Time series trend for various performance measures at Nebraska (31) site**



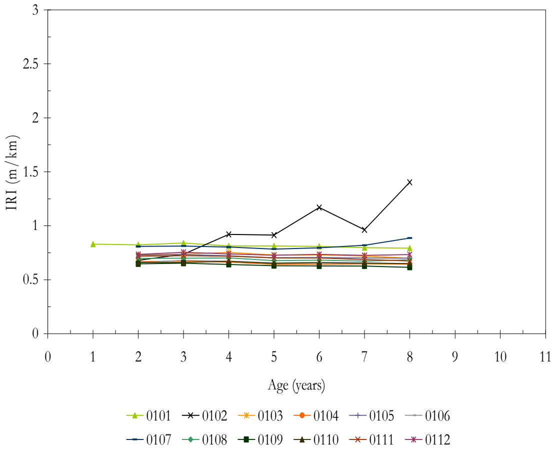
(a) Fatigue cracking

(b) longitudinal cracking-NWP



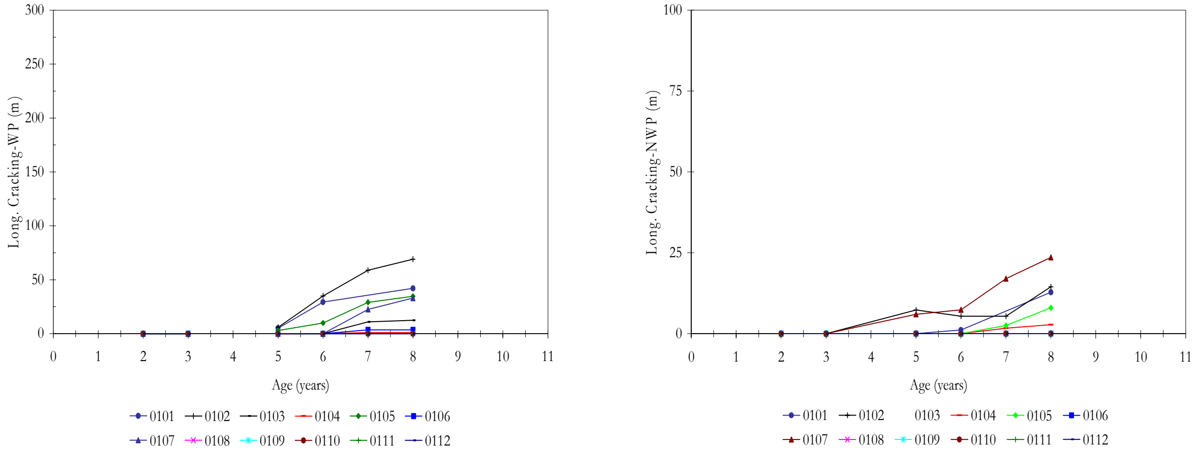
(c) Transverse cracking

(d) Rut depth



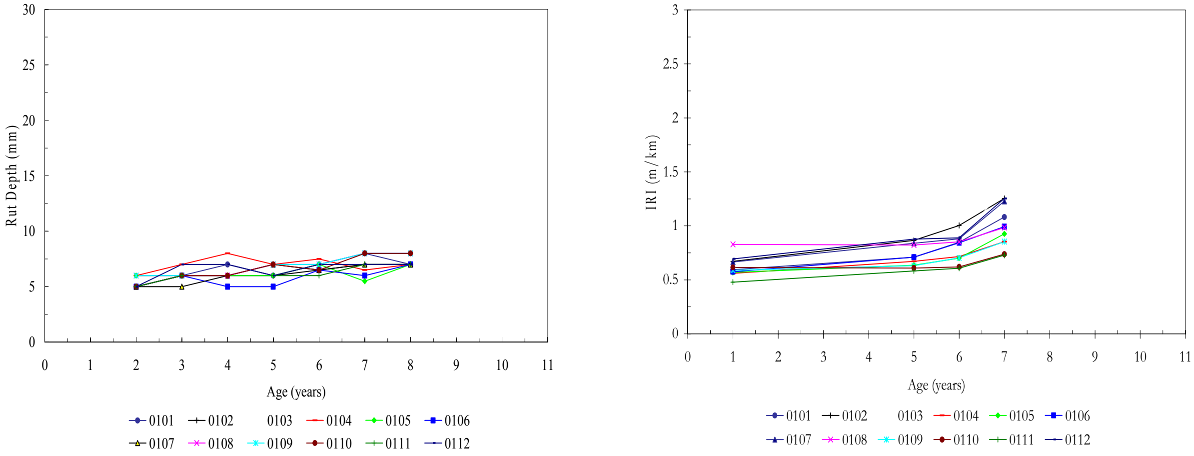
(e) Roughness (IRI)

**Figure A2- 11 Time series trend for various performance measures at Nevada (32) site**



(a) longitudinal cracking-WP

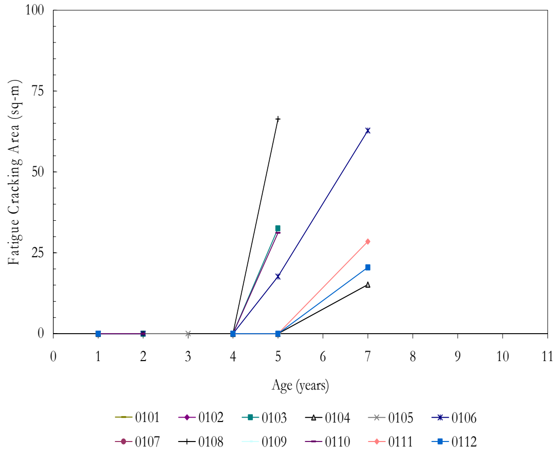
(b) longitudinal cracking-NWP



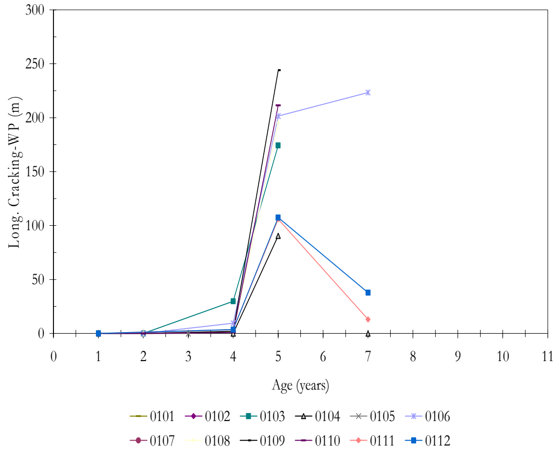
(c) Rut depth

(d) Roughness (IRI)

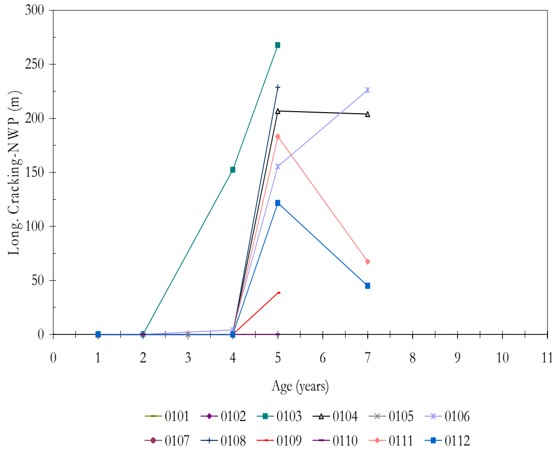
**Figure A2- 12 Time series trend for various performance measures at New Mexico (35) site**



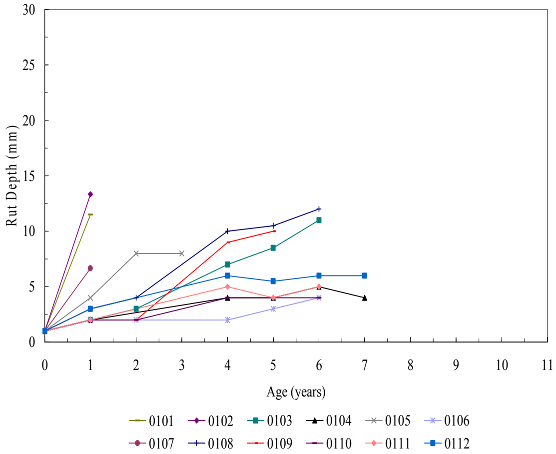
(a) Fatigue cracking



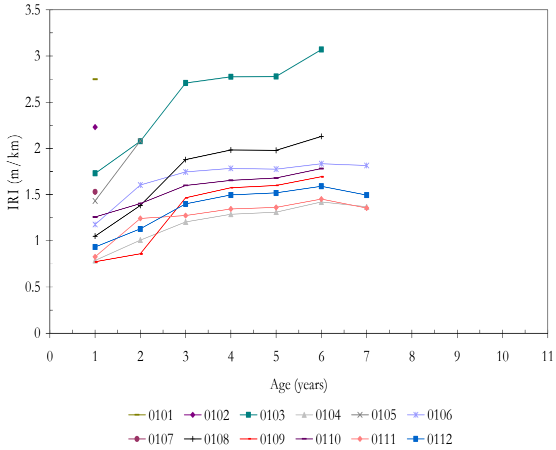
(b) longitudinal cracking-WP



(c) longitudinal cracking-NWP

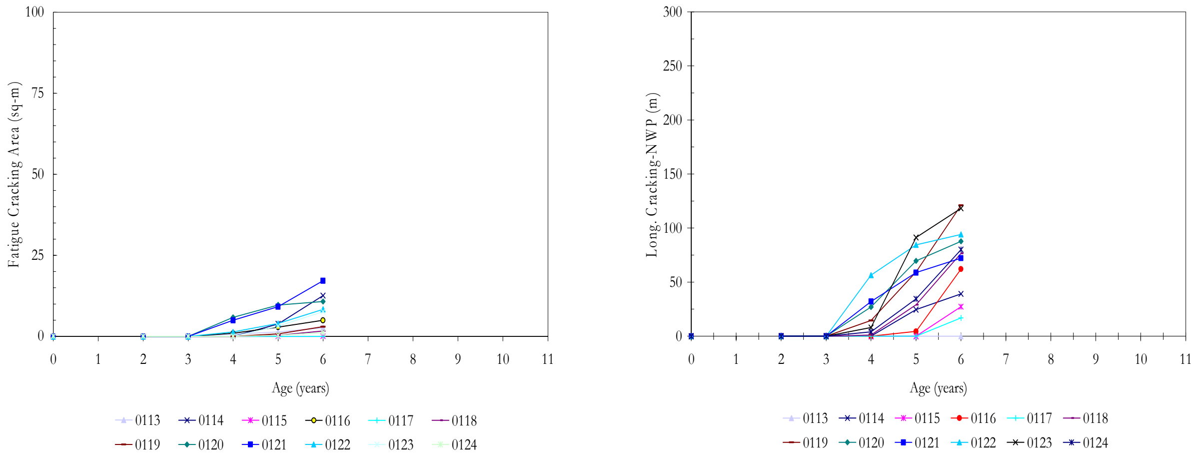


(d) Rut depth

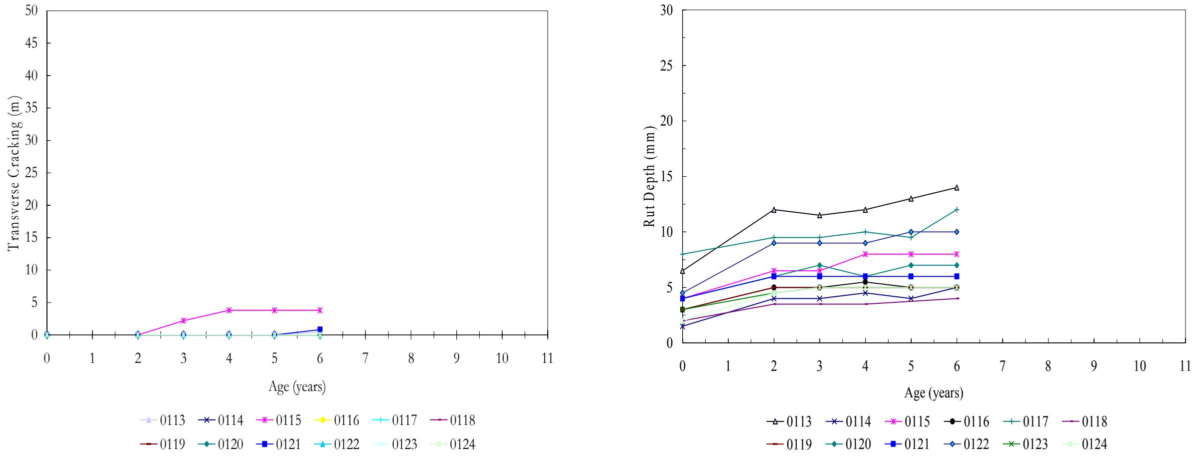


(e) Roughness (IRI)

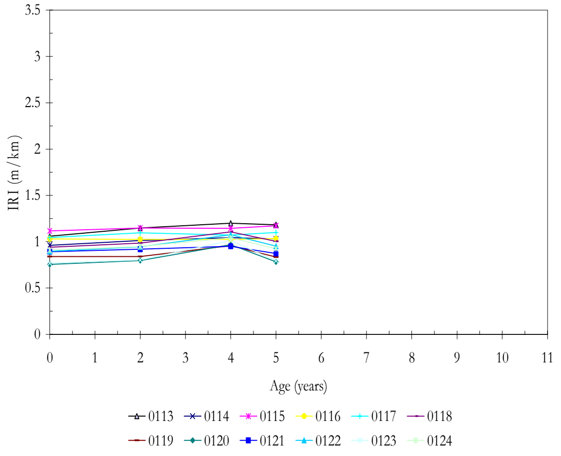
**Figure A2- 13 Time series trend for various performance measures at Ohio (39) site**



(a) Fatigue cracking (b) longitudinal cracking-NWP

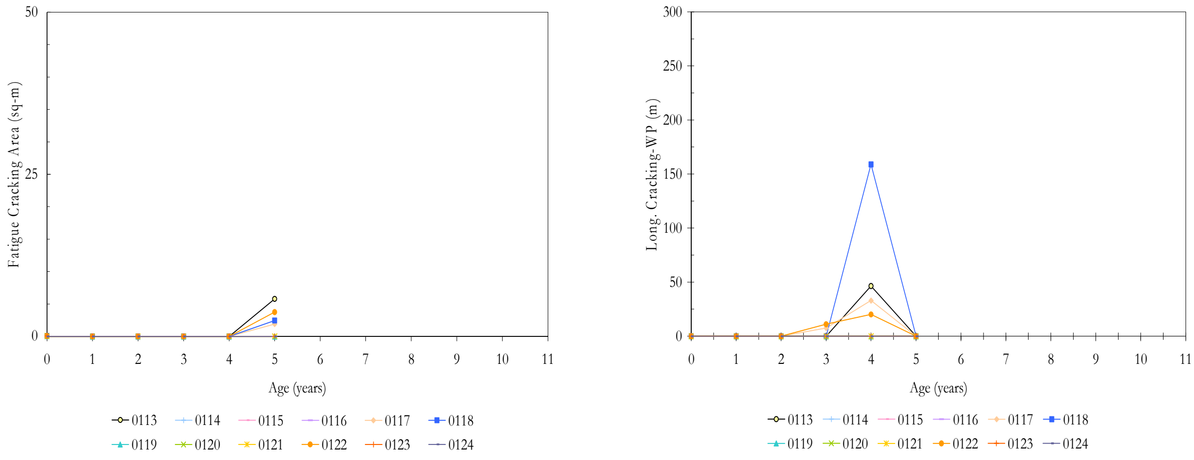


(c) Transverse cracking (d) Rut depth



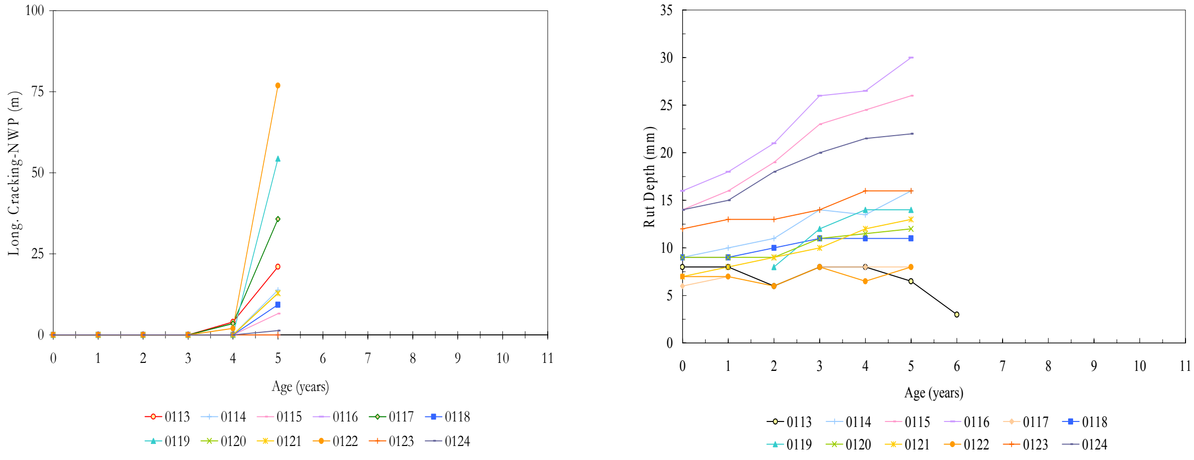
(e) Roughness (IRI)

**Figure A2- 14 Time series trend for various performance measures at Oklahoma (40) site**



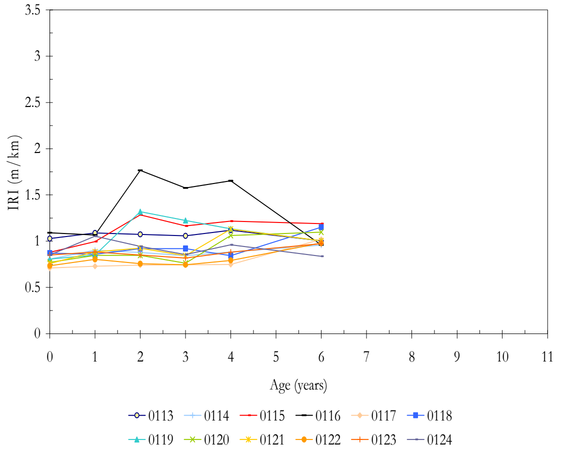
(a) Fatigue cracking

(b) longitudinal cracking-WP



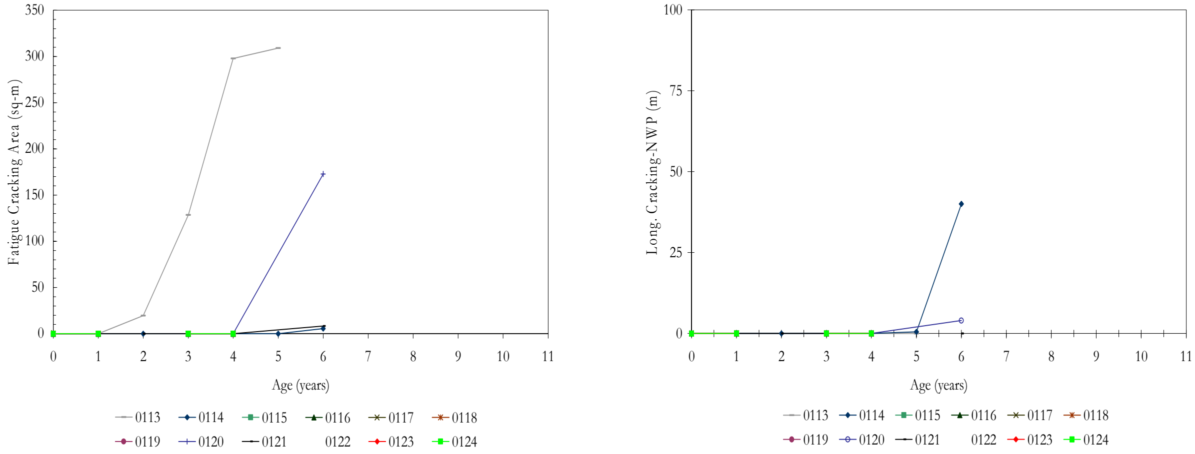
(c) longitudinal cracking-NWP

(d) Rut depth



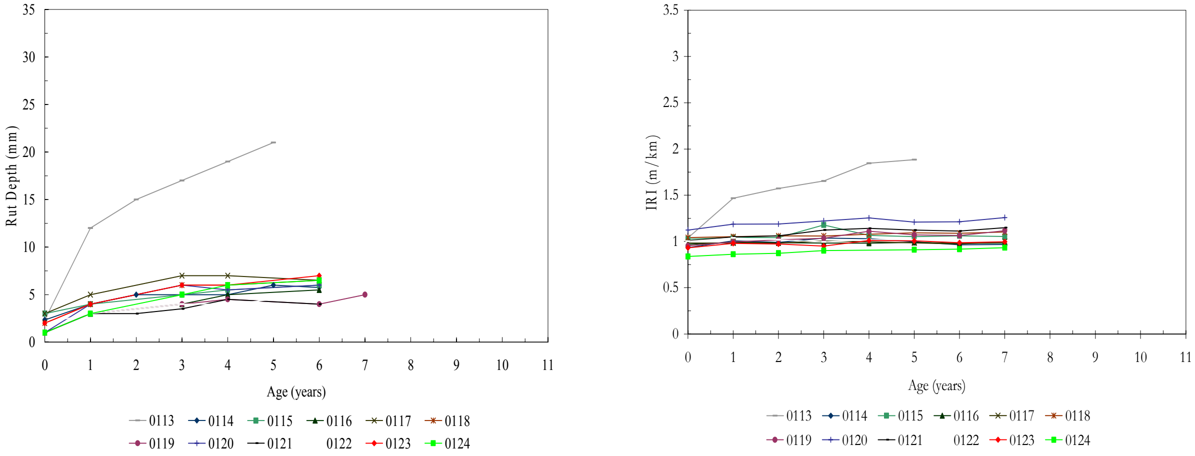
(e) Roughness (IRI)

**Figure A2- 15 Time series trend for various performance measures at Texas (48) site**



(a) Fatigue cracking

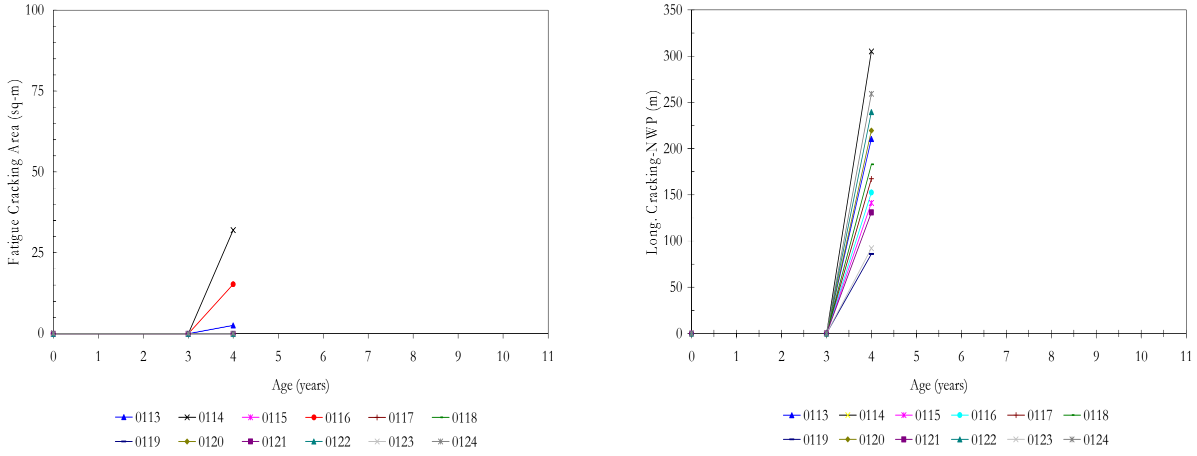
(b) longitudinal cracking-NWP



(c) Rut depth

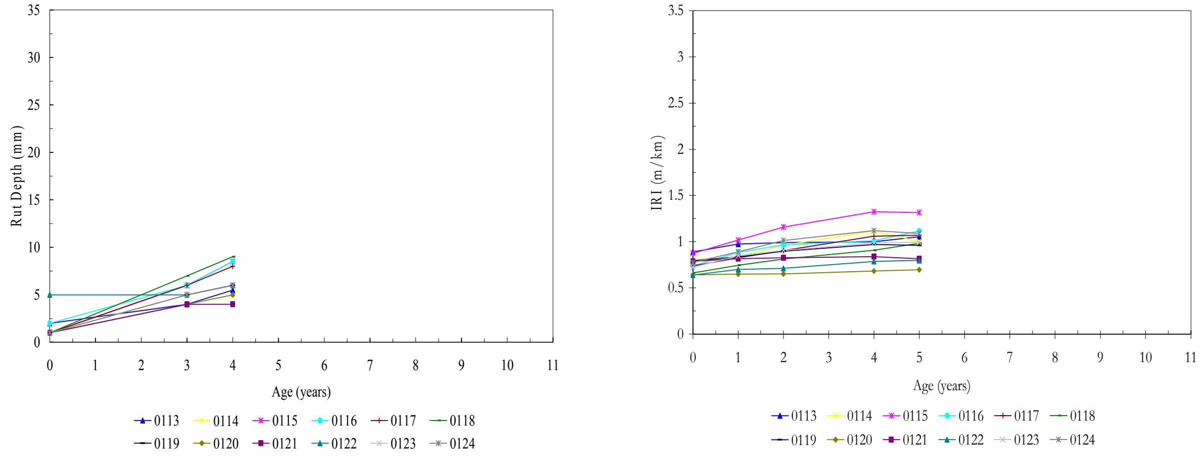
(d) Roughness (IRI)

Figure A2- 16 Time series trend for various performance measures at Virginia (51) site



(a) Fatigue cracking

(b) longitudinal cracking-NWP



(c) Rut depth

(d Roughness (IRI)

**Figure A2- 17 Time series trend for various performance measures at Wisconsin (55) site**

## Table A2- 1 Cracking Performance for Alabama (1)

| Section ID | Distress Type | Age at time of data collection (years) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 0101 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.6 | 1.2 | 0.0 | 3.0 | 38.6 | 25.3 | 31.1 | 64.9 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 4.5 | 4.5 | 51.9 | 0.1 | 16.2 | 13.7 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.8 | 0.0 | 0.9 | 0.0 | 133.1 | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.6 | 0.8 | 3.5 | 14.6 |
| 0102 | Alligator Cracking (sqm) | 0.0 | 0.9 | 2.1 | 26.3 | 25.9 | 109.2 | 99.4 | 125.8 | 112.9 | 190.1 |
| | Longitudinal Cracking - WP (m) | 0.0 | 7.9 | 3.7 | 0.7 | 30.1 | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 141.5 | 1.3 | 3.3 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.0 | 0.7 | 3.5 | 6.9 | 17.4 |
| 0103 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | | | | 34.9 | 22.9 | 28.7 | 34.4 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | | | | 30.6 | 9.7 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | | | | 30.6 | 193.7 | 69.2 | 87.5 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | | | | 0.0 | 0.0 | 1.5 | 7.9 |
| 0104 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | | | | 0.0 | 0.0 | 8.3 | 8.3 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | | | | 0.0 | 152.4 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | | | | 0.0 | 0.0 | 19.6 | 20.6 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | | | | 0.0 | 0.0 | 0.0 | 0.0 |
| 0105 | Alligator Cracking (sqm) | 0.0 | 0.0 | 21.9 | | | | 136.7 | 116.9 | 97.9 | 102.8 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 37.4 | | | | 4.3 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | | | | 0.0 | 80.6 | 5.5 | 8.6 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | | | | 5.1 | 31.1 | 29.0 | 47.0 |
| 0106 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | | | | 0.0 | 27.3 | 20.2 | 25.1 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | | | | 43.3 | 5.9 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | | | | 0.0 | 104.0 | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | | | | 0.0 | 0.0 | 0.0 | 0.0 |
| 0107 | Alligator Cracking (sqm) | 0.0 | 0.0 | 29.5 | | | | 44.3 | 12.8 | 18.4 | |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 20.4 | | | | 6.7 | 0.9 | 0.0 | |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | | | | 0.0 | 0.0 | 0.0 | |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | | | | 0.0 | 0.0 | 1.3 | |
| 0108 | Alligator Cracking (sqm) | 0.0 | 0.0 | 13.7 | | | | 108.5 | 61.8 | 70.0 | 92.4 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 35.5 | | | | 18.7 | 1.3 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | | | | 0.0 | 95.8 | 37.4 | 71.3 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | | | | 0.0 | 1.8 | 4.0 | 6.5 |
| 0109 | Alligator Cracking (sqm) | 0.0 | 0.0 | 4.6 | | | | 51.6 | 110.3 | 79.6 | 107.2 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 24.6 | | | | 18.0 | 4.9 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | | | | 21.6 | 81.9 | 62.1 | 76.6 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | | | | 0.0 | 0.0 | 9.0 | 1.2 |
| 0110 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | | | | 49.6 | 70.4 | 53.6 | 73.6 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 28.1 | | | | 5.2 | 2.9 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | | | | 0.0 | 144.8 | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | | | | 0.0 | 4.6 | 5.4 | 6.2 |
| 0111 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | | | | 60.2 | 92.5 | 67.8 | 86.4 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 5.5 | | | | 23.2 | 0.5 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | | | | 0.0 | 122.3 | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | | | | 0.0 | 0.0 | 1.2 | 2.4 |
| 0112 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | | | | 0.0 | 24.5 | 9.5 | 12.8 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | | | | 25.8 | 0.7 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | | | | 0.0 | 77.8 | 0.0 | 1.9 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | | | | 0.0 | 0.0 | 0.0 | 0.0 |

## Table A2- 2 Rutting Performance for Alabama (1)

| Section ID | Age at time of data collection (years) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 3 | 4 | 5 | 7 | 8 | 9 | 10 |
| 0101 | 4.0 | 5.0 | 5.0 | 5.5 | 5.5 | 6.0 | 7.0 | 6.0 |
| 0102 | 5.0 | 6.0 | 6.0 | 7.5 | 10.0 | 9.5 | 10.5 | 17.0 |
| 0103 | 3.0 | 4.0 | | | 6.5 | 7.0 | 8.5 | 8.0 |
| 0104 | 4.0 | 5.0 | | | 7.5 | 7.5 | 8.5 | 8.0 |
| 0105 | 5.0 | 6.0 | | | 9.0 | 9.0 | 9.5 | 10.0 |
| 0106 | 6.0 | 7.0 | | | 8.5 | 9.0 | 9.0 | 9.0 |
| 0107 | 7.0 | 8.0 | | | 7.5 | 9.0 | 8.5 | |
| 0108 | 6.0 | 7.0 | | | 7.0 | 7.5 | 7.0 | 7.0 |
| 0109 | 5.0 | 6.0 | | | 6.5 | 6.5 | 8.0 | 7.0 |
| 0110 | 8.0 | 8.0 | | | 7.5 | 7.5 | 8.0 | 7.0 |
| 0111 | 5.0 | 8.0 | | | 9.0 | 8.0 | 8.5 | 9.0 |
| 0112 | 5.0 | 7.0 | | | 9.0 | 8.5 | 10.0 | 9.0 |

Note: Rut depths are in mm

## Table A2- 3 Roughness Performance for Alabama (1)

| State 1 IRI (m/km) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Section ID | Age at time of data collection (years) | | | | | | | |
| | 1 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 0101 | | 0.68 | 0.68 | 0.72 | 0.77 | 0.71 | 0.74 | 0.77 |
| 0102 | 0.95 | 0.91 | 0.90 | 1.02 | 1.12 | 1.19 | 1.37 | 0.88 |
| 0103 | | 0.79 | 0.76 | 0.80 | | 0.83 | 0.83 | 0.87 |
| 0104 | | 0.59 | 0.64 | 0.66 | 0.82 | 0.63 | 0.65 | 0.71 |
| 0105 | | 0.61 | 0.64 | 0.63 | | 0.65 | 0.64 | 0.65 |
| 0106 | 0.75 | 0.58 | 0.61 | 0.65 | | 0.70 | 0.69 | 0.75 |
| 0107 | 0.81 | 0.66 | 0.63 | 0.67 | | 0.76 | 0.96 | 1.72 |
| 0108 | 0.88 | 0.76 | 0.74 | 0.77 | | 0.73 | 0.74 | 0.75 |
| 0109 | | 0.73 | 0.71 | 0.68 | | 0.74 | 0.75 | 0.78 |
| 0110 | | 0.69 | 0.68 | 0.76 | | 0.69 | 0.69 | 0.68 |
| 0111 | | 0.57 | 0.57 | 0.57 | | 0.59 | 0.59 | 0.61 |
| 0112 | 0.81 | 0.67 | 0.67 | 0.72 | | 0.69 | 0.73 | 0.81 |

Note: IRI is in m/km

## Table A2- 4 Cracking Performance for Arizona (4)

| Section ID | Distress Type | Age at time of data collection (years) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2 | 3 | 4 | 5 | 6 | 8 | 9 | 10 |
| 0113 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.9 | 3.0 | 12.4 | 6.3 | 7.2 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 22.6 | 34.3 | 72.5 | 106.6 | 75.1 | 68.7 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.7 | 29.9 | 43.7 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 2.3 | 44.2 | 56.4 | 76.0 |
| 0114 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 6.6 | 15.6 | 22.6 | 19.7 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 4.5 | 30.0 | 14.7 | 63.1 | 121.5 | 36.5 | 7.4 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 46.3 | 149.7 |
| | Transverse Cracking (m) | 0.0 | 0.6 | 0.0 | 0.0 | 1.0 | 9.4 | 12.6 | 29.1 |
| 0115 | Alligator Cracking (sqm) | 0.0 | | 0.0 | | 0.0 | 0.0 | 0.0 | 5.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | | 0.0 | | 25.9 | 68.9 | 91.9 | 92.4 |
| | Longitudinal Cracking - NWP (m) | 0.0 | | 0.0 | | 0.0 | 0.0 | 0.0 | 23.3 |
| | Transverse Cracking (m) | 0.0 | | 0.0 | | 0.0 | 0.0 | 1.0 | 8.5 |
| 0116 | Alligator Cracking (sqm) | 0.0 | | 0.0 | | 2.7 | 9.9 | 69.9 | 5.8 |
| | Longitudinal Cracking - WP (m) | 0.0 | | 0.0 | | 2.7 | 22.0 | 16.2 | 6.8 |
| | Longitudinal Cracking - NWP (m) | 0.0 | | 0.0 | | 0.0 | 19.5 | 15.4 | 37.4 |
| | Transverse Cracking (m) | 0.0 | | 0.0 | | 0.0 | 0.0 | 1.5 | 1.1 |
| 0117 | Alligator Cracking (sqm) | 0.0 | | 0.0 | | 0.0 | 0.0 | 0.0 | 4.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | | 0.0 | | 5.6 | 39.0 | 84.1 | 103.3 |
| | Longitudinal Cracking - NWP (m) | 0.0 | | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | | 0.0 | | 0.0 | 0.0 | 0.5 | 7.5 |
| 0118 | Alligator Cracking (sqm) | 0.0 | | 0.0 | | 8.0 | 28.6 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | | 0.0 | | 13.8 | 49.0 | 169.7 | 136.8 |
| | Longitudinal Cracking - NWP (m) | 0.0 | | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | | 0.0 | | 0.0 | 0.0 | 0.0 | 0.6 |
| 0119 | Alligator Cracking (sqm) | 0.0 | | 0.0 | | 4.6 | 2.4 | 6.8 | 20.5 |
| | Longitudinal Cracking - WP (m) | 0.0 | | 50.0 | | 53.7 | 108.0 | 127.6 | 89.9 |
| | Longitudinal Cracking - NWP (m) | 0.0 | | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | | 0.0 | | 0.0 | 4.0 | 11.0 | 17.7 |
| 0120 | Alligator Cracking (sqm) | 0.0 | | 0.0 | | 0.8 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | | 20.3 | | 69.9 | 128.7 | 123.3 | 8.1 |
| | Longitudinal Cracking - NWP (m) | 0.0 | | 0.0 | | 0.0 | 0.0 | 5.5 | 118.9 |
| | Transverse Cracking (m) | 0.0 | | 0.0 | | 0.0 | 3.8 | 39.0 | 44.5 |
| 0121 | Alligator Cracking (sqm) | 0.0 | | 0.0 | | 12.7 | 13.8 | 16.8 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | | 62.6 | | 101.6 | 124.5 | 132.3 | 152.2 |
| | Longitudinal Cracking - NWP (m) | 0.0 | | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | | 0.0 | | 0.0 | 6.1 | 36.8 | 44.6 |
| 0122 | Alligator Cracking (sqm) | 0.0 | | 0.0 | | 0.0 | 1.3 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | | 0.0 | | 39.4 | 79.1 | 112.2 | 112.7 |
| | Longitudinal Cracking - NWP (m) | 0.0 | | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | | 0.0 | | 0.0 | 0.7 | 1.1 | 1.7 |
| 0123 | Alligator Cracking (sqm) | 0.0 | | 0.0 | | 0.0 | 0.0 | 1.0 | 1.6 |
| | Longitudinal Cracking - WP (m) | 0.0 | | 9.3 | | 47.2 | 117.0 | 142.7 | 147.2 |
| | Longitudinal Cracking - NWP (m) | 0.0 | | 0.0 | | 0.0 | 0.0 | 2.0 | 15.2 |
| | Transverse Cracking (m) | 0.0 | | 0.0 | | 0.0 | 0.6 | 2.0 | 7.9 |
| 0124 | Alligator Cracking (sqm) | 0.0 | | 0.0 | | 0.0 | 0.0 | 19.2 | 17.6 |
| | Longitudinal Cracking - WP (m) | 0.0 | | 0.0 | | 31.3 | 108.3 | 106.3 | 117.7 |
| | Longitudinal Cracking - NWP (m) | 0.0 | | 0.0 | | 0.0 | 0.8 | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | | 0.0 | | 0.0 | 0.8 | 2.9 | 7.9 |

## Table A2- 5 Rutting Performance for Arizona (4)

| Section ID | Age at time of data collection (years) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 0113 | 7.0 | 7.0 | 5.5 | 6.0 | 6.5 | 5.0 | 6.0 | 7.0 | 8.0 |
| 0114 | 10.0 | 11.3 | 11.0 | 11.3 | 13.5 | 10.0 | 10.0 | 7.0 | 6.0 |
| 0115 | 4.0 | | 3.0 | | 3.5 | 4.0 | 4.0 | 3.5 | 3.0 |
| 0116 | 9.0 | | 9.0 | | 10.5 | 7.0 | 8.5 | 6.0 | 5.0 |
| 0117 | 11.0 | | 10.0 | | 13.5 | 9.0 | 10.5 | 9.0 | 9.0 |
| 0118 | 10.0 | | 9.0 | | 11.0 | 8.0 | 8.5 | 6.5 | 6.0 |
| 0119 | 21.5 | | 20.0 | | 25.0 | 16.0 | 20.0 | 16.5 | 18.0 |
| 0120 | 9.0 | | 7.0 | | 10.0 | 7.0 | 7.5 | 6.0 | 7.0 |
| 0121 | 8.0 | | 7.0 | | 9.5 | 6.0 | 6.5 | 5.0 | 6.0 |
| 0122 | 8.0 | | 7.0 | | 10.0 | 7.0 | 7.5 | 6.0 | 5.0 |
| 0123 | 8.0 | | 7.0 | | 9.5 | 4.0 | 7.5 | 7.0 | 6.0 |
| 0124 | 8.0 | | 8.0 | | 9.0 | 8.0 | 7.5 | 6.5 | 6.0 |

Note: Rut depths are in mm

## Table A2- 6 Roughness Performance for Arizona (4)

| State 4 IRI (m/km) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Section ID | Age at time of data collection (years) | | | | | | | | | |
| | 0 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 0113 | 1.17 | 1.14 | 1.14 | 1.13 | 1.19 | 1.32 | 1.36 | 1.59 | 1.43 | 1.27 |
| 0114 | 0.65 | 0.69 | 0.71 | 0.74 | 0.75 | 0.81 | 0.86 | 0.84 | 0.87 | 0.91 |
| 0115 | 0.66 | 0.66 | 0.66 | | 0.68 | 0.68 | 0.69 | 0.77 | 0.80 | 0.79 |
| 0116 | 0.67 | 0.70 | 0.71 | | 0.71 | 0.73 | 0.74 | 0.81 | 1.13 | 0.83 |
| 0117 | 0.64 | 0.61 | 0.63 | | 0.64 | 0.63 | 0.64 | 0.70 | 0.72 | 0.96 |
| 0118 | 0.82 | 0.77 | 0.82 | | 0.80 | 0.84 | 0.87 | 1.05 | 1.09 | 0.91 |
| 0119 | 0.88 | 0.83 | 0.89 | | 0.97 | 0.93 | 1.01 | 1.14 | 1.06 | 0.97 |
| 0120 | 0.91 | 0.90 | 0.99 | | 0.97 | 1.05 | 1.05 | 1.02 | 1.07 | 1.01 |
| 0121 | 0.73 | 0.73 | 0.74 | | 0.77 | 0.78 | 0.76 | 0.76 | 0.84 | 0.87 |
| 0122 | 0.93 | 0.91 | 1.00 | | 0.97 | 1.12 | 1.04 | 1.00 | 1.04 | 1.04 |
| 0123 | 0.71 | 0.67 | 0.74 | | 0.73 | 0.76 | 0.76 | 0.85 | 0.76 | 0.74 |
| 0124 | 0.55 | 0.53 | 0.57 | | 0.57 | 0.59 | 0.61 | 0.69 | 0.74 | 0.89 |

Note: IRI is in m/km

## Table A2- 7 Cracking Performance for Arkansas (5)

| Section ID | Distress Type | Age at time of data collection (years) | | | | |
|---|---|---|---|---|---|---|
| | | 3 | 6 | 7 | 8 | 9 |
| 0113 | Alligator Cracking (sqm) | 3.6 | 12.6 | 13.5 | 15.5 | 33.0 |
| | Longitudinal Cracking - WP (m) | 7.3 | 2.6 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 152.5 | 153.3 | 152.8 | 189.0 | 215.1 |
| | Transverse Cracking (m) | 0.0 | 2.7 | 3.2 | 5.9 | 11.6 |
| 0114 | Alligator Cracking (sqm) | 0.0 | 6.2 | 10.7 | 31.2 | 40.8 |
| | Longitudinal Cracking - WP (m) | 0.0 | 2.3 | 1.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 152.5 | 152.5 | 152.5 | 156.1 | 156.7 |
| | Transverse Cracking (m) | 0.0 | 0.4 | 2.4 | 9.7 | 18.6 |
| 0115 | Alligator Cracking (sqm) | 0.0 | 6.7 | 10.2 | 17.3 | 21.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 1.7 | 0.0 | 0.0 | 0.7 |
| | Longitudinal Cracking - NWP (m) | 152.0 | 152.5 | 187.0 | 237.3 | 255.1 |
| | Transverse Cracking (m) | 0.0 | 0.5 | 1.7 | 4.3 | 7.7 |
| 0116 | Alligator Cracking (sqm) | 0.0 | 2.7 | 5.4 | 10.8 | 15.5 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.7 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 152.0 | 152.5 | 175.0 | 189.6 | 225.6 |
| | Transverse Cracking (m) | 0.0 | 1.4 | 0.8 | 6.3 | 11.7 |
| 0117 | Alligator Cracking (sqm) | 0.0 | 4.0 | 11.1 | 20.1 | 23.6 |
| | Longitudinal Cracking - WP (m) | 0.7 | 1.1 | 0.5 | 0.0 | 3.6 |
| | Longitudinal Cracking - NWP (m) | 152.5 | 152.3 | 154.5 | 162.4 | 166.9 |
| | Transverse Cracking (m) | 0.0 | 0.4 | 1.3 | 5.2 | 13.1 |
| 0118 | Alligator Cracking (sqm) | 0.0 | 7.5 | 10.4 | 14.1 | 24.7 |
| | Longitudinal Cracking - WP (m) | 0.0 | 6.4 | 0.0 | 0.0 | 4.1 |
| | Longitudinal Cracking - NWP (m) | 152.5 | 152.8 | 195.3 | 207.2 | 227.1 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.8 | 3.2 | 8.4 |
| 0119 | Alligator Cracking (sqm) | 34.5 | 123.4 | 134.7 | 145.5 | 156.1 |
| | Longitudinal Cracking - WP (m) | 3.0 | 0.8 | 3.3 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 24.8 | 67.5 | 230.1 | 259.1 | 278.0 |
| | Transverse Cracking (m) | 5.9 | 9.7 | 11.3 | 38.2 | 48.3 |
| 0120 | Alligator Cracking (sqm) | 17.3 | 45.3 | 49.8 | 52.9 | 61.4 |
| | Longitudinal Cracking - WP (m) | 5.8 | 2.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 112.8 | 149.7 | 234.0 | 238.2 | 239.5 |
| | Transverse Cracking (m) | 0.3 | 8.3 | 6.4 | 14.0 | 22.1 |
| 0121 | Alligator Cracking (sqm) | 1.7 | 12.1 | 20.2 | 41.2 | 91.7 |
| | Longitudinal Cracking - WP (m) | 0.0 | 14.0 | 7.7 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 153.5 | 154.0 | 156.2 | 155.9 | 140.3 |
| | Transverse Cracking (m) | 1.5 | 3.5 | 1.9 | 8.4 | 11.9 |
| 0122 | Alligator Cracking (sqm) | 0.3 | 1.2 | 3.5 | 9.5 | 18.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 |
| | Longitudinal Cracking - NWP (m) | 138.5 | 152.5 | 157.2 | 156.5 | 161.5 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.5 | 3.7 | 11.3 |
| 0123 | Alligator Cracking (sqm) | 0.0 | 3.4 | 3.8 | 6.9 | 7.9 |
| | Longitudinal Cracking - WP (m) | 0.0 | 152.5 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 152.5 | 0.0 | 152.5 | 158.0 | 218.4 |
| | Transverse Cracking (m) | 0.0 | 0.8 | 2.2 | 4.6 | 4.9 |
| 0124 | Alligator Cracking (sqm) | 0.0 | 4.4 | 6.1 | 14.0 | 16.6 |
| | Longitudinal Cracking - WP (m) | 0.8 | 5.8 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 152.5 | 152.5 | 179.3 | 186.3 | 215.8 |
| | Transverse Cracking (m) | 0.0 | 0.4 | 0.5 | 1.5 | 6.3 |

### Table A2- 8 Rutting Performance for Arkansas (5)

| Section ID | Age at time of data collection (years) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 3 | 5 | 6 | 7 | 8 | 9 |
| 0113 | 7.0 | 3.0 | 3.0 | 4.0 | 5.0 | 3.0 | 5.0 |
| 0114 | 5.0 | 4.0 | 6.0 | 5.0 | 6.0 | 6.0 | 8.0 |
| 0115 | 4.0 | 4.0 | 7.0 | 6.0 | 6.5 | 3.0 | 7.0 |
| 0116 | 6.0 | 5.0 | 9.0 | 7.0 | 8.5 | 5.0 | 9.0 |
| 0117 | 5.0 | 4.0 | 5.0 | 6.0 | 6.5 | 5.0 | 7.0 |
| 0118 | 5.0 | 4.0 | 6.0 | 6.0 | 7.5 | 6.0 | 7.0 |
| 0119 | 6.0 | 5.0 | 6.0 | 6.0 | 6.5 | 6.0 | 8.0 |
| 0120 | 6.0 | 5.0 | 7.0 | 5.0 | 6.5 | 5.5 | 6.0 |
| 0121 | 6.0 | 5.0 | 5.0 | 6.0 | 7.0 | 5.0 | 6.0 |
| 0122 | 6.0 | 4.0 | 5.0 | 5.0 | 6.0 | 5.0 | 7.0 |
| 0123 | 5.0 | 4.0 | 5.0 | 5.0 | 6.5 | 5.5 | 7.0 |
| 0124 | 7.0 | 5.0 | 6.0 | 6.0 | 6.5 | 6.0 | 7.0 |

Note: Rut depths are in mm

### Table A2- 9 Roughness Performance for Arkansas (5)

| Section ID | Age at time of data collection (years) | | | | |
|---|---|---|---|---|---|
| | 1 | 3 | 6 | 8 | 9 |
| 0113 | 0.78 | 0.80 | 0.94 | 1.17 | 1.13 |
| 0114 | 0.74 | 0.82 | 0.89 | 0.95 | 0.97 |
| 0115 | 0.79 | 0.83 | 0.94 | 0.92 | 1.05 |
| 0116 | 0.97 | 0.91 | 0.99 | 1.07 | 1.02 |
| 0117 | 0.82 | 0.83 | 0.95 | 1.19 | 1.04 |
| 0118 | 0.75 | 0.76 | 0.86 | 0.93 | 0.92 |
| 0119 | 0.75 | 0.79 | 1.56 | 1.54 | 1.75 |
| 0120 | 0.84 | 0.87 | 1.50 | 1.40 | 1.66 |
| 0121 | 0.80 | | 0.93 | 0.94 | 1.10 |
| 0122 | 0.72 | 0.74 | 0.95 | 0.93 | 0.99 |
| 0123 | 0.75 | 0.74 | 0.91 | 0.95 | 0.99 |
| 0124 | 0.79 | 0.80 | 1.15 | 0.95 | 1.12 |

Note: IRI is in m/km

## Table A2- 10 Cracking Performance for Delaware (10)

| Section ID | Distress Type | Age at time of data collection (years) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 5 | 7 |
| 0101 | Alligator Cracking (sqm) | 0.0 | 0.0 | | 0.0 | 0.4 | 51.2 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 |
| 0102 | Alligator Cracking (sqm) | 9.8 | 0.0 | 0.0 | 183.0 | 82.9 | 100.6 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0103 | Alligator Cracking (sqm) | 0.0 | 0.0 | | 0.0 | 0.0 | 0.3 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 |
| 0104 | Alligator Cracking (sqm) | 0.0 | 0.0 | | 0.0 | 0.0 | 45.9 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 |
| 0105 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 16.4 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0106 | Alligator Cracking (sqm) | 0.0 | 0.0 | | 0.0 | 0.0 | 28.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | | 0.0 | 0.0 | 1.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 |
| 0107 | Alligator Cracking (sqm) | 0.0 | 0.0 | | 0.0 | 2.5 | 45.7 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 |
| 0108 | Alligator Cracking (sqm) | 0.0 | 0.0 | | 0.0 | 0.0 | 1.9 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 |
| 0109 | Alligator Cracking (sqm) | 0.0 | 0.0 | | 0.0 | 0.0 | 6.2 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 |
| 0110 | Alligator Cracking (sqm) | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 |
| 0111 | Alligator Cracking (sqm) | 0.0 | 0.0 | | 0.0 | 0.0 | 45.8 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 |
| 0112 | Alligator Cracking (sqm) | 0.0 | 0.0 | | 0.0 | 0.0 | 13.8 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 |

## Table A2- 11 Rutting Performance for Delaware (10)

| Section ID | Age at time of data collection (years) | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 5 | 7 |
| 0101 | 1.0 | 1.0 | | 4.5 | 5.0 | 4.0 |
| 0102 | 4.0 | 2.0 | 4.0 | 5.5 | 6.0 | 6.5 |
| 0103 | 1.0 | 1.0 | | 3.5 | 3.0 | 3.5 |
| 0104 | 1.0 | 1.0 | | 4.0 | 4.0 | 4.0 |
| 0105 | 2.0 | 1.0 | 3.0 | 5.0 | 5.0 | 4.5 |
| 0106 | 1.0 | 1.0 | | 3.0 | 2.5 | 2.5 |
| 0107 | 1.0 | 1.0 | | 3.0 | 3.0 | 3.0 |
| 0108 | 1.0 | 1.0 | | 3.5 | 3.0 | 3.0 |
| 0109 | 2.0 | 1.0 | | 3.0 | 2.0 | 2.0 |
| 0110 | 1.0 | 1.0 | | 3.0 | 3.0 | 3.0 |
| 0111 | 1.0 | 1.0 | | 3.0 | 2.5 | 3.0 |
| 0112 | 1.0 | 1.0 | | 3.0 | 3.0 | 2.5 |

Note: Rut depths are in mm

## Table A2- 12 Roughness Performance for Delaware (10)

| Section ID | Age at time of data collection (years) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 5 | 6 | 7 |
| 0101 | | 0.84 | 0.84 | 0.84 | 0.86 | 0.88 | 0.93 |
| 0102 | 0.90 | 0.80 | 0.83 | 0.84 | 0.87 | 0.89 | 0.91 |
| 0103 | | 0.74 | 0.74 | 0.75 | 0.76 | 0.77 | 0.77 |
| 0104 | | 0.83 | 0.81 | 0.81 | 0.79 | 0.79 | 0.80 |
| 0105 | | 0.68 | 0.68 | 0.70 | 0.74 | 0.77 | 0.78 |
| 0106 | | 0.72 | 0.71 | 0.73 | 0.70 | 0.69 | 0.72 |
| 0107 | | 0.59 | 0.61 | 0.61 | 0.69 | 0.70 | 0.76 |
| 0108 | | 0.68 | 0.68 | 0.69 | 0.66 | 0.66 | 0.69 |
| 0109 | | 0.71 | 0.70 | 0.72 | 0.67 | 0.66 | 0.68 |
| 0110 | | 0.66 | 0.64 | 0.64 | 0.61 | 0.61 | 0.64 |
| 0111 | | 0.67 | 0.66 | 0.68 | 0.65 | 0.65 | 0.66 |
| 0112 | | 0.57 | 0.56 | 0.56 | 0.53 | 0.53 | 0.55 |

Note: IRI is in m/km

## Table A2- 13 Cracking Performance for Florida (12)

| Section ID | Distress Type | Age at time of data collection (years) | | | |
|---|---|---|---|---|---|
| | | 1 | 4 | 6 | 7 |
| 0101 | Alligator Cracking (sqm) | 0.0 | | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | | 12.9 | 49.7 |
| | Transverse Cracking (m) | 0.0 | | 0.0 | 0.0 |
| 0102 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.1 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 1.8 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 |
| 0103 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.6 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.2 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.8 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 |
| 0104 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 3.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 |
| 0105 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.2 | 1.2 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 14.1 | 36.6 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.3 |
| 0106 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 1.0 | 18.6 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 |
| 0107 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 1.6 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 5.9 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 6.4 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 |
| 0108 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.3 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 1.0 | 6.1 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 6.0 | 33.9 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 |
| 0109 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 5.9 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 |
| 0110 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.2 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 2.5 | 6.8 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 1.0 | 10.3 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 |
| 0111 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.6 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 |
| 0112 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 6.4 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 |

## Table A2- 14 Rutting Performance for Florida (12)

| Section ID | Age at time of data collection (years) | | |
|---|---|---|---|
| | 4 | 6 | 7 |
| 0101 | 4.0 | 4.7 | 5.0 |
| 0102 | 3.0 | 3.3 | 3.0 |
| 0103 | 5.5 | 6.3 | 7.0 |
| 0104 | 4.0 | 4.7 | 5.0 |
| 0105 | 5.0 | 5.7 | 6.0 |
| 0106 | 4.0 | 4.3 | 5.0 |
| 0107 | 3.5 | 4.7 | 5.0 |
| 0108 | 4.0 | 4.0 | 5.0 |
| 0109 | 3.5 | 3.3 | 3.0 |
| 0110 | 3.5 | 4.3 | 6.0 |
| 0111 | 4.0 | 5.0 | 6.0 |
| 0112 | 3.0 | 4.3 | 4.0 |

Note: Rut depths are in mm

## Table A2- 15 Roughness Performance for Florida (12)

| Section ID | Age at time of data collection (years) | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 5 | 6 | 8 |
| 0101 | 0.83 | | | 0.76 | 0.78 | 0.88 |
| 0102 | 0.76 | 0.75 | 0.75 | 0.76 | 0.76 | 0.82 |
| 0103 | 0.74 | | | 0.74 | 0.74 | 0.79 |
| 0104 | 0.70 | 0.71 | 0.71 | 0.69 | 0.68 | 0.77 |
| 0105 | 0.66 | | | 0.67 | 0.68 | 0.77 |
| 0106 | 0.60 | | | 0.59 | 0.59 | 0.63 |
| 0107 | 0.84 | | | 0.83 | 0.82 | 0.84 |
| 0108 | 0.95 | 0.84 | 0.78 | 0.80 | 0.81 | 0.81 |
| 0109 | 0.66 | | | 0.64 | 0.63 | 0.72 |
| 0110 | 0.86 | 0.87 | 0.82 | 0.86 | 0.87 | 0.92 |
| 0111 | 0.71 | | | 0.69 | 0.69 | 0.72 |
| 0112 | 0.70 | | | 0.67 | 0.67 | 0.72 |

Note: IRI is in m/km

### Table A2- 16 Cracking Performance for Iowa (19)

| Section ID | Distress Type | Age at time of data collection (years) | | | | |
|---|---|---|---|---|---|---|
| | | 0 | 2 | 6 | 8 | 9 |
| 0101 | Alligator Cracking (sqm) | | 7.5 | 7.5 | 12.1 | 1.3 |
| | Longitudinal Cracking - WP (m) | | 0.0 | 7.3 | 15.3 | 0.0 |
| | Longitudinal Cracking - NWP (m) | | 45.3 | 182.9 | 189.3 | 37.2 |
| | Transverse Cracking (m) | | 0.0 | 15.3 | 32.0 | 9.9 |
| 0102 | Alligator Cracking (sqm) | | 0.0 | 14.5 | 57.9 | 0.0 |
| | Longitudinal Cracking - WP (m) | | 5.0 | 226.5 | 96.9 | 0.0 |
| | Longitudinal Cracking - NWP (m) | | 91.0 | 152.4 | 165.0 | 25.9 |
| | Transverse Cracking (m) | | 0.0 | 65.6 | 69.4 | 47.6 |
| 0103 | Alligator Cracking (sqm) | | 0.0 | 5.3 | 5.4 | 2.2 |
| | Longitudinal Cracking - WP (m) | | 0.0 | 17.1 | 21.4 | 6.8 |
| | Longitudinal Cracking - NWP (m) | | 0.0 | 104.7 | 108.1 | 86.5 |
| | Transverse Cracking (m) | | 0.0 | 16.4 | 34.6 | 12.8 |
| 0104 | Alligator Cracking (sqm) | | 0.0 | 0.0 | 9.9 | 2.7 |
| | Longitudinal Cracking - WP (m) | | 34.1 | 58.0 | 48.1 | 0.0 |
| | Longitudinal Cracking - NWP (m) | | 0.0 | 107.8 | 219.9 | 88.7 |
| | Transverse Cracking (m) | | 3.6 | 33.9 | 55.8 | 25.7 |
| 0105 | Alligator Cracking (sqm) | | 0.0 | 0.0 | 2.1 | 0.7 |
| | Longitudinal Cracking - WP (m) | | 18.5 | 105.0 | 103.4 | 0.0 |
| | Longitudinal Cracking - NWP (m) | | 92.0 | 221.5 | 226.6 | 158.9 |
| | Transverse Cracking (m) | | 1.0 | 25.7 | 30.3 | 8.9 |
| 0106 | Alligator Cracking (sqm) | | 0.0 | 11.5 | 15.4 | 0.0 |
| | Longitudinal Cracking - WP (m) | | 14.4 | 7.6 | 32.7 | 3.0 |
| | Longitudinal Cracking - NWP (m) | | 16.3 | 73.5 | 140.7 | 75.0 |
| | Transverse Cracking (m) | | 0.0 | 48.0 | 62.3 | 26.5 |
| 0107 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 22.8 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 74.1 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 80.3 | 126.4 | 135.8 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0108 | Alligator Cracking (sqm) | | 0.0 | 17.5 | 18.3 | 0.0 |
| | Longitudinal Cracking - WP (m) | | 47.4 | 1.0 | 8.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | | 78.5 | 162.3 | 166.9 | 23.9 |
| | Transverse Cracking (m) | | 0.0 | 15.3 | 24.7 | 5.0 |
| 0109 | Alligator Cracking (sqm) | | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | | 12.0 | 8.0 | 9.2 | 0.0 |
| | Longitudinal Cracking - NWP (m) | | 48.0 | 229.9 | 295.6 | 154.1 |
| | Transverse Cracking (m) | | 0.0 | 11.1 | 16.0 | 0.0 |
| 0110 | Alligator Cracking (sqm) | | 0.0 | 1.6 | 2.1 | 0.0 |
| | Longitudinal Cracking - WP (m) | | 3.0 | 18.2 | 26.9 | 0.0 |
| | Longitudinal Cracking - NWP (m) | | 0.0 | 69.0 | 111.7 | 75.5 |
| | Transverse Cracking (m) | | 0.0 | 13.2 | 18.7 | 7.9 |
| 0111 | Alligator Cracking (sqm) | | 0.0 | 1.1 | 1.3 | 0.0 |
| | Longitudinal Cracking - WP (m) | | 0.0 | 4.9 | 6.1 | 0.0 |
| | Longitudinal Cracking - NWP (m) | | 0.0 | 231.2 | 266.8 | 129.8 |
| | Transverse Cracking (m) | | 0.0 | 11.3 | 19.4 | 5.9 |
| 0112 | Alligator Cracking (sqm) | | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | | 0.0 | 1.2 | 5.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | | 0.0 | 153.5 | 153.8 | 1.3 |
| | Transverse Cracking (m) | | 0.0 | 10.4 | 16.3 | 6.3 |

## Table A2- 17 Rutting Performance for Iowa (19)

| State 19 Rut Depth (mm) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Section ID | Age at time of data collection (years) | | | | | | |
| | 0 | 2 | 3 | 6 | 7 | 8 | 9 |
| 0101 | 3.0 | 4.0 | 7.0 | 5.0 | 7.0 | 5.0 | 4.5 |
| 0102 | 2.0 | 4.0 | 6.0 | 6.0 | 7.0 | 8.0 | 5.5 |
| 0103 | 2.0 | | 2.5 | 3.0 | 3.0 | 2.0 | 3.0 |
| 0104 | 1.0 | 2.0 | 2.5 | 2.0 | 4.0 | 3.0 | 3.5 |
| 0105 | 3.0 | | 5.0 | 5.0 | 5.0 | 6.0 | 3.5 |
| 0106 | 2.0 | 2.0 | 3.0 | 3.0 | 4.0 | 3.0 | 4.5 |
| 0107 | 6.7 | 5.0 | 5.5 | 6.0 | 6.0 | 6.0 | 6.0 |
| 0108 | 6.0 | 8.0 | 9.0 | 9.0 | 10.0 | 10.0 | 8.0 |
| 0109 | 4.0 | 5.0 | 6.5 | 5.0 | 5.0 | 6.0 | 6.5 |
| 0110 | 2.0 | | 3.5 | 4.0 | 4.0 | 4.0 | 3.5 |
| 0111 | 2.0 | | 3.5 | 4.0 | 3.0 | 4.0 | 2.5 |
| 0112 | 4.0 | | 4.0 | 4.0 | 5.0 | 4.0 | 3.0 |

Note: Rut depths are in mm

## Table A2- 18 Roughness Performance for Iowa (19)

| State 19 IRI (m/km) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Section ID | Age at time of data collection (years) | | | | | | | | |
| | 0 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 0101 | 1.19 | 1.34 | 1.49 | 1.55 | 1.65 | | | 1.91 | 1.83 |
| 0102 | 0.88 | 1.14 | 1.35 | 1.64 | 1.93 | 2.15 | 2.32 | 2.67 | 2.45 |
| 0103 | 0.71 | 0.81 | 1.02 | 1.02 | 1.08 | | | 1.44 | 1.40 |
| 0104 | 0.80 | 0.91 | 1.06 | 1.02 | 1.11 | | | 1.35 | 1.27 |
| 0105 | 1.03 | 1.13 | 1.34 | 1.34 | 1.37 | | | 1.56 | 1.46 |
| 0106 | 0.91 | 0.96 | 1.18 | 1.11 | 1.16 | 1.21 | 1.19 | 1.31 | 1.24 |
| 0107 | | 0.99 | 1.20 | 1.10 | 1.17 | 1.13 | 1.14 | 1.14 | 1.18 |
| 0108 | 0.79 | 0.81 | 1.00 | 1.21 | 1.39 | 1.50 | 1.56 | 1.69 | 1.65 |
| 0109 | 0.79 | 0.78 | 0.95 | 0.82 | 0.85 | 0.86 | 0.87 | 1.03 | 1.05 |
| 0110 | 0.96 | 1.08 | | 1.30 | 1.42 | 1.50 | 1.53 | 1.53 | 1.54 |
| 0111 | 0.82 | 0.87 | | 1.04 | 1.10 | 1.16 | 1.16 | 1.22 | 1.24 |
| 0112 | 0.73 | 0.83 | | 0.96 | 0.98 | 1.05 | 1.05 | 1.09 | 1.06 |

Note: IRI is in m/km

## Table A2- 19 Cracking Performance for Kansas (20)

| Section ID | Distress Type | Age at time of data collection (years) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 6 | 8 |
| 0101 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | | | |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | | | |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | | | |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | | | |
| 0102 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | | | |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | | | |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | | | |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | | | |
| 0103 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 97.4 | 133.0 | 132.5 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 4.0 | 2.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 3.1 | 44.4 | 72.4 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 4.3 | 6.6 | 16.8 |
| 0104 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 37.4 | 91.7 | |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 4.0 | |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 62.0 | 101.9 | |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 2.5 | |
| 0105 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 167.0 | 165.0 | 180.4 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 63.4 | 83.7 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 2.0 | 4.3 | 12.5 |
| 0106 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 116.6 | 104.7 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 18.4 | 26.6 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 2.1 | 14.9 |
| 0107 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | | | |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | | | |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | | | |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | | | |
| 0108 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 66.5 | 334.2 | 143.4 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 1.6 | 2.6 |
| 0109 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 87.9 | 277.6 | 30.5 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 16.6 | 11.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0110 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 29.7 | 228.8 | 204.7 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 104.2 | 188.8 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 3.6 | 9.5 |
| 0111 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 122.0 | 256.2 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 3.0 | 74.4 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 2.7 | 0.0 |
| 0112 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 34.0 | 195.3 | 49.4 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 44.8 | 7.7 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.1 |

### Table A2- 20 Rutting Performance for Kansas (20)

| State 20 Rut Depth (mm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Section ID | Age at time of data collection (years) | | | | | | | |
| | 0 | 1 | 2 | 3 | 6 | 7 | 8 | 9 |
| 0101 | 1.0 | 8.8 | 15.7 | | | | | |
| 0102 | 1.0 | 15.5 | 25.7 | | | | | |
| 0103 | 1.0 | 6.0 | 6.5 | 6.0 | 8.0 | 8.0 | 5.0 | 3.0 |
| 0104 | 1.0 | 4.5 | 5.7 | 5.0 | 5.0 | 6.0 | 3.5 | 3.0 |
| 0105 | 1.0 | 6.0 | 8.0 | 13.0 | 11.0 | 15.0 | 3.0 | 5.0 |
| 0106 | 1.0 | 4.5 | 5.3 | | 4.0 | 4.0 | 6.0 | 2.0 |
| 0107 | 1.0 | 11.0 | 16.3 | | | | | |
| 0108 | 1.0 | 6.0 | 7.0 | 7.0 | 7.0 | 8.0 | 4.5 | 2.0 |
| 0109 | 1.0 | 8.0 | 7.3 | 8.0 | 14.0 | 9.0 | 5.0 | 3.0 |
| 0110 | 1.0 | 8.0 | 7.3 | 6.0 | 8.0 | 8.0 | 4.0 | 3.0 |
| 0111 | 1.0 | 5.0 | 5.3 | 5.0 | 5.0 | 4.0 | 3.0 | 2.0 |
| 0112 | 1.0 | 5.0 | 4.7 | 5.0 | 5.0 | 4.0 | 3.0 | 3.0 |

Note: Rut depths are in mm

### Table A2- 21 Roughness Performance for Kansas (20)

| State 20 IRI (m/km) | | | | | | |
|---|---|---|---|---|---|---|
| Section ID | Age at time of data collection (years) | | | | | |
| | 1 | 2 | 3 | 5 | 6 | 8 |
| 0101 | 1.12 | 1.51 | | | | |
| 0102 | 1.34 | 1.57 | | | | |
| 0103 | 0.81 | 0.96 | 1.07 | 1.46 | 1.59 | 2.05 |
| 0104 | 0.79 | 0.89 | 0.87 | 0.96 | 1.00 | 1.04 |
| 0105 | 0.99 | 1.28 | 1.47 | 2.26 | 2.21 | 2.74 |
| 0106 | 0.79 | 0.92 | | 1.16 | 1.57 | 1.53 |
| 0107 | 0.75 | 1.11 | | | | |
| 0108 | 0.78 | 0.90 | | 1.35 | 1.40 | 1.53 |
| 0109 | 0.73 | 0.89 | 0.90 | 1.06 | 1.11 | 1.20 |
| 0110 | 0.66 | 0.76 | 0.75 | 0.84 | 0.84 | 0.89 |
| 0111 | 0.77 | 0.83 | 0.77 | 0.87 | 0.90 | 0.94 |
| 0112 | 0.84 | 0.84 | 0.80 | 0.87 | 0.84 | 0.93 |

Note: IRI is in m/km

## Table A2- 22 Cracking Performance for Louisiana (22)

| Section ID | Distress Type | Age at time of data collection (years) | |
|---|---|---|---|
| | | 1 | 2 |
| 0113 | Alligator Cracking (sqm) | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 |
| 0114 | Alligator Cracking (sqm) | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 |
| 0115 | Alligator Cracking (sqm) | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 |
| 0116 | Alligator Cracking (sqm) | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 |
| 0117 | Alligator Cracking (sqm) | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 |
| 0118 | Alligator Cracking (sqm) | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 |
| 0119 | Alligator Cracking (sqm) | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 |
| 0120 | Alligator Cracking (sqm) | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 |
| 0121 | Alligator Cracking (sqm) | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 |
| 0122 | Alligator Cracking (sqm) | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 |
| 0123 | Alligator Cracking (sqm) | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 |
| 0124 | Alligator Cracking (sqm) | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 |

## Table A2- 23 Rutting Performance for Louisiana (22)

| Section ID | Age at time of data collection (years) | | | |
|---|---|---|---|---|
| | 1 | 2 | 5 | 6 |
| 0113 | 3.0 | 4.0 | 5.0 | 4.0 |
| 0114 | 2.0 | 4.0 | 5.0 | 4.0 |
| 0115 | 2.0 | 4.0 | 6.0 | 5.0 |
| 0116 | 2.0 | 4.0 | 5.0 | 5.0 |
| 0117 | 3.0 | 5.5 | 8.0 | 6.0 |
| 0118 | 3.0 | 4.5 | 5.0 | 4.0 |
| 0119 | 2.0 | 3.5 | 4.0 | 3.0 |
| 0120 | 2.0 | 3.0 | 4.0 | 4.0 |
| 0121 | 1.0 | 2.5 | 4.0 | 4.0 |
| 0122 | 2.0 | 3.0 | 5.0 | 2.0 |
| 0123 | 2.0 | 3.5 | 5.0 | 3.0 |
| 0124 | 2.0 | 3.0 | 3.0 | 4.0 |

Note: Rut depths are in mm

## Table A2- 24 Roughness Performance for Louisiana (22)

| Section ID | Age at time of data collection (years) |
|---|---|
| | 0 |
| 0113 | 0.79 |
| 0114 | 0.59 |
| 0115 | 0.63 |
| 0116 | 0.64 |
| 0117 | 0.59 |
| 0118 | 0.73 |
| 0119 | 0.62 |
| 0120 | 0.60 |
| 0121 | 0.68 |
| 0122 | 0.59 |
| 0123 | 0.55 |
| 0124 | 0.70 |

Note: IRI is in m/km

## Table A2- 25 Cracking Performance for Michigan (26)

| Section ID | Distress Type | Age at time of data collection (years) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 3 | 4 | 5 | 6 | 7 |
| 0115 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 52.9 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 24.3 | 46.2 | 152.5 | 188.9 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0116 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 15.3 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 35.1 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0117 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 34.3 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 3.3 | 61.0 | 51.0 | 61.0 | 120.4 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0118 | Alligator Cracking (sqm) | 0.0 | 0.0 | | | | | |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | | | | | |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | | | | | |
| | Transverse Cracking (m) | 0.0 | 0.0 | | | | | |
| 0120 | Alligator Cracking (sqm) | 0.0 | 0.0 | | | | | |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | | | | | |
| | Longitudinal Cracking - NWP (m) | 0.0 | 50.2 | | | | | |
| | Transverse Cracking (m) | 0.0 | 0.0 | | | | | |
| 0121 | Alligator Cracking (sqm) | 0.0 | 0.0 | | | | | |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | | | | | |
| | Longitudinal Cracking - NWP (m) | 0.0 | 5.2 | | | | | |
| | Transverse Cracking (m) | 0.0 | 0.0 | | | | | |
| 0123 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 43.5 | 0.0 | 54.8 | 136.1 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0124 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 14.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 127.7 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

## Table A2- 26 Rutting Performance for Michigan (26)

| State 26 Rut Depth (mm) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Section ID | Age at time of data collection (years) | | | | | | |
| | 0 | 1 | 3 | 4 | 5 | 6 | 7 |
| 0115 | 1.0 | 4.0 | 6.0 | 7.0 | | 12.0 | 5.0 |
| 0116 | | 3.0 | 4.0 | 4.0 | 4.0 | 5.3 | 3.0 |
| 0117 | | 4.0 | 6.0 | 7.0 | 8.0 | 9.3 | 4.0 |
| 0118 | 1.0 | 4.0 | | | | 5.0 | |
| 0120 | 1.0 | 11.0 | | | | 6.0 | |
| 0121 | 2.0 | 7.0 | | | | 5.0 | |
| 0123 | 1.0 | 3.0 | 3.0 | 4.0 | 4.0 | 6.3 | 2.0 |
| 0124 | 1.0 | 3.0 | 4.0 | 5.0 | 4.0 | 6.3 | 2.0 |

Note: Rut depths are in mm

## Table A2- 27 Roughness Performance for Michigan (26)

| State 26 IRI (m/km) | | | | | | |
|---|---|---|---|---|---|---|
| Section ID | Age at time of data collection (years) | | | | | |
| | 0 | 1 | 2 | 3 | 4 | 7 |
| 0115 | | 0.72 | 0.74 | 0.82 | 0.86 | 0.88 |
| 0116 | | 0.55 | 0.58 | 0.62 | 0.66 | 0.63 |
| 0117 | | 0.77 | 0.80 | 1.21 | 1.31 | 1.17 |
| 0118 | | 0.94 | 0.98 | 1.18 | 1.30 | 1.42 |
| 0120 | | 0.98 | 2.25 | 0.94 | 1.03 | |
| 0121 | 1.10 | 1.14 | 1.28 | 1.08 | 1.24 | |
| 0123 | | 0.48 | 0.52 | 0.54 | 0.53 | 0.56 |
| 0124 | | 0.74 | 0.75 | 0.86 | 0.85 | 0.80 |

Note: IRI is in m/km

## Table A2- 28 Cracking Performance for Montana (30)

| Section ID | Distress Type | Age at time of data collection (years) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 |
| 0113 | Alligator Cracking (sqm) | 0.0 | 0.0 | 1.0 | 14.4 | 31.1 | 44.7 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 6.2 | 0.0 | 4.2 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 152.4 | 152.4 | 152.4 | 156.5 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.5 |
| 0114 | Alligator Cracking (sqm) | 0.0 | 0.0 | 5.5 | 11.2 | 34.3 | 46.6 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 56.4 | 12.7 | 0.4 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 107.9 | 166.3 | 168.5 | 175.8 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0115 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 23.1 | 26.5 | 64.5 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.6 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 152.4 | 152.4 | 161.1 | 170.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.5 |
| 0116 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.4 | 3.0 | 8.1 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 152.4 | 152.4 | 152.4 | 152.4 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0117 | Alligator Cracking (sqm) | 0.0 | 0.0 | 2.8 | 17.3 | 26.7 | 67.3 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 21.9 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 172.0 | 188.1 | 192.4 | 207.6 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | 1.9 |
| 0118 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.5 | 1.2 | 5.7 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.3 | 0.0 | 7.2 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 152.4 | 152.4 | 152.4 | 152.4 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0119 | Alligator Cracking (sqm) | 0.0 | 0.0 | 9.4 | 31.7 | 36.5 | 47.8 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 4.6 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 154.4 | 158.4 | 162.5 | 168.7 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.7 |
| 0120 | Alligator Cracking (sqm) | 0.0 | 0.0 | 45.4 | 89.1 | 91.4 | 122.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 152.4 | 152.4 | 152.4 | 152.5 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 |
| 0121 | Alligator Cracking (sqm) | 0.0 | 0.0 | 44.9 | 46.5 | 76.5 | 107.6 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 167.0 | 163.1 | 160.3 | 168.2 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 1.3 | 2.7 | 12.5 |
| 0122 | Alligator Cracking (sqm) | 0.0 | 0.0 | 5.3 | 69.1 | 82.6 | 117.9 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 29.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 152.4 | 152.4 | 152.4 | 152.5 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0123 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 15.7 | 16.1 | 22.6 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.5 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 157.3 | 166.2 | 174.2 | 180.5 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.3 |
| 0124 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.6 | 4.3 | 8.0 | 14.8 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 3.3 | 5.3 | 1.4 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 152.4 | 152.4 | 152.4 | 166.7 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

## Table A2- 29 Rutting Performance for Montana (30)

| Section ID | Age at time of data collection (years) | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 |
| 0113 | 1.0 | 2.0 | 3.0 | 3.5 | 5.0 | 5.0 |
| 0114 | 1.0 | 1.0 | 2.0 | 2.3 | 2.0 | 3.0 |
| 0115 | 1.0 | 2.0 | 2.0 | 3.0 | 3.0 | 3.0 |
| 0116 | 1.0 | 2.0 | 2.0 | 3.0 | 3.0 | 3.0 |
| 0117 | 2.0 | 2.0 | 2.0 | 3.0 | 3.0 | 3.0 |
| 0118 | 2.0 | 2.0 | 2.0 | 2.5 | 3.0 | 3.0 |
| 0119 | 2.0 | 2.0 | 3.0 | 3.0 | 3.0 | 4.0 |
| 0120 | 2.0 | 4.0 | 5.0 | 5.5 | 7.0 | 8.0 |
| 0121 | 1.0 | 4.0 | 6.0 | 6.5 | 7.0 | 8.0 |
| 0122 | 1.0 | 2.0 | 4.0 | 4.5 | 4.0 | 5.0 |
| 0123 | 2.0 | 2.0 | 2.0 | 3.5 | 3.0 | 4.0 |
| 0124 | 1.0 | 2.0 | 2.0 | 2.5 | 2.0 | 3.0 |

Note: Rut depths are in mm

## Table A2- 30 Roughness Performance for Montana (30)

| Section ID | Age at time of data collection (years) | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 |
| 0113 | 0.69 | 0.71 | 0.72 | 0.74 | 0.77 | 0.97 |
| 0114 | 0.73 | 0.73 | 0.73 | 0.74 | 0.76 | 0.84 |
| 0115 | 0.72 | 0.74 | 0.75 | 0.71 | 0.75 | 0.80 |
| 0116 | 0.72 | 0.72 | 0.72 | 0.69 | 0.72 | 0.77 |
| 0117 | 0.66 | 0.65 | 0.64 | 0.65 | 0.69 | 0.91 |
| 0118 | 0.55 | 0.56 | 0.57 | 0.57 | 0.59 | 0.62 |
| 0119 | 1.01 | 0.99 | 0.99 | 0.96 | 0.98 | 1.05 |
| 0120 | 1.18 | 1.19 | 1.23 | 1.24 | 1.27 | 1.60 |
| 0121 | 1.20 | 1.20 | 1.22 | 1.28 | 1.26 | 1.50 |
| 0122 | 0.74 | 0.74 | 0.71 | 0.72 | 0.79 | 1.08 |
| 0123 | 0.76 | 0.77 | 0.77 | 0.80 | 0.82 | 0.89 |
| 0124 | 0.76 | 0.77 | 0.76 | 0.75 | 0.78 | 0.81 |

Note: IRI is in m/km

## Table A2- 31 Cracking Performance for Nebraska (31)

| Section ID | Distress Type | Age at time of data collection (years) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 0113 | Alligator Cracking (sqm) | 0.0 | | | | 14.4 | | | |
| | Longitudinal Cracking - WP (m) | 0.0 | | | | 96.8 | | | |
| | Longitudinal Cracking - NWP (m) | 0.0 | | | | 0.0 | | | |
| | Transverse Cracking (m) | 0.0 | | | | 0.0 | | | |
| 0114 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.8 | 12.9 | 0.0 | 0.1 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.5 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 13.3 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0115 | Alligator Cracking (sqm) | 0.0 | | | | 0.0 | | | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | | | | 0.0 | | | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | | | | 0.0 | | | 0.0 |
| | Transverse Cracking (m) | 0.0 | | | | 0.0 | | | 0.0 |
| 0116 | Alligator Cracking (sqm) | 0.0 | | | | 0.0 | | | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | | | | 0.0 | | | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | | | | 0.0 | | | 0.0 |
| | Transverse Cracking (m) | 0.0 | | | | 0.0 | | | 0.0 |
| 0117 | Alligator Cracking (sqm) | 0.0 | | | | 0.0 | | | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | | | | 0.0 | | | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | | | | 0.0 | | | 0.0 |
| | Transverse Cracking (m) | 0.0 | | | | 0.0 | | | 0.0 |
| 0118 | Alligator Cracking (sqm) | 0.0 | | | | 0.0 | | | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | | | | 0.0 | | | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | | | | 0.0 | | | 0.0 |
| | Transverse Cracking (m) | 0.0 | | | | 0.0 | | | 0.0 |
| 0119 | Alligator Cracking (sqm) | 0.0 | | | | 0.0 | | | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | | | | 0.0 | | | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | | | | 0.0 | | | 0.0 |
| | Transverse Cracking (m) | 0.0 | | | | 0.0 | | | 0.0 |
| 0120 | Alligator Cracking (sqm) | 0.0 | | | | 0.0 | | | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | | | | 0.0 | | | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | | | | 0.0 | | | 0.0 |
| | Transverse Cracking (m) | 0.0 | | | | 0.0 | | | 0.0 |
| 0121 | Alligator Cracking (sqm) | 0.0 | | | | 0.0 | | | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | | | | 0.0 | | | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | | | | 0.0 | | | 0.0 |
| | Transverse Cracking (m) | 0.0 | | | | 0.0 | | | 0.0 |
| 0122 | Alligator Cracking (sqm) | 0.0 | | | | 0.0 | | | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | | | | 0.0 | | | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | | | | 0.0 | | | 0.0 |
| | Transverse Cracking (m) | 0.0 | | | | 0.0 | | | 0.0 |
| 0123 | Alligator Cracking (sqm) | 0.0 | | | | 0.0 | | | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | | | | 0.0 | | | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | | | | 0.0 | | | 0.0 |
| | Transverse Cracking (m) | 0.0 | | | | 0.0 | | | 0.0 |
| 0124 | Alligator Cracking (sqm) | 0.0 | | | | 0.0 | | | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | | | | 0.0 | | | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | | | | 0.0 | | | 0.0 |
| | Transverse Cracking (m) | 0.0 | | | | 0.0 | | | 0.0 |

## Table A2- 32 Rutting Performance for Nebraska (31)

| Section ID | Age at time of data collection (years) | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 1 | 4 | 5 | 6 | 7 |
| 0113 | 1.0 | 8.0 | 28.0 | 29.0 | | |
| 0114 | 1.0 | 6.0 | 20.0 | 15.7 | 8.5 | 13.0 |
| 0115 | 1.0 | 5.5 | 22.0 | 22.0 | 14.0 | 15.0 |
| 0116 | 1.0 | 6.0 | 15.0 | 18.0 | 6.0 | 6.0 |
| 0117 | 1.0 | 4.5 | 18.0 | 18.0 | 5.0 | 7.0 |
| 0118 | 1.0 | 7.0 | 15.0 | 17.0 | 8.0 | 11.0 |
| 0119 | 1.0 | 4.0 | 13.0 | 14.0 | 4.0 | 5.0 |
| 0120 | 1.0 | 7.0 | 12.0 | 13.0 | 7.0 | 8.0 |
| 0121 | 1.0 | 3.5 | 11.0 | 14.0 | 4.0 | 5.0 |
| 0122 | 1.0 | 5.0 | 14.0 | 15.0 | 4.0 | 5.0 |
| 0123 | 2.0 | 6.5 | 24.0 | 25.0 | 16.0 | 15.0 |
| 0124 | 1.0 | 5.5 | 20.0 | 23.0 | 12.0 | 15.0 |

Note: Rut depths are in mm

## Table A2- 33 Roughness Performance for Nebraska (31)

| Section ID | Age at time of data collection (years) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 0113 | 1.44 | 1.80 | 1.80 | 1.95 | 1.81 | 1.88 | | |
| 0114 | 1.10 | 1.22 | 1.28 | 1.35 | 1.41 | 1.41 | 1.13 | 1.06 |
| 0115 | 1.07 | 1.19 | 1.02 | 1.05 | 1.08 | 1.11 | 1.09 | 1.03 |
| 0116 | 1.06 | 1.20 | 1.23 | 1.23 | 1.24 | 1.29 | 1.09 | 1.05 |
| 0117 | 1.12 | 1.28 | 1.03 | 1.09 | 1.06 | 1.09 | 1.11 | 0.89 |
| 0118 | 1.14 | 1.30 | 1.32 | 1.33 | 1.31 | 1.31 | 1.08 | 0.93 |
| 0119 | 1.23 | 1.37 | 1.31 | 1.31 | 1.30 | 1.34 | 1.20 | 1.00 |
| 0120 | 1.26 | 1.38 | 1.31 | 1.39 | 1.35 | 1.38 | 1.21 | 1.10 |
| 0121 | 1.21 | 1.32 | 1.28 | 1.35 | 1.43 | 1.49 | 1.37 | 1.25 |
| 0122 | 1.12 | 1.37 | 1.43 | 1.42 | 1.39 | 1.43 | 1.18 | 1.14 |
| 0123 | 0.91 | 1.06 | 1.01 | 1.09 | 1.00 | 0.98 | 0.93 | 0.78 |
| 0124 | 1.01 | 1.16 | 1.01 | 1.05 | 1.02 | 1.08 | 1.09 | 0.92 |

Note: IRI is in m/km

**Table A2- 34 Cracking Performance for Nevada (32)**

| Section ID | Distress Type | Age at time of data collection (years) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 0101 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 1.2 | 0.7 | 1.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 7.3 | 0.3 | 0.2 | 0.0 | 3.7 | 3.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 3.2 | 6.5 | 20.5 | 34.1 | 33.7 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.3 | 0.8 |
| 0102 | Alligator Cracking (sqm) | 0.0 | | 12.0 | 10.4 | 0.0 | 0.9 | 4.2 | 9.7 |
| | Longitudinal Cracking - WP (m) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 2.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | | 0.0 | 0.0 | 5.0 | 10.0 | 13.6 | 21.2 |
| | Transverse Cracking (m) | 0.0 | | 0.0 | 0.0 | 2.7 | 2.7 | 5.1 | 14.8 |
| 0103 | Alligator Cracking (sqm) | 0.0 | | 0.0 | 0.0 | 33.8 | 16.5 | 0.0 | 0.9 |
| | Longitudinal Cracking - WP (m) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 1.7 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 56.2 | 65.4 |
| | Transverse Cracking (m) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 | 0.0 |
| 0104 | Alligator Cracking (sqm) | 0.0 | | 0.0 | 5.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | | 18.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | | 0.0 | 0.0 | 7.2 | 12.5 | 29.8 | 35.3 |
| | Transverse Cracking (m) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.9 |
| 0105 | Alligator Cracking (sqm) | 0.0 | | 0.1 | 0.4 | 16.4 | 10.4 | 0.0 | 1.3 |
| | Longitudinal Cracking - WP (m) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 1.5 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 20.4 | 23.9 |
| | Transverse Cracking (m) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0106 | Alligator Cracking (sqm) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 |
| | Longitudinal Cracking - WP (m) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 1.3 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | | 0.0 | 0.0 | 0.0 | 3.9 | 4.5 | 7.7 |
| | Transverse Cracking (m) | 0.0 | | 0.0 | 0.0 | 0.0 | 1.2 | 1.0 | 1.3 |
| 0107 | Alligator Cracking (sqm) | 0.0 | | 0.1 | 0.4 | 0.0 | 0.5 | 0.0 | 0.7 |
| | Longitudinal Cracking - WP (m) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 3.6 | 1.4 |
| | Longitudinal Cracking - NWP (m) | 0.0 | | 0.0 | 1.5 | 1.8 | 2.5 | 5.2 | 8.7 |
| | Transverse Cracking (m) | 0.0 | | 0.0 | 0.6 | 1.6 | 0.0 | 8.3 | 11.5 |
| 0108 | Alligator Cracking (sqm) | 0.0 | | 0.0 | 0.0 | 8.1 | 5.2 | 0.0 | 0.2 |
| | Longitudinal Cracking - WP (m) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 6.6 | 11.3 |
| | Transverse Cracking (m) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.6 | 1.0 | 4.7 |
| 0109 | Alligator Cracking (sqm) | 0.0 | | 0.0 | 0.0 | 32.0 | 1.9 | 0.0 | 0.6 |
| | Longitudinal Cracking - WP (m) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 3.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | | 1.0 | 0.0 | 0.0 | 5.6 | 20.9 | 22.9 |
| | Transverse Cracking (m) | 0.0 | | 0.0 | 0.0 | 0.0 | 4.2 | 0.6 | 5.5 |
| 0110 | Alligator Cracking (sqm) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 |
| | Longitudinal Cracking - WP (m) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | | 0.0 | 0.0 | 0.0 | 6.2 | 8.9 | 11.0 |
| | Transverse Cracking (m) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.7 | 1.8 | 2.3 |
| 0111 | Alligator Cracking (sqm) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.5 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 1.9 | 2.2 |
| | Transverse Cracking (m) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0112 | Alligator Cracking (sqm) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.5 |
| | Transverse Cracking (m) | 0.0 | | 0.0 | 0.0 | 0.0 | 1.1 | 1.1 | 1.1 |

### Table A2- 35 Rutting Performance for Nevada (32)

| Section ID | Age at time of data collection (years) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 0101 | 2.2 | 1.7 | 2.0 | 3.7 | 4.5 | 3.3 | 2.8 | 2.5 |
| 0102 | 3.5 | | 4.0 | 5.0 | 5.0 | 4.5 | 4.5 | 5.0 |
| 0103 | 3.0 | | 5.0 | 5.0 | 4.5 | 4.5 | 4.5 | 5.0 |
| 0104 | 2.0 | | 2.0 | 4.0 | 3.0 | 3.0 | 2.5 | 2.0 |
| 0105 | 3.5 | | 5.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| 0106 | 2.5 | | 3.0 | 6.0 | 4.0 | 4.0 | 4.0 | 3.0 |
| 0107 | 3.0 | | 3.0 | 4.0 | 4.5 | 4.5 | 4.0 | 4.0 |
| 0108 | 3.3 | | 3.0 | 5.0 | 4.0 | 4.5 | 4.0 | 4.0 |
| 0109 | 4.0 | | 2.0 | 6.0 | 5.5 | 5.5 | 4.0 | 3.0 |
| 0110 | 4.0 | | 5.0 | 5.0 | 4.5 | 5.0 | 4.0 | 4.0 |
| 0111 | 3.5 | | 4.0 | 6.0 | 4.5 | 5.5 | 4.5 | 5.0 |
| 0112 | 3.5 | | 5.0 | 6.0 | 5.0 | 5.0 | 5.0 | 5.0 |

Note: Rut depths are in mm

### Table A2- 36 Roughness Performance for Nevada (32)

| Section ID | Age at time of data collection (years) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 0101 | 0.83 | 0.82 | 0.84 | 0.81 | 0.81 | 0.81 | 0.80 | 0.79 |
| 0102 | | 0.68 | 0.74 | 0.92 | 0.91 | 1.17 | 0.96 | 1.40 |
| 0103 | | 0.73 | 0.74 | 0.75 | 0.73 | 0.73 | 0.72 | 0.70 |
| 0104 | | 0.67 | 0.67 | 0.66 | 0.64 | 0.64 | 0.65 | 0.65 |
| 0105 | | 0.73 | 0.73 | 0.72 | 0.70 | 0.71 | 0.70 | 0.70 |
| 0106 | | 0.66 | 0.68 | 0.67 | 0.66 | 0.66 | 0.65 | 0.65 |
| 0107 | | 0.81 | 0.81 | 0.80 | 0.78 | 0.80 | 0.82 | 0.89 |
| 0108 | | 0.70 | 0.70 | 0.70 | 0.68 | 0.68 | 0.67 | 0.68 |
| 0109 | | 0.65 | 0.65 | 0.64 | 0.63 | 0.63 | 0.63 | 0.61 |
| 0110 | | 0.66 | 0.66 | 0.67 | 0.65 | 0.66 | 0.66 | 0.65 |
| 0111 | | 0.72 | 0.72 | 0.72 | 0.70 | 0.70 | 0.69 | 0.68 |
| 0112 | | 0.73 | 0.76 | 0.74 | 0.73 | 0.74 | 0.73 | 0.73 |

Note: IRI is in m/km

### Table A2- 37 Cracking Performance for New Mexico (35)

| Section ID | Distress Type | Age at time of data collection (years) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 2 | 3 | 5 | 6 | 7 | 8 |
| 0101 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 5.2 | 29.4 | | 42.1 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 1.2 | | 12.8 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 |
| 0102 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.7 | 1.8 | 1.8 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 6.0 | 35.1 | 58.9 | 69.2 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 7.3 | 5.4 | 5.4 | 14.5 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 |
| 0103 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 11.0 | 12.5 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 3.6 | 6.5 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0104 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 1.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 1.7 | 2.8 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0105 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 3.0 | 10.0 | 29.1 | 34.8 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 2.5 | 8.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0106 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 3.5 | 3.5 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0107 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 22.6 | 33.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 6.0 | 7.4 | 17.0 | 23.6 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0108 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0109 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0110 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0111 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0112 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

## Table A2- 38 Rutting Performance for New Mexico (35)

| Section ID | Age at time of data collection (years) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 0101 | 5.0 | 6.0 | 7.0 | 6.0 | 6.3 | 8.0 | 7.0 |
| 0102 | 5.0 | 6.0 | 6.0 | 6.0 | 6.5 | 6.0 | 7.0 |
| 0103 | 5.0 | 7.0 | 7.0 | 7.0 | 7.0 | 6.0 | 7.0 |
| 0104 | 6.0 | 7.0 | 8.0 | 7.0 | 7.5 | 6.5 | 7.0 |
| 0105 | 6.0 | 6.0 | 6.0 | 6.0 | 7.0 | 5.5 | 7.0 |
| 0106 | 5.0 | 6.0 | 5.0 | 5.0 | 6.5 | 5.5 | 7.0 |
| 0107 | 5.0 | 5.0 | 6.0 | 7.0 | 6.5 | 5.5 | 7.0 |
| 0108 | 6.0 | 6.0 | 6.0 | 7.0 | 7.0 | 6.5 | 8.0 |
| 0109 | 6.0 | 6.0 | 5.0 | 7.0 | 7.0 | 7.0 | 8.0 |
| 0110 | 5.0 | 6.0 | 6.0 | 7.0 | 6.5 | 6.5 | 8.0 |
| 0111 | 5.0 | 6.0 | 4.0 | 6.0 | 6.0 | 5.5 | 7.0 |
| 0112 | 5.0 | 7.0 | 7.0 | 6.0 | 7.0 | 6.0 | 7.0 |

Note: Rut depths are in mm

## Table A2- 39 Roughness Performance for New Mexico (35)

| Section ID | Age at time of data collection (years) | | | |
|---|---|---|---|---|
| | 1 | 5 | 6 | 7 |
| 0101 | 0.59 | 0.71 | 0.85 | 1.08 |
| 0102 | 0.67 | 0.87 | 1.00 | 1.25 |
| 0103 | 0.64 | 0.78 | 0.88 | 1.34 |
| 0104 | 0.56 | 0.67 | 0.72 | 0.85 |
| 0105 | 0.57 | 0.64 | 0.70 | 0.93 |
| 0106 | 0.58 | 0.71 | 0.84 | 0.99 |
| 0107 | 0.67 | 0.84 | 0.88 | 1.23 |
| 0108 | 0.83 | 0.82 | 0.85 | 0.98 |
| 0109 | 0.59 | 0.63 | 0.70 | 0.85 |
| 0110 | 0.62 | 0.61 | 0.62 | 0.74 |
| 0111 | 0.48 | 0.58 | 0.61 | 0.73 |
| 0112 | 0.69 | 0.88 | 0.89 | 1.25 |

Note: IRI is in m/km

## Table A2- 40 Cracking Performance for Ohio (39)

| Section ID | Distress Type | Age at time of data collection (years) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 7 |
| 0101 | Alligator Cracking (sqm) | 0.0 | | | | | |
| | Longitudinal Cracking - WP (m) | 0.0 | | | | | |
| | Longitudinal Cracking - NWP (m) | 0.0 | | | | | |
| | Transverse Cracking (m) | 0.0 | | | | | |
| 0102 | Alligator Cracking (sqm) | 0.0 | | | | | |
| | Longitudinal Cracking - WP (m) | 0.0 | | | | | |
| | Longitudinal Cracking - NWP (m) | 0.0 | | | | | |
| | Transverse Cracking (m) | 0.0 | | | | | |
| 0103 | Alligator Cracking (sqm) | 0.0 | 0.0 | | 0.0 | 32.6 | |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | | 29.8 | 174.3 | |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | | 152.4 | 267.8 | |
| | Transverse Cracking (m) | 0.0 | 0.0 | | 0.0 | 0.0 | |
| 0104 | Alligator Cracking (sqm) | 0.0 | | | 0.0 | 0.0 | 15.2 |
| | Longitudinal Cracking - WP (m) | 0.0 | | | 0.0 | 90.6 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | | | 0.0 | 206.8 | 204.0 |
| | Transverse Cracking (m) | 0.0 | | | 0.0 | 0.0 | 0.0 |
| 0105 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | | | |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | | | |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | | | |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | | | |
| 0106 | Alligator Cracking (sqm) | 0.0 | 0.0 | | 0.0 | 17.7 | 62.8 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | | 9.5 | 201.6 | 223.4 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | | 4.1 | 155.5 | 226.1 |
| | Transverse Cracking (m) | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 |
| 0107 | Alligator Cracking (sqm) | 0.0 | | | | | |
| | Longitudinal Cracking - WP (m) | 0.0 | | | | | |
| | Longitudinal Cracking - NWP (m) | 0.0 | | | | | |
| | Transverse Cracking (m) | 0.0 | | | | | |
| 0108 | Alligator Cracking (sqm) | 0.0 | 0.0 | | 0.0 | 66.4 | |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | | 1.6 | 195.5 | |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | | 0.0 | 228.7 | |
| | Transverse Cracking (m) | 0.0 | 0.0 | | 0.0 | 0.0 | |
| 0109 | Alligator Cracking (sqm) | 0.0 | 0.0 | | 0.0 | 0.0 | |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | | 2.0 | 244.1 | |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | | 0.0 | 38.4 | |
| | Transverse Cracking (m) | 0.0 | 0.0 | | 0.0 | 0.0 | |
| 0110 | Alligator Cracking (sqm) | 0.0 | 0.0 | | 0.0 | 31.2 | |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | | 0.9 | 211.5 | |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | | 0.0 | 0.0 | |
| | Transverse Cracking (m) | 0.0 | 0.0 | | 0.0 | 0.0 | |
| 0111 | Alligator Cracking (sqm) | 0.0 | | | 0.0 | 0.0 | 28.5 |
| | Longitudinal Cracking - WP (m) | 0.0 | | | 3.6 | 106.0 | 13.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | | | 0.0 | 183.1 | 67.3 |
| | Transverse Cracking (m) | 0.0 | | | 0.0 | 0.0 | 0.0 |
| 0112 | Alligator Cracking (sqm) | 0.0 | | | 0.0 | 0.0 | 20.5 |
| | Longitudinal Cracking - WP (m) | 0.0 | | | 3.5 | 107.5 | 37.8 |
| | Longitudinal Cracking - NWP (m) | 0.0 | | | 0.0 | 121.6 | 44.9 |
| | Transverse Cracking (m) | 0.0 | | | 0.0 | 0.0 | 0.0 |

## Table A2- 41 Rutting Performance for Ohio (39)

| Section ID | Age at time of data collection (years) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 0101 | 11.5 | | | | | | |
| 0102 | 13.3 | | | | | | |
| 0103 | 2.0 | 3.0 | | 7.0 | 8.5 | 11.0 | |
| 0104 | 3.0 | | | 4.0 | 4.0 | 5.0 | 4.0 |
| 0105 | 4.0 | 8.0 | 8.0 | | | | |
| 0106 | 3.0 | 2.0 | | 2.0 | 3.0 | 4.0 | 3.0 |
| 0107 | 6.7 | | | | | | |
| 0108 | 4.0 | 4.0 | | 10.0 | 10.5 | 12.0 | |
| 0109 | 3.0 | 2.0 | | 9.0 | 10.0 | 9.0 | |
| 0110 | 3.0 | 2.0 | | 4.0 | 4.0 | 4.0 | |
| 0111 | 2.5 | | | 5.0 | 4.0 | 5.0 | 4.0 |
| 0112 | 4.5 | | | 6.0 | 5.5 | 6.0 | 6.0 |

Note: Rut depths are in mm

## Table A2- 42 Roughness Performance for Ohio (39)

| Section ID | Age at time of data collection (years) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 0101 | 2.75 | | | | | | |
| 0102 | 2.23 | | | | | | |
| 0103 | 1.73 | 2.08 | 2.71 | 2.78 | 2.78 | 3.07 | |
| 0104 | 0.79 | 1.01 | 1.21 | 1.29 | 1.31 | 1.42 | 1.37 |
| 0105 | 1.43 | 2.08 | | | | | |
| 0106 | 1.18 | 1.60 | 1.75 | 1.78 | 1.78 | 1.84 | 1.81 |
| 0107 | 1.53 | | | | | | |
| 0108 | 1.05 | 1.38 | 1.88 | 1.98 | 1.98 | 2.13 | |
| 0109 | 0.77 | 0.86 | 1.47 | 1.58 | 1.60 | 1.69 | |
| 0110 | 1.26 | 1.40 | 1.60 | 1.65 | 1.68 | 1.78 | |
| 0111 | 0.83 | 1.24 | 1.27 | 1.35 | 1.36 | 1.45 | 1.36 |
| 0112 | 0.93 | 1.13 | 1.40 | 1.50 | 1.52 | 1.59 | 1.50 |

Note: IRI is in m/km

## Table A2- 43 Cracking Performance for Oklahoma (40)

| Section ID | Distress Type | Age at time of data collection (years) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0 | 2 | 3 | 4 | 5 | 6 |
| 0113 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.7 | 1.4 | 2.7 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 |
| 0114 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 3.9 | 12.6 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 24.6 | 39.2 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0115 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 27.3 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 2.2 | 3.8 | 3.8 | 3.8 |
| 0116 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 1.0 | 2.9 | 5.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 4.5 | 62.2 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0117 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 16.9 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0118 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 1.7 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 1.0 | 29.2 | 76.7 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0119 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.8 | 3.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 14.5 | 59.5 | 121.1 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0120 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 5.9 | 9.7 | 10.8 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 27.0 | 69.7 | 87.8 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0121 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 5.0 | 9.2 | 17.2 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 32.1 | 58.9 | 72.2 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.8 |
| 0122 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 1.4 | 4.0 | 8.4 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 56.5 | 84.5 | 94.2 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0123 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 3.2 | 7.7 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 8.0 | 91.3 | 118.3 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0124 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 1.2 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 4.0 | 34.5 | 80.1 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

### Table A2- 44 Rutting Performance for Oklahoma (40)

| Section ID | Age at time of data collection (years) | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 2 | 3 | 4 | 5 | 6 |
| 0113 | 6.5 | 9.0 | 11.5 | 12.0 | 10.5 | 14.0 |
| 0114 | 1.5 | 4.0 | 4.0 | 4.5 | 4.0 | 5.0 |
| 0115 | 4.0 | 6.5 | 6.5 | 8.0 | 7.0 | 8.0 |
| 0116 | 3.0 | 5.0 | 5.0 | 5.5 | 5.0 | 5.0 |
| 0117 | 8.0 | 9.5 | 9.5 | 10.0 | 9.5 | 12.0 |
| 0118 | 2.0 | 3.5 | 3.5 | 3.5 | 3.0 | 4.0 |
| 0119 | 3.0 | 5.0 | 5.0 | 5.0 | 4.5 | 5.0 |
| 0120 | 4.0 | 6.0 | 6.0 | 5.5 | 6.0 | 7.0 |
| 0121 | 4.0 | 6.0 | 5.0 | 5.5 | 5.5 | 6.0 |
| 0122 | 4.5 | 7.0 | 8.0 | 8.0 | 9.0 | 10.0 |
| 0123 | 3.0 | 4.5 | 4.5 | 4.5 | 5.0 | 5.0 |
| 0124 | 2.0 | 4.5 | 4.5 | 4.5 | 4.5 | 5.0 |

Note: Rut depths are in mm

### Table A2- 45 Roughness Performance for Oklahoma (40)

| Section ID | Age at time of data collection (years) | | | |
|---|---|---|---|---|
| | 0 | 2 | 4 | 5 |
| 0113 | 1.06 | 1.15 | 1.20 | 1.18 |
| 0114 | 0.96 | 1.01 | 1.04 | 1.03 |
| 0115 | 1.12 | 1.15 | 1.14 | 1.17 |
| 0116 | 1.03 | 1.03 | 1.03 | 1.03 |
| 0117 | 1.05 | 1.10 | 1.07 | 1.10 |
| 0118 | 0.94 | 0.99 | 1.11 | 1.00 |
| 0119 | 0.84 | 0.84 | 0.96 | 0.83 |
| 0120 | 0.75 | 0.80 | 0.97 | 0.78 |
| 0121 | 0.89 | 0.92 | 0.95 | 0.87 |
| 0122 | 0.90 | 0.95 | 1.08 | 0.95 |
| 0123 | 0.77 | 0.80 | 1.01 | 0.79 |
| 0124 | 0.91 | 0.95 | 1.04 | 0.93 |

Note: IRI is in m/km

## Table A2- 46 Cracking Performance for Texas (48)

| Section ID | Distress Type | Age at time of data collection (years) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 |
| 0113 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.8 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 46.4 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 4.0 | 21.1 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0114 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 13.8 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0115 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 6.6 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0116 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0117 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.9 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 7.7 | 33.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 3.5 | 35.8 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0118 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.5 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 159.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 9.3 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0119 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 54.4 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0120 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 12.9 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0121 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 12.9 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0122 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.8 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 11.1 | 20.2 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 2.0 | 77.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0123 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0124 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.4 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

### Table A2- 47 Rutting Performance for Texas (48)

| Section ID | Age at time of data collection (years) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| 0113 | 8.0 | 8.0 | 6.0 | 8.0 | 8.0 | 6.5 | 3.0 |
| 0114 | 9.0 | 10.0 | 11.0 | 14.0 | 13.5 | 8.5 | 2.0 |
| 0115 | 14.0 | 16.0 | 19.0 | 23.0 | 24.5 | 14.5 | 5.0 |
| 0116 | 16.0 | 18.0 | 21.0 | 26.0 | 26.5 | 16.0 | 3.0 |
| 0117 | 6.0 | 7.0 | 6.0 | 8.0 | 6.5 | 5.5 | 2.0 |
| 0118 | 9.0 | 9.0 | 10.0 | 11.0 | 10.5 | 6.0 | 3.0 |
| 0119 | 10.0 | 11.0 | 8.0 | 12.0 | 11.5 | 8.0 | 2.0 |
| 0120 | 9.0 | 9.0 | 9.0 | 11.0 | 11.5 | 7.0 | 3.0 |
| 0121 | 7.0 | 8.0 | 9.0 | 10.0 | 10.5 | 7.0 | 3.0 |
| 0122 | 7.0 | 7.0 | 6.0 | 8.0 | 6.5 | 4.5 | 3.0 |
| 0123 | 12.0 | 13.0 | 13.0 | 14.0 | 14.0 | 9.5 | 2.0 |
| 0124 | 14.0 | 15.0 | 18.0 | 20.0 | 21.5 | 11.5 | 2.0 |

Note: Rut depths are in mm

### Table A2- 48 Roughness Performance for Texas (48)

| Section ID | Age at time of data collection (years) | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 6 |
| 0113 | 1.03 | 1.09 | 1.07 | 1.06 | 1.12 | 1.00 |
| 0114 | 0.81 | 0.90 | 0.88 | 0.84 | 0.88 | 0.96 |
| 0115 | 0.88 | 1.00 | 1.28 | 1.16 | 1.22 | 1.19 |
| 0116 | 1.09 | 1.07 | 1.77 | 1.58 | 1.65 | 0.96 |
| 0117 | 0.71 | 0.73 | 0.74 | 0.74 | 0.75 | 1.02 |
| 0118 | 0.87 | 0.86 | 0.92 | 0.92 | 0.84 | 1.15 |
| 0119 | 0.81 | 0.85 | 1.32 | 1.23 | 1.13 | 1.00 |
| 0120 | 0.77 | 0.85 | 0.85 | 0.76 | 1.06 | 1.10 |
| 0121 | 0.76 | 0.88 | 0.92 | 0.84 | 1.13 | 1.00 |
| 0122 | 0.73 | 0.80 | 0.76 | 0.75 | 0.79 | 0.98 |
| 0123 | 0.85 | 0.88 | 0.85 | 0.82 | 0.88 | 0.97 |
| 0124 | 0.85 | 1.05 | 0.94 | 0.86 | 0.96 | 0.84 |

Note: IRI is in m/km

## Table A2- 49 Cracking Performance for Virginia (51)

| Section ID | Distress Type | Age at time of data collection (years) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| 0113 | Alligator Cracking (sqm) | 0.0 | 0.0 | 19.6 | 128.6 | 297.9 | 309.1 | |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.6 | 15.3 | 0.0 | 0.0 | |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.6 | 0.0 | 0.0 | 0.0 | |
| 0114 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.6 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | 40.1 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0115 | Alligator Cracking (sqm) | 0.0 | 0.0 | | 0.0 | 0.0 | | |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | | 0.0 | 0.0 | | |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | | 0.0 | 0.0 | | |
| | Transverse Cracking (m) | 0.0 | 0.0 | | 0.0 | 0.0 | | |
| 0116 | Alligator Cracking (sqm) | 0.0 | 0.0 | | 0.0 | 0.0 | | |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | | 0.0 | 0.0 | | |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | | 0.0 | 0.0 | | |
| | Transverse Cracking (m) | 0.0 | 0.0 | | 0.0 | 0.0 | | |
| 0117 | Alligator Cracking (sqm) | 0.0 | 0.0 | | 0.0 | 0.0 | | |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | | 0.0 | 0.0 | | |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | | 0.0 | 0.0 | | |
| | Transverse Cracking (m) | 0.0 | 0.0 | | 0.0 | 0.0 | | |
| 0118 | Alligator Cracking (sqm) | 0.0 | 0.0 | | 0.0 | 0.0 | | |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | | 0.0 | 0.0 | | |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | | 0.0 | 0.0 | | |
| | Transverse Cracking (m) | 0.0 | 0.0 | | 0.0 | 0.0 | | |
| 0119 | Alligator Cracking (sqm) | 0.0 | 0.0 | | 0.0 | 0.0 | | |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | | 0.0 | 0.0 | | |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | | 0.0 | 0.0 | | |
| | Transverse Cracking (m) | 0.0 | 0.0 | | 0.0 | 0.0 | | |
| 0120 | Alligator Cracking (sqm) | 0.0 | 0.0 | | 0.0 | 0.0 | | 172.9 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | | 0.0 | 0.0 | | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | | 0.0 | 0.0 | | 4.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | | 0.0 | 0.0 | | 0.0 |
| 0121 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 8.4 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 |
| 0122 | Alligator Cracking (sqm) | 0.0 | 0.0 | | 0.0 | 0.0 | | |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | | 0.0 | 0.0 | | |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | | 0.0 | 0.0 | | |
| | Transverse Cracking (m) | 0.0 | 0.0 | | 0.0 | 0.0 | | |
| 0123 | Alligator Cracking (sqm) | 0.0 | 0.0 | | 0.0 | 0.0 | | |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | | 0.0 | 0.0 | | |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | | 0.0 | 0.0 | | |
| | Transverse Cracking (m) | 0.0 | 0.0 | | 0.0 | 0.0 | | |
| 0124 | Alligator Cracking (sqm) | 0.0 | 0.0 | | 0.0 | 0.0 | | |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | | 0.0 | 0.0 | | |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | | 0.0 | 0.0 | | |
| | Transverse Cracking (m) | 0.0 | 0.0 | | 0.0 | 0.0 | | |

## Table A2- 50 Rutting Performance for Virginia (51)

| Section ID | Age at time of data collection (years) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 0113 | 2.3 | 12.0 | 15.0 | 17.0 | 19.0 | 21.0 | | |
| 0114 | 2.3 | 4.0 | 5.0 | 5.0 | 5.0 | 6.0 | 5.8 | |
| 0115 | 3.0 | 4.0 | | 5.0 | 5.5 | | 5.3 | |
| 0116 | 1.0 | 3.0 | | 4.0 | 5.0 | | 5.0 | |
| 0117 | 3.0 | 5.0 | | 7.0 | 7.0 | | 6.3 | |
| 0118 | 2.0 | 4.0 | | 6.0 | 6.0 | | 6.3 | |
| 0119 | 1.0 | 3.0 | | 4.0 | 4.5 | | 4.0 | 5.0 |
| 0120 | 1.0 | 4.0 | | 6.0 | 5.5 | | 4.7 | |
| 0121 | 1.0 | 3.0 | 3.0 | 3.5 | 4.5 | | 3.7 | |
| 0122 | 2.0 | 3.0 | | 4.0 | 4.0 | | 4.0 | |
| 0123 | 2.0 | 4.0 | | 6.0 | 6.0 | | 6.0 | |
| 0124 | 1.0 | 3.0 | | 5.0 | 6.0 | | 5.7 | |

Note: Rut depths are in mm

## Table A2- 51 Roughness Performance for Virginia (51)

| Section ID | Age at time of data collection (years) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 0113 | 1.04 | 1.47 | 1.57 | 1.65 | 1.85 | 1.89 | | |
| 0114 | 0.93 | 1.01 | 0.99 | 1.04 | 1.03 | 1.00 | 0.96 | 0.97 |
| 0115 | 1.03 | 1.04 | 1.04 | 1.18 | 1.07 | 1.05 | 1.06 | 1.05 |
| 0116 | 0.97 | 0.99 | 0.99 | 0.98 | 0.98 | 0.99 | 0.98 | 0.98 |
| 0117 | 0.98 | 0.98 | 0.98 | 1.01 | 1.00 | 0.99 | 0.97 | 1.00 |
| 0118 | 1.04 | 1.05 | 1.06 | 1.06 | 1.08 | 1.10 | 1.09 | 1.10 |
| 0119 | 0.95 | 0.99 | 1.02 | 1.03 | 1.11 | 1.07 | 1.06 | 1.12 |
| 0120 | 1.12 | 1.19 | 1.19 | 1.22 | 1.26 | 1.21 | 1.21 | 1.26 |
| 0121 | 1.01 | 1.05 | 1.06 | 1.12 | 1.14 | 1.12 | 1.11 | 1.15 |
| 0122 | 1.00 | 1.04 | 1.02 | 1.00 | 1.02 | 1.02 | 1.01 | 1.00 |
| 0123 | 0.93 | 0.98 | 0.97 | 0.95 | 1.01 | 1.01 | 0.99 | 1.00 |
| 0124 | 0.84 | 0.86 | 0.87 | 0.90 | | 0.91 | 0.92 | 0.93 |

Note: IRI is in m/km

## Table A2- 52 Cracking Performance for Wisconsin (55)

| Section ID | Distress Type | Age at time of data collection (years) | | |
|---|---|---|---|---|
| | | 0 | 3 | 4 |
| 0113 | Alligator Cracking (sqm) | 0.0 | 0.0 | 2.6 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 210.5 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 |
| 0114 | Alligator Cracking (sqm) | 0.0 | 0.0 | 32.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 305.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 |
| 0115 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 141.2 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 |
| 0116 | Alligator Cracking (sqm) | 0.0 | 0.0 | 15.3 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 152.5 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 |
| 0117 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 167.2 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 |
| 0118 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 182.9 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 |
| 0119 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 86.0 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 |
| 0120 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 219.5 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 |
| 0121 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 130.8 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 |
| 0122 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 239.5 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 |
| 0123 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 92.2 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 |
| 0124 | Alligator Cracking (sqm) | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - WP (m) | 0.0 | 0.0 | 0.0 |
| | Longitudinal Cracking - NWP (m) | 0.0 | 0.0 | 259.3 |
| | Transverse Cracking (m) | 0.0 | 0.0 | 0.0 |

## Table A2- 53 Rutting Performance for Wisconsin (55)

| Section ID | Age at time of data collection (years) | | |
|---|---|---|---|
| | 0 | 3 | 4 |
| 0113 | 2.0 | 4.0 | 5.5 |
| 0114 | 1.0 | 5.0 | 6.0 |
| 0115 | 1.0 | 6.0 | 8.5 |
| 0116 | 2.0 | 6.0 | 8.5 |
| 0117 | 1.0 | 6.0 | 8.0 |
| 0118 | 1.0 | 7.0 | 9.0 |
| 0119 | | 5.0 | 6.0 |
| 0120 | 1.0 | 4.0 | 4.0 |
| 0121 | 1.0 | 4.0 | 4.0 |
| 0122 | 5.0 | 5.0 | 6.0 |
| 0123 | 1.0 | 5.0 | 6.0 |
| 0124 | 1.0 | 5.0 | 6.0 |

Note: Rut depths are in mm

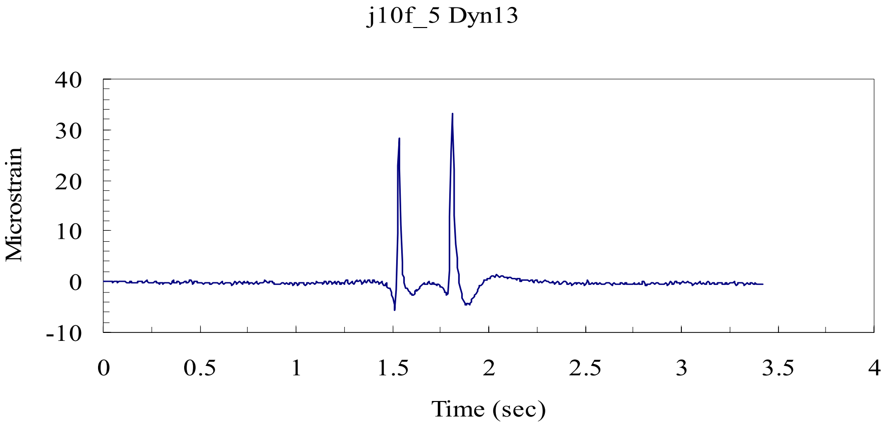
## Table A2- 54 Roughness Performance for Wisconsin (55)

| Section ID | Age at time of data collection (years) | | | | |
|---|---|---|---|---|---|
| | 0 | 1 | 2 | 4 | 5 |
| 0113 | 0.89 | 0.98 | 0.99 | 1.00 | 1.06 |
| 0114 | 0.81 | 0.84 | 0.96 | 1.12 | 1.00 |
| 0115 | 0.88 | 1.02 | 1.16 | 1.32 | 1.32 |
| 0116 | 0.74 | 0.89 | 0.97 | 1.01 | 1.12 |
| 0117 | 0.74 | 0.83 | 0.90 | 1.06 | 1.07 |
| 0118 | 0.66 | 0.75 | 0.81 | 0.91 | 0.98 |
| 0119 | 0.80 | 0.83 | 0.90 | 0.97 | 0.96 |
| 0120 | 0.64 | 0.65 | 0.65 | 0.68 | 0.70 |
| 0121 | 0.79 | 0.82 | 0.83 | 0.84 | 0.82 |
| 0122 | 0.64 | 0.70 | 0.71 | 0.79 | 0.80 |
| 0123 | 0.72 | 0.85 | 0.91 | 0.99 | 0.99 |
| 0124 | 0.78 | 0.89 | 1.01 | 1.12 | 1.09 |

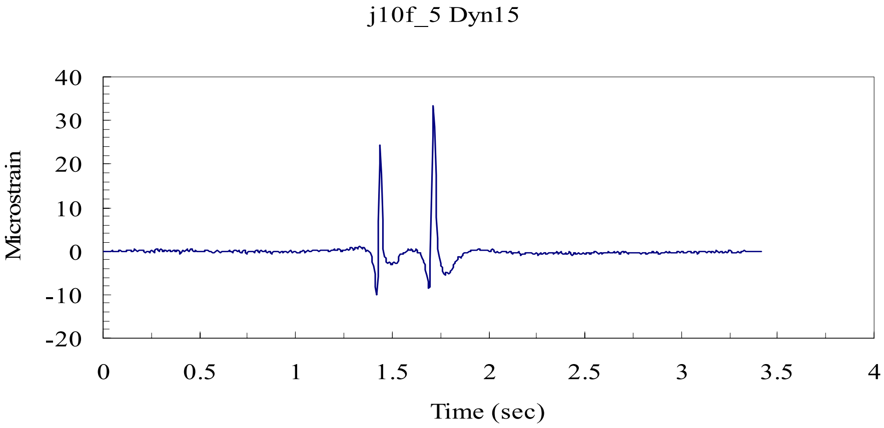
Note: IRI is in m/km

# APPENDIX A3

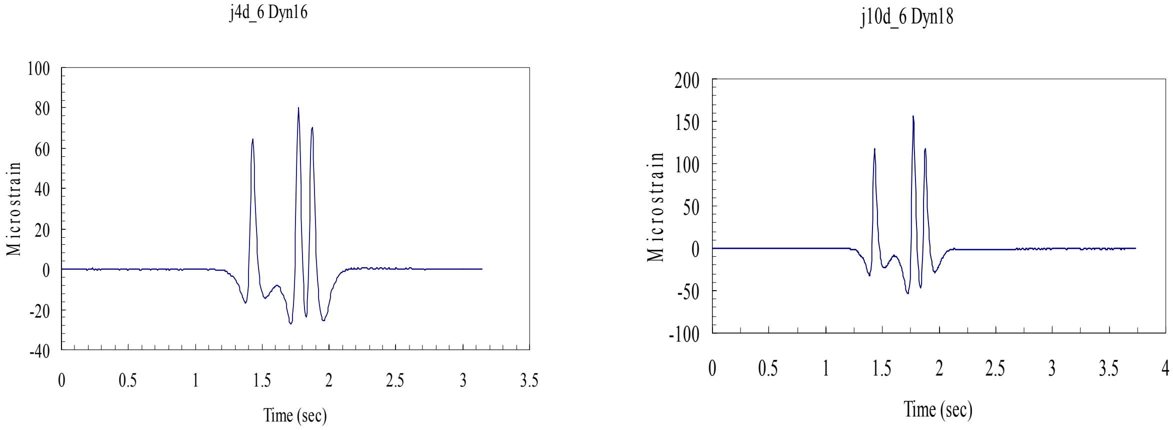
## Dynamic Load Response (DLR) Data for SPS-1 experiment (Evaluation of traces, tables for available data/descriptive statistics and mechanistic evaluations/comparisons)



(a) Longitudinal strain trace for section 110 for gauge 13 and run number 5— Truck with single rear axle



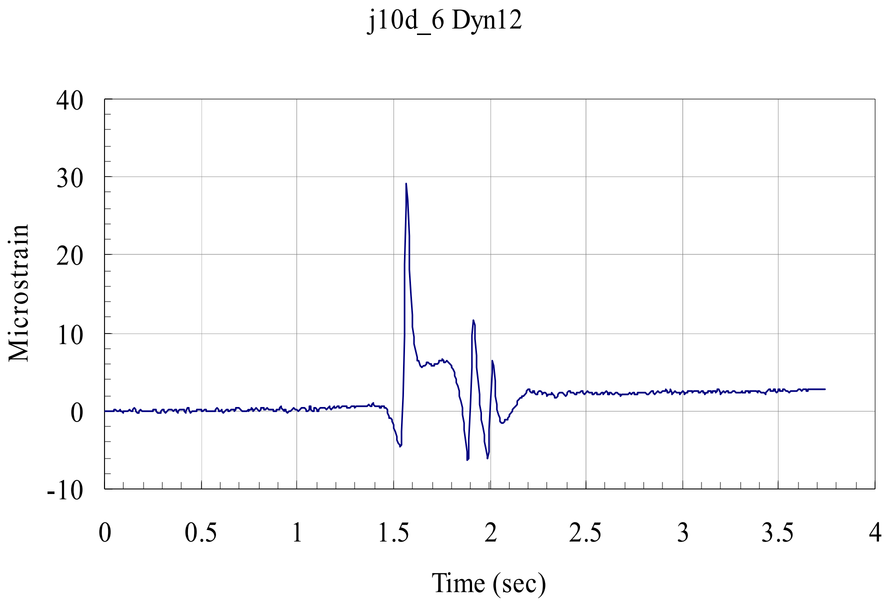
(b) Longitudinal strain trace for section 110 for gauge 15 and run number 5— Truck with single rear axle



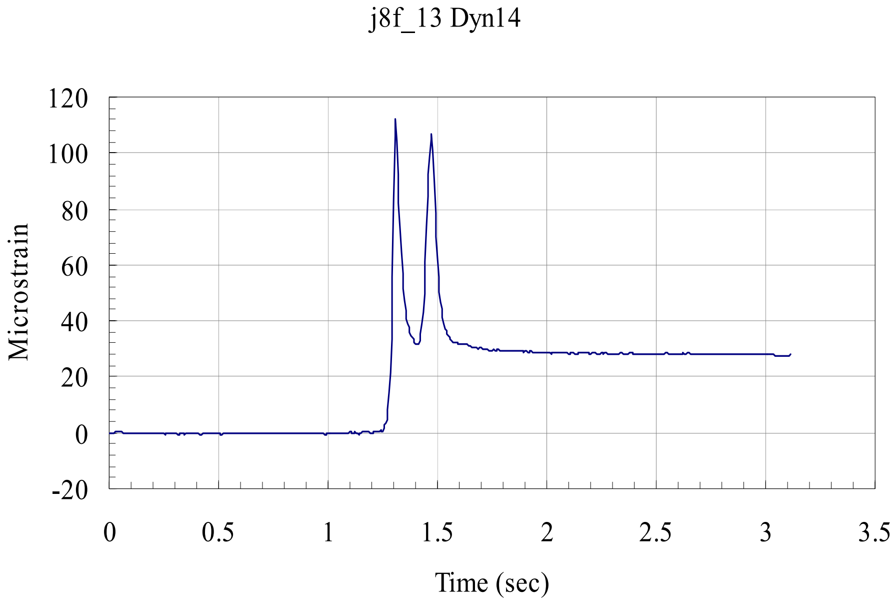
(c) Longitudinal strain trace for section 104 for gauge 16 and run number 6— Truck with tandem rear axle

(d) Longitudinal strain trace for section 110 for gauge 18 and run number 6— Truck with tandem rear axle

**Figure A3- 1 Examples of good traces— Signal is clean and separate peaks are distinguishable (the LTPP data reports correct peak values)**

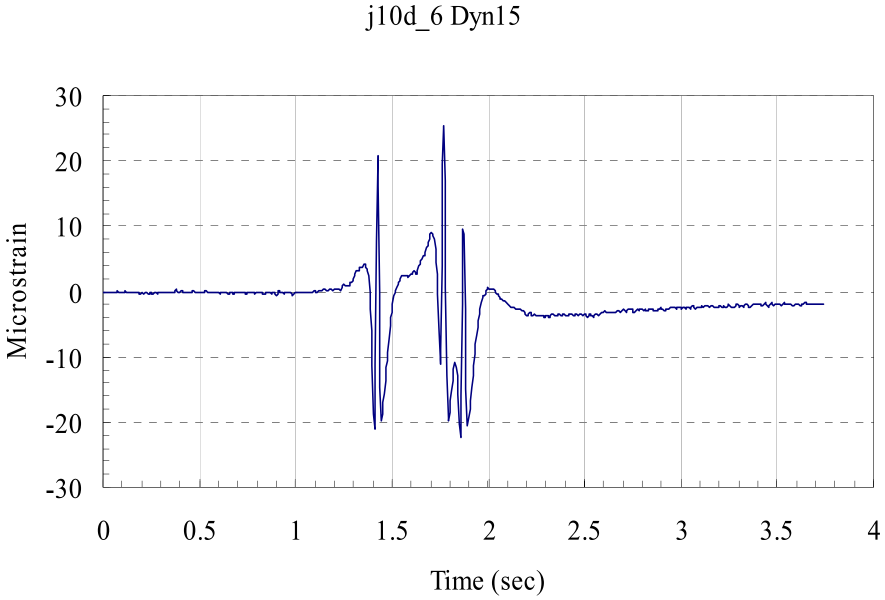


(a) Transverse strain trace for section 110 for gauge 12 and run number 6— Truck with tandem rear axle

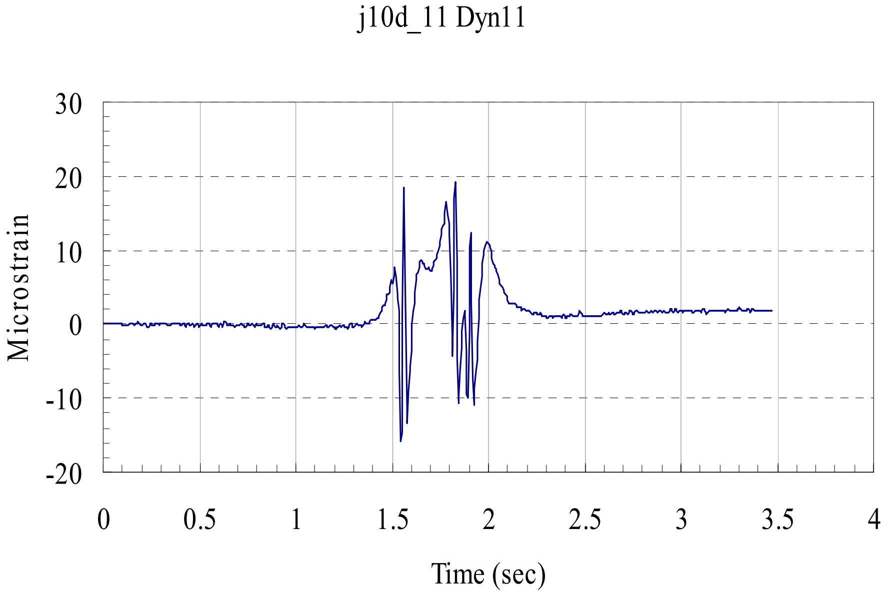


(b) Transverse strain trace for section 108 for gauge 14 and run number 13— Truck with single rear axle

**Figure A3- 2 Examples of fair traces— Signal is clean and separate peaks are distinguishable but error exists at the end of trace (the LTPP data reports correct peak values)**

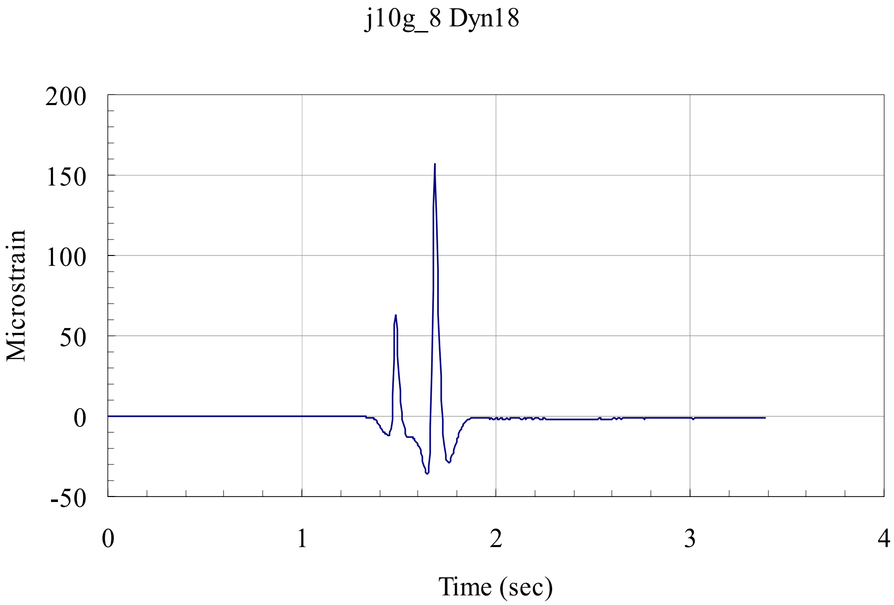


(a) Longitudinal strain trace for section 110 for gauge 15 and run number 6— Truck with tandem rear axle



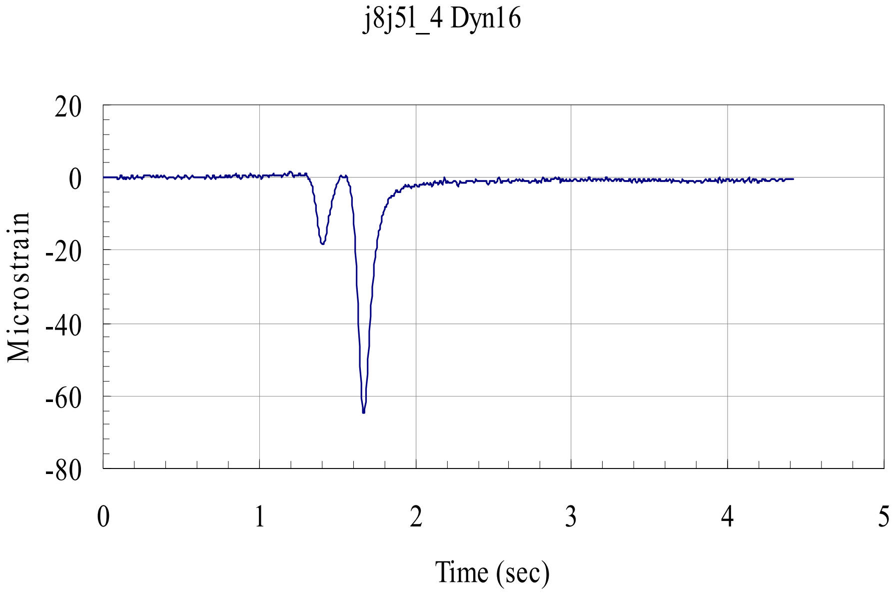
(b) Longitudinal strain trace for section 110 for gauge 11 and run number 11— Truck with tandem rear axle

**Figure A3- 3 Examples of poor traces— Signal is not clean and has a large noise**



(a) Longitudinal strain trace for section 110 for gauge 18 and run number 8— Truck with single rear axle

**Figure A3- 4 Examples of human error— Signal is clean and separate peaks are distinguishable (the LTPP data reports incorrect peak values)**



(a) Longitudinal strain trace for section 108 for gauge 16 and run number 4— Truck with single rear axle

**Figure A3- 5 Examples of unknown error— Signal is clean but has shown negative values (the LTPP data reports peak values as zero)**

**Table A3- 1 Summary of random sample—LTPP Database vs. Strain traces (OU) for DLR in OH (39)**

| Rating | 39-0102 | 39-0104 | 39-0108 | 39-0110 | Total | % |
|---|---|---|---|---|---|---|
| Good | 3 | 4 | 8 | 8 | 23 | 31% |
| Fair | 3 | 0 | 2 | 4 | 9 | 12% |
| Poor | 0 | 16 | 2 | 15 | 33 | 45% |
| Human Error | 0 | 0 | 3 | 4 | 7 | 9% |
| Unknown | 0 | 0 | 2 | 0 | 2 | 3% |
| Total | 6 | 20 | 17 | 31 | 74 | 100% |

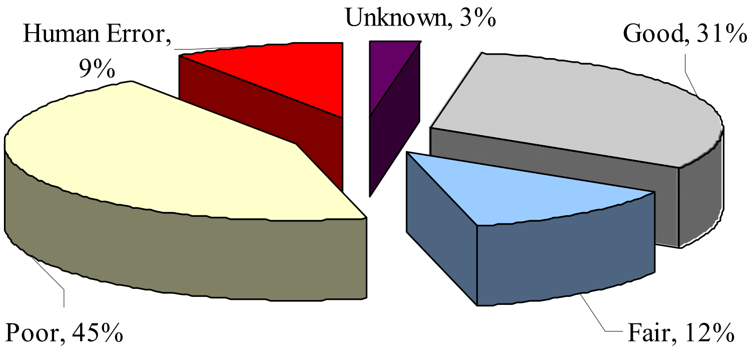
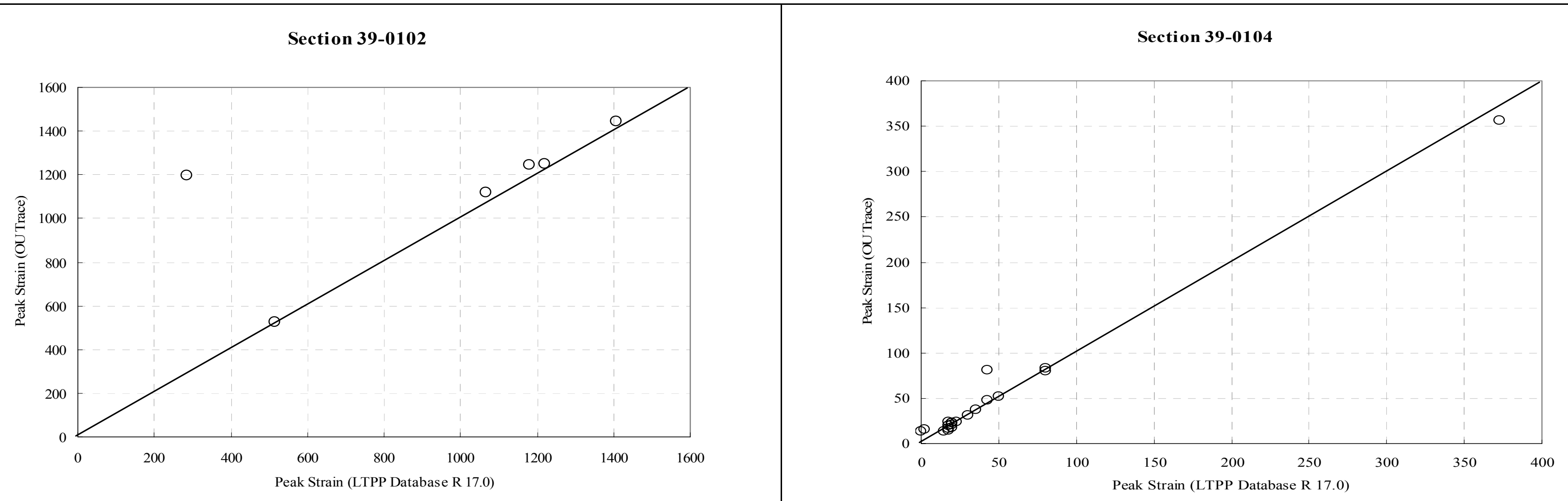
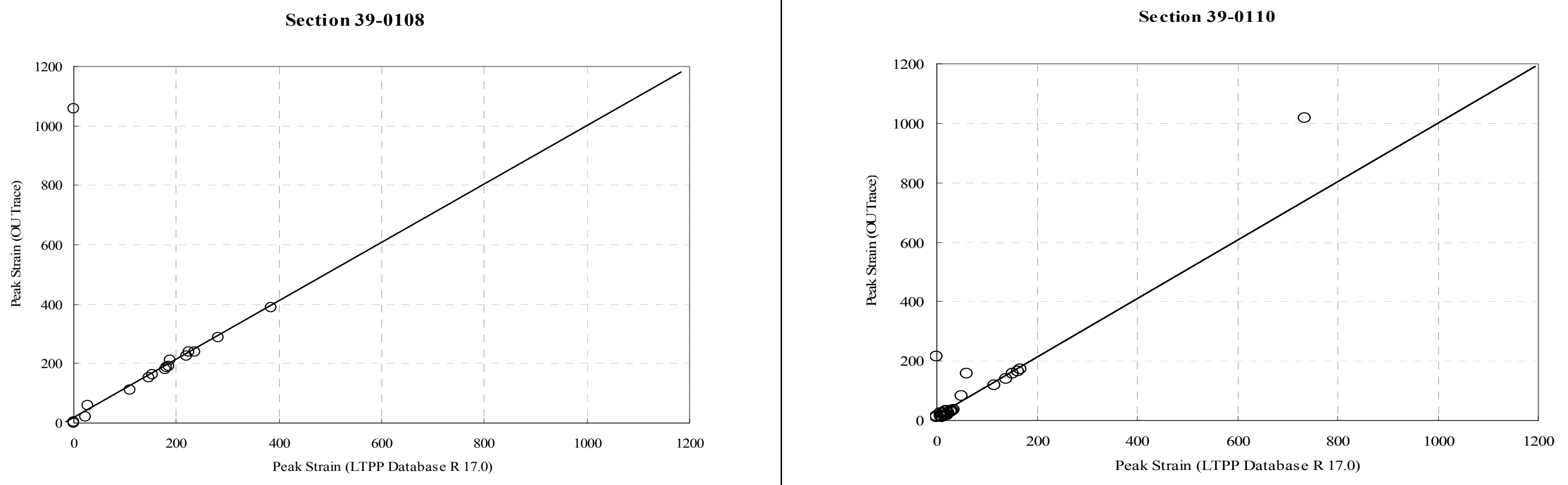


Figure A3- 6 Summary of quality check for traces from a random sample



(a) Instrumented section 39-0102

(b) Instrumented section 39-0104



(a) Instrumented section 39-0108

(a) Instrumented section 39-0110

**Figure A3- 7 Comparisons between peaks for a sample— OU traces versus LTPP DLR data**

### Table A3- 2 DLR Strains for Section 39-102 with DGAB base Type

| Section ID | Direction[1] | Test[2] | Date | Run No. | Truck Type[3] | Axle Load, KN | Speed, kph | Offset[4], mm | X[5], inches | Tire Position[6] | Gauge ID[7] | Peak Strain, micro-strain |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0102 | T | j2b | 8/3/1996 | 1 | 2 | 142.4 | 48 | 533 | 9 | 1 | Dyn9 | 660 |
| 0102 | T | j2b | 8/3/1996 | 2 | 2 | 142.4 | 48 | 330 | 17 | 3 | Dyn9 | 498 |
| 0102 | T | j2b | 8/3/1996 | 4 | 2 | 142.4 | 48 | 406 | 14 | 3 | Dyn9 | 515 |
| 0102 | L | j2b | 8/3/1996 | 5 | 2 | 142.4 | 48 | 356 | 16 | 3 | Dyn12 | 950 |
| 0102 | T | j2b | 8/3/1996 | 6 | 2 | 142.4 | 64 | 229 | 21 | 3 | Dyn9 | 1248 |
| 0102 | T | j2b | 8/3/1996 | 11 | 2 | 142.4 | 80 | 330 | 17 | 3 | Dyn9 | 678 |
| 0102 | L | j2c | 8/5/1996 | 1 | 2 | 186 | 48 | 356 | 16 | 3 | Dyn12 | 1180 |
| 0102 | L | j2c | 8/5/1996 | 2 | 2 | 186 | 48 | 305 | 18 | 3 | Dyn12 | 1258 |
| 0102 | L | j2e | 8/6/1996 | 2 | 1 | 79.1 | 48 | 178 | 23 | 4 | Dyn12 | 1418 |
| 0102 | L | j2e | 8/6/1996 | 3 | 1 | 79.1 | 48 | 305 | 18 | 3 | Dyn12 | 1363 |
| 0102 | L | j2e | 8/6/1996 | 10 | 1 | 79.1 | 64 | 330 | 17 | 3 | Dyn12 | 1408 |
| 0102 | L | j2g | 8/9/1996 | 1 | 1 | 96.9 | 48 | 279 | 19 | 3 | Dyn12 | 1065 |
| 0102 | L | j2g | 8/9/1996 | 1 | 1 | 96.9 | 48 | 279 | 19 | 3 | Dyn8 | 285 |
| 0102 | T | j2g | 8/9/1996 | 3 | 1 | 96.9 | 48 | 305 | 18 | 3 | Dyn9 | 643 |
| 0102 | T | j2g | 8/9/1996 | 5 | 1 | 96.9 | 64 | 279 | 19 | 3 | Dyn9 | 880 |
| 0102 | T | j2g | 8/9/1996 | 6 | 1 | 96.9 | 64 | 305 | 18 | 3 | Dyn9 | 848 |
| 0102 | T | j2g | 8/9/1996 | 8 | 1 | 96.9 | 64 | 254 | 20 | 3 | Dyn9 | 1220 |
| 0102 | T | j2g | 8/9/1996 | 9 | 1 | 96.9 | 80 | 254 | 20 | 3 | Dyn9 | 1105 |

Note:

1 T- strain in the transverse direction, L- strain in the longitudinal direction (in the direction of traffic flow)
2 The first two letters were designated for the section identification, the alphabetic order represents when the test measurements were taken.
3 1- For ODOT single axle dump truck, 2- For ODOT tandem axle dump truck.
4 Offset from the edge of the pavement to the outer edge of the wheel.
5 The distance between outer edge of the wheel and strain gauge location.
6 Tire position, 1- Outer tire over gauge, 2- Dual tires straddle gauge, 3- Inner tire over gauge, 4- Dual tire outside gauge.
7 Gauge location; All gauges are at the bottom of asphalt layer.

**Table A3- 3 DLR Strains for Section 39-104 with ATB base Type**

| Section ID | Direction | Test | Date | Run No. | Truck Type | Axle Load, KN | Speed, kph | Offset, mm | x, inches | Tire Position | Gauge ID | Peak Strain, microstrain |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0104 | L | j4b | 8/3/1996 | 2 | 2 | 142.4 | 48 | 178 | 23 | 4 | Dyn15 | 20 |
| 0104 | T | j4b | 8/3/1996 | 7 | 2 | 142.4 | 64 | 152 | 24 | 4 | Dyn10 | 25 |
| 0104 | L | j4b | 8/3/1996 | 8 | 2 | 142.4 | 64 | 229 | 21 | 3 | Dyn16 | 50 |
| 0104 | L | j4b | 8/3/1996 | 9 | 2 | 142.4 | 64 | 305 | 18 | 3 | Dyn11 | 5 |
| 0104 | L | j4b | 8/3/1996 | 9 | 2 | 142.4 | 64 | 305 | 18 | 3 | Dyn15 | 15 |
| 0104 | T | j4b | 8/3/1996 | 10 | 2 | 142.4 | 80 | 203 | 22 | 4 | Dyn10 | 22.5 |
| 0104 | L | j4b | 8/3/1996 | 11 | 2 | 142.4 | 80 | 254 | 20 | 3 | Dyn18 | 47.5 |
| 0104 | L | j4b | 8/3/1996 | 12 | 2 | 142.4 | 80 | 483 | 11 | 2 | Dyn15 | 0 |
| 0104 | L | j4b | 8/3/1996 | 12 | 2 | 142.4 | 80 | 483 | 11 | 2 | Dyn18 | 35 |
| 0104 | L | j4c | 8/5/1996 | 2 | 2 | 186 | 48 | 203 | 22 | 4 | Dyn11 | 25 |
| 0104 | L | j4c | 8/5/1996 | 2 | 2 | 186 | 48 | 203 | 22 | 4 | Dyn13 | 32.5 |
| 0104 | L | j4c | 8/5/1996 | 3 | 2 | 186 | 48 | 127 | 25 | 4 | Dyn13 | 27.5 |
| 0104 | L | j4c | 8/5/1996 | 4 | 2 | 186 | 48 | 305 | 18 | 3 | Dyn13 | 17.5 |
| 0104 | L | j4c | 8/5/1996 | 4 | 2 | 186 | 48 | 305 | 18 | 3 | Dyn18 | 90 |
| 0104 | L | j4c | 8/5/1996 | 5 | 2 | 186 | 48 | 203 | 22 | 4 | Dyn15 | 40 |
| 0104 | T | j4c | 8/5/1996 | 6 | 2 | 186 | 64 | 203 | 22 | 4 | Dyn10 | 67.5 |
| 0104 | T | j4c | 8/5/1996 | 6 | 2 | 186 | 64 | 203 | 22 | 4 | Dyn12 | 52.5 |
| 0104 | L | j4c | 8/5/1996 | 6 | 2 | 186 | 64 | 203 | 22 | 4 | Dyn18 | 97.5 |
| 0104 | L | j4c | 8/5/1996 | 7 | 2 | 186 | 64 | 152 | 24 | 4 | Dyn11 | 17.5 |
| 0104 | T | j4c | 8/5/1996 | 7 | 2 | 186 | 64 | 152 | 24 | 4 | Dyn12 | 30 |
| 0104 | L | j4c | 8/5/1996 | 7 | 2 | 186 | 64 | 152 | 24 | 4 | Dyn15 | 20 |
| 0104 | L | j4c | 8/5/1996 | 8 | 2 | 186 | 64 | 279 | 19 | 3 | Dyn11 | 12.5 |
| 0104 | L | j4c | 8/5/1996 | 8 | 2 | 186 | 64 | 279 | 19 | 3 | Dyn17 | 77.5 |
| 0104 | L | j4c | 8/5/1996 | 9 | 2 | 186 | 64 | 203 | 22 | 4 | Dyn16 | 65 |
| 0104 | L | j4d | 8/6/1996 | 6 | 1 | 79.1 | 48 | 254 | 20 | 3 | Dyn11 | 20 |
| 0104 | L | j4d | 8/6/1996 | 6 | 1 | 79.1 | 48 | 254 | 20 | 3 | Dyn16 | 80 |
| 0104 | L | j4d | 8/6/1996 | 7 | 1 | 79.1 | 64 | 229 | 21 | 3 | Dyn15 | 22.5 |
| 0104 | T | j4d | 8/6/1996 | 8 | 1 | 79.1 | 64 | 178 | 23 | 4 | Dyn14 | 27.5 |
| 0104 | L | j4d | 8/6/1996 | 9 | 1 | 79.1 | 64 | 229 | 21 | 3 | Dyn13 | 20 |
| 0104 | L | j4d | 8/6/1996 | 10 | 1 | 79.1 | 64 | 305 | 18 | 3 | Dyn11 | 15 |
| 0104 | L | j4d | 8/6/1996 | 10 | 1 | 79.1 | 64 | 305 | 18 | 3 | Dyn18 | 62.5 |

**Table A3- 3 DLR Strains for Section 39-104 with ATB base Type (continued…..)**

| Section ID | Direction | Test | Date | Run No. | Truck Type | Axle Load, KN | Speed, kph | Offset, mm | x, inches | Tire Position | Gauge ID | Peak Strain, microstrain |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0104 | L | j4d | 8/6/1996 | 11 | 1 | 79.1 | 64 | 229 | 21 | 3 | Dyn15 | 22.5 |
| 0104 | T | j4d | 8/6/1996 | 12 | 1 | 79.1 | 80 | 254 | 20 | 3 | Dyn10 | 22.5 |
| 0104 | T | j4d | 8/6/1996 | 12 | 1 | 79.1 | 80 | 254 | 20 | 3 | Dyn14 | 17.5 |
| 0104 | L | j4d | 8/6/1996 | 12 | 1 | 79.1 | 80 | 254 | 20 | 3 | Dyn16 | 50 |
| 0104 | L | j4d | 8/6/1996 | 12 | 1 | 79.1 | 80 | 254 | 20 | 3 | Dyn18 | 80 |
| 0104 | L | j4d | 8/6/1996 | 13 | 1 | 79.1 | 80 | 152 | 24 | 4 | Dyn18 | 82.5 |
| 0104 | T | j4d | 8/6/1996 | 14 | 1 | 79.1 | 80 | 203 | 22 | 4 | Dyn10 | 27.5 |
| 0104 | L | j4e | 8/6/1996 | 1 | 1 | 79.1 | 48 | 229 | 21 | 3 | Dyn11 | 27.5 |
| 0104 | L | j4e | 8/6/1996 | 1 | 1 | 79.1 | 48 | 229 | 21 | 3 | Dyn13 | 10 |
| 0104 | L | j4e | 8/6/1996 | 4 | 1 | 79.1 | 48 | 279 | 19 | 3 | Dyn13 | 25 |
| 0104 | L | j4e | 8/6/1996 | 5 | 1 | 79.1 | 48 | 229 | 21 | 3 | Dyn13 | 35 |
| 0104 | L | j4e | 8/6/1996 | 5 | 1 | 79.1 | 48 | 229 | 21 | 3 | Dyn15 | 42.5 |
| 0104 | L | j4e | 8/6/1996 | 6 | 1 | 79.1 | 64 | 229 | 21 | 3 | Dyn15 | 30 |
| 0104 | L | j4e | 8/6/1996 | 6 | 1 | 79.1 | 64 | 229 | 21 | 3 | Dyn16 | 85 |
| 0104 | L | j4e | 8/6/1996 | 7 | 1 | 79.1 | 64 | 203 | 22 | 4 | Dyn11 | 22.5 |
| 0104 | L | j4e | 8/6/1996 | 7 | 1 | 79.1 | 64 | 203 | 22 | 4 | Dyn13 | 27.5 |
| 0104 | T | j4e | 8/6/1996 | 8 | 1 | 79.1 | 64 | 203 | 22 | 4 | Dyn10 | 70 |
| 0104 | T | j4e | 8/6/1996 | 8 | 1 | 79.1 | 64 | 203 | 22 | 4 | Dyn12 | 57.5 |
| 0104 | T | j4e | 8/6/1996 | 9 | 1 | 79.1 | 64 | 305 | 18 | 3 | Dyn14 | 22.5 |
| 0104 | L | j4e | 8/6/1996 | 9 | 1 | 79.1 | 64 | 305 | 18 | 3 | Dyn15 | 20 |
| 0104 | L | j4e | 8/6/1996 | 10 | 1 | 79.1 | 64 | 229 | 21 | 3 | Dyn13 | 20 |
| 0104 | L | j4e | 8/6/1996 | 10 | 1 | 79.1 | 64 | 229 | 21 | 3 | Dyn18 | 42.5 |
| 0104 | L | j4e | 8/6/1996 | 11 | 1 | 79.1 | 80 | 254 | 20 | 3 | Dyn11 | 10 |
| 0104 | T | j4e | 8/6/1996 | 13 | 1 | 79.1 | 80 | 279 | 19 | 3 | Dyn10 | 0 |
| 0104 | L | j4f | 8/7/1996 | 1 | 1 | 79.1 | 48 | 229 | 21 | 3 | Dyn18 | 67.5 |
| 0104 | L | j4f | 8/7/1996 | 2 | 1 | 79.1 | 48 | 203 | 22 | 4 | Dyn15 | 27.5 |
| 0104 | L | j4f | 8/7/1996 | 7 | 1 | 79.1 | 64 | 279 | 19 | 3 | Dyn15 | 17.5 |
| 0104 | L | j4f | 8/7/1996 | 10 | 1 | 79.1 | 64 | 279 | 19 | 3 | Dyn15 | 17.5 |
| 0104 | L | j4f | 8/7/1996 | 10 | 1 | 79.1 | 64 | 279 | 19 | 3 | Dyn17 | 372.6 |
| 0104 | L | j4f | 8/7/1996 | 11 | 1 | 79.1 | 80 | 229 | 21 | 3 | Dyn11 | 12.5 |
| 0104 | L | j4f | 8/7/1996 | 12 | 1 | 79.1 | 80 | 229 | 21 | 3 | Dyn11 | 12.5 |

### Table A3- 3 DLR Strains for Section 39-104 with ATB base Type (continued…..)

| Section ID | Direction | Test | Date | Run No. | Truck Type | Axle Load, KN | Speed, kph | Offset, mm | x, inches | Tire Position | Gauge ID | Peak Strain, micro-strain |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0104 | L | j4g | 8/9/1996 | 2 | 1 | 96.9 | 48 | 254 | 20 | 3 | Dyn11 | 2.5 |
| 0104 | L | j4g | 8/9/1996 | 2 | 1 | 96.9 | 48 | 254 | 20 | 3 | Dyn15 | 20 |
| 0104 | L | j4g | 8/9/1996 | 6 | 1 | 96.9 | 64 | 203 | 22 | 4 | Dyn15 | 15 |
| 0104 | L | j4g | 8/9/1996 | 7 | 1 | 96.9 | 64 | 229 | 21 | 3 | Dyn13 | 15 |
| 0104 | L | j4g | 8/9/1996 | 10 | 1 | 96.9 | 80 | 279 | 19 | 3 | Dyn16 | 75 |
| 0104 | L | j6j4k | 7/2/1997 | 2 | 1 | 79.1 | 48 | 508 | 10 | 2 | Dyn34 | 0 |
| 0104 | L | j6j4k | 7/2/1997 | 3 | 1 | 79.1 | 48 | 178 | 23 | 4 | Dyn34 | 42.5 |
| 0104 | L | j6j4k | 7/2/1997 | 4 | 1 | 79.1 | 48 | 432 | 13 | 3 | Dyn40 | 57.5 |
| 0104 | L | j6j4k | 7/2/1997 | 7 | 1 | 79.1 | 64 | 229 | 21 | 3 | Dyn39 | 0 |
| 0104 | L | j6j4k | 7/2/1997 | 8 | 1 | 79.1 | 64 | 178 | 23 | 4 | Dyn34 | 115 |
| 0104 | L | j6j4k | 7/2/1997 | 9 | 1 | 79.1 | 64 | 203 | 22 | 4 | Dyn34 | 270 |
| 0104 | L | j6j4k | 7/2/1997 | 15 | 1 | 79.1 | 80 | 127 | 25 | 4 | Dyn40 | 22.5 |
| 0104 | L | j6j4k | 7/2/1997 | 16 | 1 | 79.1 | 80 | 127 | 25 | 4 | Dyn40 | 27.5 |
| 0104 | L | j6j4k | 7/2/1997 | 17 | 1 | 79.1 | 80 | 203 | 22 | 4 | Dyn34 | 167.5 |
| 0104 | L | j6j4k | 7/2/1997 | 24 | 2 | 142.4 | 48 | 178 | 23 | 4 | Dyn40 | 82.5 |
| 0104 | L | j6j4k | 7/2/1997 | 25 | 2 | 142.4 | 64 | 152 | 24 | 4 | Dyn34 | 0 |
| 0104 | L | j6j4k | 7/2/1997 | 25 | 2 | 142.4 | 64 | 152 | 24 | 4 | Dyn40 | 57.5 |
| 0104 | L | j6j4k | 7/2/1997 | 26 | 2 | 142.4 | 64 | 51 | 28 | 4 | Dyn40 | 62.5 |
| 0104 | L | j6j4k | 7/2/1997 | 27 | 2 | 142.4 | 64 | 203 | 22 | 4 | Dyn34 | 0 |
| 0104 | L | j6j4k | 7/2/1997 | 28 | 2 | 142.4 | 64 | 152 | 24 | 4 | Dyn40 | 72.5 |
| 0104 | L | j6j4k | 7/2/1997 | 29 | 2 | 142.4 | 64 | 127 | 25 | 4 | Dyn40 | 35 |
| 0104 | L | j6j4k | 7/2/1997 | 35 | 2 | 142.4 | 80 | 0 | 30 | 4 | Dyn40 | 32.5 |
| 0104 | L | j6j4k | 7/2/1997 | 36 | 2 | 142.4 | 80 | 0 | 30 | 4 | Dyn40 | 15 |
| 0104 | L | j6j4k | 7/2/1997 | 39 | 2 | 142.4 | 80 | 0 | 30 | 4 | Dyn40 | 27.5 |

### Table A3- 4 DLR Strains for Section 39-108 with PATB+DGAB base Type

| Section ID | Direction | Test | Date | Run No. | Truck Type | Axle Load, KN | Speed, kph | Offset, mm | x, inches | Tire Position | Gauge ID | Peak Strain, micro-strain |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0108 | L | j8c | 8/5/1996 | 6 | 2 | 186 | 64 | 229 | 21 | 3 | Dyn15 | 268 |
| 0108 | L | j8c | 8/5/1996 | 7 | 2 | 186 | 64 | 178 | 23 | 4 | Dyn15 | 268 |
| 0108 | L | j8c | 8/5/1996 | 9 | 2 | 186 | 64 | 254 | 20 | 3 | Dyn13 | 225 |
| 0108 | T | j8c | 8/5/1996 | 9 | 2 | 186 | 64 | 254 | 20 | 3 | Dyn14 | 385 |
| 0108 | L | j8c | 8/5/1996 | 10 | 2 | 186 | 64 | 381 | 15 | 3 | Dyn11 | 210 |
| 0108 | T | j8d | 8/6/1996 | 2 | 2 | 186 | 48 | 305 | 18 | 3 | Dyn12 | 148 |
| 0108 | L | j8d | 8/6/1996 | 3 | 2 | 186 | 48 | 254 | 20 | 3 | Dyn11 | 183 |
| 0108 | L | j8d | 8/6/1996 | 4 | 1 | 79.1 | 48 | 305 | 18 | 3 | Dyn11 | 200 |
| 0108 | L | j8d | 8/6/1996 | 5 | 1 | 79.1 | 48 | 203 | 22 | 4 | Dyn13 | 233 |
| 0108 | L | j8d | 8/6/1996 | 5 | 1 | 79.1 | 48 | 203 | 22 | 4 | Dyn15 | 238 |
| 0108 | L | j8d | 8/6/1996 | 6 | 1 | 79.1 | 48 | 203 | 22 | 4 | Dyn11 | 180 |
| 0108 | L | j8d | 8/6/1996 | 7 | 1 | 79.1 | 64 | 254 | 20 | 3 | Dyn15 | 210 |
| 0108 | L | j8d | 8/6/1996 | 8 | 1 | 79.1 | 64 | 279 | 19 | 3 | Dyn11 | 178 |
| 0108 | L | j8d | 8/6/1996 | 8 | 1 | 79.1 | 64 | 279 | 19 | 3 | Dyn13 | 180 |
| 0108 | L | j8d | 8/6/1996 | 8 | 1 | 79.1 | 64 | 279 | 19 | 3 | Dyn15 | 188 |
| 0108 | L | j8d | 8/6/1996 | 9 | 1 | 79.1 | 64 | 330 | 17 | 3 | Dyn11 | 195 |
| 0108 | L | j8d | 8/6/1996 | 9 | 1 | 79.1 | 64 | 330 | 17 | 3 | Dyn15 | 235 |
| 0108 | T | j8d | 8/6/1996 | 11 | 1 | 79.1 | 64 | 279 | 19 | 3 | Dyn12 | 165 |
| 0108 | L | j8d | 8/6/1996 | 12 | 1 | 79.1 | 80 | 279 | 19 | 3 | Dyn15 | 198 |
| 0108 | L | j8d | 8/6/1996 | 13 | 1 | 79.1 | 80 | 254 | 20 | 3 | Dyn11 | 178 |
| 0108 | L | j8d | 8/6/1996 | 15 | 1 | 79.1 | 80 | 152 | 24 | 4 | Dyn15 | 218 |
| 0108 | L | j8e | 8/6/1996 | 1 | 1 | 79.1 | 48 | 203 | 22 | 4 | Dyn11 | 215 |
| 0108 | L | j8e | 8/6/1996 | 1 | 1 | 79.1 | 48 | 203 | 22 | 4 | Dyn13 | 255 |
| 0108 | L | j8e | 8/6/1996 | 4 | 1 | 79.1 | 48 | 254 | 20 | 3 | Dyn11 | 205 |
| 0108 | L | j8e | 8/6/1996 | 4 | 1 | 79.1 | 48 | 254 | 20 | 3 | Dyn13 | 253 |
| 0108 | L | j8e | 8/6/1996 | 5 | 1 | 79.1 | 48 | 203 | 22 | 4 | Dyn11 | 210 |
| 0108 | L | j8e | 8/6/1996 | 5 | 1 | 79.1 | 48 | 203 | 22 | 4 | Dyn13 | 265 |
| 0108 | T | j8e | 8/6/1996 | 7 | 1 | 79.1 | 64 | 229 | 21 | 3 | Dyn10 | 283 |
| 0108 | L | j8e | 8/6/1996 | 7 | 1 | 79.1 | 64 | 229 | 21 | 3 | Dyn18 | 23 |
| 0108 | L | j8e | 8/6/1996 | 9 | 1 | 79.1 | 64 | 279 | 19 | 3 | Dyn13 | 225 |

**Table A3- 4 DLR Strains for Section 39-108 with PATB+DGAB base Type (continued…..)**

| Section ID | Direction | Test | Date | Run No. | Truck Type | Axle Load, KN | Speed, kph | Offset, mm | x, inches | Tire Position | Gauge ID | Peak Strain, micro-strain |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0108 | T | j8e | 8/6/1996 | 9 | 1 | 79.1 | 64 | 279 | 19 | 3 | Dyn14 | 258 |
| 0108 | T | j8e | 8/6/1996 | 10 | 1 | 79.1 | 80 | 178 | 23 | 4 | Dyn10 | 268 |
| 0108 | T | j8e | 8/6/1996 | 12 | 1 | 79.1 | 80 | 178 | 23 | 4 | Dyn14 | 260 |
| 0108 | L | j8e | 8/6/1996 | 12 | 1 | 79.1 | 80 | 178 | 23 | 4 | Dyn15 | 230 |
| 0108 | L | j8f | 8/7/1996 | 2 | 1 | 79.1 | 48 | 279 | 19 | 3 | Dyn11 | 138 |
| 0108 | L | j8f | 8/7/1996 | 3 | 1 | 79.1 | 48 | 254 | 20 | 3 | Dyn11 | 148 |
| 0108 | L | j8f | 8/7/1996 | 3 | 1 | 79.1 | 48 | 254 | 20 | 3 | Dyn13 | 180 |
| 0108 | L | j8f | 8/7/1996 | 4 | 1 | 79.1 | 48 | 279 | 19 | 3 | Dyn13 | 195 |
| 0108 | L | j8f | 8/7/1996 | 8 | 1 | 79.1 | 64 | 305 | 18 | 3 | Dyn11 | 158 |
| 0108 | L | j8f | 8/7/1996 | 8 | 1 | 79.1 | 64 | 305 | 18 | 3 | Dyn13 | 175 |
| 0108 | T | j8f | 8/7/1996 | 9 | 1 | 79.1 | 64 | 305 | 18 | 3 | Dyn12 | 105 |
| 0108 | L | j8f | 8/7/1996 | 9 | 1 | 79.1 | 64 | 305 | 18 | 3 | Dyn13 | 180 |
| 0108 | T | j8f | 8/7/1996 | 11 | 1 | 79.1 | 80 | 254 | 20 | 3 | Dyn12 | 110 |
| 0108 | L | j8f | 8/7/1996 | 13 | 1 | 79.1 | 80 | 305 | 18 | 3 | Dyn13 | 148 |
| 0108 | T | j8f | 8/7/1996 | 13 | 1 | 79.1 | 80 | 305 | 18 | 3 | Dyn14 | 110 |
| 0108 | L | j8g | 8/9/1996 | 1 | 1 | 96.9 | 48 | 279 | 19 | 3 | Dyn11 | 175 |
| 0108 | L | j8g | 8/9/1996 | 2 | 1 | 96.9 | 48 | 254 | 20 | 3 | Dyn13 | 223 |
| 0108 | L | j8g | 8/9/1996 | 2 | 1 | 96.9 | 48 | 254 | 20 | 3 | Dyn15 | 228 |
| 0108 | L | j8g | 8/9/1996 | 3 | 1 | 96.9 | 48 | 254 | 20 | 3 | Dyn11 | 185 |
| 0108 | L | j8g | 8/9/1996 | 3 | 1 | 96.9 | 48 | 254 | 20 | 3 | Dyn13 | 220 |
| 0108 | L | j8g | 8/9/1996 | 3 | 1 | 96.9 | 48 | 254 | 20 | 3 | Dyn15 | 235 |
| 0108 | L | j8g | 8/9/1996 | 5 | 1 | 96.9 | 64 | 254 | 20 | 3 | Dyn15 | 210 |
| 0108 | L | j8g | 8/9/1996 | 6 | 1 | 96.9 | 64 | 254 | 20 | 3 | Dyn15 | 218 |
| 0108 | L | j8g | 8/9/1996 | 9 | 1 | 96.9 | 80 | 254 | 20 | 3 | Dyn13 | 188 |
| 0108 | T | j8g | 8/9/1996 | 10 | 1 | 96.9 | 80 | 279 | 19 | 3 | Dyn12 | 210 |
| 0108 | L | j8g | 8/9/1996 | 11 | 1 | 96.9 | 80 | 229 | 21 | 3 | Dyn15 | 208 |
| 0108 | T | j8j5l | 7/3/1997 | 2 | 1 | 110.8 | 48 | 51 | 28 | 4 | Dyn10 | 0 |
| 0108 | T | j8j5l | 7/3/1997 | 3 | 1 | 110.8 | 48 | 152 | 24 | 4 | Dyn10 | 203 |

**Table A3- 4 DLR Strains for Section 39-108 with PATB+DGAB base Type (continued…..)**

| Section ID | Direction | Test | Date | Run No. | Truck Type | Axle Load, KN | Speed, kph | Offset, mm | x, inches | Tire Position | Gauge ID | Peak Strain, micro-strain |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0108 | L | j8j5l | 7/3/1997 | 4 | 1 | 110.8 | 48 | 102 | 26 | 4 | Dyn13 | 0 |
| 0108 | L | j8j5l | 7/3/1997 | 4 | 1 | 110.8 | 48 | 102 | 26 | 4 | Dyn16 | 0 |
| 0108 | L | j8j5l | 7/3/1997 | 6 | 1 | 110.8 | 48 | 178 | 23 | 4 | Dyn15 | 20 |
| 0108 | L | j8j5l | 7/3/1997 | 6 | 1 | 110.8 | 48 | 178 | 23 | 4 | Dyn16 | 0 |
| 0108 | T | j8j5l | 7/3/1997 | 7 | 1 | 110.8 | 64 | 152 | 24 | 4 | Dyn14 | 163 |
| 0108 | T | j8j5l | 7/3/1997 | 8 | 1 | 110.8 | 64 | 203 | 22 | 4 | Dyn10 | 110 |
| 0108 | T | j8j5l | 7/3/1997 | 8 | 1 | 110.8 | 64 | 203 | 22 | 4 | Dyn14 | 113 |
| 0108 | L | j8j5l | 7/3/1997 | 8 | 1 | 110.8 | 64 | 203 | 22 | 4 | Dyn16 | 0 |
| 0108 | L | j8j5l | 7/3/1997 | 9 | 1 | 110.8 | 64 | 203 | 22 | 4 | Dyn16 | 0 |
| 0108 | T | j8j5l | 7/3/1997 | 10 | 1 | 110.8 | 64 | 152 | 24 | 4 | Dyn14 | 110 |
| 0108 | L | j8j5l | 7/3/1997 | 10 | 1 | 110.8 | 64 | 152 | 24 | 4 | Dyn16 | 0 |
| 0108 | L | j8j5l | 7/3/1997 | 12 | 1 | 110.8 | 64 | 254 | 20 | 3 | Dyn15 | 0 |
| 0108 | L | j8j5l | 7/3/1997 | 12 | 1 | 110.8 | 64 | 254 | 20 | 3 | Dyn16 | 0 |
| 0108 | T | j8j5l | 7/3/1997 | 13 | 1 | 110.8 | 80 | 305 | 18 | 3 | Dyn14 | 113 |
| 0108 | L | j8j5l | 7/3/1997 | 15 | 1 | 110.8 | 80 | 25 | 29 | 4 | Dyn16 | 0 |
| 0108 | L | j8j5l | 7/3/1997 | 17 | 1 | 110.8 | 80 | 178 | 23 | 4 | Dyn16 | 0 |
| 0108 | T | j8j5l | 7/3/1997 | 18 | 1 | 110.8 | 80 | 76 | 27 | 4 | Dyn14 | 28 |
| 0108 | L | j8j5l | 7/3/1997 | 18 | 1 | 110.8 | 80 | 76 | 27 | 4 | Dyn16 | 0 |
| 0108 | L | j8j5l | 7/3/1997 | 24 | 2 | 213.7 | 48 | 127 | 25 | 4 | Dyn11 | 278 |
| 0108 | T | j8j5l | 7/3/1997 | 29 | 2 | 213.7 | 80 | 152 | 24 | 4 | Dyn10 | 0 |
| 0108 | T | j8j5l | 7/3/1997 | 30 | 2 | 213.7 | 80 | 203 | 22 | 4 | Dyn14 | 133 |
| 0108 | L | j8j5l | 7/3/1997 | 30 | 2 | 213.7 | 80 | 203 | 22 | 4 | Dyn16 | 0 |
| 0108 | L | j8j5l | 7/3/1997 | 31 | 2 | 213.7 | 80 | 102 | 26 | 4 | Dyn15 | 0 |
| 0108 | T | j8j5l | 7/3/1997 | 32 | 2 | 213.7 | 80 | 51 | 28 | 4 | Dyn14 | 115 |
| 0108 | T | j8j5l | 7/3/1997 | 33 | 2 | 213.7 | 80 | 0 | 30 | 4 | Dyn14 | 153 |
| 0108 | L | j8j5l | 7/3/1997 | 33 | 2 | 213.7 | 80 | 0 | 30 | 4 | Dyn16 | 0 |
| 0108 | L | j8j5l | 7/3/1997 | 35 | 2 | 213.7 | 80 | 0 | 30 | 4 | Dyn11 | 0 |
| 0108 | T | j8j5l | 7/3/1997 | 35 | 2 | 213.7 | 80 | 0 | 30 | 4 | Dyn14 | 53 |
| 0108 | T | j8j5l | 7/3/1997 | 36 | 2 | 213.7 | 80 | 0 | 30 | 4 | Dyn14 | 128 |
| 0108 | L | j8j5l | 7/3/1997 | 36 | 2 | 213.7 | 80 | 0 | 30 | 4 | Dyn16 | 0 |

## Table A3- 5 DLR Strains for Section 39-110 with ATB+PATB base Type

| Section ID | Direction | Test | Date | Run No. | Truck Type | Axle Load, KN | Speed, kph | Offset, mm | x, inches | Tire Position | Gauge ID | Peak Strain, micro-strain |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0110 | L | j10c | 8/5/1996 | 1 | 2 | 186 | 48 | 406 | 14 | 3 | Dyn15 | -8 |
| 0110 | L | j10c | 8/5/1996 | 1 | 2 | 186 | 48 | 406 | 14 | 3 | Dyn18 | 138 |
| 0110 | L | j10c | 8/5/1996 | 2 | 2 | 186 | 48 | 178 | 23 | 4 | Dyn13 | 23 |
| 0110 | L | j10c | 8/5/1996 | 4 | 2 | 186 | 48 | 203 | 22 | 4 | Dyn11 | 8 |
| 0110 | L | j10c | 8/5/1996 | 4 | 2 | 186 | 48 | 203 | 22 | 4 | Dyn13 | 15 |
| 0110 | L | j10c | 8/5/1996 | 4 | 2 | 186 | 48 | 203 | 22 | 4 | Dyn15 | 0 |
| 0110 | L | j10c | 8/5/1996 | 6 | 2 | 186 | 64 | 127 | 25 | 4 | Dyn13 | 23 |
| 0110 | L | j10d | 8/6/1996 | 2 | 2 | 186 | 48 | 203 | 22 | 4 | Dyn18 | 148 |
| 0110 | L | j10d | 8/6/1996 | 5 | 1 | 79.1 | 48 | 127 | 25 | 4 | Dyn11 | 30 |
| 0110 | L | j10d | 8/6/1996 | 5 | 1 | 79.1 | 48 | 127 | 25 | 4 | Dyn13 | 38 |
| 0110 | T | j10d | 8/6/1996 | 6 | 1 | 79.1 | 48 | 152 | 24 | 4 | Dyn12 | 28 |
| 0110 | L | j10d | 8/6/1996 | 6 | 1 | 79.1 | 48 | 152 | 24 | 4 | Dyn13 | 35 |
| 0110 | L | j10d | 8/6/1996 | 6 | 1 | 79.1 | 48 | 152 | 24 | 4 | Dyn15 | 23 |
| 0110 | L | j10d | 8/6/1996 | 6 | 1 | 79.1 | 48 | 152 | 24 | 4 | Dyn18 | 153 |
| 0110 | L | j10d | 8/6/1996 | 7 | 1 | 79.1 | 64 | 254 | 20 | 3 | Dyn13 | 25 |
| 0110 | L | j10d | 8/6/1996 | 8 | 1 | 79.1 | 64 | 152 | 24 | 4 | Dyn18 | 115 |
| 0110 | L | j10d | 8/6/1996 | 9 | 1 | 79.1 | 64 | 254 | 20 | 3 | Dyn18 | 113 |
| 0110 | L | j10d | 8/6/1996 | 10 | 1 | 79.1 | 64 | 178 | 23 | 4 | Dyn11 | 23 |
| 0110 | T | j10d | 8/6/1996 | 10 | 1 | 79.1 | 64 | 178 | 23 | 4 | Dyn12 | 23 |
| 0110 | L | j10d | 8/6/1996 | 11 | 1 | 79.1 | 64 | 229 | 21 | 3 | Dyn11 | 20 |
| 0110 | L | j10d | 8/6/1996 | 11 | 1 | 79.1 | 64 | 229 | 21 | 3 | Dyn15 | 10 |
| 0110 | L | j10d | 8/6/1996 | 12 | 1 | 79.1 | 80 | 229 | 21 | 3 | Dyn11 | 18 |
| 0110 | L | j10d | 8/6/1996 | 14 | 1 | 79.1 | 80 | 127 | 25 | 4 | Dyn11 | 23 |
| 0110 | T | j10d | 8/6/1996 | 16 | 1 | 79.1 | 80 | 152 | 24 | 4 | Dyn10 | 20 |
| 0110 | L | j10d | 8/6/1996 | 16 | 1 | 79.1 | 80 | 152 | 24 | 4 | Dyn15 | 3 |
| 0110 | L | j10e | 8/6/1996 | 1 | 1 | 79.1 | 48 | 203 | 22 | 4 | Dyn11 | 18 |

## Table A3- 5 DLR Strains for Section 39-110 with ATB+PATB base Type (continued…..)

| Section ID | Direction | Test | Date | Run No. | Truck Type | Axle Load, KN | Speed, kph | Offset, mm | x, inches | Tire Position | Gauge ID | Peak Strain, micro-strain |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0110 | L | j10e | 8/6/1996 | 1 | 1 | 79.1 | 48 | 203 | 22 | 4 | Dyn18 | 168 |
| 0110 | L | j10e | 8/6/1996 | 2 | 1 | 79.1 | 48 | 279 | 19 | 3 | Dyn11 | -3 |
| 0110 | L | j10e | 8/6/1996 | 2 | 1 | 79.1 | 48 | 279 | 19 | 3 | Dyn15 | -18 |
| 0110 | L | j10e | 8/6/1996 | 3 | 1 | 79.1 | 48 | 279 | 19 | 3 | Dyn13 | 8 |
| 0110 | L | j10e | 8/6/1996 | 5 | 1 | 79.1 | 64 | 229 | 21 | 3 | Dyn11 | 13 |
| 0110 | L | j10e | 8/6/1996 | 5 | 1 | 79.1 | 64 | 229 | 21 | 3 | Dyn15 | -15 |
| 0110 | L | j10e | 8/6/1996 | 6 | 1 | 79.1 | 64 | 229 | 21 | 3 | Dyn18 | 165 |
| 0110 | L | j10e | 8/6/1996 | 7 | 1 | 79.1 | 64 | 305 | 18 | 3 | Dyn13 | 8 |
| 0110 | L | j10e | 8/6/1996 | 7 | 1 | 79.1 | 64 | 305 | 18 | 3 | Dyn15 | 0 |
| 0110 | T | j10e | 8/6/1996 | 9 | 1 | 79.1 | 80 | 203 | 22 | 4 | Dyn12 | 23 |
| 0110 | L | j10e | 8/6/1996 | 9 | 1 | 79.1 | 80 | 203 | 22 | 4 | Dyn15 | 15 |
| 0110 | L | j10e | 8/6/1996 | 10 | 1 | 79.1 | 80 | 279 | 19 | 3 | Dyn15 | 0 |
| 0110 | L | j10e | 8/6/1996 | 11 | 1 | 79.1 | 80 | 254 | 20 | 3 | Dyn11 | 5 |
| 0110 | L | j10e | 8/6/1996 | 11 | 1 | 79.1 | 80 | 254 | 20 | 3 | Dyn18 | 140 |
| 0110 | L | j10e | 8/6/1996 | 12 | 1 | 79.1 | 80 | 305 | 18 | 3 | Dyn18 | 133 |
| 0110 | L | j10f | 8/7/1996 | 2 | 1 | 79.1 | 48 | 203 | 22 | 4 | Dyn13 | 28 |
| 0110 | L | j10f | 8/7/1996 | 4 | 1 | 79.1 | 48 | 203 | 22 | 4 | Dyn11 | 25 |
| 0110 | L | j10f | 8/7/1996 | 5 | 1 | 79.1 | 48 | 254 | 20 | 3 | Dyn13 | 28 |
| 0110 | L | j10f | 8/7/1996 | 5 | 1 | 79.1 | 48 | 254 | 20 | 3 | Dyn15 | 33 |
| 0110 | L | j10f | 8/7/1996 | 7 | 1 | 79.1 | 64 | 305 | 18 | 3 | Dyn15 | 25 |
| 0110 | L | j10f | 8/7/1996 | 8 | 1 | 79.1 | 64 | 229 | 21 | 3 | Dyn13 | 23 |
| 0110 | L | j10f | 8/7/1996 | 9 | 1 | 79.1 | 64 | 254 | 20 | 3 | Dyn11 | 25 |
| 0110 | L | j10f | 8/7/1996 | 9 | 1 | 79.1 | 64 | 254 | 20 | 3 | Dyn15 | 23 |
| 0110 | T | j10f | 8/7/1996 | 11 | 1 | 79.1 | 80 | 229 | 21 | 3 | Dyn12 | 25 |
| 0110 | L | j10f | 8/7/1996 | 11 | 1 | 79.1 | 80 | 229 | 21 | 3 | Dyn13 | 28 |
| 0110 | L | j10f | 8/7/1996 | 12 | 1 | 79.1 | 80 | 279 | 19 | 3 | Dyn13 | 25 |
| 0110 | L | j10f | 8/7/1996 | 13 | 1 | 79.1 | 80 | 254 | 20 | 3 | Dyn11 | 20 |
| 0110 | L | j10f | 8/7/1996 | 13 | 1 | 79.1 | 80 | 254 | 20 | 3 | Dyn18 | 115 |
| 0110 | L | j10g | 8/9/1996 | 2 | 1 | 96.9 | 48 | 254 | 20 | 3 | Dyn15 | 10 |

### Table A3- 5 DLR Strains for Section 39-110 with ATB+PATB base Type (continued…..)

| Section ID | Direction | Test | Date | Run No. | Truck Type | Axle Load, KN | Speed, kph | Offset, mm | x, inches | Tire Position | Gauge ID | Peak Strain, micro-strain |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0110 | T | j10g | 8/9/1996 | 3 | 1 | 96.9 | 48 | 279 | 19 | 3 | Dyn10 | 20 |
| 0110 | L | j10g | 8/9/1996 | 3 | 1 | 96.9 | 48 | 279 | 19 | 3 | Dyn11 | 18 |
| 0110 | L | j10g | 8/9/1996 | 3 | 1 | 96.9 | 48 | 279 | 19 | 3 | Dyn18 | 163 |
| 0110 | T | j10g | 8/9/1996 | 5 | 1 | 96.9 | 64 | 203 | 22 | 4 | Dyn10 | 28 |
| 0110 | L | j10g | 8/9/1996 | 5 | 1 | 96.9 | 64 | 203 | 22 | 4 | Dyn11 | 18 |
| 0110 | L | j10g | 8/9/1996 | 6 | 1 | 96.9 | 64 | 254 | 20 | 3 | Dyn18 | 145 |
| 0110 | L | j10g | 8/9/1996 | 7 | 1 | 96.9 | 64 | 254 | 20 | 3 | Dyn15 | 10 |
| 0110 | L | j10g | 8/9/1996 | 7 | 1 | 96.9 | 64 | 254 | 20 | 3 | Dyn18 | 140 |
| 0110 | L | j10g | 8/9/1996 | 8 | 1 | 96.9 | 64 | 254 | 20 | 3 | Dyn15 | 10 |
| 0110 | L | j10g | 8/9/1996 | 8 | 1 | 96.9 | 64 | 254 | 20 | 3 | Dyn18 | 60 |
| 0110 | T | j10g | 8/9/1996 | 9 | 1 | 96.9 | 80 | 203 | 22 | 4 | Dyn10 | 23 |
| 0110 | T | j10g | 8/9/1996 | 9 | 1 | 96.9 | 80 | 203 | 22 | 4 | Dyn12 | 20 |
| 0110 | T | j10g | 8/9/1996 | 9 | 1 | 96.9 | 80 | 203 | 22 | 4 | Dyn14 | 15 |
| 0110 | L | j10g | 8/9/1996 | 11 | 1 | 96.9 | 80 | 279 | 19 | 3 | Dyn13 | 18 |
| 0110 | L | j10g | 8/9/1996 | 12 | 1 | 96.9 | 80 | 254 | 20 | 3 | Dyn13 | 0 |
| 0110 | L | j10g | 8/9/1996 | 12 | 1 | 96.9 | 80 | 254 | 20 | 3 | Dyn15 | 8 |
| 0110 | L | j10j9k | 7/2/1997 | 2 | 1 | 79.1 | 48 | 330 | 17 | 3 | DYN13 | 20 |
| 0110 | L | j10j9k | 7/2/1997 | 2 | 1 | 79.1 | 48 | 330 | 17 | 3 | DYN15 | 18 |
| 0110 | T | j10j9k | 7/2/1997 | 3 | 1 | 79.1 | 48 | 203 | 22 | 4 | DYN14 | 25 |
| 0110 | L | j10j9k | 7/2/1997 | 4 | 1 | 79.1 | 48 | 559 | 8 | 1 | DYN13 | 18 |
| 0110 | L | j10j9k | 7/2/1997 | 4 | 1 | 79.1 | 48 | 559 | 8 | 1 | DYN15 | 15 |
| 0110 | L | j10j9k | 7/2/1997 | 6 | 1 | 79.1 | 48 | 203 | 22 | 4 | DYN13 | 18 |
| 0110 | L | j10j9k | 7/2/1997 | 6 | 1 | 79.1 | 48 | 203 | 22 | 4 | DYN15 | 8 |
| 0110 | T | j10j9k | 7/2/1997 | 8 | 1 | 79.1 | 64 | 203 | 22 | 4 | DYN12 | 735 |
| 0110 | L | j10j9k | 7/2/1997 | 8 | 1 | 79.1 | 64 | 203 | 22 | 4 | DYN13 | 13 |
| 0110 | L | j10j9k | 7/2/1997 | 8 | 1 | 79.1 | 64 | 203 | 22 | 4 | DYN18 | 68 |
| 0110 | T | j10j9k | 7/2/1997 | 9 | 1 | 79.1 | 64 | 178 | 23 | 4 | DYN12 | 0 |
| 0110 | L | j10j9k | 7/2/1997 | 9 | 1 | 79.1 | 64 | 178 | 23 | 4 | DYN13 | 8 |

## Table A3- 5 DLR Strains for Section 39-110 with ATB+PATB base Type (continued…..)

| Section ID | Direction | Test | Date | Run No. | Truck Type | Axle Load, KN | Speed, kph | Offset, mm | x, inches | Tire Position | Gauge ID | Peak Strain, micro-strain |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0110 | L | j10j9k | 7/2/1997 | 10 | 1 | 79.1 | 64 | 203 | 22 | 4 | DYN13 | 13 |
| 0110 | L | j10j9k | 7/2/1997 | 10 | 1 | 79.1 | 64 | 203 | 22 | 4 | DYN15 | 0 |
| 0110 | L | j10j9k | 7/2/1997 | 11 | 1 | 79.1 | 64 | 152 | 24 | 4 | DYN18 | 53 |
| 0110 | L | j10j9k | 7/2/1997 | 12 | 1 | 79.1 | 64 | 51 | 28 | 4 | DYN15 | 0 |
| 0110 | L | j10j9k | 7/2/1997 | 13 | 1 | 79.1 | 80 | 102 | 26 | 4 | DYN13 | 8 |
| 0110 | L | j10j9k | 7/2/1997 | 13 | 1 | 79.1 | 80 | 102 | 26 | 4 | DYN15 | 0 |
| 0110 | L | j10j9k | 7/2/1997 | 14 | 1 | 79.1 | 80 | 102 | 26 | 4 | DYN13 | 8 |
| 0110 | T | j10j9k | 7/2/1997 | 14 | 1 | 79.1 | 80 | 102 | 26 | 4 | DYN14 | 5 |
| 0110 | L | j10j9k | 7/2/1997 | 14 | 1 | 79.1 | 80 | 102 | 26 | 4 | DYN18 | 48 |
| 0110 | T | j10j9k | 7/2/1997 | 16 | 1 | 79.1 | 80 | 102 | 26 | 4 | DYN12 | 0 |
| 0110 | L | j10j9k | 7/2/1997 | 16 | 1 | 79.1 | 80 | 102 | 26 | 4 | DYN18 | 50 |
| 0110 | T | j10j9k | 7/2/1997 | 17 | 1 | 79.1 | 80 | 152 | 24 | 4 | DYN14 | 13 |
| 0110 | L | j10j9k | 7/2/1997 | 17 | 1 | 79.1 | 80 | 152 | 24 | 4 | DYN15 | 0 |
| 0110 | T | j10j9k | 7/2/1997 | 18 | 1 | 79.1 | 80 | 25 | 29 | 4 | DYN12 | 28 |
| 0110 | L | j10j9k | 7/2/1997 | 18 | 1 | 79.1 | 80 | 25 | 29 | 4 | DYN18 | 50 |
| 0110 | L | j10j9k | 7/2/1997 | 24 | 2 | 142.4 | 48 | 152 | 24 | 4 | DYN18 | 98 |
| 0110 | T | j10j9k | 7/2/1997 | 25 | 2 | 142.4 | 64 | 102 | 26 | 4 | DYN14 | 8 |
| 0110 | L | j10j9k | 7/2/1997 | 26 | 2 | 142.4 | 64 | 76 | 27 | 4 | DYN15 | 5 |
| 0110 | L | j10j9k | 7/2/1997 | 28 | 2 | 142.4 | 64 | 203 | 22 | 4 | DYN13 | 8 |
| 0110 | T | j10j9k | 7/2/1997 | 28 | 2 | 142.4 | 64 | 203 | 22 | 4 | DYN14 | 0 |
| 0110 | L | j10j9k | 7/2/1997 | 28 | 2 | 142.4 | 64 | 203 | 22 | 4 | DYN18 | 45 |
| 0110 | L | j10j9k | 7/2/1997 | 29 | 2 | 142.4 | 64 | 203 | 22 | 4 | DYN18 | 58 |
| 0110 | L | j10j9k | 7/2/1997 | 33 | 2 | 142.4 | 80 | 330 | 17 | 3 | DYN18 | 65 |
| 0110 | L | j10j9k | 7/2/1997 | 34 | 2 | 142.4 | 80 | 279 | 19 | 3 | DYN15 | 0 |
| 0110 | L | j10j9k | 7/2/1997 | 38 | 2 | 142.4 | 80 | 0 | 30 | 4 | DYN15 | 0 |
| 0110 | L | j10j9k | 7/2/1997 | 38 | 2 | 142.4 | 80 | 0 | 30 | 4 | DYN18 | 55 |
| 0110 | L | j10j9k | 7/2/1997 | 39 | 2 | 142.4 | 80 | 0 | 30 | 4 | DYN13 | 8 |
| 0110 | L | j10j9k | 7/2/1997 | 39 | 2 | 142.4 | 80 | 0 | 30 | 4 | DYN15 | 8 |
| 0110 | T | j10j9k | 7/2/1997 | 40 | 2 | 142.4 | 80 | 0 | 30 | 4 | DYN12 | 90 |

### Table A3- 6 Peak strain Data for section 39-102

| Direction | Gauge ID | Truck type | Load | Speed | Tire position 1 | Tire position 3 | Tire position 4 |
|---|---|---|---|---|---|---|---|
| | | | | | Peak Strain (micro strain) | | |
| L | Dyn12 | 1 | 79.1 | 48 | | 1363 | 1418 |
| | | | | 64 | | 1408 | |
| | | | 96.9 | 48 | | 1065 | |
| | | 2 | 142.4 | 48 | | 950 | |
| | | | 186.0 | 48 | | 1219 | |
| | Dyn8 | 1 | 96.9 | 48 | | 285 | |
| T | Dyn9 | 1 | 96.9 | 48 | | 643 | |
| | | | | 64 | | 983 | |
| | | | | 80 | | 1105 | |
| | | 2 | 142.4 | 48 | 660.1 | 506 | |
| | | | | 64 | | 1248 | |
| | | | | 80 | | 678 | |

## Table A3- 7 Peak strain Data for section 39-104

| Direction | Gauge ID | Truck type | Load | Speed | Tire position | | |
|---|---|---|---|---|---|---|---|
| | | | | | 2 | 3 | 4 |
| | | | | | Peak Strain (micro strain) | | |
| L | Dyn11 | 1 | 79.1 | 48 | | 24 | |
| | | | | 64 | | 15 | 23 |
| | | | | 80 | | 12 | |
| | | | 96.9 | 48 | | 3 | |
| | | 2 | 142.4 | 64 | | 5 | |
| | | | 186 | 48 | | | 25 |
| | | | | 64 | | 13 | 18 |
| | Dyn13 | 1 | 79.1 | 48 | | 23 | |
| | | | | 64 | | 20 | 28 |
| | | | 96.9 | 64 | | 15 | |
| | | 2 | 186 | 48 | | 18 | 30 |
| | Dyn15 | 1 | 79.1 | 48 | | 43 | 28 |
| | | | | 64 | | 22 | |
| | | | 96.9 | 48 | | 20 | |
| | | | | 64 | | | 15 |
| | | 2 | 142.4 | 48 | | | 20 |
| | | | | 64 | | | |
| | | | | 80 | | | |
| | | | 186 | 48 | | | 40 |
| | | | | 64 | | | 20 |
| | Dyn16 | 1 | 79.1 | 48 | | 80 | |
| | | | | 64 | | 85 | |
| | | | | 80 | | 50 | |
| | | | 96.9 | 80 | | 75 | |
| | | 2 | 142.4 | 64 | | 50 | |
| | | | 186 | 64 | | | 65 |
| | Dyn17 | 1 | 79.1 | 64 | | 373 | |
| | | 2 | 186 | 64 | | 78 | |
| | Dyn18 | 1 | 79.1 | 48 | | 68 | |
| | | | | 64 | | 53 | |
| | | | | 80 | | 80 | 83 |
| | | 2 | 142.4 | 80 | 35 | 48 | |
| | | | 186 | 48 | | 90 | |
| | | | | 64 | | | 98 |
| T | Dyn12 | 1 | 79.1 | 64 | | | 58 |
| | | 2 | 186 | 64 | | | 41 |
| | Dyn14 | 1 | 79.1 | 64 | | 23 | 28 |
| | | | | 80 | | 18 | |

## Table A3- 8 Peak strain Data for section 39-108

| Direction | Gauge ID | Truck type | Load | Speed | Tire position | |
|---|---|---|---|---|---|---|
| | | | | | 3 | 4 |
| | | | | | Peak Strain (micro strain) | |
| L | Dyn11 | 1 | 79.1 | 48 | 173 | 202 |
| | | | | 64 | 177 | |
| | | | | 80 | 178 | |
| | | | 96.9 | 48 | 180 | |
| | | 2 | 186 | 48 | 183 | |
| | | | | 64 | 210 | |
| | | | 213.7 | 48 | | 278 |
| | | | | 80 | | |
| | Dyn13 | 1 | 79.1 | 48 | 209 | 251 |
| | | | | 64 | 190 | |
| | | | | 80 | 148 | |
| | | | 96.9 | 48 | 221 | |
| | | | | 80 | 188 | |
| | | | 110.8 | 48 | | |
| | | 2 | 186 | 64 | 225 | |
| | Dyn15 | 1 | 79.1 | 48 | | 238 |
| | | | | 64 | 211 | |
| | | | | 80 | 198 | 224 |
| | | | 96.9 | 48 | 231 | |
| | | | | 64 | 214 | |
| | | | | 80 | 208 | |
| | | | 110.8 | 48 | | 20 |
| | | | | 64 | | |
| | | 2 | 186 | 64 | 268 | 268 |
| | | | 213.7 | 80 | | |
| | Dyn16 | 1 | 110.8 | 48 | | |
| | | | | 64 | | |
| | | | | 80 | | |
| | | 2 | 213.7 | 80 | | |
| | Dyn18 | 1 | 79.1 | 64 | 23 | |
| T | Dyn12 | 1 | 79.1 | 64 | 135 | |
| | | | | 80 | 110 | |
| | | | 96.9 | 80 | 210 | |
| | | 2 | 186 | 48 | 148 | |
| | Dyn14 | 1 | 79.1 | 64 | 258 | |
| | | | | 80 | 110 | 260 |
| | | | 110.8 | 64 | | 128 |
| | | | | 80 | 113 | 28 |
| | | 2 | 186 | 64 | 385 | |
| | | | 213.7 | 80 | | 116 |

## Table A3- 9 Peak strain Data for section 39-110

| Direction | Gauge ID | Truck type | Load | Speed | Tire position | | |
|---|---|---|---|---|---|---|---|
| | | | | | 1 | 3 | 4 |
| | | | | | Peak Strain (micro strain) | | |
| L | Dyn11 | 1 | 79.1 | 48 | | | 24 |
| | | | | 64 | | 19 | 23 |
| | | | | 80 | | 14 | 23 |
| | | | 96.9 | 48 | | 18 | |
| | | | | 64 | | | 18 |
| | | 2 | 186 | 48 | | | 8 |
| | Dyn13 | 1 | 79.1 | 48 | 18 | 18 | 29 |
| | | | | 64 | | 18 | 11 |
| | | | | 80 | | 26 | 8 |
| | | | 96.9 | 80 | | 9 | |
| | | 2 | 142.4 | 64 | | | 8 |
| | | | | 80 | | | 8 |
| | | | 186 | 48 | | | 19 |
| | | | | 64 | | | 23 |
| | Dyn15 | 1 | 79.1 | 48 | 15 | 11 | 15 |
| | | | | 64 | | 9 | |
| | | | | 80 | | | 4 |
| | | | 96.9 | 48 | | 10 | |
| | | | | 64 | | 10 | |
| | | | | 80 | | 8 | |
| | | 2 | 142.4 | 64 | | | 5 |
| | | | | 80 | | | 4 |
| | | | 186 | 48 | | | |
| | Dyn18 | 1 | 79.1 | 48 | | | 160 |
| | | | | 64 | | 139 | 78 |
| | | | | 80 | | 129 | 49 |
| | | | 96.9 | 48 | | 163 | |
| | | | | 64 | | 115 | |
| | | 2 | 142.4 | 48 | | | 98 |
| | | | | 64 | | | 51 |
| | | | | 80 | | 65 | 55 |
| | | | 186 | 48 | | 138 | 148 |
| T | Dyn12 | 1 | 79.1 | 48 | | | 28 |
| | | | | 64 | | | 253 |
| | | | | 80 | | 25 | 17 |
| | | | 96.9 | 80 | | | 20 |
| | | 2 | 142.4 | 80 | | | 90 |
| | Dyn14 | 1 | 79.1 | 48 | | | 25 |
| | | | | 80 | | | 9 |
| | | | 96.9 | 80 | | | 15 |
| | | 2 | 142.4 | 64 | | | 4 |

### Table A3- 10 Average Peak Surface Deflections for section 39-102

| LVDT ID | Truck Type | Load, KN | Speed, kph | Tire position | | |
|---|---|---|---|---|---|---|
| | | | | 1 | 3 | 4 |
| | | | | Peak Surface Deflection (mils) | | |
| LVDT1 | 1 | 79.1 | 64 | | 38.32 | 74.50 |
| | | | 80 | | 58.98 | |
| | | 96.9 | 48 | | 68.59 | |
| | | | 80 | | 75.42 | |
| | 2 | 142.4 | 48 | 47.79 | 53.06 | |
| | | | 64 | | 59.83 | |
| | | | 80 | | 65.18 | |
| | | 186 | 48 | | 77.75 | 86.38 |
| | | | 64 | | 79.04 | |
| LVDT2 | 1 | 79.1 | 48 | | 23.57 | |
| | | | 64 | | 19.20 | 25.06 |
| | | 96.9 | 80 | | 19.00 | |
| LVDT3 | 1 | 79.1 | 48 | | 19.83 | 30.98 |
| | | | 64 | | 26.75 | 32.33 |
| | | | 80 | | 23.00 | |
| | | 96.9 | 48 | | 21.16 | |
| | | | 80 | | 22.97 | |
| | 2 | 142.4 | 48 | | 13.72 | |
| | | | 64 | | 15.00 | 19.02 |
| | | | 80 | | 11.91 | |
| | | 186 | 48 | | 28.84 | 37.19 |
| | | | 64 | | 25.75 | 36.96 |
| LVDT4 | 1 | 79.1 | 48 | | 79.70 | |
| | | | 64 | | 73.97 | 82.07 |
| | | | 80 | | 67.24 | |
| | | 96.9 | 64 | | 77.25 | |
| | | | 80 | | 71.42 | |
| | 2 | 142.4 | 48 | | 49.26 | |
| | | | 64 | | 58.81 | |
| | | | 80 | | 57.85 | |
| | | 186 | 48 | | 76.40 | 82.36 |
| | | | 64 | | 91.15 | 96.64 |

### Table A3- 11 Average Peak Surface Deflections for section 39-104

| LVDT ID | Truck Type | Load, KN | Speed, kph | Tire position | | |
|---|---|---|---|---|---|---|
| | | | | 2 | 3 | 4 |
| | | | | Peak Surface Deflection (mils) | | |
| LVDT1 | 1 | 79.1 | 48 | | 16.78 | |
| | | | 64 | | 17.72 | 17.32 |
| | 2 | 142.4 | 48 | | 12.61 | |
| | | 186 | 48 | | | 18.49 |
| LVDT2 | 1 | 79.1 | 48 | | 6.57 | 6.39 |
| | | | 64 | | 4.92 | 6.76 |
| | | | 80 | | 4.27 | |
| | | 96.9 | 48 | | 4.21 | 4.61 |
| | | | 64 | | 3.67 | |
| | | | 80 | | 2.65 | |
| | 2 | 142.4 | 48 | | 3.72 | |
| | | | 64 | | 4.07 | 3.75 |
| | | 186 | 48 | | 3.05 | |
| | | | 64 | | 4.80 | 7.71 |
| LVDT3 | 1 | 79.1 | 48 | | | 6.26 |
| | | | 64 | | 11.48 | |
| | | | 80 | | 13.89 | |
| | 2 | 142.4 | 80 | 4.72 | | |
| | | 186 | 48 | | 5.49 | |
| LVDT4 | 1 | 79.1 | 64 | | 15.76 | 10.11 |
| | 2 | 142.4 | 80 | 10.47 | | 10.50 |
| | | 186 | 48 | | 15.69 | |
| | | | 64 | | 15.33 | 16.92 |

## Table A3- 12 Average Peak Surface Deflections for section 39-108

| LVDT ID | Truck Type | Load, KN | Speed, kph | Tire position | |
|---|---|---|---|---|---|
| | | | | 3 | 4 |
| | | | | Peak Surface Deflection (mils) | |
| LVDT1 | 1 | 79.1 | 80 | | 11.61 |
| | | 110.8 | 48 | | 16.34 |
| | | | 64 | 7.52 | 13.51 |
| | | | 80 | | 10.86 |
| | 2 | 213.7 | 48 | | 19.05 |
| | | | 64 | | 17.83 |
| | | | 80 | | 14.33 |
| LVDT2 | 1 | 79.1 | 48 | 28.88 | 26.05 |
| | | | 64 | 26.65 | 26.60 |
| | | 96.9 | 48 | 23.13 | |
| | | 110.8 | 48 | | 21.02 |
| | | | 64 | 17.54 | 18.64 |
| | | | 80 | | 16.60 |
| | 2 | 186 | 48 | 31.46 | 34.03 |
| | | | 64 | 29.64 | 30.80 |
| | | 213.7 | 48 | | 26.56 |
| | | | 80 | | 21.88 |
| LVDT3 | 1 | 79.1 | 64 | 48.11 | |
| | | | 80 | 40.42 | |
| | | 96.9 | 80 | 37.57 | |
| | | 110.8 | 48 | | 12.48 |
| | | | 64 | 7.14 | 22.92 |
| | | | 80 | | 11.44 |
| | 2 | 186 | 48 | 24.17 | |
| | | | 64 | 37.10 | |
| | | 213.7 | 48 | | 17.86 |
| | | | 64 | | 18.89 |
| | | | 80 | | 16.58 |
| LVDT4 | 1 | 79.1 | 48 | 47.53 | |
| | | | 64 | 52.16 | 52.79 |
| | | | 80 | 59.33 | 61.45 |
| | | 96.9 | 48 | 36.15 | |
| | | 110.8 | 48 | | 7.64 |
| | | | 64 | 7.58 | 7.93 |
| | | | 80 | | 5.88 |
| | 2 | 186 | 64 | 47.61 | |
| | | 213.7 | 48 | | 12.59 |
| | | | 64 | | 13.24 |
| | | | 80 | | 10.59 |

## Table A3- 13 Average Peak Surface Deflections for section 39-110

| LVDT ID | Truck Type | Load, KN | Speed, kph | Tire position | |
|---|---|---|---|---|---|
| | | | | 3 | 4 |
| | | | | Peak Surface Deflection (mils) | |
| LVDT1 | 1 | 79.1 | 48 | 5.74 | 4.61 |
| | | | 64 | 6.01 | 5.53 |
| | | | 80 | 5.54 | 5.05 |
| | | 96.9 | 48 | 6.08 | |
| | 2 | 142.4 | 48 | | 11.20 |
| | | | 64 | | 9.47 |
| | | | 80 | 10.29 | 8.06 |
| | | 186 | 48 | 6.02 | |
| | | | 64 | | 6.36 |
| LVDT2 | 1 | 79.1 | 48 | | 27.31 |
| | | | 64 | 28.81 | 23.15 |
| | | | 80 | 19.21 | 21.97 |
| | | 96.9 | 48 | | 23.77 |
| | | | 64 | 20.55 | |
| | 2 | 142.4 | 64 | | 25.64 |
| | | | 80 | 20.19 | 19.31 |
| | | 186 | 48 | 28.91 | 30.74 |
| | | | 64 | | 27.98 |
| LVDT3 | 2 | 142.4 | 80 | | 3.37 |
| | | 186 | 48 | 4.75 | |
| LVDT4 | 1 | 79.1 | 64 | 4.97 | 3.81 |
| | | | 80 | | 3.52 |
| | 2 | 142.4 | 48 | | 9.36 |
| | | | 64 | | 6.77 |
| | | | 80 | 9.26 | |
| | | 186 | 48 | 0.50 | |

### Table A3- 14 Average Pressure at top of subgrade for section 39-102

| PC ID | Truck Type | Load, KN | Speed, kph | Tire position | | |
|---|---|---|---|---|---|---|
| | | | | 1 | 3 | 4 |
| | | | | Pressure, psi | | |
| PC1 | 1 | 79.1 | 48 | | 15.17 | 16.24 |
| | | | 64 | | 13.19 | 12.37 |
| | | | 80 | | 13.83 | |
| | | 96.9 | 48 | | 17.36 | |
| | | | 64 | | 14.57 | |
| | | | 80 | | 17.02 | |
| | 2 | 142.4 | 48 | 9.48 | 14.18 | |
| | | | 64 | | 12.73 | |
| | | | 80 | | 13.07 | |
| | | 186 | 48 | | 16.66 | 17.78 |
| | | | 64 | | 14.76 | 15.34 |
| PC2 | 1 | 79.1 | 48 | | 16.85 | 17.66 |
| | | | 64 | | 15.21 | 15.90 |
| | | 96.9 | 48 | | 20.57 | |
| | | | 64 | | 16.96 | |
| | | | 80 | | 20.80 | |
| | 2 | 142.4 | 48 | 12.56 | 14.08 | |
| | | | 64 | | 17.15 | 16.21 |
| | | | 80 | | 13.18 | |
| | | 186 | 48 | | 19.74 | 21.50 |
| | | | 64 | | 19.97 | 20.40 |

### Table A3- 15 Average Pressure at top of subgrade for section 39-104

| PC ID | Truck Type | Load, KN | Speed, kph | Tire position | |
|---|---|---|---|---|---|
| | | | | 3 | 4 |
| | | | | Pressure, psi | |
| PC1 | 1 | 79.1 | 48 | 6.54 | |
| | | | 64 | 6.91 | 5.85 |
| | | | 80 | 4.77 | |
| | | 96.9 | 64 | 5.67 | |
| | 2 | 186 | 48 | 7.24 | 6.60 |
| PC2 | 1 | 79.1 | 48 | 6.52 | |
| | | | 64 | 5.10 | 4.99 |
| | | | 80 | 5.16 | |
| | | 96.9 | 64 | | 5.06 |
| | | | 80 | 4.17 | 5.19 |
| | 2 | 186 | 48 | 6.59 | 6.16 |

## Table A3- 16 Average Pressure at top of subgrade for section 39-108

| PC ID | Truck Type | Load, KN | Speed, kph | Tire position | |
|---|---|---|---|---|---|
| | | | | 3 | 4 |
| | | | | Pressure, psi | |
| PC1 | 1 | 79.1 | 48 | 9.30 | 10.18 |
| | | | 64 | 10.55 | |
| | | | 80 | 11.42 | |
| | | 110.8 | 48 | | 6.79 |
| | | | 64 | 7.58 | 7.60 |
| | | | 80 | 8.00 | 6.93 |
| | 2 | 186 | 48 | 11.13 | |
| | | | 64 | 11.54 | 12.04 |
| | | 213.7 | 48 | | 8.75 |
| | | | 64 | | 9.00 |
| | | | 80 | | 7.81 |
| PC2 | 1 | 79.1 | 48 | 9.79 | 10.73 |
| | | | 64 | 11.48 | 11.48 |
| | | | 80 | | 11.57 |
| | | 96.9 | 48 | 10.50 | |
| | | 110.8 | 48 | | 4.70 |
| | | | 64 | 6.87 | 6.76 |
| | | | 80 | 6.37 | 5.29 |
| | 2 | 186 | 48 | 11.67 | 12.06 |
| | | 213.7 | 48 | | 7.93 |
| | | | 64 | | 8.31 |
| | | | 80 | | 7.71 |

## Table A3- 17 Average Pressure at top of subgrade for section 39-110

| PC ID | Truck Type | Load, KN | Speed, kph | Tire position | | |
|---|---|---|---|---|---|---|
| | | | | 1 | 3 | 4 |
| | | | | Pressure, psi | | |
| PC1 | 1 | 79.1 | 48 | | 3.90 | 6.03 |
| | | | 80 | | 6.07 | 6.12 |
| | | 96.9 | 80 | | 5.84 | |
| | 2 | 186 | 48 | | 6.55 | 7.07 |
| PC2 | 1 | 79.1 | 48 | 3.07 | | 4.66 |
| | | | 64 | | 4.37 | 4.38 |
| | | | 80 | | 4.54 | 3.89 |
| | 2 | 142.4 | 48 | | | 5.47 |
| | | | 64 | | | 5.22 |
| | | | 80 | | 5.18 | 4.56 |
| | | 186 | 48 | | 5.22 | 5.09 |
| | | | 64 | | | 5.96 |

## Table A3- 18 Descriptive Statistics for measured strains

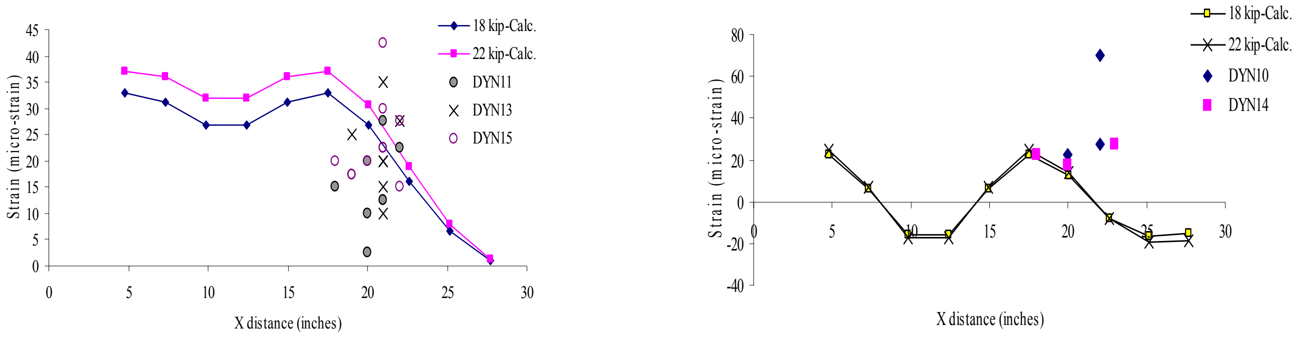
| | | | Section | | | |
|---|---|---|---|---|---|---|
| | | | 102 | 104 | 108 | 110 |
| | | | strain | strain | strain | strain |
| Direction | L | Count | 7 | 60 | 46 | 60 |
| | | Minimum | 950.20 | 12.50 | 22.50 | 12.50 |
| | | Maximum | 1417.70 | 97.50 | 277.50 | 167.50 |
| | | Mean | 1234.49 | 38.96 | 203.15 | 54.38 |
| | | Median | 1257.70 | 27.50 | 208.75 | 27.50 |
| | | Mode | 950.20 | 20.00 | 180.00 | 17.50 |
| | | Percentile 05 | 950.20 | 13.75 | 147.50 | 13.75 |
| | | Percentile 25 | 1065.20 | 20.00 | 180.00 | 20.00 |
| | | Percentile 75 | 1407.70 | 57.50 | 227.50 | 66.25 |
| | | Percentile 95 | 1417.70 | 83.75 | 267.50 | 157.50 |
| | | Percentile 99 | 1417.70 | 97.50 | 277.50 | 167.50 |
| | | Standard Error of Mean | 67.78 | 3.13 | 6.30 | 6.37 |
| | | Standard Deviation | 179.34 | 24.24 | 42.74 | 49.35 |
| | T | Count | 10 | 12 | 21 | 14 |
| | | Minimum | 497.60 | 17.50 | 52.50 | 12.50 |
| | | Maximum | 1247.70 | 70.00 | 282.50 | 90.00 |
| | | Mean | 829.38 | 36.88 | 157.38 | 26.96 |
| | | Median | 762.60 | 27.50 | 132.50 | 22.50 |
| | | Mode | 497.60 | 22.50 | 110.00 | 20.00 |
| | | Percentile 05 | 497.60 | 17.50 | 105.00 | 12.50 |
| | | Percentile 25 | 642.60 | 22.50 | 110.00 | 20.00 |
| | | Percentile 75 | 1105.20 | 55.00 | 202.50 | 27.50 |
| | | Percentile 95 | 1247.70 | 70.00 | 267.50 | 90.00 |
| | | Percentile 99 | 1247.70 | 70.00 | 282.50 | 90.00 |
| | | Standard Error of Mean | 88.33 | 5.55 | 14.09 | 4.99 |
| | | Standard Deviation | 279.31 | 19.22 | 64.58 | 18.69 |

## Table A3- 19 Descriptive Statistics for measured pressures

| | Section ID | | | |
|---|---|---|---|---|
| | 102 | 104 | 108 | 110 |
| | Pressure at top of subgrade, psi | Pressure at top of subgrade, psi | Pressure at top of subgrade, psi | Pressure at top of subgrade, psi |
| Count | 71 | 38 | 79 | 64 |
| Minimum | 9.48 | 2.77 | 1.83 | 3.05 |
| Maximum | 21.50 | 7.76 | 13.09 | 7.51 |
| Mean | 16.38 | 5.88 | 9.09 | 5.10 |
| Median | 16.59 | 5.71 | 8.93 | 5.00 |
| Mode | 12.56 | 4.73 | 8.00 | 3.49 |
| Percentile 05 | 12.40 | 4.06 | 5.86 | 3.44 |
| Percentile 25 | 14.44 | 5.19 | 7.41 | 4.30 |
| Percentile 75 | 17.78 | 6.82 | 11.21 | 5.86 |
| Percentile 95 | 21.00 | 7.41 | 12.06 | 7.29 |
| Percentile 99 | 21.50 | 7.76 | 13.09 | 7.51 |
| Standard Error of Mean | .34 | .18 | .25 | .14 |
| Standard Deviation | 2.86 | 1.12 | 2.25 | 1.12 |

## Table A3- 20 Descriptive Statistics for measured surface deflections

| | | | Section ID | | | |
|---|---|---|---|---|---|---|
| | | | 102 | 104 | 108 | 110 |
| | | | Surface Deflection (mils) | Surface Deflection (mils) | Surface Deflection (mils) | Surface Deflection (mils) |
| Anchor Reference | Deep | Count | 47 | 15 | 48 | 41 |
| | | Minimum | 38.30 | 10.10 | 5.30 | .50 |
| | | Maximum | 96.60 | 20.00 | 61.50 | 13.20 |
| | | Mean | 71.00 | 15.45 | 19.59 | 6.34 |
| | | Median | 74.10 | 16.80 | 13.50 | 6.00 |
| | | Mode | 68.60 | 17.00 | 11.60 | 4.30 |
| | | Percentile 05 | 49.30 | 10.10 | 7.00 | 3.00 |
| | | Percentile 25 | 59.80 | 12.60 | 9.25 | 4.50 |
| | | Percentile 75 | 79.50 | 17.00 | 19.00 | 7.70 |
| | | Percentile 95 | 90.20 | 20.00 | 59.30 | 10.40 |
| | | Percentile 99 | 96.60 | 20.00 | 61.50 | 13.20 |
| | | Standard Error of Mean | 1.84 | .80 | 2.35 | .42 |
| | | Standard Deviation | 12.63 | 3.11 | 16.31 | 2.66 |
| | Shallow | Count | 27 | 38 | 50 | 39 |
| | | Minimum | 11.90 | 2.60 | 7.10 | 3.40 |
| | | Maximum | 37.20 | 13.90 | 48.10 | 32.20 |
| | | Mean | 23.50 | 5.48 | 23.94 | 23.27 |
| | | Median | 23.00 | 4.65 | 23.15 | 23.50 |
| | | Mode | 19.00 | 2.60 | 17.80 | 21.60 |
| | | Percentile 05 | 13.70 | 2.60 | 11.40 | 4.70 |
| | | Percentile 25 | 19.20 | 3.70 | 17.80 | 20.20 |
| | | Percentile 75 | 26.70 | 7.00 | 28.50 | 28.90 |
| | | Percentile 95 | 37.00 | 11.50 | 40.20 | 31.30 |
| | | Percentile 99 | 37.20 | 13.90 | 48.10 | 32.20 |
| | | Standard Error of Mean | 1.20 | .42 | 1.17 | 1.11 |
| | | Standard Deviation | 6.25 | 2.56 | 8.26 | 6.93 |



(a) Strain at bottom of AC layer – Longitudinal

(b) Strain at bottom of AC layer – Transverse

**Figure A3- 8 Comparison of calculated and measured strains for Single Axle – Section 39-104**

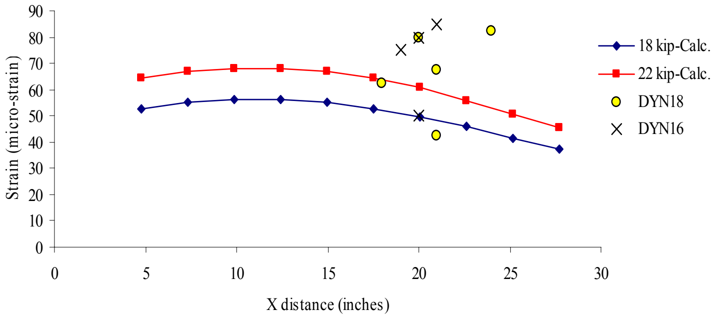
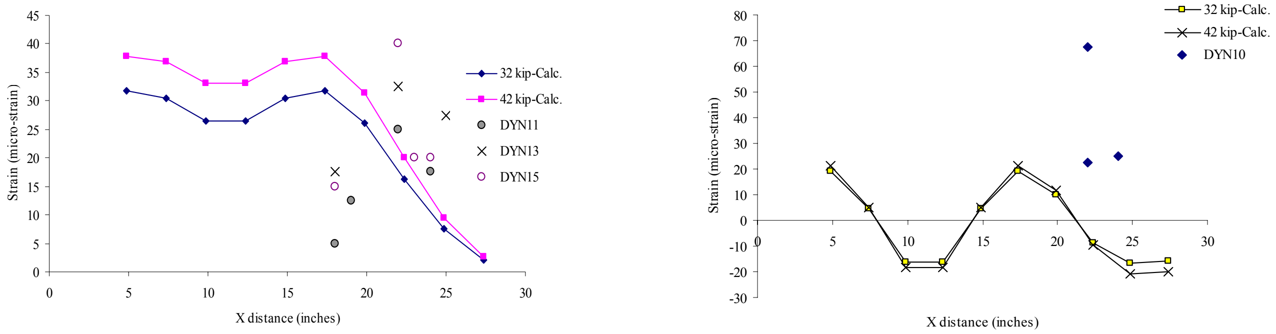


**Figure A3- 9 Comparison of calculated and measured strains for Single Axle – Section 39-104 (at bottom of asphalt treated base)**



(a) Strain at bottom of AC layer – Longitudinal

(b) Strain at bottom of AC layer – Transverse

**Figure A3- 10 Comparison of calculated and measured strains for Tandem Axle – Section 39-104**

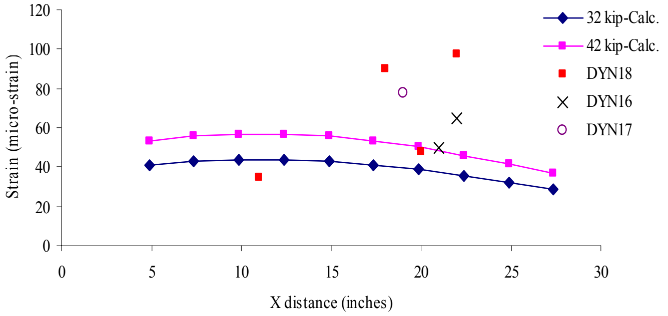
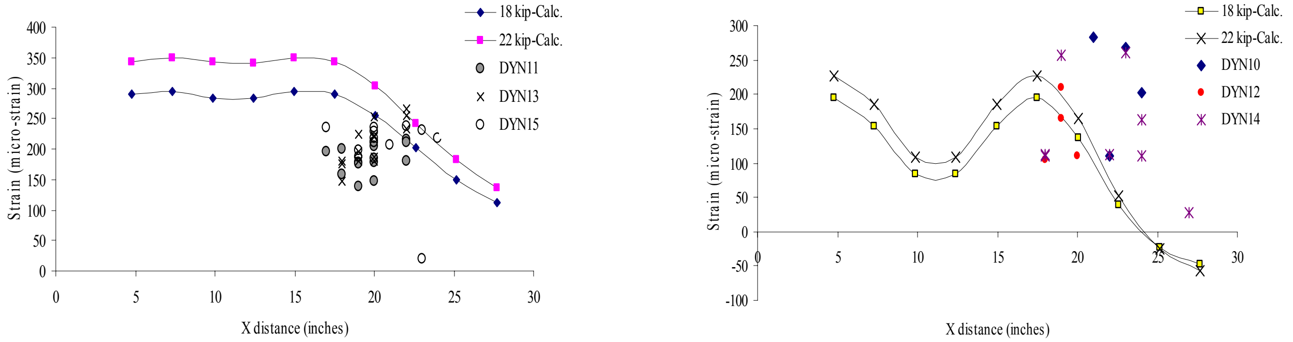


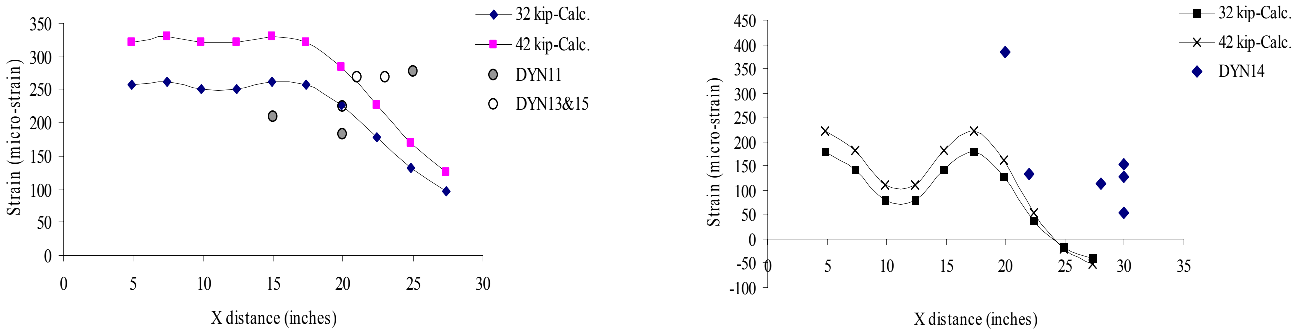
**Figure A3- 11 Comparison of calculated and measured strains for Tandem Axle – Section 39-104 (at bottom of asphalt treated base)**



(a) Strain at bottom of AC layer – Longitudinal

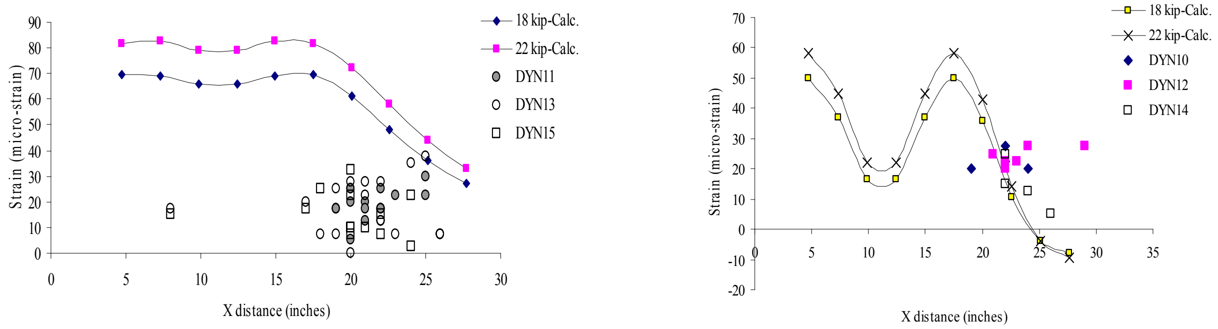
(b) Strain at bottom of AC layer – Transverse

**Figure A3- 12 Comparison of calculated and measured strains for Single Axle – Section 39-108**



(a) Strain at bottom of AC layer under outer wheels – Longitudinal (b) Strain at bottom of AC layer between wheels – Longitudinal

**Figure A3- 13 Comparison of calculated and measured strains for Tandem Axle – Section 39-108**



(a) Strain at bottom of AC layer – Longitudinal (b) Strain at bottom of AC layer – Transverse

**Figure A3- 14 Comparison of calculated and measured strains for Single Axle – Section 39-110**

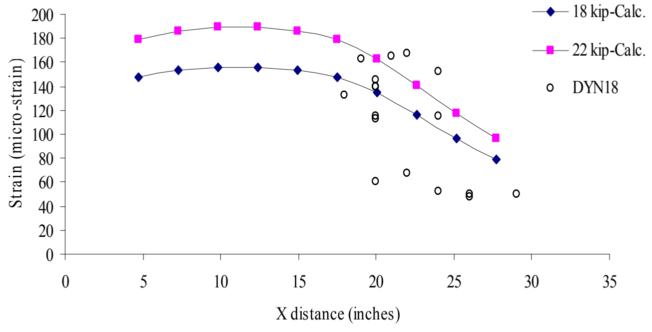
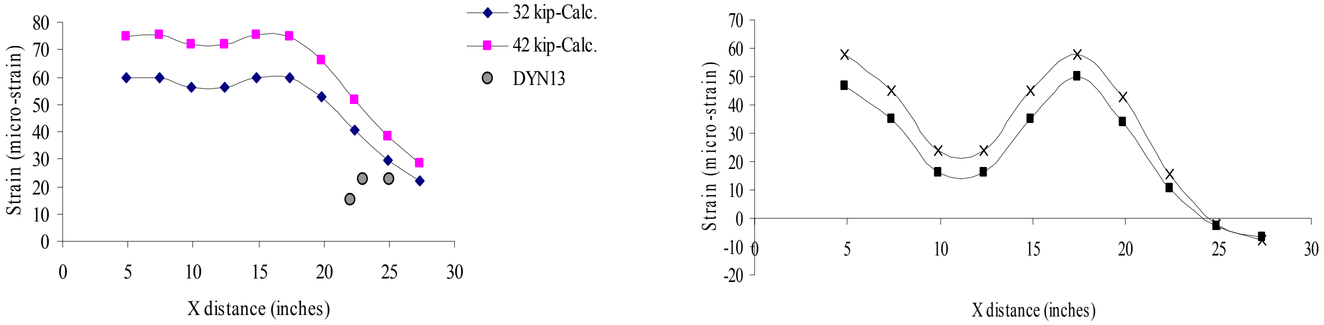


**Figure A3- 15 Comparison of calculated and measured strains for Single Axle – Section 39-110 (at bottom of asphalt treated base)**



(a) Strain at bottom of AC layer – Longitudinal

(b) Strain at bottom of AC layer – Transverse

**Figure A3- 16 Comparison of calculated and measured strains for Tandem Axle – Section 39-110**

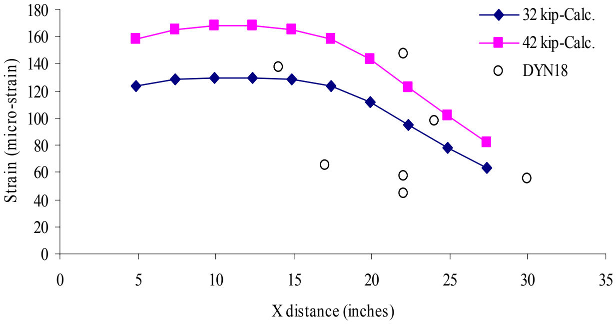
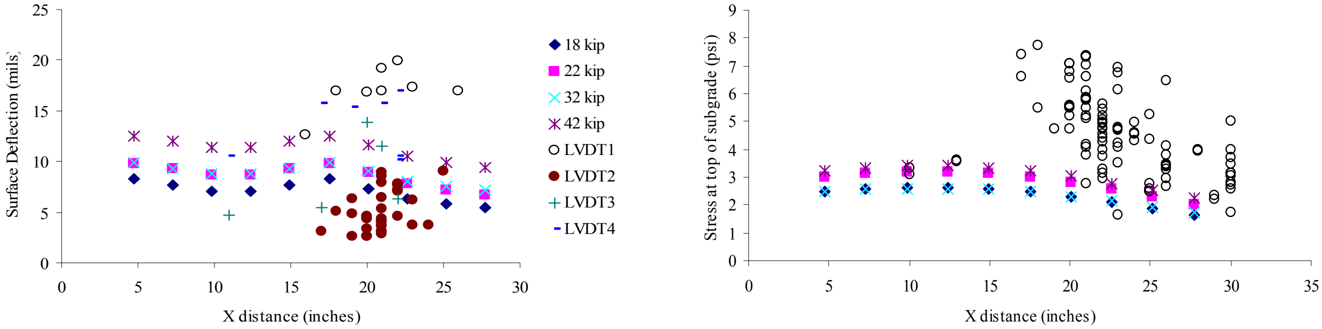
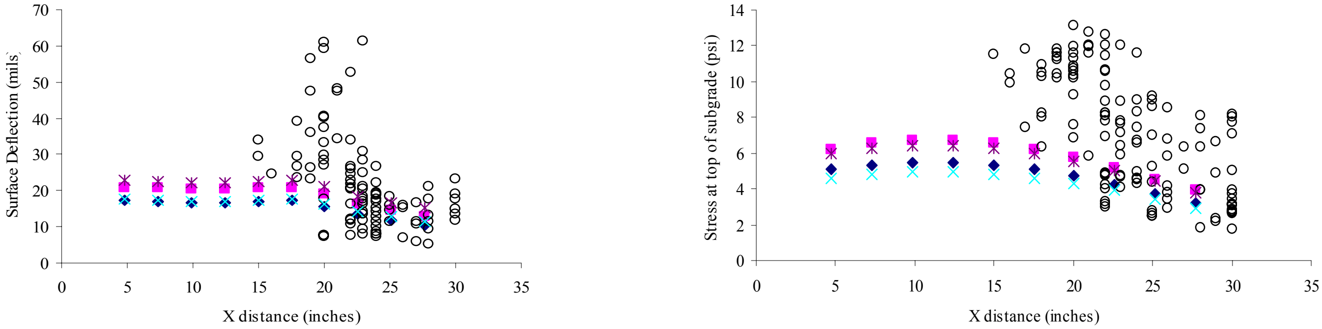


**Figure A3- 17 Comparison of calculated and measured strains for Tandem Axle – Section 39-110 (at bottom of asphalt treated base)**



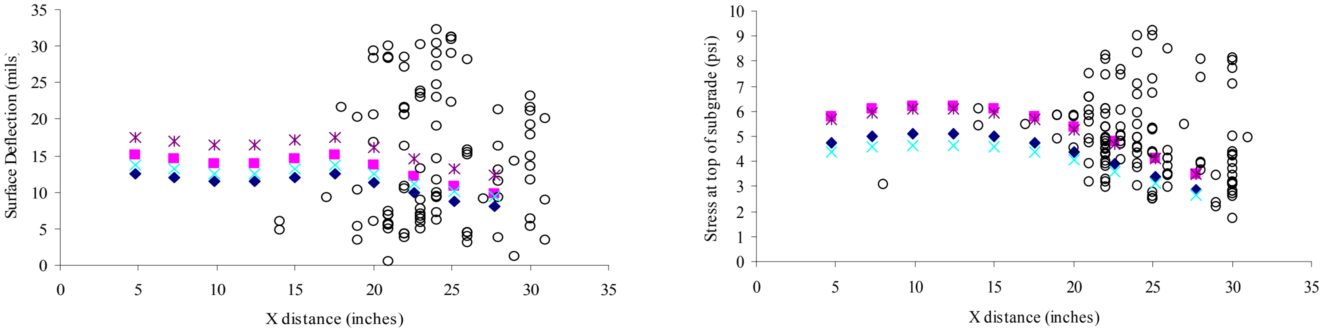
(a) Surface Deflection (b) Stress

**Figure A3- 18 Comparison of calculated and measured deflections and stress – Section 39-104**



(a) Surface Deflection (b) Stress

**Figure A3- 19 Comparison of calculated and measured deflections and stress – Section 39-108**



(a) Surface Deflection (b) Stress

**Figure A3- 20 Comparison of calculated and measured deflections and stress – Section 39-110**

# APPENDIX A4

## Site-level Analysis for SPS-1 experiment
## (Tables for site-level analysis)

Table A4- 1 Level-A analysis for Fatigue Cracking

| Zone | Subgrade | State No. | AC Thickness, in | | Drainage | | Base Type | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 4 | 7 | ND | D | DGAB | ATB | ATB+ DGAB | PATB+ DGAB | PATB+ ATB |
| WF | F | 19 | 1.08 | 0.92 | 1.39 | 0.61 | 2.45 | 0.67 | 0.74 | 1.03 | 0.10 |
| WF | F | 20 | 0.99 | 1.01 | 0.88 | 1.12 | 0.00 | 0.92 | 1.25 | 1.57 | 1.26 |
| WF | F | 26 | 0.75 | 1.25 | 1.66 | 0.34 | 0.00 | 2.26 | 2.28 | 0.00 | 0.46 |
| WF | F | 31 | 1.71 | 0.29 | 2.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| WF | F | 39 | 0.85 | 1.15 | 1.12 | 0.88 | 0.00 | 0.81 | 2.16 | 1.15 | 0.88 |
| WF | F | Average | 1.08 | 0.92 | 1.41 | 0.59 | 1.49 | 0.93 | 1.29 | 0.75 | 0.54 |
| WF | C | 5 | 0.83 | 1.17 | 0.53 | 1.47 | 0.79 | 0.43 | 0.55 | 2.92 | 0.31 |
| WF | C | 10 | 1.30 | 0.70 | 1.51 | 0.49 | 2.84 | 0.65 | 0.62 | 0.54 | 0.36 |
| WF | C | 55 | 0.86 | 1.14 | 2.00 | 0.00 | 3.17 | 1.83 | 0.00 | 0.00 | 0.00 |
| WF | C | Average | 1.00 | 1.00 | 1.35 | 0.65 | 2.27 | 0.97 | 0.39 | 1.15 | 0.22 |
| WF | Both | Average | 1.05 | 0.95 | 1.39 | 0.61 | 1.78 | 0.95 | 0.95 | 0.90 | 0.42 |
| WNF | F | 1 | 1.12 | 0.88 | 0.93 | 1.07 | 1.26 | 0.32 | 1.24 | 1.24 | 0.95 |
| WNF | F | 22 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| WNF | F | 51 | 1.99 | 0.01 | 1.43 | 0.57 | 3.95 | 0.00 | 0.00 | 1.05 | 0.00 |
| WNF | F | Average | 1.37 | 0.63 | 1.12 | 0.88 | 2.07 | 0.44 | 0.75 | 1.09 | 0.65 |
| WNF | C | 12 | 1.77 | 0.23 | 1.01 | 0.99 | 0.14 | 0.84 | 2.05 | 1.78 | 0.19 |
| WNF | C | 40 | 1.43 | 0.57 | 0.55 | 1.45 | 1.21 | 0.49 | 0.12 | 2.20 | 0.98 |
| WNF | C | 48 | 1.73 | 0.27 | 1.46 | 0.54 | 2.29 | 0.00 | 1.72 | 0.00 | 0.99 |
| WNF | C | Average | 1.64 | 0.36 | 1.01 | 0.99 | 1.22 | 0.44 | 1.30 | 1.33 | 0.72 |
| WNF | Both | Average | 1.51 | 0.49 | 1.06 | 0.94 | 1.64 | 0.44 | 1.02 | 1.21 | 0.68 |
| DF | C | 30 | 1.30 | 0.70 | 0.59 | 1.41 | 0.77 | 0.58 | 0.57 | 2.04 | 1.04 |
| DF | C | 32 | 1.38 | 0.62 | 1.44 | 0.56 | 1.30 | 1.73 | 0.93 | 1.02 | 0.01 |
| DF | C | Average | 1.34 | 0.66 | 1.01 | 0.99 | 1.03 | 1.16 | 0.75 | 1.53 | 0.53 |
| DNF | F | 35 | 1.85 | 0.15 | 1.80 | 0.20 | 4.07 | 0.59 | 0.00 | 0.35 | 0.00 |
| DNF | C | 4 | 1.18 | 0.82 | 1.24 | 0.76 | 1.23 | 1.61 | 0.70 | 0.97 | 0.48 |
| DNF | Both | Average | 1.51 | 0.49 | 1.52 | 0.48 | 2.65 | 1.10 | 0.35 | 0.66 | 0.24 |
| All Zones | F | Average | 1.26 | 0.74 | 1.36 | 0.64 | 1.97 | 0.73 | 0.96 | 0.82 | 0.52 |
| All Zones | C | Average | 1.31 | 0.69 | 1.15 | 0.85 | 1.53 | 0.91 | 0.81 | 1.27 | 0.48 |
| Overall | | Average | 1.28 | 0.72 | 1.25 | 0.75 | 1.75 | 0.82 | 0.89 | 1.05 | 0.50 |

Table A4- 2 Level-A analysis for Longitudinal Wheel Path Cracking

| Zone | Subgrade | State No. | AC Thickness, in | | Drainage | | Base Type | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 4 | 7 | ND | D | DGAB | ATB | ATB+ DGAB | PATB+ DGAB | PATB+ ATB |
| WF | F | 19 | 1.41 | 0.59 | 1.60 | 0.40 | 1.88 | 0.92 | 1.49 | 0.47 | 0.24 |
| WF | F | 20 | 1.11 | 0.89 | 2.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 |
| WF | F | 26 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| WF | F | 31 | 1.98 | 0.02 | 2.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| WF | F | 39 | 0.78 | 1.22 | 1.06 | 0.94 | 0.00 | 0.81 | 1.96 | 1.37 | 0.86 |
| WF | F | Average | 1.26 | 0.74 | 1.53 | 0.47 | 1.58 | 1.55 | 0.89 | 0.57 | 0.42 |
| WF | C | 5 | 0.42 | 1.58 | 0.29 | 1.71 | 0.30 | 0.11 | 0.61 | 0.70 | 3.28 |
| WF | C | 10 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| WF | C | 55 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| WF | C | Average | 0.81 | 1.19 | 0.76 | 1.24 | 0.77 | 0.70 | 0.87 | 0.90 | 1.76 |
| WF | Both | Average | 1.09 | 0.91 | 1.24 | 0.76 | 1.27 | 1.23 | 0.88 | 0.69 | 0.92 |
| WNF | F | 1 | 0.60 | 1.40 | 1.41 | 0.59 | 1.02 | 2.19 | 0.70 | 0.61 | 0.49 |
| WNF | F | 22 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| WNF | F | 51 | 1.90 | 0.10 | 2.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| WNF | F | Average | 1.17 | 0.83 | 1.47 | 0.53 | 2.34 | 1.06 | 0.57 | 0.54 | 0.50 |
| WNF | C | 12 | 0.81 | 1.19 | 0.02 | 1.98 | 0.00 | 0.08 | 0.00 | 2.16 | 2.76 |
| WNF | C | 40 | 2.00 | 0.00 | 2.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 |
| WNF | C | 48 | 1.72 | 0.28 | 1.79 | 0.21 | 0.88 | 0.00 | 3.76 | 0.00 | 0.36 |
| WNF | C | Average | 1.51 | 0.49 | 1.27 | 0.73 | 0.29 | 1.69 | 1.25 | 0.72 | 1.04 |
| WNF | Both | Average | 1.34 | 0.66 | 1.37 | 0.63 | 1.32 | 1.38 | 0.91 | 0.63 | 0.77 |
| DF | C | 30 | 0.50 | 1.50 | 1.63 | 0.37 | 3.00 | 0.29 | 1.04 | 0.09 | 0.57 |
| DF | C | 32 | 0.64 | 1.36 | 1.47 | 0.53 | 1.73 | 1.83 | 0.47 | 0.97 | 0.00 |
| DF | C | Average | 0.57 | 1.43 | 1.55 | 0.45 | 2.37 | 1.06 | 0.76 | 0.53 | 0.28 |
| DNF | F | 35 | 1.49 | 0.51 | 1.73 | 0.27 | 3.22 | 0.32 | 1.00 | 0.46 | 0.00 |
| DNF | C | 4 | 1.00 | 1.00 | 0.72 | 1.28 | 0.76 | 0.54 | 0.99 | 1.43 | 1.29 |
| DNF | Both | Average | 1.24 | 0.76 | 1.23 | 0.77 | 1.99 | 0.43 | 0.99 | 0.95 | 0.64 |
| All Zones | F | Average | 1.25 | 0.75 | 1.53 | 0.47 | 2.01 | 1.25 | 0.79 | 0.55 | 0.40 |
| All Zones | C | Average | 1.01 | 0.99 | 1.10 | 0.90 | 0.96 | 1.09 | 0.99 | 0.82 | 1.14 |
| Overall | | Average | 1.13 | 0.87 | 1.32 | 0.68 | 1.49 | 1.17 | 0.89 | 0.68 | 0.77 |

Table A4- 3 Level-A analysis for Longitudinal Non -Wheel Path Cracking

| Zone | Subgrade | State No. | AC Thickness, in | | Drainage | | Base Type | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 4 | 7 | ND | D | DGAB | ATB | ATB+ DGAB | PATB+ DGAB | PATB+ ATB |
| WF | F | 19 | 1.03 | 0.97 | 0.96 | 1.04 | 0.91 | 0.88 | 1.13 | 1.14 | 0.95 |
| WF | F | 20 | 0.91 | 1.09 | 1.18 | 0.82 | 0.00 | 1.94 | 1.19 | 0.16 | 1.70 |
| WF | F | 26 | 0.33 | 1.67 | 1.04 | 0.96 | 0.00 | 1.61 | 1.84 | 0.00 | 1.55 |
| WF | F | 31 | 0.00 | 2.00 | 2.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| WF | F | 39 | 1.14 | 0.86 | 1.48 | 0.52 | 0.00 | 2.02 | 1.62 | 0.76 | 0.61 |
| WF | F | Average | 0.68 | 1.32 | 1.33 | 0.67 | 1.18 | 1.29 | 1.16 | 0.41 | 0.96 |
| WF | C | 5 | 1.01 | 0.99 | 1.02 | 0.98 | 0.94 | 1.11 | 1.00 | 1.06 | 0.90 |
| WF | C | 10 | 0.00 | 2.00 | 2.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 |
| WF | C | 55 | 1.08 | 0.92 | 1.03 | 0.97 | 1.24 | 0.83 | 0.99 | 0.82 | 1.12 |
| WF | C | Average | 0.70 | 1.30 | 1.35 | 0.65 | 0.72 | 0.65 | 2.33 | 0.63 | 0.67 |
| WF | Both | Average | 0.69 | 1.31 | 1.34 | 0.66 | 1.01 | 1.05 | 1.60 | 0.49 | 0.85 |
| WNF | F | 1 | 0.96 | 1.04 | 1.00 | 1.00 | 0.67 | 1.61 | 0.73 | 1.15 | 0.84 |
| WNF | F | 22 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| WNF | F | 51 | 0.24 | 1.76 | 1.76 | 0.24 | 4.58 | 0.00 | 0.00 | 0.42 | 0.00 |
| WNF | F | Average | 0.73 | 1.27 | 1.25 | 0.75 | 2.08 | 0.87 | 0.58 | 0.86 | 0.61 |
| WNF | C | 12 | 0.58 | 1.42 | 1.43 | 0.57 | 2.02 | 0.09 | 1.85 | 0.86 | 0.19 |
| WNF | C | 40 | 1.06 | 0.94 | 0.43 | 1.57 | 0.32 | 0.50 | 0.63 | 1.73 | 1.82 |
| WNF | C | 48 | 1.09 | 0.91 | 0.71 | 1.29 | 0.93 | 0.16 | 1.19 | 1.38 | 1.35 |
| WNF | C | Average | 0.91 | 1.09 | 0.86 | 1.14 | 1.09 | 0.25 | 1.22 | 1.32 | 1.12 |
| WNF | Both | Average | 0.82 | 1.18 | 1.06 | 0.94 | 1.59 | 0.56 | 0.90 | 1.09 | 0.87 |
| DF | C | 30 | 0.96 | 1.04 | 1.01 | 0.99 | 0.97 | 0.97 | 1.07 | 0.99 | 1.00 |
| DF | C | 32 | 0.93 | 1.07 | 1.55 | 0.45 | 1.39 | 2.16 | 0.64 | 0.60 | 0.21 |
| DF | C | Average | 0.95 | 1.05 | 1.28 | 0.72 | 1.18 | 1.56 | 0.86 | 0.80 | 0.60 |
| DNF | F | 35 | 1.67 | 0.33 | 1.17 | 0.83 | 2.16 | 0.71 | 0.52 | 1.61 | 0.00 |
| DNF | C | 4 | 1.09 | 0.91 | 1.39 | 0.61 | 2.79 | 1.08 | 0.00 | 0.99 | 0.14 |
| DNF | Both | Average | 1.38 | 0.62 | 1.28 | 0.72 | 2.48 | 0.89 | 0.26 | 1.30 | 0.07 |
| All Zones | F | Average | 0.81 | 1.19 | 1.29 | 0.71 | 1.59 | 1.08 | 0.89 | 0.69 | 0.74 |
| All Zones | C | Average | 0.87 | 1.13 | 1.17 | 0.83 | 1.18 | 0.77 | 1.37 | 0.94 | 0.75 |
| Overall | | Average | 0.84 | 1.16 | 1.23 | 0.77 | 1.38 | 0.92 | 1.13 | 0.81 | 0.74 |

Table A4- 4 Level-A analysis for Transverse Cracking

| Zone | Subgrade | State No. | AC Thickness, in | | Drainage | | Base Type | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 4 | 7 | ND | D | DGAB | ATB | ATB+ DGAB | PATB+ DGAB | PATB+ ATB |
| WF | F | 19 | 0.95 | 1.05 | 1.55 | 0.45 | 1.60 | 1.23 | 1.35 | 0.32 | 0.49 |
| WF | F | 20 | 1.22 | 0.78 | 1.57 | 0.43 | 0.00 | 1.80 | 2.21 | 0.26 | 0.73 |
| WF | F | 26 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| WF | F | 31 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| WF | F | 39 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| WF | F | Average | 1.03 | 0.97 | 1.22 | 0.78 | 0.92 | 1.21 | 1.31 | 0.71 | 0.85 |
| WF | C | 5 | 0.86 | 1.14 | 0.72 | 1.28 | 1.02 | 0.64 | 0.62 | 2.26 | 0.46 |
| WF | C | 10 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| WF | C | 55 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| WF | C | Average | 0.95 | 1.05 | 0.91 | 1.09 | 1.01 | 0.88 | 0.87 | 1.42 | 0.82 |
| WF | Both | Average | 1.00 | 1.00 | 1.11 | 0.89 | 0.95 | 1.08 | 1.15 | 0.98 | 0.84 |
| WNF | F | 1 | 1.47 | 0.53 | 1.56 | 0.44 | 0.90 | 0.27 | 3.03 | 0.44 | 0.36 |
| WNF | F | 22 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| WNF | F | 51 | 2.00 | 0.00 | 2.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| WNF | F | Average | 1.49 | 0.51 | 1.52 | 0.48 | 2.30 | 0.42 | 1.34 | 0.48 | 0.45 |
| WNF | C | 12 | 2.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 |
| WNF | C | 40 | 0.20 | 1.80 | 1.87 | 0.13 | 0.17 | 4.60 | 0.00 | 0.23 | 0.00 |
| WNF | C | 48 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| WNF | C | Average | 1.07 | 0.93 | 1.62 | 0.38 | 0.39 | 1.87 | 2.00 | 0.41 | 0.33 |
| WNF | Both | Average | 1.28 | 0.72 | 1.57 | 0.43 | 1.34 | 1.15 | 1.67 | 0.44 | 0.39 |
| DF | C | 30 | 1.31 | 0.69 | 0.72 | 1.28 | 0.91 | 0.91 | 0.47 | 2.54 | 0.18 |
| DF | C | 32 | 1.31 | 0.69 | 0.80 | 1.20 | 2.13 | 0.11 | 0.27 | 2.07 | 0.43 |
| DF | C | Average | 1.31 | 0.69 | 0.76 | 1.24 | 1.52 | 0.51 | 0.37 | 2.31 | 0.30 |
| DNF | F | 35 | 2.00 | 0.00 | 2.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| DNF | C | 4 | 1.47 | 0.53 | 0.96 | 1.04 | 2.61 | 0.17 | 0.12 | 1.87 | 0.23 |
| DNF | Both | Average | 1.73 | 0.27 | 1.48 | 0.52 | 3.80 | 0.08 | 0.06 | 0.93 | 0.12 |
| All Zones | F | Average | 1.29 | 0.71 | 1.41 | 0.59 | 1.83 | 0.81 | 1.18 | 0.56 | 0.62 |
| All Zones | C | Average | 1.13 | 0.87 | 1.12 | 0.88 | 1.09 | 1.05 | 1.05 | 1.33 | 0.48 |
| Overall | | Average | 1.21 | 0.79 | 1.26 | 0.74 | 1.46 | 0.93 | 1.11 | 0.94 | 0.55 |

Table A4- 5 Level-A analysis for Rutting

| Zone | Subgrade | State No. | AC Thickness, in | | Drainage | | Base Type | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 4 | 7 | ND | D | DGAB | ATB | ATB+ DGAB | PATB+ DGAB | PATB+ ATB |
| WF | F | 19 | 0.93 | 1.07 | 0.89 | 1.11 | 1.22 | 0.63 | 0.89 | 1.49 | 0.77 |
| WF | F | 20 | 1.20 | 0.80 | 1.17 | 0.83 | 2.12 | 0.59 | 0.70 | 1.09 | 0.51 |
| WF | F | 26 | 0.89 | 1.11 | 1.10 | 0.90 | 0.00 | 1.44 | 1.32 | 1.25 | 1.00 |
| WF | F | 31 | 0.95 | 1.05 | 1.13 | 0.87 | 1.47 | 1.00 | 0.84 | 0.62 | 1.07 |
| WF | F | 39 | 1.05 | 0.95 | 1.10 | 0.90 | 1.73 | 0.84 | 0.68 | 1.13 | 0.63 |
| WF | F | Average | 1.00 | 1.00 | 1.08 | 0.92 | 1.31 | 0.90 | 0.88 | 1.11 | 0.79 |
| WF | C | 5 | 0.99 | 1.01 | 1.00 | 1.00 | 0.87 | 1.11 | 1.02 | 1.01 | 0.98 |
| WF | C | 10 | 1.07 | 0.93 | 1.18 | 0.82 | 1.40 | 1.02 | 1.01 | 0.77 | 0.80 |
| WF | C | 55 | 0.96 | 1.04 | 1.15 | 0.85 | 0.85 | 1.24 | 1.26 | 0.73 | 0.92 |
| WF | C | Average | 1.01 | 0.99 | 1.11 | 0.89 | 1.04 | 1.13 | 1.10 | 0.84 | 0.90 |
| WF | Both | Average | 1.00 | 1.00 | 1.09 | 0.91 | 1.21 | 0.98 | 0.96 | 1.01 | 0.83 |
| WNF | F | 1 | 1.09 | 0.91 | 1.02 | 0.98 | 1.00 | 0.93 | 1.11 | 0.93 | 1.04 |
| WNF | F | 22 | 0.96 | 1.04 | 1.16 | 0.84 | 1.00 | 1.12 | 1.26 | 0.83 | 0.80 |
| WNF | F | 51 | 1.11 | 0.89 | 1.24 | 0.76 | 1.79 | 0.77 | 0.98 | 0.67 | 0.79 |
| WNF | F | Average | 1.05 | 0.95 | 1.14 | 0.86 | 1.26 | 0.94 | 1.11 | 0.81 | 0.87 |
| WNF | C | 12 | 1.05 | 0.95 | 1.06 | 0.94 | 0.85 | 1.19 | 1.10 | 0.88 | 0.98 |
| WNF | C | 40 | 1.06 | 0.94 | 1.10 | 0.90 | 1.22 | 0.96 | 1.05 | 0.85 | 0.92 |
| WNF | C | 48 | 0.91 | 1.09 | 1.08 | 0.92 | 0.80 | 1.74 | 0.66 | 0.81 | 0.99 |
| WNF | C | Average | 1.01 | 0.99 | 1.08 | 0.92 | 0.96 | 1.30 | 0.93 | 0.85 | 0.96 |
| WNF | Both | Average | 1.03 | 0.97 | 1.11 | 0.89 | 1.11 | 1.12 | 1.02 | 0.83 | 0.92 |
| DF | C | 30 | 1.23 | 0.77 | 0.80 | 1.20 | 0.90 | 0.81 | 0.78 | 1.56 | 0.96 |
| DF | C | 32 | 1.12 | 0.88 | 0.96 | 1.04 | 0.90 | 0.85 | 1.14 | 0.99 | 1.11 |
| DF | C | Average | 1.18 | 0.82 | 0.88 | 1.12 | 0.90 | 0.83 | 0.96 | 1.27 | 1.04 |
| DNF | F | 35 | 0.97 | 1.03 | 1.00 | 1.00 | 1.00 | 1.06 | 0.94 | 1.02 | 0.98 |
| DNF | C | 4 | 0.87 | 1.13 | 0.91 | 1.09 | 0.97 | 0.68 | 1.12 | 1.36 | 0.87 |
| DNF | Both | Average | 0.92 | 1.08 | 0.95 | 1.05 | 0.98 | 0.87 | 1.03 | 1.19 | 0.93 |
| All Zones | F | Average | 1.02 | 0.98 | 1.09 | 0.91 | 1.26 | 0.93 | 0.97 | 1.00 | 0.84 |
| All Zones | C | Average | 1.03 | 0.97 | 1.03 | 0.97 | 0.97 | 1.07 | 1.01 | 1.00 | 0.95 |
| Overall | | Average | 1.02 | 0.98 | 1.06 | 0.94 | 1.12 | 1.00 | 0.99 | 1.00 | 0.90 |

Table A4- 6 Level-A analysis for IRI

| Zone | Subgrade | State No. | AC Thickness, in | | Drainage | | Base Type | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 4 | 7 | ND | D | DGAB | ATB | ATB+ DGAB | PATB+ DGAB | PATB+ ATB |
| WF | F | 19 | 1.01 | 0.99 | 1.11 | 0.89 | 1.43 | 0.89 | 0.95 | 0.85 | 0.88 |
| WF | F | 20 | 1.07 | 0.93 | 1.19 | 0.81 | 1.13 | 0.97 | 1.35 | 0.88 | 0.67 |
| WF | F | 26 | 1.11 | 0.89 | 1.03 | 0.97 | 0.00 | 0.98 | 1.59 | 1.53 | 0.91 |
| WF | F | 31 | 1.11 | 0.89 | 1.03 | 0.97 | 1.25 | 0.91 | 0.91 | 1.05 | 0.89 |
| WF | F | 39 | 1.01 | 0.99 | 1.16 | 0.84 | 1.39 | 1.05 | 0.93 | 0.85 | 0.77 |
| WF | F | Average | 1.06 | 0.94 | 1.10 | 0.90 | 1.04 | 0.96 | 1.15 | 1.03 | 0.82 |
| WF | C | 5 | 0.99 | 1.01 | 0.92 | 1.08 | 0.95 | 0.95 | 0.92 | 1.26 | 0.92 |
| WF | C | 10 | 0.99 | 1.01 | 1.10 | 0.90 | 1.19 | 1.06 | 0.99 | 0.93 | 0.83 |
| WF | C | 55 | 0.91 | 1.09 | 1.09 | 0.91 | 1.04 | 1.19 | 0.99 | 0.83 | 0.95 |
| WF | C | Average | 0.96 | 1.04 | 1.04 | 0.96 | 1.06 | 1.06 | 0.97 | 1.01 | 0.90 |
| WF | Both | Average | 1.02 | 0.98 | 1.08 | 0.92 | 1.05 | 1.00 | 1.08 | 1.02 | 0.85 |
| WNF | F | 1 | 1.06 | 0.94 | 1.01 | 0.99 | 1.16 | 0.99 | 0.87 | 1.09 | 0.89 |
| WNF | F | 22 | 1.05 | 0.95 | 1.03 | 0.97 | 1.07 | 0.98 | 1.02 | 0.98 | 0.95 |
| WNF | F | 51 | 1.09 | 0.91 | 1.04 | 0.96 | 1.24 | 0.92 | 0.94 | 1.03 | 0.88 |
| WNF | F | Average | 1.06 | 0.94 | 1.03 | 0.97 | 1.15 | 0.96 | 0.94 | 1.03 | 0.91 |
| WNF | C | 12 | 1.00 | 1.00 | 0.98 | 1.02 | 1.07 | 0.99 | 0.88 | 1.04 | 1.02 |
| WNF | C | 40 | 1.00 | 1.00 | 1.07 | 0.93 | 1.08 | 1.06 | 1.04 | 0.88 | 0.95 |
| WNF | C | 48 | 1.03 | 0.97 | 1.05 | 0.95 | 0.96 | 1.23 | 0.91 | 1.02 | 0.87 |
| WNF | C | Average | 1.01 | 0.99 | 1.03 | 0.97 | 1.04 | 1.09 | 0.95 | 0.98 | 0.95 |
| WNF | Both | Average | 1.04 | 0.96 | 1.03 | 0.97 | 1.09 | 1.03 | 0.94 | 1.01 | 0.93 |
| DF | C | 30 | 1.08 | 0.92 | 0.83 | 1.17 | 0.93 | 0.87 | 0.79 | 1.45 | 0.97 |
| DF | C | 32 | 1.07 | 0.93 | 1.04 | 0.96 | 1.24 | 0.93 | 0.93 | 0.96 | 0.94 |
| DF | C | Average | 1.07 | 0.93 | 0.94 | 1.06 | 1.08 | 0.90 | 0.86 | 1.21 | 0.95 |
| DNF | F | 35 | 1.07 | 0.93 | 1.04 | 0.96 | 1.12 | 1.03 | 0.94 | 1.02 | 0.90 |
| DNF | C | 4 | 1.11 | 0.89 | 1.01 | 0.99 | 1.23 | 0.87 | 0.92 | 1.06 | 0.93 |
| DNF | Both | Average | 1.09 | 0.91 | 1.02 | 0.98 | 1.17 | 0.95 | 0.93 | 1.04 | 0.91 |
| All Zones | F | Average | 1.06 | 0.94 | 1.07 | 0.93 | 1.09 | 0.97 | 1.06 | 1.03 | 0.86 |
| All Zones | C | Average | 1.02 | 0.98 | 1.01 | 0.99 | 1.08 | 1.02 | 0.93 | 1.05 | 0.93 |
| Overall | | Average | 1.04 | 0.96 | 1.04 | 0.96 | 1.08 | 0.99 | 0.99 | 1.04 | 0.89 |

Table A4- 7 Level-B analysis for Fatigue Cracking

| Zone | Subgrade | State | AC Thickness effect (inches) | | | | | | | | | | Base Thickness effect (inches) | | | | Base Type effect | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | DGAB | | ATB | | ATB+DGAB | | PATB+DGAB | | PATB+ATB | | PATB+DGAB | | PATB+ATB | | 8" | | 12" | |
| | | | 4 | 7 | 4 | 7 | 4 | 7 | 4 | 7 | 4 | 7 | 12 | 16 | 12 | 16 | ATB | ATB+DGAB | ATB | ATB+DGAB |
| WF | F | 19 | 1.52 | 0.48 | 0.97 | 1.03 | 0.21 | 1.79 | 1.21 | 0.79 | 0.49 | 1.51 | 2.00 | 0.00 | 2.00 | 0.00 | 1.62 | 0.38 | 0.68 | 1.32 |
| WF | F | 20 | 1.00 | 1.00 | 1.32 | 0.68 | 1.32 | 0.68 | 0.00 | 2.00 | 0.75 | 1.25 | 1.20 | 0.80 | 1.08 | 0.92 | 0.84 | 1.16 | 0.85 | 1.15 |
| WF | F | 26 | 1.00 | 1.00 | 0.45 | 1.55 | 0.00 | 2.00 | 1.00 | 1.00 | 0.00 | 2.00 | 1.00 | 1.00 | 0.00 | 2.00 | 1.21 | 0.79 | 2.00 | 0.00 |
| WF | F | 31 | 1.71 | 0.29 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| WF | F | 39 | 1.00 | 1.00 | 1.40 | 0.60 | 0.00 | 2.00 | 0.00 | 2.00 | 0.83 | 1.17 | 2.00 | 0.00 | 1.16 | 0.84 | 2.00 | 0.00 | 0.36 | 1.64 |
| WF | F | Average | 1.25 | 0.75 | 1.03 | 0.97 | 0.51 | 1.49 | 0.64 | 1.36 | 0.61 | 1.39 | 1.44 | 0.56 | 1.05 | 0.95 | 1.34 | 0.66 | 0.98 | 1.02 |
| WF | C | 5 | 0.90 | 1.10 | 0.78 | 1.22 | 0.98 | 1.02 | 0.51 | 1.49 | 1.03 | 0.97 | 1.09 | 0.91 | 0.69 | 1.31 | 0.96 | 1.04 | 0.76 | 1.24 |
| WF | C | 10 | 1.47 | 0.53 | 0.01 | 1.99 | 0.72 | 1.28 | 1.84 | 0.16 | 2.00 | 0.00 | 0.46 | 1.54 | 1.54 | 0.46 | 0.03 | 1.97 | 1.24 | 0.76 |
| WF | C | 55 | 0.20 | 1.80 | 2.00 | 0.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 2.00 | 0.00 |
| WF | C | Average | 0.86 | 1.14 | 0.93 | 1.07 | 0.90 | 1.10 | 1.12 | 0.88 | 1.34 | 0.66 | 0.85 | 1.15 | 1.08 | 0.92 | 0.66 | 1.34 | 1.33 | 0.67 |
| WF | Both | Average | 1.10 | 0.90 | 0.99 | 1.01 | 0.65 | 1.35 | 0.82 | 1.18 | 0.89 | 1.11 | 1.22 | 0.78 | 1.06 | 0.94 | 1.08 | 0.92 | 1.11 | 0.89 |
| WNF | F | 1 | 1.59 | 0.41 | 1.74 | 0.26 | 1.71 | 0.29 | 0.46 | 1.54 | 0.83 | 1.17 | 0.97 | 1.03 | 1.73 | 0.27 | 0.42 | 1.58 | 0.38 | 1.62 |
| WNF | F | 22 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| WNF | F | 51 | 1.98 | 0.02 | 1.00 | 1.00 | 1.00 | 1.00 | 2.00 | 0.00 | 1.00 | 1.00 | 1.93 | 0.07 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| WNF | F | Average | 1.53 | 0.47 | 1.25 | 0.75 | 1.24 | 0.76 | 1.15 | 0.85 | 0.94 | 1.06 | 1.30 | 0.70 | 1.24 | 0.76 | 0.81 | 1.19 | 0.79 | 1.21 |
| WNF | C | 12 | 2.00 | 0.00 | 2.00 | 0.00 | 2.00 | 0.00 | 1.83 | 0.17 | 0.00 | 2.00 | 2.00 | 0.00 | 1.00 | 1.00 | 0.58 | 1.42 | 1.00 | 1.00 |
| WNF | C | 40 | 0.43 | 1.57 | 2.00 | 0.00 | 2.00 | 0.00 | 1.75 | 0.25 | 1.36 | 0.64 | 0.90 | 1.10 | 1.74 | 0.26 | 1.00 | 1.00 | 1.60 | 0.40 |
| WNF | C | 48 | 2.00 | 0.00 | 1.00 | 1.00 | 1.13 | 0.87 | 1.00 | 1.00 | 2.00 | 0.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.00 | 2.00 | 0.00 | 2.00 |
| WNF | C | Average | 1.48 | 0.52 | 1.67 | 0.33 | 1.71 | 0.29 | 1.53 | 0.47 | 1.12 | 0.88 | 1.30 | 0.70 | 1.25 | 0.75 | 0.53 | 1.47 | 0.87 | 1.13 |
| WNF | Both | Average | 1.50 | 0.50 | 1.46 | 0.54 | 1.47 | 0.53 | 1.34 | 0.66 | 1.03 | 0.97 | 1.30 | 0.70 | 1.25 | 0.75 | 0.67 | 1.33 | 0.83 | 1.17 |
| DF | C | 30 | 1.08 | 0.92 | 0.20 | 1.80 | 0.13 | 1.87 | 1.41 | 0.59 | 1.74 | 0.26 | 1.11 | 0.89 | 1.30 | 0.70 | 1.00 | 1.00 | 1.21 | 0.79 |
| DF | C | 32 | 1.82 | 0.18 | 1.86 | 0.14 | 1.98 | 0.02 | 0.16 | 1.84 | 1.27 | 0.73 | 0.58 | 1.42 | 2.00 | 0.00 | 1.27 | 0.73 | 1.85 | 0.15 |
| DF | C | Average | 1.45 | 0.55 | 1.03 | 0.97 | 1.05 | 0.95 | 0.79 | 1.21 | 1.50 | 0.50 | 0.85 | 1.15 | 1.65 | 0.35 | 1.14 | 0.86 | 1.53 | 0.47 |
| DNF | F | 35 | 2.00 | 0.00 | 0.67 | 1.33 | 1.00 | 1.00 | 2.00 | 0.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 2.00 | 0.00 | 2.00 | 0.00 |
| DNF | C | 4 | 0.65 | 1.35 | 1.88 | 0.12 | 1.78 | 0.22 | 0.78 | 1.22 | 0.11 | 1.89 | 0.05 | 1.95 | 0.13 | 1.87 | 1.11 | 0.89 | 1.41 | 0.59 |
| DNF | Both | Average | 1.33 | 0.67 | 1.27 | 0.73 | 1.39 | 0.61 | 1.39 | 0.61 | 0.55 | 1.45 | 0.52 | 1.48 | 0.57 | 1.43 | 1.56 | 0.44 | 1.71 | 0.29 |
| All Zones | F | Average | 1.42 | 0.58 | 1.06 | 0.94 | 0.80 | 1.20 | 0.96 | 1.04 | 0.77 | 1.23 | 1.34 | 0.66 | 1.11 | 0.89 | 1.23 | 0.77 | 1.03 | 0.97 |
| All Zones | C | Average | 1.17 | 0.83 | 1.30 | 0.70 | 1.30 | 0.70 | 1.14 | 0.86 | 1.17 | 0.83 | 0.91 | 1.09 | 1.16 | 0.84 | 0.77 | 1.23 | 1.23 | 0.77 |
| Overall | | Average | 1.30 | 0.70 | 1.18 | 0.82 | 1.05 | 0.95 | 1.05 | 0.95 | 0.97 | 1.03 | 1.13 | 0.87 | 1.13 | 0.87 | 1.00 | 1.00 | 1.13 | 0.87 |

Table A4- 8 Level-B analysis for Longitudinal Wheel Path Cracking

| Zone | Subgrade | State | AC Thickness effect (inches) | | | | | | | | | | Base Thickness effect (inches) | | | | Base Type effect | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | DGAB | | ATB | | ATB+DGAB | | PATB+DGAB | | PATB+ATB | | PATB+DGAB | | PATB+ATB | | 8" | | 12" | |
| | | | 4 | 7 | 4 | 7 | 4 | 7 | 4 | 7 | 4 | 7 | 12 | 16 | 12 | 16 | ATB | ATB+DGAB | ATB | ATB+DGAB |
| WF | F | 19 | 1.87 | 0.13 | 0.58 | 1.42 | 1.62 | 0.38 | 1.55 | 0.45 | 0.32 | 1.68 | 1.08 | 0.92 | 1.26 | 0.74 | 0.36 | 1.64 | 1.39 | 0.61 |
| WF | F | 20 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 2.00 | 0.00 | 2.00 | 0.00 |
| WF | F | 26 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| WF | F | 31 | 1.98 | 0.02 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| WF | F | 39 | 1.00 | 1.00 | 1.50 | 0.50 | 0.00 | 2.00 | 0.00 | 2.00 | 0.65 | 1.35 | 0.89 | 1.11 | 0.88 | 1.12 | 2.00 | 0.00 | 0.35 | 1.65 |
| WF | F | Average | 1.37 | 0.63 | 1.01 | 0.99 | 0.92 | 1.08 | 0.91 | 1.09 | 0.79 | 1.21 | 0.99 | 1.01 | 1.03 | 0.97 | 1.27 | 0.73 | 1.15 | 0.85 |
| WF | C | 5 | 1.27 | 0.73 | 0.41 | 1.59 | 1.26 | 0.74 | 1.39 | 0.61 | 0.02 | 1.98 | 0.34 | 1.66 | 1.92 | 0.08 | 0.54 | 1.46 | 0.11 | 1.89 |
| WF | C | 10 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| WF | C | 55 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| WF | C | Average | 1.09 | 0.91 | 0.80 | 1.20 | 1.09 | 0.91 | 1.13 | 0.87 | 0.67 | 1.33 | 0.78 | 1.22 | 1.31 | 0.69 | 0.85 | 1.15 | 0.70 | 1.30 |
| WF | Both | Average | 1.27 | 0.73 | 0.94 | 1.06 | 0.98 | 1.02 | 0.99 | 1.01 | 0.75 | 1.25 | 0.91 | 1.09 | 1.13 | 0.87 | 1.11 | 0.89 | 0.98 | 1.02 |
| WNF | F | 1 | 0.62 | 1.38 | 0.38 | 1.62 | 0.58 | 1.42 | 0.77 | 1.23 | 1.12 | 0.88 | 1.02 | 0.98 | 0.99 | 1.01 | 1.34 | 0.66 | 1.56 | 0.44 |
| WNF | F | 22 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| WNF | F | 51 | 1.90 | 0.10 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| WNF | F | Average | 1.17 | 0.83 | 0.79 | 1.21 | 0.86 | 1.14 | 0.92 | 1.08 | 1.04 | 0.96 | 1.01 | 0.99 | 1.00 | 1.00 | 1.11 | 0.89 | 1.19 | 0.81 |
| WNF | C | 12 | 1.00 | 1.00 | 2.00 | 0.00 | 1.00 | 1.00 | 1.21 | 0.79 | 0.45 | 1.55 | 2.00 | 0.00 | 0.00 | 2.00 | 2.00 | 0.00 | 1.00 | 1.00 |
| WNF | C | 40 | 1.00 | 1.00 | 2.00 | 0.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 2.00 | 0.00 |
| WNF | C | 48 | 2.00 | 0.00 | 1.00 | 1.00 | 1.61 | 0.39 | 1.00 | 1.00 | 2.00 | 0.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.00 | 2.00 | 0.00 | 2.00 |
| WNF | C | Average | 1.33 | 0.67 | 1.67 | 0.33 | 1.20 | 0.80 | 1.07 | 0.93 | 1.15 | 0.85 | 1.33 | 0.67 | 0.67 | 1.33 | 1.00 | 1.00 | 1.00 | 1.00 |
| WNF | Both | Average | 1.25 | 0.75 | 1.23 | 0.77 | 1.03 | 0.97 | 1.00 | 1.00 | 1.09 | 0.91 | 1.17 | 0.83 | 0.83 | 1.17 | 1.06 | 0.94 | 1.09 | 0.91 |
| DF | C | 30 | 0.27 | 1.73 | 0.00 | 2.00 | 0.73 | 1.27 | 0.00 | 2.00 | 1.58 | 0.42 | 1.00 | 1.00 | 0.10 | 1.90 | 0.61 | 1.39 | 0.00 | 2.00 |
| DF | C | 32 | 0.39 | 1.61 | 0.31 | 1.69 | 1.07 | 0.93 | 1.51 | 0.49 | 1.00 | 1.00 | 0.24 | 1.76 | 1.00 | 1.00 | 1.06 | 0.94 | 1.75 | 0.25 |
| DF | C | Average | 0.33 | 1.67 | 0.16 | 1.84 | 0.90 | 1.10 | 0.76 | 1.24 | 1.29 | 0.71 | 0.62 | 1.38 | 0.55 | 1.45 | 0.84 | 1.16 | 0.88 | 1.12 |
| DNF | F | 35 | 1.23 | 0.77 | 1.84 | 0.16 | 1.83 | 0.17 | 2.00 | 0.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.48 | 1.52 | 0.44 | 1.56 |
| DNF | C | 4 | 1.19 | 0.81 | 0.28 | 1.72 | 1.23 | 0.77 | 1.05 | 0.95 | 0.91 | 1.09 | 0.75 | 1.25 | 1.12 | 0.88 | 1.10 | 0.90 | 0.22 | 1.78 |
| DNF | Both | Average | 1.21 | 0.79 | 1.06 | 0.94 | 1.53 | 0.47 | 1.52 | 0.48 | 0.96 | 1.04 | 0.88 | 1.12 | 1.06 | 0.94 | 0.79 | 1.21 | 0.33 | 1.67 |
| All Zones | F | Average | 1.29 | 0.71 | 1.03 | 0.97 | 1.00 | 1.00 | 1.04 | 0.96 | 0.90 | 1.10 | 1.00 | 1.00 | 1.01 | 0.99 | 1.13 | 0.87 | 1.08 | 0.92 |
| All Zones | C | Average | 1.01 | 0.99 | 0.89 | 1.11 | 1.10 | 0.90 | 1.02 | 0.98 | 1.00 | 1.00 | 0.93 | 1.07 | 0.90 | 1.10 | 0.92 | 1.08 | 0.79 | 1.21 |
| Overall | | Average | 1.15 | 0.85 | 0.96 | 1.04 | 1.05 | 0.95 | 1.03 | 0.97 | 0.95 | 1.05 | 0.96 | 1.04 | 0.96 | 1.04 | 1.03 | 0.97 | 0.93 | 1.07 |

Table A4- 9 Level-B analysis for Longitudinal Non -Wheel Path Cracking

| Zone | Subgrade | State | AC Thickness effect (inches) | | | | | | | | | | Base Thickness effect (inches) | | | | Base Type effect | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | DGAB | | ATB | | ATB+DGAB | | PATB+DGAB | | PATB+ATB | | PATB+DGAB | | PATB+ATB | | 8" | | 12" | |
| | | | 4 | 7 | 4 | 7 | 4 | 7 | 4 | 7 | 4 | 7 | 12 | 16 | 12 | 16 | ATB | ATB+DGAB | ATB | ATB+DGAB |
| WF | F | 19 | 0.95 | 1.05 | 0.83 | 1.17 | 1.36 | 0.64 | 0.80 | 1.20 | 1.27 | 0.73 | 0.69 | 1.31 | 1.36 | 0.64 | 0.64 | 1.36 | 1.17 | 0.83 |
| WF | F | 20 | 1.00 | 1.00 | 0.76 | 1.24 | 1.53 | 0.47 | 0.00 | 2.00 | 0.32 | 1.68 | 0.00 | 2.00 | 1.17 | 0.83 | 0.90 | 1.10 | 1.62 | 0.38 |
| WF | F | 26 | 1.00 | 1.00 | 0.24 | 1.76 | 0.00 | 2.00 | 1.00 | 1.00 | 0.00 | 2.00 | 1.00 | 1.00 | 1.14 | 0.86 | 1.21 | 0.79 | 2.00 | 0.00 |
| WF | F | 31 | 0.00 | 2.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| WF | F | 39 | 1.00 | 1.00 | 1.06 | 0.94 | 0.00 | 2.00 | 0.00 | 2.00 | 2.00 | 0.00 | 1.71 | 0.29 | 1.20 | 0.80 | 2.00 | 0.00 | 1.08 | 0.92 |
| WF | F | Average | 0.79 | 1.21 | 0.78 | 1.22 | 0.78 | 1.22 | 0.56 | 1.44 | 0.92 | 1.08 | 0.88 | 1.12 | 1.17 | 0.83 | 1.15 | 0.85 | 1.37 | 0.63 |
| WF | C | 5 | 1.07 | 0.93 | 0.94 | 1.06 | 1.10 | 0.90 | 0.94 | 1.06 | 0.97 | 1.03 | 1.16 | 0.84 | 0.88 | 1.12 | 1.13 | 0.87 | 0.98 | 1.02 |
| WF | C | 10 | 1.00 | 1.00 | 1.00 | 1.00 | 0.00 | 2.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.00 | 2.00 |
| WF | C | 55 | 0.96 | 1.04 | 1.04 | 0.96 | 1.04 | 0.96 | 1.34 | 0.66 | 1.15 | 0.85 | 1.25 | 0.75 | 0.52 | 1.48 | 0.92 | 1.08 | 0.91 | 1.09 |
| WF | C | Average | 1.01 | 0.99 | 0.99 | 1.01 | 0.72 | 1.28 | 1.09 | 0.91 | 1.04 | 0.96 | 1.14 | 0.86 | 0.80 | 1.20 | 1.02 | 0.98 | 0.63 | 1.37 |
| WF | Both | Average | 0.87 | 1.13 | 0.86 | 1.14 | 0.75 | 1.25 | 0.76 | 1.24 | 0.96 | 1.04 | 0.98 | 1.02 | 1.03 | 0.97 | 1.10 | 0.90 | 1.09 | 0.91 |
| WNF | F | 1 | 1.05 | 0.95 | 1.80 | 0.20 | 0.96 | 1.04 | 0.00 | 2.00 | 0.82 | 1.18 | 0.92 | 1.08 | 1.21 | 0.79 | 1.61 | 0.39 | 0.61 | 1.39 |
| WNF | F | 22 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| WNF | F | 51 | 0.00 | 2.00 | 1.00 | 1.00 | 1.00 | 1.00 | 2.00 | 0.00 | 1.00 | 1.00 | 2.00 | 0.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| WNF | F | Average | 0.68 | 1.32 | 1.27 | 0.73 | 0.99 | 1.01 | 1.00 | 1.00 | 0.94 | 1.06 | 1.31 | 0.69 | 1.07 | 0.93 | 1.20 | 0.80 | 0.87 | 1.13 |
| WNF | C | 12 | 0.04 | 1.96 | 0.42 | 1.58 | 1.50 | 0.50 | 0.41 | 1.59 | 0.05 | 1.95 | 1.76 | 0.24 | 2.00 | 0.00 | 0.03 | 1.97 | 0.26 | 1.74 |
| WNF | C | 40 | 0.00 | 2.00 | 1.41 | 0.59 | 1.71 | 0.29 | 0.92 | 1.08 | 1.13 | 0.87 | 1.07 | 0.93 | 1.28 | 0.72 | 1.24 | 0.76 | 0.79 | 1.21 |
| WNF | C | 48 | 1.24 | 0.76 | 0.00 | 2.00 | 0.41 | 1.59 | 0.38 | 1.62 | 1.98 | 0.02 | 1.00 | 1.00 | 0.00 | 2.00 | 0.29 | 1.71 | 0.00 | 2.00 |
| WNF | C | Average | 0.43 | 1.57 | 0.61 | 1.39 | 1.21 | 0.79 | 0.57 | 1.43 | 1.06 | 0.94 | 1.28 | 0.72 | 1.09 | 0.91 | 0.52 | 1.48 | 0.35 | 1.65 |
| WNF | Both | Average | 0.55 | 1.45 | 0.94 | 1.06 | 1.10 | 0.90 | 0.78 | 1.22 | 1.00 | 1.00 | 1.29 | 0.71 | 1.08 | 0.92 | 0.86 | 1.14 | 0.61 | 1.39 |
| DF | C | 30 | 0.98 | 1.02 | 0.97 | 1.03 | 0.88 | 1.12 | 0.99 | 1.01 | 0.96 | 1.04 | 0.96 | 1.04 | 1.05 | 0.95 | 0.91 | 1.09 | 1.00 | 1.00 |
| DF | C | 32 | 0.71 | 1.29 | 1.21 | 0.79 | 1.49 | 0.51 | 0.70 | 1.30 | 0.18 | 1.82 | 0.55 | 1.45 | 1.67 | 0.33 | 1.47 | 0.53 | 1.68 | 0.32 |
| DF | C | Average | 0.85 | 1.15 | 1.09 | 0.91 | 1.18 | 0.82 | 0.84 | 1.16 | 0.57 | 1.43 | 0.75 | 1.25 | 1.36 | 0.64 | 1.19 | 0.81 | 1.34 | 0.66 |
| DNF | F | 35 | 1.30 | 0.70 | 1.38 | 0.62 | 2.00 | 0.00 | 2.00 | 0.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.97 | 1.03 | 2.00 | 0.00 |
| DNF | C | 4 | 0.54 | 1.46 | 1.48 | 0.52 | 1.00 | 1.00 | 2.00 | 0.00 | 0.00 | 2.00 | 2.00 | 0.00 | 1.93 | 0.07 | 2.00 | 0.00 | 2.00 | 0.00 |
| DNF | Both | Average | 0.92 | 1.08 | 1.43 | 0.57 | 1.50 | 0.50 | 2.00 | 0.00 | 0.50 | 1.50 | 1.50 | 0.50 | 1.46 | 0.54 | 1.49 | 0.51 | 2.00 | 0.00 |
| All Zones | F | Average | 0.81 | 1.19 | 1.01 | 0.99 | 0.98 | 1.02 | 0.87 | 1.13 | 0.93 | 1.07 | 1.04 | 0.96 | 1.12 | 0.88 | 1.15 | 0.85 | 1.28 | 0.72 |
| All Zones | C | Average | 0.73 | 1.27 | 0.94 | 1.06 | 1.01 | 0.99 | 0.96 | 1.04 | 0.83 | 1.17 | 1.20 | 0.80 | 1.15 | 0.85 | 1.00 | 1.00 | 0.85 | 1.15 |
| Overall | | Average | 0.77 | 1.23 | 0.98 | 1.02 | 1.00 | 1.00 | 0.92 | 1.08 | 0.88 | 1.12 | 1.12 | 0.88 | 1.13 | 0.87 | 1.07 | 0.93 | 1.06 | 0.94 |

Table A4- 10 Level-B analysis for Transverse Cracking

| Zone | Subgrade | State | AC Thickness effect (inches) | | | | | | | | | | Base Thickness effect (inches) | | | | Base Type effect | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | DGAB | | ATB | | ATB+DGAB | | PATB+DGAB | | PATB+ATB | | PATB+DGAB | | PATB+ATB | | 8" | | 12" | |
| | | | 4 | 7 | 4 | 7 | 4 | 7 | 4 | 7 | 4 | 7 | 12 | 16 | 12 | 16 | ATB | ATB+DGAB | ATB | ATB+DGAB |
| WF | F | 19 | 1.55 | 0.45 | 0.71 | 1.29 | 0.64 | 1.36 | 0.00 | 2.00 | 0.93 | 1.07 | 1.26 | 0.74 | 1.05 | 0.95 | 1.01 | 0.99 | 0.93 | 1.07 |
| WF | F | 20 | 1.00 | 1.00 | 1.76 | 0.24 | 1.01 | 0.99 | 0.00 | 2.00 | 0.29 | 1.71 | 2.00 | 0.00 | 1.01 | 0.99 | 1.18 | 0.82 | 0.33 | 1.67 |
| WF | F | 26 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| WF | F | 31 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| WF | F | 39 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| WF | F | Average | 1.11 | 0.89 | 1.09 | 0.91 | 0.93 | 1.07 | 0.60 | 1.40 | 0.85 | 1.15 | 1.25 | 0.75 | 1.01 | 0.99 | 1.04 | 0.96 | 0.85 | 1.15 |
| WF | C | 5 | 0.84 | 1.16 | 1.18 | 0.82 | 0.77 | 1.23 | 0.51 | 1.49 | 1.21 | 0.79 | 1.31 | 0.69 | 1.15 | 0.85 | 0.82 | 1.18 | 1.23 | 0.77 |
| WF | C | 10 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| WF | C | 55 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| WF | C | Average | 0.95 | 1.05 | 1.06 | 0.94 | 0.92 | 1.08 | 0.84 | 1.16 | 1.07 | 0.93 | 1.10 | 0.90 | 1.05 | 0.95 | 0.94 | 1.06 | 1.08 | 0.92 |
| WF | Both | Average | 1.05 | 0.95 | 1.08 | 0.92 | 0.93 | 1.07 | 0.69 | 1.31 | 0.93 | 1.07 | 1.20 | 0.80 | 1.03 | 0.97 | 1.00 | 1.00 | 0.94 | 1.06 |
| WNF | F | 1 | 1.18 | 0.82 | 2.00 | 0.00 | 2.00 | 0.00 | 0.26 | 1.74 | 0.21 | 1.79 | 1.12 | 0.88 | 2.00 | 0.00 | 0.17 | 1.83 | 1.00 | 1.00 |
| WNF | F | 22 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| WNF | F | 51 | 2.00 | 0.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| WNF | F | Average | 1.39 | 0.61 | 1.33 | 0.67 | 1.33 | 0.67 | 0.75 | 1.25 | 0.74 | 1.26 | 1.04 | 0.96 | 1.33 | 0.67 | 0.72 | 1.28 | 1.00 | 1.00 |
| WNF | C | 12 | 1.00 | 1.00 | 1.00 | 1.00 | 2.00 | 0.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.00 | 2.00 | 1.00 | 1.00 |
| WNF | C | 40 | 2.00 | 0.00 | 0.00 | 2.00 | 1.00 | 1.00 | 2.00 | 0.00 | 1.00 | 1.00 | 0.00 | 2.00 | 1.00 | 1.00 | 2.00 | 0.00 | 1.00 | 1.00 |
| WNF | C | 48 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| WNF | C | Average | 1.33 | 0.67 | 0.67 | 1.33 | 1.33 | 0.67 | 1.33 | 0.67 | 1.00 | 1.00 | 0.67 | 1.33 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| WNF | Both | Average | 1.36 | 0.64 | 1.00 | 1.00 | 1.33 | 0.67 | 1.04 | 0.96 | 0.87 | 1.13 | 0.85 | 1.15 | 1.17 | 0.83 | 0.86 | 1.14 | 1.00 | 1.00 |
| DF | C | 30 | 2.00 | 0.00 | 0.00 | 2.00 | 0.00 | 2.00 | 1.50 | 0.50 | 0.00 | 2.00 | 0.09 | 1.91 | 2.00 | 0.00 | 1.32 | 0.68 | 1.00 | 1.00 |
| DF | C | 32 | 1.91 | 0.09 | 0.47 | 1.53 | 0.00 | 2.00 | 1.45 | 0.55 | 0.49 | 1.51 | 0.80 | 1.20 | 0.00 | 2.00 | 2.00 | 0.00 | 0.46 | 1.54 |
| DF | C | Average | 1.95 | 0.05 | 0.24 | 1.76 | 0.00 | 2.00 | 1.47 | 0.53 | 0.24 | 1.76 | 0.44 | 1.56 | 1.00 | 1.00 | 1.66 | 0.34 | 0.73 | 1.27 |
| DNF | F | 35 | 2.00 | 0.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| DNF | C | 4 | 1.52 | 0.48 | 0.41 | 1.59 | 0.14 | 1.86 | 1.46 | 0.54 | 0.47 | 1.53 | 1.00 | 1.00 | 0.95 | 1.05 | 1.08 | 0.92 | 1.61 | 0.39 |
| DNF | Both | Average | 1.76 | 0.24 | 0.71 | 1.29 | 0.57 | 1.43 | 1.23 | 0.77 | 0.73 | 1.27 | 1.00 | 1.00 | 0.98 | 1.02 | 1.04 | 0.96 | 1.30 | 0.70 |
| All Zones | F | Average | 1.30 | 0.70 | 1.16 | 0.84 | 1.07 | 0.93 | 0.70 | 1.30 | 0.83 | 1.17 | 1.15 | 0.85 | 1.12 | 0.88 | 0.93 | 1.07 | 0.92 | 1.08 |
| All Zones | C | Average | 1.36 | 0.64 | 0.67 | 1.33 | 0.77 | 1.23 | 1.21 | 0.79 | 0.80 | 1.20 | 0.80 | 1.20 | 1.01 | 0.99 | 1.14 | 0.86 | 1.03 | 0.97 |
| Overall | | Average | 1.33 | 0.67 | 0.92 | 1.08 | 0.92 | 1.08 | 0.95 | 1.05 | 0.81 | 1.19 | 0.98 | 1.02 | 1.06 | 0.94 | 1.03 | 0.97 | 0.98 | 1.02 |

Table A4- 11 Level-B analysis for Rutting

| Zone | Subgrade | State | AC Thickness effect (inches) | | | | | | | | | | Base Thickness effect (inches) | | | | Base Type effect | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | DGAB | | ATB | | ATB+DGAB | | PATB+DGAB | | PATB+ATB | | PATB+DGAB | | PATB+ATB | | 8" | | 12" | |
| | | | 4 | 7 | 4 | 7 | 4 | 7 | 4 | 7 | 4 | 7 | 12 | 16 | 12 | 16 | ATB | ATB+DGAB | ATB | ATB+DGAB |
| WF | F | 19 | 1.09 | 0.91 | 0.94 | 1.06 | 1.10 | 0.90 | 0.89 | 1.11 | 0.97 | 1.03 | 1.20 | 0.80 | 0.91 | 1.09 | 0.76 | 1.24 | 0.91 | 1.09 |
| WF | F | 20 | 1.27 | 0.73 | 1.13 | 0.87 | 1.25 | 0.75 | 1.43 | 0.57 | 0.81 | 1.19 | 0.88 | 1.12 | 0.99 | 1.01 | 0.86 | 1.14 | 0.99 | 1.01 |
| WF | F | 26 | 1.00 | 1.00 | 0.65 | 1.35 | 0.79 | 1.21 | 2.00 | 0.00 | 0.00 | 2.00 | 1.11 | 0.89 | 0.98 | 1.02 | 1.09 | 0.91 | 0.95 | 1.05 |
| WF | F | 31 | 1.37 | 0.63 | 0.75 | 1.25 | 1.06 | 0.94 | 1.03 | 0.97 | 0.66 | 1.34 | 1.11 | 0.89 | 1.06 | 0.94 | 1.23 | 0.77 | 0.92 | 1.08 |
| WF | F | 39 | 1.07 | 0.93 | 1.32 | 0.68 | 1.40 | 0.60 | 0.85 | 1.15 | 1.14 | 0.86 | 1.08 | 0.92 | 0.85 | 1.15 | 1.08 | 0.92 | 1.16 | 0.84 |
| WF | F | Average | 1.16 | 0.84 | 0.96 | 1.04 | 1.12 | 0.88 | 1.24 | 0.76 | 0.72 | 1.28 | 1.07 | 0.93 | 0.96 | 1.04 | 1.00 | 1.00 | 0.98 | 1.02 |
| WF | C | 5 | 0.82 | 1.18 | 1.14 | 0.86 | 1.06 | 0.94 | 0.96 | 1.04 | 0.96 | 1.04 | 1.01 | 0.99 | 0.96 | 1.04 | 1.00 | 1.00 | 1.08 | 0.92 |
| WF | C | 10 | 1.12 | 0.88 | 0.91 | 1.09 | 1.28 | 0.72 | 1.06 | 0.94 | 0.97 | 1.03 | 1.16 | 0.84 | 1.01 | 0.99 | 0.83 | 1.17 | 1.21 | 0.79 |
| WF | C | 55 | 0.93 | 1.07 | 1.00 | 1.00 | 1.07 | 0.93 | 0.80 | 1.20 | 1.01 | 0.99 | 0.99 | 1.01 | 1.00 | 1.00 | 1.03 | 0.97 | 0.96 | 1.04 |
| WF | C | Average | 0.96 | 1.04 | 1.02 | 0.98 | 1.14 | 0.86 | 0.94 | 1.06 | 0.98 | 1.02 | 1.06 | 0.94 | 0.99 | 1.01 | 0.95 | 1.05 | 1.09 | 0.91 |
| WF | Both | Average | 1.08 | 0.92 | 0.98 | 1.02 | 1.13 | 0.87 | 1.13 | 0.87 | 0.81 | 1.19 | 1.07 | 0.93 | 0.97 | 1.03 | 0.99 | 1.01 | 1.02 | 0.98 |
| WNF | F | 1 | 1.26 | 0.74 | 0.97 | 1.03 | 1.02 | 0.98 | 1.08 | 0.92 | 1.07 | 0.93 | 1.01 | 0.99 | 0.97 | 1.03 | 0.89 | 1.11 | 0.94 | 1.06 |
| WNF | F | 22 | 1.01 | 0.99 | 0.97 | 1.03 | 0.82 | 1.18 | 1.03 | 0.97 | 0.95 | 1.05 | 1.04 | 0.96 | 1.05 | 0.95 | 0.87 | 1.13 | 1.02 | 0.98 |
| WNF | F | 51 | 1.53 | 0.47 | 0.95 | 1.05 | 0.97 | 1.03 | 1.01 | 0.99 | 0.82 | 1.18 | 1.15 | 0.85 | 1.03 | 0.97 | 0.89 | 1.11 | 0.87 | 1.13 |
| WNF | F | Average | 1.27 | 0.73 | 0.96 | 1.04 | 0.94 | 1.06 | 1.04 | 0.96 | 0.95 | 1.05 | 1.07 | 0.93 | 1.02 | 0.98 | 0.88 | 1.12 | 0.94 | 1.06 |
| WNF | C | 12 | 0.82 | 1.18 | 1.16 | 0.84 | 1.12 | 0.88 | 1.08 | 0.92 | 1.00 | 1.00 | 1.12 | 0.88 | 1.12 | 0.88 | 1.06 | 0.94 | 1.02 | 0.98 |
| WNF | C | 40 | 1.45 | 0.55 | 0.83 | 1.17 | 0.51 | 1.49 | 1.09 | 0.91 | 1.29 | 0.71 | 1.04 | 0.96 | 1.02 | 0.98 | 0.84 | 1.16 | 1.20 | 0.80 |
| WNF | C | 48 | 0.81 | 1.19 | 1.03 | 0.97 | 1.16 | 0.84 | 0.97 | 1.03 | 0.62 | 1.38 | 1.03 | 0.97 | 0.85 | 1.15 | 1.50 | 0.50 | 1.40 | 0.60 |
| WNF | C | Average | 1.03 | 0.97 | 1.01 | 0.99 | 0.93 | 1.07 | 1.05 | 0.95 | 0.97 | 1.03 | 1.06 | 0.94 | 0.99 | 1.01 | 1.13 | 0.87 | 1.21 | 0.79 |
| WNF | Both | Average | 1.15 | 0.85 | 0.98 | 1.02 | 0.93 | 1.07 | 1.04 | 0.96 | 0.96 | 1.04 | 1.06 | 0.94 | 1.01 | 0.99 | 1.01 | 0.99 | 1.08 | 0.92 |
| DF | C | 30 | 1.30 | 0.70 | 1.00 | 1.00 | 0.97 | 1.03 | 1.34 | 0.66 | 1.20 | 0.80 | 0.97 | 1.03 | 1.15 | 0.85 | 1.00 | 1.00 | 1.03 | 0.97 |
| DF | C | 32 | 1.20 | 0.80 | 1.26 | 0.74 | 1.20 | 0.80 | 0.98 | 1.02 | 1.05 | 0.95 | 0.95 | 1.05 | 0.98 | 1.02 | 0.88 | 1.12 | 0.82 | 1.18 |
| DF | C | Average | 1.25 | 0.75 | 1.13 | 0.87 | 1.08 | 0.92 | 1.16 | 0.84 | 1.13 | 0.87 | 0.96 | 1.04 | 1.07 | 0.93 | 0.94 | 1.06 | 0.93 | 1.07 |
| DNF | F | 35 | 0.97 | 1.03 | 0.97 | 1.03 | 1.03 | 0.97 | 0.94 | 1.06 | 0.96 | 1.04 | 1.00 | 1.00 | 0.94 | 1.06 | 1.03 | 0.97 | 1.09 | 0.91 |
| DNF | C | 4 | 0.83 | 1.17 | 1.36 | 0.64 | 0.88 | 1.12 | 0.53 | 1.47 | 1.00 | 1.00 | 1.06 | 0.94 | 0.99 | 1.01 | 0.52 | 1.48 | 0.97 | 1.03 |
| DNF | Both | Average | 0.90 | 1.10 | 1.16 | 0.84 | 0.96 | 1.04 | 0.74 | 1.26 | 0.98 | 1.02 | 1.03 | 0.97 | 0.97 | 1.03 | 0.77 | 1.23 | 1.03 | 0.97 |
| All Zones | F | Average | 1.17 | 0.83 | 0.96 | 1.04 | 1.05 | 0.95 | 1.14 | 0.86 | 0.82 | 1.18 | 1.06 | 0.94 | 0.98 | 1.02 | 0.97 | 1.03 | 0.98 | 1.02 |
| All Zones | C | Average | 1.03 | 0.97 | 1.08 | 0.92 | 1.03 | 0.97 | 0.98 | 1.02 | 1.01 | 0.99 | 1.04 | 0.96 | 1.01 | 0.99 | 0.96 | 1.04 | 1.08 | 0.92 |
| Overall | | Average | 1.10 | 0.90 | 1.02 | 0.98 | 1.04 | 0.96 | 1.06 | 0.94 | 0.91 | 1.09 | 1.05 | 0.95 | 0.99 | 1.01 | 0.96 | 1.04 | 1.03 | 0.97 |

Table A4- 12 Level-B analysis for IRI

| Zone | Subgrade | State | AC Thickness effect (inches) | | | | | | | | | | Base Thickness effect (inches) | | | | Base Type effect | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | DGAB | | ATB | | ATB+DGAB | | PATB+DGAB | | PATB+ATB | | PATB+DGAB | | PATB+ATB | | 8" | | 12" | |
| | | | 4 | 7 | 4 | 7 | 4 | 7 | 4 | 7 | 4 | 7 | 12 | 16 | 12 | 16 | ATB | ATB+DGAB | ATB | ATB+DGAB |
| WF | F | 19 | 1.12 | 0.88 | 1.02 | 0.98 | 1.09 | 0.91 | 0.97 | 1.03 | 0.86 | 1.14 | 1.23 | 0.77 | 1.06 | 0.94 | 0.94 | 1.06 | 1.00 | 1.00 |
| WF | F | 20 | 1.05 | 0.95 | 1.22 | 0.78 | 1.24 | 0.76 | 0.90 | 1.10 | 1.03 | 0.97 | 1.12 | 0.88 | 1.00 | 1.00 | 0.83 | 1.17 | 0.85 | 1.15 |
| WF | F | 26 | 1.00 | 1.00 | 0.85 | 1.15 | 1.04 | 0.96 | 2.00 | 0.00 | 0.00 | 2.00 | 0.98 | 1.02 | 0.80 | 1.20 | 0.85 | 1.15 | 0.67 | 1.33 |
| WF | F | 31 | 1.20 | 0.80 | 1.04 | 0.96 | 1.06 | 0.94 | 1.04 | 0.96 | 1.14 | 0.86 | 0.96 | 1.04 | 0.96 | 1.04 | 1.01 | 0.99 | 0.99 | 1.01 |
| WF | F | 39 | 0.86 | 1.14 | 1.36 | 0.64 | 1.02 | 0.98 | 0.96 | 1.04 | 0.92 | 1.08 | 1.12 | 0.88 | 0.96 | 1.04 | 1.20 | 0.80 | 0.85 | 1.15 |
| WF | F | Average | 1.05 | 0.95 | 1.10 | 0.90 | 1.09 | 0.91 | 1.17 | 0.83 | 0.79 | 1.21 | 1.08 | 0.92 | 0.96 | 1.04 | 0.97 | 1.03 | 0.87 | 1.13 |
| WF | C | 5 | 1.06 | 0.94 | 1.03 | 0.97 | 0.92 | 1.08 | 0.89 | 1.11 | 0.97 | 1.03 | 1.18 | 0.82 | 0.94 | 1.06 | 0.96 | 1.04 | 1.07 | 0.93 |
| WF | C | 10 | 1.00 | 1.00 | 0.97 | 1.03 | 1.03 | 0.97 | 1.01 | 0.99 | 0.98 | 1.02 | 1.00 | 1.00 | 1.10 | 0.90 | 1.01 | 0.99 | 1.06 | 0.94 |
| WF | C | 55 | 1.01 | 0.99 | 0.89 | 1.11 | 0.95 | 1.05 | 0.89 | 1.11 | 0.86 | 1.14 | 0.91 | 1.09 | 0.95 | 1.05 | 1.12 | 0.88 | 1.07 | 0.93 |
| WF | C | Average | 1.02 | 0.98 | 0.97 | 1.03 | 0.96 | 1.04 | 0.93 | 1.07 | 0.94 | 1.06 | 1.03 | 0.97 | 1.00 | 1.00 | 1.03 | 0.97 | 1.06 | 0.94 |
| WF | Both | Average | 1.04 | 0.96 | 1.05 | 0.95 | 1.04 | 0.96 | 1.08 | 0.92 | 0.84 | 1.16 | 1.06 | 0.94 | 0.97 | 1.03 | 0.99 | 1.01 | 0.94 | 1.06 |
| WNF | F | 1 | 1.18 | 0.82 | 1.10 | 0.90 | 0.97 | 1.03 | 1.15 | 0.85 | 0.97 | 1.03 | 1.01 | 0.99 | 0.89 | 1.11 | 1.13 | 0.87 | 1.00 | 1.00 |
| WNF | F | 22 | 1.14 | 0.86 | 1.01 | 0.99 | 1.11 | 0.89 | 1.02 | 0.98 | 0.97 | 1.03 | 0.94 | 1.06 | 0.88 | 1.12 | 1.03 | 0.97 | 0.94 | 1.06 |
| WNF | F | 51 | 1.28 | 0.72 | 0.96 | 1.04 | 1.05 | 0.95 | 1.04 | 0.96 | 1.03 | 0.97 | 1.05 | 0.95 | 1.04 | 0.96 | 1.04 | 0.96 | 0.95 | 1.05 |
| WNF | F | Average | 1.20 | 0.80 | 1.02 | 0.98 | 1.04 | 0.96 | 1.07 | 0.93 | 0.99 | 1.01 | 1.00 | 1.00 | 0.94 | 1.06 | 1.06 | 0.94 | 0.96 | 1.04 |
| WNF | C | 12 | 0.98 | 1.02 | 1.03 | 0.97 | 1.08 | 0.92 | 1.06 | 0.94 | 0.89 | 1.11 | 1.10 | 0.90 | 1.01 | 0.99 | 1.03 | 0.97 | 1.08 | 0.92 |
| WNF | C | 40 | 1.07 | 0.93 | 0.94 | 1.06 | 0.99 | 1.01 | 1.00 | 1.00 | 1.03 | 0.97 | 0.98 | 1.02 | 0.96 | 1.04 | 1.03 | 0.97 | 0.99 | 1.01 |
| WNF | C | 48 | 1.07 | 0.93 | 1.05 | 0.95 | 1.07 | 0.93 | 0.97 | 1.03 | 0.98 | 1.02 | 1.00 | 1.00 | 1.01 | 0.99 | 1.16 | 0.84 | 1.14 | 0.86 |
| WNF | C | Average | 1.04 | 0.96 | 1.01 | 0.99 | 1.05 | 0.95 | 1.01 | 0.99 | 0.97 | 1.03 | 1.03 | 0.97 | 0.99 | 1.01 | 1.07 | 0.93 | 1.07 | 0.93 |
| WNF | Both | Average | 1.12 | 0.88 | 1.02 | 0.98 | 1.04 | 0.96 | 1.04 | 0.96 | 0.98 | 1.02 | 1.01 | 0.99 | 0.96 | 1.04 | 1.07 | 0.93 | 1.02 | 0.98 |
| DF | C | 30 | 1.04 | 0.96 | 0.98 | 1.02 | 0.88 | 1.12 | 1.15 | 0.85 | 1.03 | 0.97 | 1.01 | 0.99 | 1.03 | 0.97 | 1.01 | 0.99 | 1.10 | 0.90 |
| DF | C | 32 | 1.12 | 0.88 | 1.05 | 0.95 | 1.04 | 0.96 | 1.11 | 0.89 | 1.04 | 0.96 | 1.04 | 0.96 | 0.98 | 1.02 | 1.01 | 0.99 | 0.99 | 1.01 |
| DF | C | Average | 1.08 | 0.92 | 1.02 | 0.98 | 0.96 | 1.04 | 1.13 | 0.87 | 1.04 | 0.96 | 1.03 | 0.97 | 1.00 | 1.00 | 1.01 | 0.99 | 1.05 | 0.95 |
| DNF | F | 35 | 1.08 | 0.92 | 1.15 | 0.85 | 0.95 | 1.05 | 1.10 | 0.90 | 1.11 | 0.89 | 1.10 | 0.90 | 0.77 | 1.23 | 1.14 | 0.86 | 0.94 | 1.06 |
| DNF | C | 4 | 1.23 | 0.77 | 1.06 | 0.94 | 1.12 | 0.88 | 0.95 | 1.05 | 1.18 | 0.82 | 1.13 | 0.87 | 1.06 | 0.94 | 1.01 | 0.99 | 0.94 | 1.06 |
| DNF | Both | Average | 1.16 | 0.84 | 1.10 | 0.90 | 1.04 | 0.96 | 1.02 | 0.98 | 1.14 | 0.86 | 1.11 | 0.89 | 0.92 | 1.08 | 1.08 | 0.92 | 0.94 | 1.06 |
| All Zones | F | Average | 1.10 | 0.90 | 1.08 | 0.92 | 1.06 | 0.94 | 1.13 | 0.87 | 0.89 | 1.11 | 1.06 | 0.94 | 0.93 | 1.07 | 1.02 | 0.98 | 0.91 | 1.09 |
| All Zones | C | Average | 1.06 | 0.94 | 1.00 | 1.00 | 1.01 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.04 | 0.96 | 1.00 | 1.00 | 1.04 | 0.96 | 1.05 | 0.95 |
| Overall | | Average | 1.08 | 0.92 | 1.04 | 0.96 | 1.03 | 0.97 | 1.07 | 0.93 | 0.94 | 1.06 | 1.05 | 0.95 | 0.97 | 1.03 | 1.03 | 0.97 | 0.98 | 1.02 |

# APPENDIX A5

## Data Analysis for SPS-1 experiment (Standard deviate summary tables for various performance measures-Level A & Level B)

Table A5- 1 Standard deviate summary - Fatigue Cracking

| Design Factors | | Comparison | Overall | By subgrade | | By climatic zone | | | | By subgrade and zone | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | WF | | WNF | | DF | | DNF | |
| | | | | Fine | Coarse | WF | WNF | DF | DNF | F | C | F | C | F | C | F | C |
| HMA thickness | | 4" | 0.21 | 0.17 | 0.24 | 0.02 | 0.38 | 0.33 | 0.25 | 0.02 | 0.01 | 0.28 | 0.44 | | 0.33 | 0.32 | 0.19 |
| | | 7" | -0.20 | -0.15 | -0.24 | -0.02 | -0.38 | -0.33 | -0.25 | -0.02 | -0.01 | -0.28 | -0.44 | | -0.33 | -0.32 | -0.19 |
| Base thickness | Overall | 8" | 0.05 | 0.07 | 0.03 | 0.02 | 0.20 | 0.18 | -0.38 | 0.17 | -0.11 | 0.11 | 0.26 | | 0.18 | -0.25 | -0.51 |
| | | 12" | 0.07 | 0.16 | 0.01 | 0.22 | -0.11 | -0.23 | 0.34 | 0.19 | 0.26 | -0.01 | -0.18 | | -0.23 | 0.40 | 0.28 |
| | | 16" | -0.28 | -0.53 | -0.10 | -0.57 | -0.21 | 0.14 | 0.09 | -0.74 | -0.37 | -0.23 | -0.20 | | 0.14 | -0.37 | 0.56 |
| | ND | 8" | 0.10 | 0.46 | -0.17 | 0.23 | 0.00 | 0.18 | 0.07 | 0.47 | -0.32 | 0.40 | -0.26 | | 0.18 | 0.58 | -0.45 |
| | | 12" | 0.21 | 0.31 | 0.12 | 0.10 | 0.31 | 0.61 | -0.25 | 0.25 | -0.31 | 0.33 | 0.29 | | 0.61 | 0.41 | -0.91 |
| | D | 8" | -0.03 | -0.23 | 0.13 | -0.18 | 0.02 | -0.08 | 0.14 | -0.11 | -0.36 | -0.44 | 0.33 | | -0.08 | -0.14 | 0.42 |
| | | 12" | -0.20 | -0.45 | 0.02 | 0.01 | -0.23 | -0.70 | -0.04 | -0.46 | 1.41 | -0.33 | -0.16 | | -0.70 | -0.67 | 0.59 |
| | | 16" | -0.22 | -0.39 | -0.07 | -0.27 | -0.26 | -0.40 | 0.19 | -0.33 | -0.10 | -0.34 | -0.21 | | -0.40 | -0.67 | 1.05 |
| Base type | Overall | DGAB | 0.37 | 0.45 | 0.32 | 0.47 | 0.32 | 0.33 | 0.28 | 0.47 | 0.47 | 0.43 | 0.24 | | 0.33 | 0.42 | 0.13 |
| | | ATB | -0.30 | -0.36 | -0.25 | -0.34 | -0.33 | -0.22 | -0.15 | -0.35 | -0.32 | -0.42 | -0.28 | | -0.22 | -0.27 | -0.02 |
| | | ATB/DGAB | -0.12 | -0.03 | -0.18 | -0.13 | 0.04 | -0.28 | -0.32 | 0.10 | -0.36 | -0.04 | 0.10 | | -0.28 | -0.37 | -0.28 |
| | ND | DGAB | 0.51 | 1.17 | 0.04 | 0.69 | 0.14 | 1.12 | 0.56 | 1.20 | -0.33 | 0.82 | -0.31 | | 1.12 | 1.82 | -0.69 |
| | | ATB | -0.07 | -0.02 | -0.12 | -0.31 | 0.30 | 0.22 | -0.81 | -0.28 | -0.40 | 0.57 | 0.11 | | 0.22 | -0.43 | -1.20 |
| | D | ATB/DGAB | 0.05 | 0.11 | 0.00 | 0.25 | 0.03 | -0.15 | -0.03 | 0.43 | -0.21 | -0.28 | 0.23 | | -0.15 | 0.10 | -0.17 |
| | | DGAB | -0.12 | -0.24 | -0.02 | -0.15 | -0.19 | -0.25 | 0.27 | -0.14 | -0.18 | -0.33 | -0.10 | | -0.25 | -0.32 | 0.85 |
| | | ATB | -0.19 | -0.48 | 0.07 | -0.15 | -0.12 | -0.54 | -0.08 | -0.46 | 0.81 | -0.40 | 0.07 | | -0.54 | -0.67 | 0.51 |
| Drainage | Overall | ND | 0.11 | 0.21 | 0.05 | 0.23 | -0.02 | -0.07 | 0.27 | 0.31 | 0.16 | 0.03 | -0.05 | | -0.07 | 0.30 | 0.25 |
| | | D | -0.11 | -0.21 | -0.05 | -0.23 | 0.02 | 0.07 | -0.27 | -0.31 | -0.16 | -0.03 | 0.05 | | 0.07 | -0.30 | -0.25 |
| | DGAB | ND | 0.68 | 1.22 | 0.38 | 1.16 | 0.42 | -0.01 | 0.84 | 1.56 | 0.90 | 0.81 | 0.16 | | -0.01 | 1.38 | 0.30 |
| | | D | 0.17 | -0.01 | 0.28 | 0.06 | 0.25 | 0.56 | -0.10 | -0.07 | 0.18 | 0.18 | 0.29 | | 0.56 | -0.22 | 0.02 |
| | ATB | ND | -0.17 | -0.30 | -0.06 | -0.12 | -0.52 | 0.08 | 0.30 | -0.17 | -0.06 | -0.67 | -0.41 | | 0.08 | -0.12 | 0.71 |
| | | D | -0.39 | -0.40 | -0.38 | -0.50 | -0.21 | -0.42 | -0.44 | -0.50 | -0.50 | -0.24 | -0.18 | | -0.42 | -0.37 | -0.52 |

Table A5- 2 Standard deviate summary - Structural Rutting

| Design Factors | | Comparison | Overall | By subgrade | | By climatic zone | | | | By subgrade and zone | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | WF | | WNF | | DF | | DNF | |
| | | | | Fine | Coarse | WF | WNF | DF | DNF | F | C | F | C | F | C | F | C |
| HMA thickness | | 4" | 0.06 | -0.13 | 0.23 | -0.06 | 0.09 | 0.60 | -0.51 | -0.14 | 0.00 | 0.00 | 0.21 | | 0.60 | -0.51 | |
| | | 7" | -0.06 | 0.13 | -0.23 | 0.06 | -0.08 | -0.60 | 0.51 | 0.14 | 0.00 | 0.00 | -0.21 | | -0.60 | 0.51 | |
| Base thickness | Overall | 8" | 0.13 | 0.07 | 0.19 | 0.06 | 0.29 | 0.00 | 0.01 | 0.23 | -0.06 | -0.04 | 0.76 | | 0.00 | 0.01 | |
| | | 12" | -0.04 | -0.01 | -0.07 | 0.06 | -0.04 | -0.23 | -0.26 | -0.19 | 0.28 | 0.23 | -0.45 | | -0.23 | -0.26 | |
| | | 16" | -0.21 | -0.12 | -0.29 | -0.29 | -0.59 | 0.58 | 0.62 | -0.01 | -0.57 | -0.48 | -0.76 | | 0.58 | 0.62 | |
| | ND | 8" | 0.38 | 0.39 | 0.36 | 0.15 | 0.82 | -0.02 | 0.15 | 0.30 | 0.04 | 0.55 | 1.23 | | -0.02 | 0.15 | |
| | | 12" | -0.08 | -0.12 | -0.05 | 0.18 | -0.10 | -0.70 | -0.16 | -0.62 | 0.80 | 0.28 | -0.67 | | -0.70 | -0.16 | |
| | D | 8" | -0.21 | -0.38 | -0.07 | -0.23 | -0.29 | 0.02 | -0.20 | -0.27 | -0.20 | -0.52 | 0.05 | | 0.02 | -0.20 | |
| | | 12" | -0.13 | -0.15 | -0.11 | -0.21 | -0.23 | 0.48 | -0.41 | 0.12 | -0.50 | -0.29 | -0.13 | | 0.48 | -0.41 | |
| | | 16" | -0.23 | -0.17 | -0.29 | -0.37 | -0.57 | 0.58 | 0.62 | -0.17 | -0.57 | -0.44 | -0.76 | | 0.58 | 0.62 | |
| Base type | Overall | DGAB | -0.05 | 0.11 | -0.18 | 0.11 | -0.35 | 0.16 | 0.21 | 0.76 | -0.32 | -0.39 | -0.30 | | 0.16 | 0.21 | |
| | | ATB | -0.08 | -0.21 | 0.04 | -0.16 | 0.00 | -0.17 | 0.17 | -0.45 | 0.11 | -0.10 | 0.15 | | -0.17 | 0.17 | |
| | | ATB/DGAB | 0.30 | 0.27 | 0.34 | 0.15 | 0.85 | 0.03 | -0.95 | -0.22 | 0.52 | 1.17 | 0.37 | | 0.03 | -0.95 | |
| | ND | DGAB | 0.10 | 0.43 | -0.14 | 0.13 | 0.30 | -0.43 | -0.02 | 0.52 | 0.00 | 0.54 | -0.05 | | -0.43 | -0.02 | |
| | | ATB | 0.14 | 0.01 | 0.27 | 0.24 | 0.19 | -0.67 | 0.95 | -0.27 | 0.75 | -0.03 | 0.51 | | -0.67 | 0.95 | |
| | D | ATB/DGAB | 0.20 | 0.06 | 0.34 | 0.12 | 0.59 | 0.03 | -0.95 | -0.28 | 0.52 | 0.73 | 0.37 | | 0.03 | -0.95 | |
| | | DGAB | -0.10 | 0.02 | -0.20 | -0.03 | -0.52 | 0.55 | 0.36 | 0.61 | -0.53 | -0.55 | -0.46 | | 0.55 | 0.36 | |
| | | ATB | -0.28 | -0.46 | -0.11 | -0.50 | -0.20 | 0.17 | -0.35 | -0.72 | -0.31 | -0.28 | -0.09 | | 0.17 | -0.35 | |
| Drainage | Overall | ND | 0.17 | 0.18 | 0.16 | 0.20 | 0.39 | -0.36 | 0.00 | -0.09 | 0.42 | 0.46 | 0.28 | | -0.36 | 0.00 | |
| | | D | -0.16 | -0.17 | -0.16 | -0.19 | -0.37 | 0.36 | 0.00 | 0.08 | -0.42 | -0.44 | -0.28 | | 0.36 | 0.00 | |
| | DGAB | ND | 0.22 | 0.63 | -0.14 | 0.44 | 0.30 | -0.43 | -0.02 | 1.09 | 0.00 | 0.54 | -0.05 | | -0.43 | -0.02 | |
| | | D | -0.08 | 0.04 | -0.20 | -0.01 | -0.52 | 0.55 | 0.36 | 0.58 | -0.53 | -0.55 | -0.46 | | 0.55 | 0.36 | |
| | ATB | ND | 0.14 | 0.01 | 0.27 | 0.24 | 0.19 | -0.67 | 0.95 | -0.27 | 0.75 | -0.03 | 0.51 | | -0.67 | 0.95 | |
| | | D | -0.28 | -0.46 | -0.11 | -0.50 | -0.20 | 0.17 | -0.35 | -0.72 | -0.31 | -0.28 | -0.09 | | 0.17 | -0.35 | |

Table A5- 3 Standard deviate summary - Change in IRI

| Design Factors | | Comparison | Overall | By subgrade | | By climatic zone | | | | By subgrade and zone | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | WF | | WNF | | DF | | DNF | |
| | | | | Fine | Coarse | WF | WNF | DF | DNF | F | C | F | C | F | C | F | C |
| HMA thickness | | 4" | 0.13 | 0.26 | 0.02 | 0.06 | 0.15 | 0.41 | 0.09 | 0.19 | -0.14 | 0.28 | 0.07 | | 0.41 | 0.57 | -0.39 |
| | | 7" | -0.13 | -0.26 | -0.02 | -0.06 | -0.15 | -0.41 | -0.09 | -0.19 | 0.14 | -0.28 | -0.07 | | -0.41 | -0.57 | 0.39 |
| Base thickness | Overall | 8" | 0.25 | 0.24 | 0.25 | 0.27 | 0.39 | -0.04 | 0.10 | 0.16 | 0.43 | 0.42 | 0.36 | | -0.04 | 0.27 | -0.06 |
| | | 12" | -0.14 | -0.12 | -0.17 | -0.09 | -0.26 | 0.10 | -0.31 | 0.02 | -0.26 | -0.35 | -0.20 | | 0.10 | -0.31 | -0.32 |
| | | 16" | -0.24 | -0.28 | -0.21 | -0.41 | -0.32 | -0.15 | 0.52 | -0.40 | -0.43 | -0.17 | -0.42 | | -0.15 | 0.09 | 0.94 |
| | ND | 8" | 0.42 | 0.50 | 0.35 | 0.49 | 0.50 | -0.08 | 0.46 | 0.54 | 0.41 | 0.32 | 0.61 | | -0.08 | 0.65 | 0.27 |
| | | 12" | -0.05 | 0.01 | -0.10 | -0.05 | -0.15 | 0.04 | 0.11 | 0.14 | -0.34 | -0.38 | 0.01 | | 0.04 | 0.19 | 0.02 |
| | D | 8" | -0.02 | -0.17 | 0.10 | -0.10 | 0.22 | 0.03 | -0.43 | -0.52 | 0.46 | 0.57 | 0.00 | | 0.03 | -0.29 | -0.56 |
| | | 12" | -0.28 | -0.29 | -0.26 | -0.13 | -0.43 | 0.18 | -0.94 | -0.13 | -0.13 | -0.32 | -0.50 | | 0.18 | -1.06 | -0.82 |
| | | 16" | -0.24 | -0.28 | -0.21 | -0.41 | -0.32 | -0.15 | 0.52 | -0.40 | -0.43 | -0.17 | -0.42 | | -0.15 | 0.09 | 0.94 |
| Base type | Overall | DGAB | 0.17 | 0.29 | 0.06 | 0.21 | 0.10 | 0.43 | -0.10 | 0.28 | 0.11 | 0.43 | -0.12 | | 0.43 | 0.08 | -0.28 |
| | | ATB | -0.22 | -0.27 | -0.17 | -0.24 | -0.21 | -0.34 | -0.01 | -0.30 | -0.15 | -0.30 | -0.15 | | -0.34 | -0.06 | 0.04 |
| | | ATB/DGAB | 0.13 | -0.02 | 0.27 | 0.10 | 0.26 | -0.23 | 0.28 | 0.11 | 0.09 | -0.34 | 0.66 | | -0.23 | -0.05 | 0.61 |
| | ND | DGAB | 0.55 | 0.88 | 0.29 | 0.64 | 0.41 | 0.78 | 0.32 | 1.10 | 0.03 | 0.51 | 0.35 | | 0.78 | 0.75 | -0.11 |
| | | ATB | -0.10 | -0.02 | -0.18 | -0.03 | -0.15 | -0.61 | 0.24 | -0.04 | -0.02 | -0.25 | -0.08 | | -0.61 | 0.55 | -0.07 |
| | D | ATB/DGAB | 0.13 | -0.02 | 0.27 | 0.10 | 0.26 | -0.23 | 0.28 | 0.11 | 0.09 | -0.34 | 0.66 | | -0.23 | -0.05 | 0.61 |
| | | DGAB | -0.07 | -0.06 | -0.08 | -0.05 | -0.10 | 0.21 | -0.39 | -0.19 | 0.17 | 0.38 | -0.43 | | 0.21 | -0.37 | -0.40 |
| | | ATB | -0.29 | -0.44 | -0.17 | -0.39 | -0.24 | -0.16 | -0.18 | -0.49 | -0.24 | -0.32 | -0.19 | | -0.16 | -0.47 | 0.11 |
| Drainage | Overall | ND | 0.18 | 0.25 | 0.13 | 0.22 | 0.17 | -0.02 | 0.28 | 0.34 | 0.03 | -0.03 | 0.31 | | -0.02 | 0.42 | 0.15 |
| | | D | -0.18 | -0.25 | -0.13 | -0.22 | -0.17 | 0.02 | -0.28 | -0.34 | -0.03 | 0.03 | -0.31 | | 0.02 | -0.42 | -0.15 |
| | DGAB | ND | 0.55 | 0.88 | 0.29 | 0.64 | 0.41 | 0.78 | 0.32 | 1.10 | 0.03 | 0.51 | 0.35 | | 0.78 | 0.75 | -0.11 |
| | | D | -0.07 | -0.06 | -0.08 | -0.05 | -0.10 | 0.21 | -0.39 | -0.19 | 0.17 | 0.38 | -0.43 | | 0.21 | -0.37 | -0.40 |
| | ATB | ND | -0.10 | -0.02 | -0.18 | -0.03 | -0.15 | -0.61 | 0.24 | -0.04 | -0.02 | -0.25 | -0.08 | | -0.61 | 0.55 | -0.07 |
| | | D | -0.29 | -0.44 | -0.17 | -0.39 | -0.24 | -0.16 | -0.18 | -0.49 | -0.24 | -0.32 | -0.19 | | -0.16 | -0.47 | 0.11 |

Table A5- 4 Standard deviate summary – Transverse Cracking

| Design Factors | | Comparison | Overall | By subgrade | | By climatic zone | | | | By subgrade and zone | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | WF | | WNF | | DF | | DNF | |
| | | | | Fine | Coarse | WF | WNF | DF | DNF | F | C | F | C | F | C | F | C |
| HMA thickness | | 4" | 0.14 | 0.19 | 0.11 | -0.09 | -0.09 | -0.31 | 0.25 | -0.06 | -0.15 | 0.27 | 0.02 | | 0.21 | 0.29 | 0.37 |
| | | 7" | -0.14 | -0.19 | -0.11 | 0.09 | 0.09 | 0.31 | -0.25 | 0.06 | 0.15 | -0.27 | -0.02 | | -0.21 | -0.29 | -0.37 |
| Base thickness | Overall | 8" | 0.13 | 0.04 | 0.18 | -0.07 | 0.42 | -0.03 | -0.11 | -0.42 | 0.29 | 0.43 | 0.40 | | -0.03 | -0.29 | 0.06 |
| | | 12" | -0.08 | 0.13 | -0.22 | 0.29 | -0.30 | -0.21 | 0.12 | 0.70 | -0.12 | -0.30 | -0.31 | | -0.21 | 0.40 | -0.17 |
| | | 16" | -0.11 | -0.41 | 0.09 | -0.56 | -0.29 | 0.59 | -0.01 | -0.70 | -0.41 | -0.33 | -0.24 | | 0.59 | -0.29 | 0.26 |
| | ND | 8" | 0.18 | 0.24 | 0.15 | 0.16 | 0.00 | 0.91 | -0.02 | 0.37 | -0.05 | 0.10 | -0.06 | | 0.91 | 0.14 | -0.18 |
| | | 12" | 0.05 | 0.12 | 0.00 | 0.23 | -0.21 | -0.21 | 0.39 | 0.10 | 0.37 | 0.15 | -0.46 | | -0.21 | 0.08 | 0.71 |
| | D | 8" | -0.07 | -0.31 | 0.08 | -0.40 | 0.35 | -0.44 | 0.14 | -0.70 | -0.15 | -0.47 | 0.90 | | -0.44 | 0.97 | -0.68 |
| | | 12" | 0.00 | 0.04 | -0.03 | 0.01 | 0.15 | -0.37 | -0.05 | 0.17 | -0.22 | 0.11 | 0.18 | | -0.37 | -0.65 | 0.56 |
| | | 16" | -0.26 | -0.26 | -0.27 | -0.21 | -0.18 | -0.25 | -0.66 | -0.28 | -0.12 | -0.02 | -0.29 | | -0.25 | -0.65 | -0.67 |
| Base type | Overall | DGAB | 0.29 | 0.14 | 0.39 | 0.30 | -0.07 | 0.62 | 0.66 | -0.10 | 0.69 | 0.12 | -0.27 | | 0.62 | 0.40 | 0.92 |
| | | ATB | -0.30 | -0.27 | -0.32 | -0.34 | -0.14 | -0.44 | -0.46 | -0.16 | -0.52 | -0.32 | 0.04 | | -0.44 | -0.29 | -0.64 |
| | | ATB/DGAB | 0.04 | 0.33 | -0.15 | 0.10 | 0.53 | -0.45 | -0.50 | 0.64 | -0.44 | 0.49 | 0.56 | | -0.45 | -0.29 | -0.71 |
| | ND | DGAB | 0.30 | 0.59 | 0.14 | 0.24 | 0.13 | 0.11 | 1.08 | 0.58 | 0.00 | 0.49 | -0.11 | | 0.11 | 0.80 | 1.37 |
| | | ATB | 0.02 | 0.17 | -0.09 | 0.14 | -0.35 | 0.61 | -0.03 | 0.23 | 0.01 | 0.22 | -0.73 | | 0.61 | -0.17 | 0.11 |
| | D | ATB/DGAB | 0.04 | -0.14 | 0.18 | 0.23 | -0.10 | 0.33 | -0.49 | 0.02 | 0.47 | -0.34 | 0.06 | | 0.33 | -0.30 | -0.68 |
| | | DGAB | 0.00 | -0.02 | 0.02 | -0.15 | 0.20 | -0.25 | 0.24 | -0.17 | -0.12 | 0.01 | 0.33 | | -0.25 | 0.43 | 0.04 |
| | | ATB | -0.23 | -0.31 | -0.17 | -0.22 | 0.01 | -0.46 | -0.61 | -0.24 | -0.20 | -0.27 | 0.19 | | -0.46 | -0.65 | -0.58 |
| Drainage | Overall | ND | 0.15 | 0.39 | -0.01 | 0.20 | 0.29 | -0.16 | 0.13 | 0.69 | -0.30 | 0.29 | 0.28 | | -0.16 | 0.29 | -0.03 |
| | | D | -0.15 | -0.39 | 0.01 | -0.20 | -0.29 | 0.16 | -0.13 | -0.69 | 0.30 | -0.29 | -0.28 | | 0.16 | -0.29 | 0.03 |
| | DGAB | ND | 0.53 | 0.97 | 0.23 | 0.47 | 0.22 | 0.35 | 1.36 | 0.98 | -0.04 | 0.72 | -0.27 | | 0.35 | 1.44 | 1.27 |
| | | D | 0.13 | -0.42 | 0.49 | 0.18 | -0.27 | 0.79 | 0.20 | -0.82 | 1.19 | -0.28 | -0.26 | | 0.79 | -0.29 | 0.68 |
| | ATB | ND | -0.12 | -0.12 | -0.12 | 0.03 | 0.12 | -0.38 | -0.48 | 0.47 | -0.41 | -0.33 | 0.57 | | -0.38 | -0.29 | -0.67 |
| | | D | -0.42 | -0.37 | -0.46 | -0.58 | -0.31 | -0.47 | -0.45 | -0.57 | -0.59 | -0.31 | -0.31 | | -0.47 | -0.29 | -0.62 |

Table A5- 5 Standard deviate summary – Longitudinal Cracking (WP)

| Design Factors | | Comparison | Overall | By subgrade | | By climatic zone | | | | By subgrade and zone | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | WF | | WNF | | DF | | DNF | |
| | | | | Fine | Coarse | WF | WNF | DF | DNF | F | C | F | C | F | C | F | C |
| HMA thickness | | 4" | 0.01 | 0.10 | -0.05 | 0.03 | 0.07 | -0.31 | 0.16 | 0.14 | -0.26 | -0.07 | 0.17 | | -0.31 | 0.33 | 0.00 |
| | | 7" | -0.01 | -0.09 | 0.05 | -0.03 | -0.07 | 0.31 | -0.16 | -0.13 | 0.26 | 0.07 | -0.17 | | 0.31 | -0.33 | 0.00 |
| Base thickness | Overall | 8" | 0.05 | 0.18 | -0.05 | 0.06 | 0.01 | 0.08 | 0.10 | 0.23 | -0.34 | 0.07 | -0.03 | | 0.08 | 0.30 | -0.11 |
| | | 12" | 0.04 | -0.01 | 0.08 | 0.06 | 0.09 | 0.09 | -0.17 | -0.05 | 0.37 | 0.07 | 0.11 | | 0.09 | -0.03 | -0.31 |
| | | 16" | -0.22 | -0.39 | -0.07 | -0.27 | -0.26 | -0.40 | 0.19 | -0.33 | -0.10 | -0.34 | -0.21 | | -0.40 | -0.67 | 1.05 |
| | ND | 8" | 0.10 | 0.46 | -0.17 | 0.23 | 0.00 | 0.18 | 0.07 | 0.47 | -0.32 | 0.40 | -0.26 | | 0.18 | 0.58 | -0.45 |
| | | 12" | 0.21 | 0.31 | 0.12 | 0.10 | 0.31 | 0.61 | -0.25 | 0.25 | -0.31 | 0.33 | 0.29 | | 0.61 | 0.41 | -0.91 |
| | D | 8" | -0.03 | -0.23 | 0.13 | -0.18 | 0.02 | -0.08 | 0.14 | -0.11 | -0.36 | -0.44 | 0.33 | | -0.08 | -0.14 | 0.42 |
| | | 12" | -0.20 | -0.45 | 0.02 | 0.01 | -0.23 | -0.70 | -0.04 | -0.46 | 1.41 | -0.33 | -0.16 | | -0.70 | -0.67 | 0.59 |
| | | 16" | -0.22 | -0.39 | -0.07 | -0.27 | -0.26 | -0.40 | 0.19 | -0.33 | -0.10 | -0.34 | -0.21 | | -0.40 | -0.67 | 1.05 |
| Base type | Overall | DGAB | 0.13 | 0.28 | 0.01 | 0.15 | -0.06 | 0.30 | 0.39 | 0.31 | -0.24 | 0.13 | -0.18 | | 0.30 | 0.54 | 0.24 |
| | | ATB | -0.14 | -0.30 | -0.01 | -0.21 | 0.05 | -0.24 | -0.37 | -0.39 | 0.32 | -0.01 | 0.09 | | -0.24 | -0.58 | -0.17 |
| | | ATB/DGAB | 0.05 | 0.11 | 0.00 | 0.25 | 0.03 | -0.15 | -0.03 | 0.43 | -0.21 | -0.28 | 0.23 | | -0.15 | 0.10 | -0.17 |
| | ND | DGAB | 0.51 | 1.17 | 0.04 | 0.69 | 0.14 | 1.12 | 0.56 | 1.20 | -0.33 | 0.82 | -0.31 | | 1.12 | 1.82 | -0.69 |
| | | ATB | -0.07 | -0.02 | -0.12 | -0.31 | 0.30 | 0.22 | -0.81 | -0.28 | -0.40 | 0.57 | 0.11 | | 0.22 | -0.43 | -1.20 |
| | D | ATB/DGAB | 0.05 | 0.11 | 0.00 | 0.25 | 0.03 | -0.15 | -0.03 | 0.43 | -0.21 | -0.28 | 0.23 | | -0.15 | 0.10 | -0.17 |
| | | DGAB | -0.12 | -0.24 | -0.02 | -0.15 | -0.19 | -0.25 | 0.27 | -0.14 | -0.18 | -0.33 | -0.10 | | -0.25 | -0.32 | 0.85 |
| | | ATB | -0.19 | -0.48 | 0.07 | -0.15 | -0.12 | -0.54 | -0.08 | -0.46 | 0.81 | -0.40 | 0.07 | | -0.54 | -0.67 | 0.51 |
| Drainage | Overall | ND | 0.15 | 0.38 | -0.02 | 0.16 | 0.15 | 0.39 | -0.09 | 0.35 | -0.31 | 0.37 | 0.01 | | 0.39 | 0.50 | -0.68 |
| | | D | -0.15 | -0.36 | 0.02 | -0.15 | -0.15 | -0.39 | 0.09 | -0.31 | 0.31 | -0.37 | -0.01 | | -0.39 | -0.50 | 0.68 |
| | DGAB | ND | 0.51 | 1.17 | 0.04 | 0.69 | 0.14 | 1.12 | 0.56 | 1.20 | -0.33 | 0.82 | -0.31 | | 1.12 | 1.82 | -0.69 |
| | | D | -0.12 | -0.24 | -0.02 | -0.15 | -0.19 | -0.25 | 0.27 | -0.14 | -0.18 | -0.33 | -0.10 | | -0.25 | -0.32 | 0.85 |
| | ATB | ND | -0.07 | -0.02 | -0.12 | -0.31 | 0.30 | 0.22 | -0.81 | -0.28 | -0.40 | 0.57 | 0.11 | | 0.22 | -0.43 | -1.20 |
| | | D | -0.19 | -0.48 | 0.07 | -0.15 | -0.12 | -0.54 | -0.08 | -0.46 | 0.81 | -0.40 | 0.07 | | -0.54 | -0.67 | 0.51 |

Table A5- 6 Standard deviate summary - Longitudinal Cracking (NWP)

| Design Factors | | Comparison | Overall | By subgrade | | By climatic zone | | | | By subgrade and zone | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | WF | | WNF | | DF | | DNF | |
| | | | | Fine | Coarse | WF | WNF | DF | DNF | F | C | F | C | F | C | F | C |
| HMA thickness | | 4" | -0.07 | -0.08 | -0.07 | -0.09 | -0.09 | -0.31 | 0.25 | -0.19 | 0.01 | -0.15 | -0.04 | | -0.31 | 0.43 | 0.06 |
| | | 7" | 0.07 | 0.07 | 0.07 | 0.09 | 0.09 | 0.31 | -0.25 | 0.17 | -0.01 | 0.15 | 0.04 | | 0.31 | -0.43 | -0.06 |
| Base thickness | Overall | 8" | 0.08 | 0.03 | 0.12 | -0.05 | 0.14 | 0.37 | 0.05 | -0.01 | -0.09 | -0.13 | 0.32 | | 0.37 | 0.47 | -0.38 |
| | | 12" | 0.03 | 0.08 | -0.01 | 0.14 | -0.07 | -0.27 | 0.22 | 0.13 | 0.14 | 0.14 | -0.20 | | -0.27 | -0.21 | 0.65 |
| | | 16" | -0.26 | -0.26 | -0.27 | -0.21 | -0.18 | -0.25 | -0.66 | -0.28 | -0.12 | -0.02 | -0.29 | | -0.25 | -0.65 | -0.67 |
| | ND | 8" | 0.18 | 0.24 | 0.15 | 0.16 | 0.00 | 0.91 | -0.02 | 0.37 | -0.05 | 0.10 | -0.06 | | 0.91 | 0.14 | -0.18 |
| | | 12" | 0.05 | 0.12 | 0.00 | 0.23 | -0.21 | -0.21 | 0.39 | 0.10 | 0.37 | 0.15 | -0.46 | | -0.21 | 0.08 | 0.71 |
| | D | 8" | -0.07 | -0.31 | 0.08 | -0.40 | 0.35 | -0.44 | 0.14 | -0.70 | -0.15 | -0.47 | 0.90 | | -0.44 | 0.97 | -0.68 |
| | | 12" | 0.00 | 0.04 | -0.03 | 0.01 | 0.15 | -0.37 | -0.05 | 0.17 | -0.22 | 0.11 | 0.18 | | -0.37 | -0.65 | 0.56 |
| | | 16" | -0.26 | -0.26 | -0.27 | -0.21 | -0.18 | -0.25 | -0.66 | -0.28 | -0.12 | -0.02 | -0.29 | | -0.25 | -0.65 | -0.67 |
| Base type | Overall | DGAB | 0.12 | 0.19 | 0.07 | -0.02 | 0.17 | -0.10 | 0.58 | 0.05 | -0.07 | 0.21 | 0.15 | | -0.10 | 0.58 | 0.57 |
| | | ATB | -0.13 | -0.11 | -0.14 | -0.08 | -0.13 | -0.03 | -0.38 | -0.04 | -0.12 | -0.07 | -0.18 | | -0.03 | -0.46 | -0.30 |
| | | ATB/DGAB | 0.04 | -0.14 | 0.18 | 0.23 | -0.10 | 0.33 | -0.49 | 0.02 | 0.47 | -0.34 | 0.06 | | 0.33 | -0.30 | -0.68 |
| | ND | DGAB | 0.30 | 0.59 | 0.14 | 0.24 | 0.13 | 0.11 | 1.08 | 0.58 | 0.00 | 0.49 | -0.11 | | 0.11 | 0.80 | 1.37 |
| | | ATB | 0.02 | 0.17 | -0.09 | 0.14 | -0.35 | 0.61 | -0.03 | 0.23 | 0.01 | 0.22 | -0.73 | | 0.61 | -0.17 | 0.11 |
| | D | ATB/DGAB | 0.04 | -0.14 | 0.18 | 0.23 | -0.10 | 0.33 | -0.49 | 0.02 | 0.47 | -0.34 | 0.06 | | 0.33 | -0.30 | -0.68 |
| | | DGAB | 0.00 | -0.02 | 0.02 | -0.15 | 0.20 | -0.25 | 0.24 | -0.17 | -0.12 | 0.01 | 0.33 | | -0.25 | 0.43 | 0.04 |
| | | ATB | -0.23 | -0.31 | -0.17 | -0.22 | 0.01 | -0.46 | -0.61 | -0.24 | -0.20 | -0.27 | 0.19 | | -0.46 | -0.65 | -0.58 |
| Drainage | Overall | ND | 0.12 | 0.18 | 0.08 | 0.20 | -0.11 | 0.35 | 0.19 | 0.23 | 0.16 | 0.13 | -0.26 | | 0.35 | 0.11 | 0.27 |
| | | D | -0.11 | -0.17 | -0.08 | -0.19 | 0.11 | -0.35 | -0.19 | -0.21 | -0.16 | -0.13 | 0.26 | | -0.35 | -0.11 | -0.27 |
| | DGAB | ND | 0.30 | 0.59 | 0.14 | 0.24 | 0.13 | 0.11 | 1.08 | 0.58 | 0.00 | 0.49 | -0.11 | | 0.11 | 0.80 | 1.37 |
| | | D | 0.00 | -0.02 | 0.02 | -0.15 | 0.20 | -0.25 | 0.24 | -0.17 | -0.12 | 0.01 | 0.33 | | -0.25 | 0.43 | 0.04 |
| | ATB | ND | 0.02 | 0.17 | -0.09 | 0.14 | -0.35 | 0.61 | -0.03 | 0.23 | 0.01 | 0.22 | -0.73 | | 0.61 | -0.17 | 0.11 |
| | | D | -0.23 | -0.31 | -0.17 | -0.22 | 0.01 | -0.46 | -0.61 | -0.24 | -0.20 | -0.27 | 0.19 | | -0.46 | -0.65 | -0.58 |

Table A5- 7 Effect of HMA surface thickness on Fatigue cracking- Level B

| Drainage | Base Type | Base Thickness | HMA thickness | Std. deviate | Mean | Std. Deviation | N | P-value |
|---|---|---|---|---|---|---|---|---|
| ND | DGAB | 8 | 4 | 0.89 | 31.45 | 61.49 | 8 | 0.123 |
|  |  |  | 7 | -0.26 | 9.44 | 12.11 | 6 |  |
|  |  | 12 | 4 | 1.79 | 31.99 | 39.73 | 6 | 0.043 |
|  |  |  | 7 | 0.35 | 9.63 | 9.09 | 8 |  |
|  | ATB | 8 | 4 | 0.09 | 7.39 | 9.53 | 7 | 0.340 |
|  |  |  | 7 | -0.31 | 7.68 | 12.40 | 9 |  |
|  |  | 12 | 4 | 0.00 | 5.23 | 5.81 | 9 | 0.084 |
|  |  |  | 7 | -0.45 | 5.30 | 7.94 | 7 |  |
|  | ATB/DGAB | 8 | 4 | 0.46 | 18.25 | 38.16 | 6 | 0.663 |
|  |  |  | 7 | -0.31 | 7.09 | 11.75 | 9 |  |
|  |  | 12 | 4 | -0.31 | 3.15 | 4.93 | 8 | 0.800 |
|  |  |  | 7 | -0.15 | 9.27 | 10.40 | 7 |  |
| D | DGAB | 8 | 4 | 0.27 | 9.11 | 11.16 | 6 | 0.910 |
|  |  |  | 7 | 0.11 | 21.83 | 46.15 | 8 |  |
|  |  | 12 | 4 | 0.31 | 27.15 | 37.24 | 8 | 0.225 |
|  |  |  | 7 | 0.26 | 16.10 | 26.14 | 7 |  |
|  |  | 16 | 4 | 0.34 | 16.78 | 26.49 | 8 | 0.260 |
|  |  |  | 7 | -0.28 | 11.96 | 28.08 | 7 |  |
|  | ATB | 8 | 4 | 0.05 | 11.40 | 26.79 | 8 | 0.260 |
|  |  |  | 7 | -0.39 | 9.65 | 19.65 | 7 |  |
|  |  | 12 | 4 | -0.32 | 13.11 | 23.80 | 7 | 0.430 |
|  |  |  | 7 | -0.49 | 3.00 | 5.31 | 8 |  |
|  |  | 16 | 4 | -0.70 | 3.24 | 4.40 | 7 | 0.253 |
|  |  |  | 7 | -0.49 | 3.53 | 4.24 | 9 |  |

Table A5- 8 Effect of base type on Fatigue cracking- Level B

| Drainage | Base Thickness | HMA thickness | Base Type | Std. deviate | Mean | Std. Deviation | N | P-value |
|---|---|---|---|---|---|---|---|---|
| ND | 8 | 4 | DGAB | 0.89 | 31.45 | 61.49 | 8 | 0.498 |
| | | | ATB | 0.09 | 7.39 | 9.53 | 7 | |
| | | | ATB/DGAB | 0.46 | 18.25 | 38.16 | 6 | |
| | | 7 | DGAB | -0.26 | 9.44 | 12.11 | 6 | 0.981 |
| | | | ATB | -0.31 | 7.68 | 12.40 | 9 | |
| | | | ATB/DGAB | -0.31 | 7.09 | 11.75 | 9 | |
| | 12 | 4 | DGAB | 1.79 | 31.99 | 39.73 | 6 | 0.003 |
| | | | ATB | 0.00 | 5.23 | 5.81 | 9 | |
| | | | ATB/DGAB | -0.31 | 3.15 | 4.93 | 8 | |
| | | 7 | DGAB | 0.35 | 9.63 | 9.09 | 8 | 0.192 |
| | | | ATB | -0.45 | 5.30 | 7.94 | 7 | |
| | | | ATB/DGAB | -0.15 | 9.27 | 10.40 | 7 | |
| D | 8 | 4 | DGAB | 0.27 | 9.11 | 11.16 | 6 | 0.686 |
| | | | ATB | 0.05 | 11.40 | 26.79 | 8 | |
| | | 7 | DGAB | 0.11 | 21.83 | 46.15 | 8 | 0.310 |
| | | | ATB | -0.39 | 9.65 | 19.65 | 7 | |
| | 12 | 4 | DGAB | 0.31 | 27.15 | 37.24 | 8 | 0.171 |
| | | | ATB | -0.32 | 13.11 | 23.80 | 7 | |
| | | 7 | DGAB | 0.26 | 16.10 | 26.14 | 7 | 0.028 |
| | | | ATB | -0.49 | 3.00 | 5.31 | 8 | |
| | 16 | 4 | DGAB | 0.34 | 16.78 | 26.49 | 8 | 0.016 |
| | | | ATB | -0.70 | 3.24 | 4.40 | 7 | |
| | | 7 | DGAB | -0.28 | 11.96 | 28.08 | 7 | 0.522 |
| | | | ATB | -0.49 | 3.53 | 4.24 | 9 | |

Table A5- 9 Effect of base thickness on Fatigue cracking- Level B

| Drainage | Base Type | HMA thickness | Base Thickness | Std. deviate | Mean | Std. Deviation | N | P-value |
|---|---|---|---|---|---|---|---|---|
| ND | DGAB | 4 | 8 | 0.89 | 31.45 | 61.49 | 8 | 0.291 |
| | | | 12 | 1.79 | 31.99 | 39.73 | 6 | |
| | | 7 | 8 | -0.26 | 9.44 | 12.11 | 6 | 0.217 |
| | | | 12 | 0.35 | 9.63 | 9.09 | 8 | |
| | ATB | 4 | 8 | 0.09 | 7.39 | 9.53 | 7 | 0.861 |
| | | | 12 | 0.00 | 5.23 | 5.81 | 9 | |
| | | 7 | 8 | -0.31 | 7.68 | 12.40 | 9 | 0.637 |
| | | | 12 | -0.45 | 5.30 | 7.94 | 7 | |
| | ATB/DGAB | 4 | 8 | 0.46 | 18.25 | 38.16 | 6 | 0.116 |
| | | | 12 | -0.31 | 3.15 | 4.93 | 8 | |
| | | 7 | 8 | -0.31 | 7.09 | 11.75 | 9 | 0.620 |
| | | | 12 | -0.15 | 9.27 | 10.40 | 7 | |
| D | DGAB | 4 | 8 | 0.27 | 9.11 | 11.16 | 6 | 0.992 |
| | | | 12 | 0.31 | 27.15 | 37.24 | 8 | |
| | | | 16 | 0.34 | 16.78 | 26.49 | 8 | |
| | | 7 | 8 | 0.11 | 21.83 | 46.15 | 8 | 0.586 |
| | | | 12 | 0.26 | 16.10 | 26.14 | 7 | |
| | | | 16 | -0.28 | 11.96 | 28.08 | 7 | |
| | ATB | 4 | 8 | 0.05 | 11.40 | 26.79 | 8 | 0.097 |
| | | | 12 | -0.32 | 13.11 | 23.80 | 7 | |
| | | | 16 | -0.70 | 3.24 | 4.40 | 7 | |
| | | 7 | 8 | -0.39 | 9.65 | 19.65 | 7 | 0.823 |
| | | | 12 | -0.49 | 3.00 | 5.31 | 8 | |
| | | | 16 | -0.49 | 3.53 | 4.24 | 9 | |

Table A5- 10 Effect of drainage on Fatigue cracking- Level B

| Base Type | Base Thickness | HMA thickness | Drainage | Mean | Std. Deviation | N | P-value |
|---|---|---|---|---|---|---|---|
| DGAB | 8 | 4 | ND | 31.45 | 61.49 | 8 | 0.430 |
| | | | D | 9.11 | 11.16 | 6 | |
| | | 7 | ND | 9.44 | 12.11 | 6 | 0.493 |
| | | | D | 21.83 | 46.15 | 8 | |
| | 12 | 4 | ND | 31.99 | 39.73 | 6 | 0.934 |
| | | | D | 27.15 | 37.24 | 8 | |
| | | 7 | ND | 9.63 | 9.09 | 8 | 0.782 |
| | | | D | 16.10 | 26.14 | 7 | |
| | 16 | 4 | ND | | | | |
| | | | D | 16.78 | 26.49 | 8 | |
| | | 7 | ND | | | | |
| | | | D | 11.96 | 28.08 | 7 | |
| ATB | 8 | 4 | ND | 7.39 | 9.53 | 7 | 0.039 |
| | | | D | 11.40 | 26.79 | 8 | |
| | | 7 | ND | 7.68 | 12.40 | 9 | 0.846 |
| | | | D | 9.65 | 19.65 | 7 | |
| | 12 | 4 | ND | 5.23 | 5.81 | 9 | 0.500 |
| | | | D | 13.11 | 23.80 | 7 | |
| | | 7 | ND | 5.30 | 7.94 | 7 | 0.883 |
| | | | D | 3.00 | 5.31 | 8 | |
| | 16 | 4 | ND | | | | |
| | | | D | 3.24 | 4.40 | 7 | |
| | | 7 | ND | | | | |
| | | | D | 3.53 | 4.24 | 9 | |
| ATB/DGAB | 8 | 4 | ND | 18.25 | 38.16 | 6 | |
| | | | D | | | | |
| | | 7 | ND | 7.09 | 11.75 | 9 | |
| | | | D | | | | |
| | 12 | 4 | ND | 3.15 | 4.93 | 8 | |
| | | | D | | | | |
| | | 7 | ND | 9.27 | 10.40 | 7 | |
| | | | D | | | | |

Table A5- 11 Effect of HMA surface thickness on longitudinal cracking-WP- Level B

| Drainage | Base Type | Base Thickness | HMA thickness | Std. deviate | Mean | Std. Deviation | N | P-value |
|---|---|---|---|---|---|---|---|---|
| ND | DGAB | 8 | 4 | 0.84 | 24.31 | 37.64 | 7 | 0.657 |
| | | | 7 | 0.45 | 8.87 | 9.80 | 5 | |
| | | 12 | 4 | 0.73 | 26.52 | 37.85 | 5 | 0.445 |
| | | | 7 | 0.07 | 8.25 | 14.83 | 7 | |
| | ATB | 8 | 4 | -0.23 | 18.71 | 33.09 | 6 | 0.365 |
| | | | 7 | -0.33 | 8.60 | 21.71 | 7 | |
| | | 12 | 4 | -0.15 | 1.38 | 3.49 | 7 | 0.520 |
| | | | 7 | 0.46 | 15.85 | 16.56 | 6 | |
| | ATB/DGAB | 8 | 4 | 0.11 | 16.40 | 25.56 | 5 | 0.482 |
| | | | 7 | -0.17 | 8.76 | 17.44 | 7 | |
| | | 12 | 4 | 0.31 | 16.12 | 28.80 | 7 | 0.559 |
| | | | 7 | -0.04 | 27.17 | 54.56 | 6 | |
| D | DGAB | 8 | 4 | 0.29 | 8.54 | 9.26 | 5 | 0.101 |
| | | | 7 | -0.21 | 12.31 | 31.68 | 7 | |
| | | 12 | 4 | -0.31 | 10.11 | 26.37 | 7 | 0.547 |
| | | | 7 | -0.12 | 16.95 | 33.98 | 6 | |
| | | 16 | 4 | -0.02 | 17.11 | 43.43 | 7 | 0.612 |
| | | | 7 | -0.23 | 20.01 | 42.93 | 6 | |
| | ATB | 8 | 4 | -0.12 | 11.58 | 26.52 | 7 | 0.770 |
| | | | 7 | 0.01 | 18.82 | 36.58 | 6 | |
| | | 12 | 4 | -0.74 | 7.89 | 15.68 | 6 | 0.088 |
| | | | 7 | 0.32 | 17.58 | 35.77 | 7 | |
| | | 16 | 4 | -0.43 | 9.73 | 19.80 | 6 | 0.480 |
| | | | 7 | -0.23 | 11.12 | 28.12 | 7 | |

Table A5- 12 Effect of base type on longitudinal cracking-WP- Level B

| Drainage | Base Thickness | HMA thickness | Base Type | Std. deviate | Mean | Std. Deviation | N | P-value |
|---|---|---|---|---|---|---|---|---|
| ND | 8 | 4 | DGAB | 0.84 | 24.31 | 37.64 | 7 | 0.260 |
| | | | ATB | -0.23 | 18.71 | 33.09 | 6 | |
| | | | ATB/DGAB | 0.11 | 16.40 | 25.56 | 5 | |
| | | 7 | DGAB | 0.45 | 8.87 | 9.80 | 5 | 0.095 |
| | | | ATB | -0.33 | 8.60 | 21.71 | 7 | |
| | | | ATB/DGAB | -0.17 | 8.76 | 17.44 | 7 | |
| | 12 | 4 | DGAB | 0.73 | 26.52 | 37.85 | 5 | 0.587 |
| | | | ATB | -0.15 | 1.38 | 3.49 | 7 | |
| | | | ATB/DGAB | 0.31 | 16.12 | 28.80 | 7 | |
| | | 7 | DGAB | 0.07 | 8.25 | 14.83 | 7 | 0.793 |
| | | | ATB | 0.46 | 15.85 | 16.56 | 6 | |
| | | | ATB/DGAB | -0.04 | 27.17 | 54.56 | 6 | |
| D | 8 | 4 | DGAB | 0.29 | 8.54 | 9.26 | 5 | 0.124 |
| | | | ATB | -0.12 | 11.58 | 26.52 | 7 | |
| | | 7 | DGAB | -0.21 | 12.31 | 31.68 | 7 | 0.643 |
| | | | ATB | 0.01 | 18.82 | 36.58 | 6 | |
| | 12 | 4 | DGAB | -0.31 | 10.11 | 26.37 | 7 | 0.005 |
| | | | ATB | -0.74 | 7.89 | 15.68 | 6 | |
| | | 7 | DGAB | -0.12 | 16.95 | 33.98 | 6 | 0.499 |
| | | | ATB | 0.32 | 17.58 | 35.77 | 7 | |
| | 16 | 4 | DGAB | -0.02 | 17.11 | 43.43 | 7 | 0.350 |
| | | | ATB | -0.43 | 9.73 | 19.80 | 6 | |
| | | 7 | DGAB | -0.23 | 20.01 | 42.93 | 6 | 0.992 |
| | | | ATB | -0.23 | 11.12 | 28.12 | 7 | |

Table A5- 13 Effect of base thickness on longitudinal cracking-WP- Level B

| Drainage | Base Type | HMA thickness | Base Thickness | Std. deviate | Mean | Std. Deviation | N | P-value |
|---|---|---|---|---|---|---|---|---|
| ND | DGAB | 4 | 8 | 0.84 | 24.31 | 37.64 | 7 | 0.916 |
| | | | 12 | 0.73 | 26.52 | 37.85 | 5 | |
| | | 7 | 8 | 0.45 | 8.87 | 9.80 | 5 | 0.608 |
| | | | 12 | 0.07 | 8.25 | 14.83 | 7 | |
| | ATB | 4 | 8 | -0.23 | 18.71 | 33.09 | 6 | 0.905 |
| | | | 12 | -0.15 | 1.38 | 3.49 | 7 | |
| | | 7 | 8 | -0.33 | 8.60 | 21.71 | 7 | 0.250 |
| | | | 12 | 0.46 | 15.85 | 16.56 | 6 | |
| | ATB/DGAB | 4 | 8 | 0.11 | 16.40 | 25.56 | 5 | 0.762 |
| | | | 12 | 0.31 | 16.12 | 28.80 | 7 | |
| | | 7 | 8 | -0.17 | 8.76 | 17.44 | 7 | 0.725 |
| | | | 12 | -0.04 | 27.17 | 54.56 | 6 | |
| D | DGAB | 4 | 8 | 0.29 | 8.54 | 9.26 | 5 | 0.251 |
| | | | 12 | -0.31 | 10.11 | 26.37 | 7 | |
| | | | 16 | -0.02 | 17.11 | 43.43 | 7 | |
| | | 7 | 8 | -0.21 | 12.31 | 31.68 | 7 | 0.951 |
| | | | 12 | -0.12 | 16.95 | 33.98 | 6 | |
| | | | 16 | -0.23 | 20.01 | 42.93 | 6 | |
| | ATB | 4 | 8 | -0.12 | 11.58 | 26.52 | 7 | 0.063 |
| | | | 12 | -0.74 | 7.89 | 15.68 | 6 | |
| | | | 16 | -0.43 | 9.73 | 19.80 | 6 | |
| | | 7 | 8 | 0.01 | 18.82 | 36.58 | 6 | 0.615 |
| | | | 12 | 0.32 | 17.58 | 35.77 | 7 | |
| | | | 16 | -0.23 | 11.12 | 28.12 | 7 | |

Table A5- 14 Effect of drainage on longitudinal cracking-WP- Level B

| Base Type | Base Thickness | HMA thickness | Drainage | Mean | Std. Deviation | N | P-value |
|---|---|---|---|---|---|---|---|
| DGAB | 8 | 4 | ND | 24.31 | 37.64 | 7 | 0.497 |
| | | | D | 8.54 | 9.26 | 5 | |
| | | 7 | ND | 8.87 | 9.80 | 5 | 0.162 |
| | | | D | 12.31 | 31.68 | 7 | |
| | 12 | 4 | ND | 26.52 | 37.85 | 5 | 0.469 |
| | | | D | 10.11 | 26.37 | 7 | |
| | | 7 | ND | 8.25 | 14.83 | 7 | 0.447 |
| | | | D | 16.95 | 33.98 | 6 | |
| | 16 | 4 | ND | | | | |
| | | | D | 17.11 | 43.43 | 7 | |
| | | 7 | ND | | | | |
| | | | D | 20.01 | 42.93 | 6 | |
| ATB | 8 | 4 | ND | 18.71 | 33.09 | 6 | 0.106 |
| | | | D | 11.58 | 26.52 | 7 | |
| | | 7 | ND | 8.60 | 21.71 | 7 | 0.761 |
| | | | D | 18.82 | 36.58 | 6 | |
| | 12 | 4 | ND | 1.38 | 3.49 | 7 | 0.389 |
| | | | D | 7.89 | 15.68 | 6 | |
| | | 7 | ND | 15.85 | 16.56 | 6 | 0.868 |
| | | | D | 17.58 | 35.77 | 7 | |
| | 16 | 4 | ND | | | | |
| | | | D | 9.73 | 19.80 | 6 | |
| | | 7 | ND | | | | |
| | | | D | 11.12 | 28.12 | 7 | |
| ATB/DGAB | 8 | 4 | ND | 16.40 | 25.56 | 5 | |
| | | | D | | | | |
| | | 7 | ND | 8.76 | 17.44 | 7 | |
| | | | D | | | | |
| | 12 | 4 | ND | 16.12 | 28.80 | 7 | |
| | | | D | | | | |
| | | 7 | ND | 27.17 | 54.56 | 6 | |
| | | | D | | | | |

Table A5- 15 Effect of HMA surface thickness on longitudinal cracking-NWP- Level B

| Drainage | Base Type | Base Thickness | HMA thickness | Std. deviate | Mean | Std. Deviation | N | P-value |
|---|---|---|---|---|---|---|---|---|
| ND | DGAB | 8 | 4 | -0.19 | 59.14 | 76.31 | 8 | 0.166 |
| | | | 7 | 0.49 | 30.57 | 43.46 | 6 | |
| | | 12 | 4 | -0.06 | 24.11 | 41.16 | 6 | 0.208 |
| | | | 7 | 0.93 | 64.44 | 68.72 | 8 | |
| | ATB | 8 | 4 | 0.60 | 52.29 | 62.44 | 7 | 0.291 |
| | | | 7 | -0.02 | 62.53 | 78.22 | 9 | |
| | | 12 | 4 | -0.35 | 51.93 | 70.62 | 9 | 0.285 |
| | | | 7 | -0.01 | 43.13 | 64.30 | 7 | |
| | ATB/DGAB | 8 | 4 | 0.39 | 40.01 | 73.69 | 6 | 0.572 |
| | | | 7 | 0.07 | 59.01 | 72.52 | 9 | |
| | | 12 | 4 | -0.32 | 53.45 | 75.53 | 9 | 0.328 |
| | | | 7 | 0.19 | 35.09 | 50.77 | 7 | |
| D | DGAB | 8 | 4 | -0.09 | 20.48 | 41.49 | 6 | 0.773 |
| | | | 7 | 0.09 | 60.77 | 76.58 | 8 | |
| | | 12 | 4 | 0.38 | 68.43 | 75.11 | 9 | 0.297 |
| | | | 7 | -0.02 | 38.64 | 47.37 | 7 | |
| | | 16 | 4 | -0.42 | 48.46 | 64.70 | 9 | 0.244 |
| | | | 7 | 0.08 | 41.36 | 75.47 | 7 | |
| | ATB | 8 | 4 | 0.23 | 67.28 | 69.32 | 8 | 0.119 |
| | | | 7 | -0.59 | 16.71 | 29.09 | 7 | |
| | | 12 | 4 | -0.21 | 42.44 | 70.47 | 7 | 0.983 |
| | | | 7 | -0.22 | 53.97 | 62.47 | 9 | |
| | | 16 | 4 | -0.66 | 22.85 | 34.98 | 7 | 0.040 |
| | | | 7 | -0.05 | 62.98 | 76.65 | 9 | |

Table A5- 16 Effect of base type on longitudinal cracking-NWP- Level B

| Drainage | Base Thickness | HMA thickness | Base Type | Std. deviate | Mean | Std. Deviation | N | P-value |
|---|---|---|---|---|---|---|---|---|
| ND | 8 | 4 | DGAB | -0.19 | 59.14 | 76.31 | 8 | 0.297 |
| | | | ATB | 0.60 | 52.29 | 62.44 | 7 | |
| | | | ATB/DGAB | 0.39 | 40.01 | 73.69 | 6 | |
| | | 7 | DGAB | 0.49 | 30.57 | 43.46 | 6 | 0.642 |
| | | | ATB | -0.02 | 62.53 | 78.22 | 9 | |
| | | | ATB/DGAB | 0.07 | 59.01 | 72.52 | 9 | |
| | 12 | 4 | DGAB | -0.06 | 24.11 | 41.16 | 6 | 0.591 |
| | | | ATB | -0.35 | 51.93 | 70.62 | 9 | |
| | | | ATB/DGAB | -0.32 | 53.45 | 75.53 | 9 | |
| | | 7 | DGAB | 0.93 | 64.44 | 68.72 | 8 | 0.391 |
| | | | ATB | -0.01 | 43.13 | 64.30 | 7 | |
| | | | ATB/DGAB | 0.19 | 35.09 | 50.77 | 7 | |
| D | 8 | 4 | DGAB | -0.09 | 20.48 | 41.49 | 6 | 0.642 |
| | | | ATB | 0.23 | 67.28 | 69.32 | 8 | |
| | | 7 | DGAB | 0.09 | 60.77 | 76.58 | 8 | 0.134 |
| | | | ATB | -0.59 | 16.71 | 29.09 | 7 | |
| | 12 | 4 | DGAB | 0.38 | 68.43 | 75.11 | 9 | 0.16 |
| | | | ATB | -0.21 | 42.44 | 70.47 | 7 | |
| | | 7 | DGAB | -0.02 | 38.64 | 47.37 | 7 | 0.645 |
| | | | ATB | -0.22 | 53.97 | 62.47 | 9 | |
| | 16 | 4 | DGAB | -0.42 | 48.46 | 64.70 | 9 | 0.315 |
| | | | ATB | -0.66 | 22.85 | 34.98 | 7 | |
| | | 7 | DGAB | 0.08 | 41.36 | 75.47 | 7 | 0.774 |
| | | | ATB | -0.05 | 62.98 | 76.65 | 9 | |

Table A5- 17 Effect of base thickness on longitudinal cracking-NWP- Level B

| Drainage | Base Type | HMA thickness | Base Thickness | Std. deviate | Mean | Std. Deviation | N | P-value |
|---|---|---|---|---|---|---|---|---|
| ND | DGAB | 4 | 8 | -0.19 | 59.14 | 76.31 | 8 | 0.718 |
| | | | 12 | -0.06 | 24.11 | 41.16 | 6 | |
| | | 7 | 8 | 0.49 | 30.57 | 43.46 | 6 | 0.587 |
| | | | 12 | 0.93 | 64.44 | 68.72 | 8 | |
| | ATB | 4 | 8 | 0.60 | 52.29 | 62.44 | 7 | 0.070 |
| | | | 12 | -0.35 | 51.93 | 70.62 | 9 | |
| | | 7 | 8 | -0.02 | 62.53 | 78.22 | 9 | 0.968 |
| | | | 12 | -0.01 | 43.13 | 64.30 | 7 | |
| | ATB/DGAB | 4 | 8 | 0.39 | 40.01 | 73.69 | 6 | 0.070 |
| | | | 12 | -0.32 | 53.45 | 75.53 | 9 | |
| | | 7 | 8 | 0.07 | 59.01 | 72.52 | 9 | 0.845 |
| | | | 12 | 0.19 | 35.09 | 50.77 | 7 | |
| D | DGAB | 4 | 8 | -0.09 | 20.48 | 41.49 | 6 | 0.182 |
| | | | 12 | 0.38 | 68.43 | 75.11 | 9 | |
| | | | 16 | -0.42 | 48.46 | 64.70 | 9 | |
| | | 7 | 8 | 0.09 | 60.77 | 76.58 | 8 | 0.972 |
| | | | 12 | -0.02 | 38.64 | 47.37 | 7 | |
| | | | 16 | 0.08 | 41.36 | 75.47 | 7 | |
| | ATB | 4 | 8 | 0.23 | 67.28 | 69.32 | 8 | 0.162 |
| | | | 12 | -0.21 | 42.44 | 70.47 | 7 | |
| | | | 16 | -0.66 | 22.85 | 34.98 | 7 | |
| | | 7 | 8 | -0.59 | 16.71 | 29.09 | 7 | 0.383 |
| | | | 12 | -0.22 | 53.97 | 62.47 | 9 | |
| | | | 16 | -0.05 | 62.98 | 76.65 | 9 | |

Table A5- 18 Effect of drainage on longitudinal cracking-NWP- Level B

| Base Type | Base Thickness | HMA thickness | Drainage | Mean | Std. Deviation | N | P-value |
|---|---|---|---|---|---|---|---|
| DGAB | 8 | 4 | ND | 59.14 | 76.31 | 8 | 0.859 |
| | | | D | 20.48 | 41.49 | 6 | |
| | | 7 | ND | 30.57 | 43.46 | 6 | 0.498 |
| | | | D | 60.77 | 76.58 | 8 | |
| | 12 | 4 | ND | 24.11 | 41.16 | 6 | 0.593 |
| | | | D | 68.43 | 75.11 | 9 | |
| | | 7 | ND | 64.44 | 68.72 | 8 | 0.165 |
| | | | D | 38.64 | 47.37 | 7 | |
| | 16 | 4 | ND | | | | |
| | | | D | 48.46 | 64.70 | 9 | |
| | | 7 | ND | | | | |
| | | | D | 41.36 | 75.47 | 7 | |
| ATB | 8 | 4 | ND | 52.29 | 62.44 | 7 | 0.284 |
| | | | D | 67.28 | 69.32 | 8 | |
| | | 7 | ND | 62.53 | 78.22 | 9 | 0.191 |
| | | | D | 16.71 | 29.09 | 7 | |
| | 12 | 4 | ND | 51.93 | 70.62 | 9 | 0.657 |
| | | | D | 42.44 | 70.47 | 7 | |
| | | 7 | ND | 43.13 | 64.30 | 7 | 0.645 |
| | | | D | 53.97 | 62.47 | 9 | |
| | 16 | 4 | ND | | | | |
| | | | D | 22.85 | 34.98 | 7 | |
| | | 7 | ND | | | | |
| | | | D | 62.98 | 76.65 | 9 | |
| ATB/DGAB | 8 | 4 | ND | 40.01 | 73.69 | 6 | |
| | | | D | | | | |
| | | 7 | ND | 59.01 | 72.52 | 9 | |
| | | | D | | | | |
| | 12 | 4 | ND | 53.45 | 75.53 | 9 | |
| | | | D | | | | |
| | | 7 | ND | 35.09 | 50.77 | 7 | |
| | | | D | | | | |

Table A5- 19 Effect of HMA surface thickness on transverse cracking- Level B

| Drainage | Base Type | Base Thickness | HMA thickness | Std. deviate | Mean | Std. Deviation | N | P-value |
|---|---|---|---|---|---|---|---|---|
| ND | DGAB | 8 | 4 | 1.11 | 7.6 | 13.0 | 5 | 0.078 |
| | | | 7 | -0.31 | 3.9 | 6.9 | 5 | |
| | | 12 | 4 | 1.48 | 12.9 | 23.4 | 5 | 0.042 |
| | | | 7 | -0.18 | 3.5 | 4.8 | 5 | |
| | ATB | 8 | 4 | -0.31 | 4.3 | 8.4 | 5 | 0.325 |
| | | | 7 | 0.44 | 2.1 | 1.4 | 5 | |
| | | 12 | 4 | -0.45 | 1.1 | 2.2 | 5 | 0.362 |
| | | | 7 | -0.16 | 7.1 | 15.6 | 5 | |
| | ATB/DGAB | 8 | 4 | 1.04 | 8.8 | 12.2 | 5 | 0.158 |
| | | | 7 | -0.32 | 1.5 | 2.2 | 5 | |
| | | 12 | 4 | -0.52 | 0.7 | 1.4 | 5 | 0.210 |
| | | | 7 | -0.03 | 8.3 | 18.1 | 5 | |
| D | DGAB | 8 | 4 | -0.10 | 1.0 | 2.1 | 5 | 0.516 |
| | | | 7 | 0.44 | 7.0 | 11.6 | 5 | |
| | | 12 | 4 | 0.16 | 6.1 | 8.5 | 5 | 0.278 |
| | | | 7 | -0.22 | 3.5 | 5.6 | 5 | |
| | | 16 | 4 | 0.71 | 6.0 | 7.4 | 5 | 0.176 |
| | | | 7 | -0.23 | 2.4 | 3.2 | 5 | |
| | ATB | 8 | 4 | -0.48 | 1.0 | 1.8 | 5 | 0.093 |
| | | | 7 | -0.26 | 3.3 | 5.0 | 5 | |
| | | 12 | 4 | -0.46 | 2.3 | 4.8 | 5 | 0.690 |
| | | | 7 | -0.42 | 1.2 | 1.4 | 5 | |
| | | 16 | 4 | -0.43 | 2.1 | 4.3 | 5 | 0.552 |
| | | | 7 | -0.50 | 0.9 | 1.3 | 5 | |

Table A5- 20 Effect of base type on transverse cracking- Level B

| Drainage | Base Thickness | HMA thickness | Base Type | Std. deviate | Mean | Std. Deviation | N | P-value |
|---|---|---|---|---|---|---|---|---|
| ND | 8 | 4 | DGAB | 1.11 | 7.6 | 13.0 | 5 | 0.254 |
| | | | ATB | -0.31 | 4.3 | 8.4 | 5 | |
| | | | ATB/DGAB | 1.04 | 8.8 | 12.2 | 5 | |
| | | 7 | DGAB | -0.31 | 3.9 | 6.9 | 5 | 0.363 |
| | | | ATB | 0.44 | 2.1 | 1.4 | 5 | |
| | | | ATB/DGAB | -0.32 | 1.5 | 2.2 | 5 | |
| | 12 | 4 | DGAB | 1.48 | 12.9 | 23.4 | 5 | 0.006 |
| | | | ATB | -0.45 | 1.1 | 2.2 | 5 | |
| | | | ATB/DGAB | -0.52 | 0.7 | 1.4 | 5 | |
| | | 7 | DGAB | -0.18 | 3.5 | 4.8 | 5 | 0.919 |
| | | | ATB | -0.16 | 7.1 | 15.6 | 5 | |
| | | | ATB/DGAB | -0.03 | 8.3 | 18.1 | 5 | |
| D | 8 | 4 | DGAB | -0.10 | 1.0 | 2.1 | 5 | 0.489 |
| | | | ATB | -0.48 | 1.0 | 1.8 | 5 | |
| | | 7 | DGAB | 0.44 | 7.0 | 11.6 | 5 | 0.294 |
| | | | ATB | -0.26 | 3.3 | 5.0 | 5 | |
| | 12 | 4 | DGAB | 0.16 | 6.1 | 8.5 | 5 | 0.095 |
| | | | ATB | -0.46 | 2.3 | 4.8 | 5 | |
| | | 7 | DGAB | -0.22 | 3.5 | 5.6 | 5 | 0.094 |
| | | | ATB | -0.42 | 1.2 | 1.4 | 5 | |
| | 16 | 4 | DGAB | 0.71 | 6.0 | 7.4 | 5 | 0.098 |
| | | | ATB | -0.43 | 2.1 | 4.3 | 5 | |
| | | 7 | DGAB | -0.23 | 2.4 | 3.2 | 5 | 0.233 |
| | | | ATB | -0.50 | 0.9 | 1.3 | 5 | |

Table A5- 21 Effect of base thickness on transverse cracking- Level B

| Drainage | Base Type | HMA thickness | Base Thickness | Std. deviate | Mean | Std. Deviation | N | P-value |
|---|---|---|---|---|---|---|---|---|
| ND | DGAB | 4 | 8 | 1.11 | 7.6 | 13.0 | 5 | 0.717 |
| | | | 12 | 1.48 | 12.9 | 23.4 | 5 | |
| | | 7 | 8 | -0.31 | 3.9 | 6.9 | 5 | 0.477 |
| | | | 12 | -0.18 | 3.5 | 4.8 | 5 | |
| | ATB | 4 | 8 | -0.31 | 4.3 | 8.4 | 5 | 0.358 |
| | | | 12 | -0.45 | 1.1 | 2.2 | 5 | |
| | | 7 | 8 | 0.44 | 2.1 | 1.4 | 5 | 0.457 |
| | | | 12 | -0.16 | 7.1 | 15.6 | 5 | |
| | ATB/DGAB | 4 | 8 | 1.04 | 8.8 | 12.2 | 5 | 0.112 |
| | | | 12 | -0.52 | 0.7 | 1.4 | 5 | |
| | | 7 | 8 | -0.32 | 1.5 | 2.2 | 5 | 0.440 |
| | | | 12 | -0.03 | 8.3 | 18.1 | 5 | |
| D | DGAB | 4 | 8 | -0.10 | 1.0 | 2.1 | 5 | 0.512 |
| | | | 12 | 0.16 | 6.1 | 8.5 | 5 | |
| | | | 16 | 0.71 | 6.0 | 7.4 | 5 | |
| | | 7 | 8 | 0.44 | 7.0 | 11.6 | 5 | 0.379 |
| | | | 12 | -0.22 | 3.5 | 5.6 | 5 | |
| | | | 16 | -0.23 | 2.4 | 3.2 | 5 | |
| | ATB | 4 | 8 | -0.48 | 1.0 | 1.8 | 5 | 0.906 |
| | | | 12 | -0.46 | 2.3 | 4.8 | 5 | |
| | | | 16 | -0.43 | 2.1 | 4.3 | 5 | |
| | | 7 | 8 | -0.26 | 3.3 | 5.0 | 5 | 0.130 |
| | | | 12 | -0.42 | 1.2 | 1.4 | 5 | |
| | | | 16 | -0.50 | 0.9 | 1.3 | 5 | |

Table A5- 22 Effect of drainage on transverse cracking- Level B

| Base Type | Base Thickness | HMA Thickness | Drainage | Mean | Std. Deviation | N | P-value |
|---|---|---|---|---|---|---|---|
| DGAB | 8 | 4 | ND | 7.6 | 13.0 | 5 | 0.198 |
| | | | D | 1.0 | 2.1 | 5 | |
| | | 7 | ND | 3.9 | 6.9 | 5 | 0.265 |
| | | | D | 7.0 | 11.6 | 5 | |
| | 12 | 4 | ND | 12.9 | 23.4 | 5 | 0.258 |
| | | | D | 6.1 | 8.5 | 5 | |
| | | 7 | ND | 3.5 | 4.8 | 5 | 0.354 |
| | | | D | 3.5 | 5.6 | 5 | |
| | 16 | 4 | ND | | | | |
| | | | D | 6.0 | 7.4 | 5 | |
| | | 7 | ND | | | | |
| | | | D | 2.4 | 3.2 | 5 | |
| ATB | 8 | 4 | ND | 4.3 | 8.4 | 5 | 0.112 |
| | | | D | 1.0 | 1.8 | 5 | |
| | | 7 | ND | 2.1 | 1.4 | 5 | 0.811 |
| | | | D | 3.3 | 5.0 | 5 | |
| | 12 | 4 | ND | 1.1 | 2.2 | 5 | 0.925 |
| | | | D | 2.3 | 4.8 | 5 | |
| | | 7 | ND | 7.1 | 15.6 | 5 | 0.408 |
| | | | D | 1.2 | 1.4 | 5 | |
| | 16 | 4 | ND | | | | |
| | | | D | 2.1 | 4.3 | 5 | |
| | | 7 | ND | | | | |
| | | | D | 0.9 | 1.3 | 5 | |
| ATB/DGAB | 8 | 4 | ND | 8.8 | 12.2 | 5 | |
| | | | D | | | | |
| | | 7 | ND | 1.5 | 2.2 | 5 | |
| | | | D | | | | |
| | 12 | 4 | ND | 0.7 | 1.4 | 5 | |
| | | | D | | | | |
| | | 7 | ND | 8.3 | 18.1 | 5 | |
| | | | D | | | | |

Table A5- 23 Effect of HMA surface thickness on overall rutting- Level B

| Drainage | Base Type | Base Thickness | HMA Thickness | Std. deviate | Mean | Std. Deviation | N | P-value |
|---|---|---|---|---|---|---|---|---|
| ND | DGAB | 8 | 4 | 0.57 | 10.06 | 8.48 | 8 | 0.547 |
| | | | 7 | 0.10 | 6.84 | 3.65 | 8 | |
| | | 12 | 4 | 0.95 | 9.06 | 6.53 | 8 | 0.044 |
| | | | 7 | -0.23 | 6.20 | 3.26 | 8 | |
| | ATB | 8 | 4 | 0.09 | 5.57 | 1.90 | 8 | 0.682 |
| | | | 7 | 0.29 | 7.02 | 4.22 | 9 | |
| | | 12 | 4 | 0.09 | 6.08 | 2.29 | 9 | 0.403 |
| | | | 7 | -0.33 | 4.68 | 1.77 | 8 | |
| | ATB/DGAB | 8 | 4 | 0.55 | 6.28 | 1.54 | 8 | 0.954 |
| | | | 7 | 0.57 | 7.45 | 2.52 | 9 | |
| | | 12 | 4 | -0.02 | 6.26 | 2.90 | 9 | 0.126 |
| | | | 7 | -0.60 | 4.58 | 1.97 | 8 | |
| D | DGAB | 8 | 4 | 0.05 | 6.77 | 3.91 | 8 | 0.965 |
| | | | 7 | 0.03 | 6.91 | 5.27 | 8 | |
| | | 12 | 4 | -0.12 | 6.04 | 1.79 | 9 | 0.470 |
| | | | 7 | 0.22 | 6.16 | 2.38 | 8 | |
| | | 16 | 4 | -0.34 | 5.40 | 1.49 | 9 | 0.734 |
| | | | 7 | -0.18 | 5.63 | 2.10 | 8 | |
| | ATB | 8 | 4 | -0.27 | 5.85 | 2.03 | 8 | 0.964 |
| | | | 7 | -0.29 | 4.89 | 1.59 | 8 | |
| | | 12 | 4 | -0.41 | 4.76 | 1.80 | 8 | 0.590 |
| | | | 7 | -0.23 | 6.58 | 4.64 | 9 | |
| | | 16 | 4 | -0.15 | 5.07 | 2.00 | 8 | 0.571 |
| | | | 7 | -0.32 | 6.22 | 4.05 | 9 | |

Table A5- 24 Effect of base type on overall rutting- Level B

| Drainage | Base Thickness | HMA Thickness | Base Type | Std. deviate | Mean | Std. Deviation | N | P-value |
|---|---|---|---|---|---|---|---|---|
| ND | 8 | 4 | DGAB | 0.57 | 10.06 | 8.48 | 8 | 0.713 |
| | | | ATB | 0.09 | 5.57 | 1.90 | 8 | |
| | | | ATB/DGAB | 0.55 | 6.28 | 1.54 | 8 | |
| | | 7 | DGAB | 0.10 | 6.84 | 3.65 | 8 | 0.643 |
| | | | ATB | 0.29 | 7.02 | 4.22 | 9 | |
| | | | ATB/DGAB | 0.57 | 7.45 | 2.52 | 9 | |
| | 12 | 4 | DGAB | 0.95 | 9.06 | 6.53 | 8 | 0.163 |
| | | | ATB | 0.09 | 6.08 | 2.29 | 9 | |
| | | | ATB/DGAB | -0.02 | 6.26 | 2.90 | 9 | |
| | | 7 | DGAB | -0.23 | 6.20 | 3.26 | 8 | 0.608 |
| | | | ATB | -0.33 | 4.68 | 1.77 | 8 | |
| | | | ATB/DGAB | -0.60 | 4.58 | 1.97 | 8 | |
| D | 8 | 4 | DGAB | 0.05 | 6.77 | 3.91 | 8 | 0.346 |
| | | | ATB | -0.27 | 5.85 | 2.03 | 8 | |
| | | 7 | DGAB | 0.03 | 6.91 | 5.27 | 8 | 0.517 |
| | | | ATB | -0.29 | 4.89 | 1.59 | 8 | |
| | 12 | 4 | DGAB | -0.12 | 6.04 | 1.79 | 9 | 0.504 |
| | | | ATB | -0.41 | 4.76 | 1.80 | 8 | |
| | | 7 | DGAB | 0.22 | 6.16 | 2.38 | 8 | 0.262 |
| | | | ATB | -0.23 | 6.58 | 4.64 | 9 | |
| | 16 | 4 | DGAB | -0.34 | 5.40 | 1.49 | 9 | 0.650 |
| | | | ATB | -0.15 | 5.07 | 2.00 | 8 | |
| | | 7 | DGAB | -0.18 | 5.63 | 2.10 | 8 | 0.709 |
| | | | ATB | -0.32 | 6.22 | 4.05 | 9 | |

Table A5- 25 Effect of base thickness on overall rutting- Level B

| Drainage | Base Type | HMA thickness | Base Thickness | Std. deviate | Mean | Std. Deviation | N | P-value |
|---|---|---|---|---|---|---|---|---|
| ND | DGAB | 4-inch | 8 | 0.57 | 10.06 | 8.48 | 8 | 0.654 |
| | | | 12 | 0.95 | 9.06 | 6.53 | 8 | |
| | | 7-inch | 8 | 0.10 | 6.84 | 3.65 | 8 | 0.462 |
| | | | 12 | -0.23 | 6.20 | 3.26 | 8 | |
| | ATB | 4-inch | 8 | 0.09 | 5.57 | 1.90 | 8 | 0.99 |
| | | | 12 | 0.09 | 6.08 | 2.29 | 9 | |
| | | 7-inch | 8 | 0.29 | 7.02 | 4.22 | 9 | 0.22 |
| | | | 12 | -0.33 | 4.68 | 1.77 | 8 | |
| | ATB/DGAB | 4-inch | 8 | 0.55 | 6.28 | 1.54 | 8 | 0.178 |
| | | | 12 | -0.02 | 6.26 | 2.90 | 9 | |
| | | 7-inch | 8 | 0.57 | 7.45 | 2.52 | 9 | 0.013 |
| | | | 12 | -0.60 | 4.58 | 1.97 | 8 | |
| D | DGAB | 4-inch | 8 | 0.05 | 6.77 | 3.91 | 8 | 0.650 |
| | | | 12 | -0.12 | 6.04 | 1.79 | 9 | |
| | | | 16 | -0.34 | 5.40 | 1.49 | 9 | |
| | | 7-inch | 8 | 0.03 | 6.91 | 5.27 | 8 | 0.754 |
| | | | 12 | 0.22 | 6.16 | 2.38 | 8 | |
| | | | 16 | -0.18 | 5.63 | 2.10 | 8 | |
| | ATB | 4-inch | 8 | -0.27 | 5.85 | 2.03 | 8 | 0.778 |
| | | | 12 | -0.41 | 4.76 | 1.80 | 8 | |
| | | | 16 | -0.15 | 5.07 | 2.00 | 8 | |
| | | 7-inch | 8 | -0.29 | 4.89 | 1.59 | 8 | 0.927 |
| | | | 12 | -0.23 | 6.58 | 4.64 | 9 | |
| | | | 16 | -0.32 | 6.22 | 4.05 | 9 | |

Table A5- 26 Effect of drainage on overall rutting- Level B

| Base Type | Base Thickness | HMA thickness | Drainage | Mean | Std. Deviation | N | P-value |
|---|---|---|---|---|---|---|---|
| DGAB | 8 | 4-inch | ND | 10.06 | 8.48 | 8 | 0.460 |
| | | | D | 6.77 | 3.91 | 8 | |
| | | 7-inch | ND | 6.84 | 3.65 | 8 | 0.903 |
| | | | D | 6.91 | 5.27 | 8 | |
| | 12 | 4-inch | ND | 9.06 | 6.53 | 8 | 0.385 |
| | | | D | 6.04 | 1.79 | 9 | |
| | | 7-inch | ND | 6.20 | 3.26 | 8 | 0.148 |
| | | | D | 6.16 | 2.38 | 8 | |
| | 16 | 4-inch | ND | | | | |
| | | | D | 5.40 | 1.49 | 9 | |
| | | 7-inch | ND | | | | |
| | | | D | 5.63 | 2.10 | 8 | |
| ATB | 8 | 4-inch | ND | 5.57 | 1.90 | 8 | 0.080 |
| | | | D | 5.85 | 2.03 | 8 | |
| | | 7-inch | ND | 7.02 | 4.22 | 9 | 0.280 |
| | | | D | 4.89 | 1.59 | 8 | |
| | 12 | 4-inch | ND | 6.08 | 2.29 | 9 | 0.282 |
| | | | D | 4.76 | 1.80 | 8 | |
| | | 7-inch | ND | 4.68 | 1.77 | 8 | 0.792 |
| | | | D | 6.58 | 4.64 | 9 | |
| | 16 | 4-inch | ND | | | | |
| | | | D | 5.07 | 2.00 | 8 | |
| | | 7-inch | ND | | | | |
| | | | D | 6.22 | 4.05 | 9 | |
| ATB/DGAB | 8 | 4-inch | ND | 6.28 | 1.54 | 8 | |
| | | 7-inch | ND | 7.45 | 2.52 | 9 | |
| | 12 | 4-inch | ND | 6.26 | 2.90 | 9 | |
| | | 7-inch | ND | 4.58 | 1.97 | 8 | |

Table A5- 27 Effect of HMA surface thickness on structural rutting- Level B

| Drainage | Base Type | Base Thickness | HMA Thickness | Std. deviate | Mean | Std. Deviation | N | P-value |
|---|---|---|---|---|---|---|---|---|
| ND | DGAB | 8 | 4 | -0.11 | 5.75 | 3.14 | 5 | 0.874 |
| | | | 7 | -0.24 | 4.96 | 1.26 | 6 | |
| | | 12 | 4 | 0.53 | 6.00 | 2.36 | 6 | 0.245 |
| | | | 7 | -0.24 | 4.63 | 1.40 | 6 | |
| | ATB | 8 | 4 | 0.26 | 5.55 | 2.05 | 7 | 0.639 |
| | | | 7 | 0.50 | 6.09 | 2.05 | 7 | |
| | | 12 | 4 | 0.23 | 5.27 | 1.74 | 7 | 0.405 |
| | | | 7 | -0.28 | 4.73 | 1.91 | 7 | |
| | ATB/DGAB | 8 | 4 | 0.71 | 6.11 | 1.58 | 7 | 0.658 |
| | | | 7 | 0.94 | 6.59 | 2.14 | 7 | |
| | | 12 | 4 | 0.18 | 5.17 | 1.90 | 7 | 0.114 |
| | | | 7 | -0.60 | 4.60 | 2.12 | 7 | |
| D | DGAB | 8 | 4 | -0.06 | 5.52 | 1.81 | 7 | 0.320 |
| | | | 7 | -0.37 | 4.65 | 1.26 | 6 | |
| | | 12 | 4 | -0.07 | 5.15 | 1.15 | 6 | 0.430 |
| | | | 7 | 0.45 | 6.27 | 2.55 | 7 | |
| | | 16 | 4 | -0.36 | 4.92 | 1.27 | 7 | 0.665 |
| | | | 7 | -0.08 | 5.44 | 2.20 | 7 | |
| | ATB | 8 | 4 | -0.30 | 5.19 | 1.86 | 6 | 0.919 |
| | | | 7 | -0.26 | 4.80 | 1.69 | 7 | |
| | | 12 | 4 | -0.35 | 4.91 | 1.89 | 7 | 0.783 |
| | | | 7 | -0.24 | 4.79 | 1.02 | 7 | |
| | | 16 | 4 | -0.03 | 5.25 | 2.09 | 7 | 0.349 |
| | | | 7 | -0.34 | 4.64 | 1.34 | 7 | |

Table A5- 28 Effect of base type on structural rutting- Level B

| Drainage | Base Thickness | HMA Thickness | Base Type | Std. deviate | Mean | Std. Deviation | N | P-value |
|---|---|---|---|---|---|---|---|---|
| ND | 8 | 4 | DGAB | -0.11 | 5.75 | 3.14 | 5 | 0.484 |
| | | | ATB | 0.26 | 5.55 | 2.05 | 7 | |
| | | | ATB/DGAB | 0.71 | 6.11 | 1.58 | 7 | |
| | | 7 | DGAB | -0.24 | 4.96 | 1.26 | 6 | 0.138 |
| | | | ATB | 0.50 | 6.09 | 2.05 | 7 | |
| | | | ATB/DGAB | 0.94 | 6.59 | 2.14 | 7 | |
| | 12 | 4 | DGAB | 0.53 | 6.00 | 2.36 | 6 | 0.851 |
| | | | ATB | 0.23 | 5.27 | 1.74 | 7 | |
| | | | ATB/DGAB | 0.18 | 5.17 | 1.90 | 7 | |
| | | 7 | DGAB | -0.24 | 4.63 | 1.40 | 6 | 0.681 |
| | | | ATB | -0.28 | 4.73 | 1.91 | 7 | |
| | | | ATB/DGAB | -0.60 | 4.60 | 2.12 | 7 | |
| D | 8 | 4 | DGAB | -0.06 | 5.52 | 1.81 | 7 | 0.548 |
| | | | ATB | -0.30 | 5.19 | 1.86 | 6 | |
| | | 7 | DGAB | -0.37 | 4.65 | 1.26 | 6 | 0.722 |
| | | | ATB | -0.26 | 4.80 | 1.69 | 7 | |
| | 12 | 4 | DGAB | -0.07 | 5.15 | 1.15 | 6 | 0.619 |
| | | | ATB | -0.35 | 4.91 | 1.89 | 7 | |
| | | 7 | DGAB | 0.45 | 6.27 | 2.55 | 7 | 0.187 |
| | | | ATB | -0.24 | 4.79 | 1.02 | 7 | |
| | 16 | 4 | DGAB | -0.36 | 4.92 | 1.27 | 7 | 0.538 |
| | | | ATB | -0.03 | 5.25 | 2.09 | 7 | |
| | | 7 | DGAB | -0.08 | 5.44 | 2.20 | 7 | 0.581 |
| | | | ATB | -0.34 | 4.64 | 1.34 | 7 | |

Table A5- 29 Effect of base thickness on structural rutting- Level B

| Drainage | Base Type | HMA Thickness | Base Thickness | Std. deviate | Mean | Std. Deviation | N | P-value |
|---|---|---|---|---|---|---|---|---|
| ND | DGAB | 4 | 8 | -0.11 | 5.75 | 3.14 | 5 | 0.502 |
| | | | 12 | 0.53 | 6.00 | 2.36 | 6 | |
| | | 7 | 8 | -0.24 | 4.96 | 1.26 | 6 | 0.990 |
| | | | 12 | -0.24 | 4.63 | 1.40 | 6 | |
| | ATB | 4 | 8 | 0.26 | 5.55 | 2.05 | 7 | 0.957 |
| | | | 12 | 0.23 | 5.27 | 1.74 | 7 | |
| | | 7 | 8 | 0.50 | 6.09 | 2.05 | 7 | 0.162 |
| | | | 12 | -0.28 | 4.73 | 1.91 | 7 | |
| | ATB/DGAB | 4 | 8 | 0.71 | 6.11 | 1.58 | 7 | 0.307 |
| | | | 12 | 0.18 | 5.17 | 1.90 | 7 | |
| | | 7 | 8 | 0.94 | 6.59 | 2.14 | 7 | 0.008 |
| | | | 12 | -0.60 | 4.60 | 2.12 | 7 | |
| D | DGAB | 4 | 8 | -0.06 | 5.52 | 1.81 | 7 | 0.818 |
| | | | 12 | -0.07 | 5.15 | 1.15 | 6 | |
| | | | 16 | -0.36 | 4.92 | 1.27 | 7 | |
| | | 7 | 8 | -0.37 | 4.65 | 1.26 | 6 | 0.346 |
| | | | 12 | 0.45 | 6.27 | 2.55 | 7 | |
| | | | 16 | -0.08 | 5.44 | 2.20 | 7 | |
| | ATB | 4 | 8 | -0.30 | 5.19 | 1.86 | 6 | 0.729 |
| | | | 12 | -0.35 | 4.91 | 1.89 | 7 | |
| | | | 16 | -0.03 | 5.25 | 2.09 | 7 | |
| | | 7 | 8 | -0.26 | 4.80 | 1.69 | 7 | 0.925 |
| | | | 12 | -0.24 | 4.79 | 1.02 | 7 | |
| | | | 16 | -0.34 | 4.64 | 1.34 | 7 | |

Table A5- 30 Effect of drainage on structural rutting- Level B

| Base Type | Base Thickness | HMA Thickness | Drainage | Mean | Std. Deviation | N | P-value |
|---|---|---|---|---|---|---|---|
| DGAB | 8 | 4 | ND | 5.75 | 3.14 | 5 | 0.943 |
| | | | D | 5.52 | 1.81 | 7 | |
| | | 7 | ND | 4.96 | 1.26 | 6 | 0.807 |
| | | | D | 4.65 | 1.26 | 6 | |
| | 12 | 4 | ND | 6.00 | 2.36 | 6 | 0.322 |
| | | | D | 5.15 | 1.15 | 6 | |
| | | 7 | ND | 4.63 | 1.40 | 6 | 0.061 |
| | | | D | 6.27 | 2.55 | 7 | |
| | 16 | 4 | ND | | | | |
| | | | D | 4.92 | 1.27 | 7 | |
| | | 7 | ND | | | | |
| | | | D | 5.44 | 2.20 | 7 | |
| ATB | 8 | 4 | ND | 5.55 | 2.05 | 7 | 0.427 |
| | | | D | 5.19 | 1.86 | 6 | |
| | | 7 | ND | 6.09 | 2.05 | 7 | 0.224 |
| | | | D | 4.80 | 1.69 | 7 | |
| | 12 | 4 | ND | 5.27 | 1.74 | 7 | 0.298 |
| | | | D | 4.91 | 1.89 | 7 | |
| | | 7 | ND | 4.73 | 1.91 | 7 | 0.935 |
| | | | D | 4.79 | 1.02 | 7 | |
| | 16 | 4 | ND | | | | |
| | | | D | 5.25 | 2.09 | 7 | |
| | | 7 | ND | | | | |
| | | | D | 4.64 | 1.34 | 7 | |
| ATB/DGAB | 8 | 4 | ND | 6.11 | 1.58 | 7 | |
| | | | D | | | | |
| | | 7 | ND | 6.59 | 2.14 | 7 | |
| | | | D | | | | |
| | 12 | 4 | ND | 5.17 | 1.90 | 7 | |
| | | | D | | | | |
| | | 7 | ND | 4.60 | 2.12 | 7 | |
| | | | D | | | | |

Table A5- 31 Effect of HMA surface thickness on ΔIRI - Level B

| Drainage | Base Type | Base Thickness | HMA Thickness | Std. deviate | Mean | Std. Deviation | N | P-value |
|---|---|---|---|---|---|---|---|---|
| ND | DGAB | 8 | 4 | 0.72 | 0.29 | 0.32 | 8 | 0.784 |
| | | | 7 | 0.52 | 0.57 | 0.89 | 8 | |
| | | 12 | 4 | 0.95 | 0.65 | 0.74 | 8 | 0.089 |
| | | | 7 | 0.00 | 0.13 | 0.11 | 8 | |
| | ATB | 8 | 4 | 0.47 | 0.52 | 0.57 | 8 | 0.403 |
| | | | 7 | 0.14 | 0.16 | 0.18 | 9 | |
| | | 12 | 4 | -0.67 | 0.04 | 0.11 | 9 | 0.252 |
| | | | 7 | -0.32 | 0.22 | 0.24 | 8 | |
| | ATB/DGAB | 8 | 4 | 0.46 | 0.48 | 0.64 | 8 | 0.683 |
| | | | 7 | 0.26 | 0.16 | 0.19 | 9 | |
| | | 12 | 4 | 0.07 | 0.14 | 0.17 | 9 | 0.384 |
| | | | 7 | -0.27 | 0.27 | 0.33 | 8 | |
| D | DGAB | 8 | 4 | 0.45 | 0.36 | 0.30 | 8 | 0.358 |
| | | | 7 | -0.17 | 0.19 | 0.36 | 8 | |
| | | 12 | 4 | 0.25 | 0.21 | 0.29 | 9 | 0.167 |
| | | | 7 | -0.53 | 0.34 | 0.54 | 8 | |
| | | 16 | 4 | -0.13 | 0.15 | 0.12 | 9 | 0.514 |
| | | | 7 | -0.35 | 0.26 | 0.34 | 8 | |
| | ATB | 8 | 4 | 0.09 | 0.15 | 0.12 | 8 | 0.096 |
| | | | 7 | -0.46 | 0.19 | 0.26 | 8 | |
| | | 12 | 4 | -0.53 | 0.18 | 0.23 | 8 | 0.275 |
| | | | 7 | -0.35 | 0.10 | 0.12 | 9 | |
| | | 16 | 4 | -0.38 | 0.19 | 0.26 | 8 | 0.544 |
| | | | 7 | -0.13 | 0.12 | 0.17 | 9 | |

Table A5- 32 Effect of base type on ΔIRI - Level B

| Drainage | Base Thickness | HMA Thickness | Base Type | Std. deviate | Mean | Std. Deviation | N | P-value |
|---|---|---|---|---|---|---|---|---|
| ND | 8 | 4 | DGAB | 0.72 | 0.29 | 0.32 | 8 | 0.897 |
|  |  |  | ATB | 0.47 | 0.52 | 0.57 | 8 |  |
|  |  |  | ATB/DGAB | 0.46 | 0.48 | 0.64 | 8 |  |
|  |  | 7 | DGAB | 0.52 | 0.57 | 0.89 | 8 | 0.679 |
|  |  |  | ATB | 0.14 | 0.16 | 0.18 | 9 |  |
|  |  |  | ATB/DGAB | 0.26 | 0.16 | 0.19 | 9 |  |
|  | 12 | 4 | DGAB | 0.95 | 0.65 | 0.74 | 8 | 0.016 |
|  |  |  | ATB | -0.67 | 0.04 | 0.11 | 9 |  |
|  |  |  | ATB/DGAB | 0.07 | 0.14 | 0.17 | 9 |  |
|  |  | 7 | DGAB | 0.00 | 0.13 | 0.11 | 8 | 0.319 |
|  |  |  | ATB | -0.32 | 0.22 | 0.24 | 8 |  |
|  |  |  | ATB/DGAB | -0.27 | 0.27 | 0.33 | 8 |  |
| D | 8 | 4 | DGAB | 0.45 | 0.36 | 0.30 | 8 | 0.529 |
|  |  |  | ATB | 0.09 | 0.15 | 0.12 | 8 |  |
|  |  | 7 | DGAB | -0.17 | 0.19 | 0.36 | 8 | 0.531 |
|  |  |  | ATB | -0.46 | 0.19 | 0.26 | 8 |  |
|  | 12 | 4 | DGAB | 0.25 | 0.21 | 0.29 | 9 | 0.065 |
|  |  |  | ATB | -0.53 | 0.18 | 0.23 | 8 |  |
|  |  | 7 | DGAB | -0.53 | 0.34 | 0.54 | 8 | 0.663 |
|  |  |  | ATB | -0.35 | 0.10 | 0.12 | 9 |  |
|  | 16 | 4 | DGAB | -0.13 | 0.15 | 0.12 | 9 | 0.489 |
|  |  |  | ATB | -0.38 | 0.19 | 0.26 | 8 |  |
|  |  | 7 | DGAB | -0.35 | 0.26 | 0.34 | 8 | 0.574 |
|  |  |  | ATB | -0.13 | 0.12 | 0.17 | 9 |  |

Table A5- 33 Effect of base thickness on ΔIRI - Level B

| Drainage | Base Type | HMA Thickness | Base Thickness | Std. deviate | Mean | Std. Deviation | N | P-value |
|---|---|---|---|---|---|---|---|---|
| ND | DGAB | 4 | 8 | 0.72 | 0.29 | 0.32 | 8 | 0.772 |
| | | | 12 | 0.95 | 0.65 | 0.74 | 8 | |
| | | 7 | 8 | 0.52 | 0.57 | 0.89 | 8 | 0.177 |
| | | | 12 | 0.00 | 0.13 | 0.11 | 8 | |
| | ATB | 4 | 8 | 0.47 | 0.52 | 0.57 | 8 | 0.005 |
| | | | 12 | -0.67 | 0.04 | 0.11 | 9 | |
| | | 7 | 8 | 0.14 | 0.16 | 0.18 | 9 | 0.183 |
| | | | 12 | -0.32 | 0.22 | 0.24 | 8 | |
| | ATB/DGAB | 4 | 8 | 0.46 | 0.48 | 0.64 | 8 | 0.450 |
| | | | 12 | 0.07 | 0.14 | 0.17 | 9 | |
| | | 7 | 8 | 0.26 | 0.16 | 0.19 | 9 | 0.143 |
| | | | 12 | -0.27 | 0.27 | 0.33 | 8 | |
| D | DGAB | 4 | 8 | 0.45 | 0.36 | 0.30 | 8 | 0.568 |
| | | | 12 | 0.25 | 0.21 | 0.29 | 9 | |
| | | | 16 | -0.13 | 0.15 | 0.12 | 9 | |
| | | 7 | 8 | -0.17 | 0.19 | 0.36 | 8 | 0.758 |
| | | | 12 | -0.53 | 0.34 | 0.54 | 8 | |
| | | | 16 | -0.35 | 0.26 | 0.34 | 8 | |
| | ATB | 4 | 8 | 0.09 | 0.15 | 0.12 | 8 | 0.071 |
| | | | 12 | -0.53 | 0.18 | 0.23 | 8 | |
| | | | 16 | -0.38 | 0.19 | 0.26 | 8 | |
| | | 7 | 8 | -0.46 | 0.19 | 0.26 | 8 | 0.622 |
| | | | 12 | -0.35 | 0.10 | 0.12 | 9 | |
| | | | 16 | -0.13 | 0.12 | 0.17 | 9 | |

Table A5- 34 Effect of drainage on ΔIRI - Level B

| Base Type | Base Thickness | HMA Thickness | Drainage | Mean | Std. Deviation | N | P-value |
|---|---|---|---|---|---|---|---|
| DGAB | 8 | 4 | ND | 0.29 | 0.32 | 8 | 0.752 |
| | | | D | 0.36 | 0.30 | 8 | |
| | | 7 | ND | 0.57 | 0.89 | 8 | 0.203 |
| | | | D | 0.19 | 0.36 | 8 | |
| | 12 | 4 | ND | 0.65 | 0.74 | 8 | 0.277 |
| | | | D | 0.21 | 0.29 | 9 | |
| | | 7 | ND | 0.13 | 0.11 | 8 | 0.105 |
| | | | D | 0.34 | 0.54 | 8 | |
| | 16 | 4 | ND | | | | |
| | | | D | 0.15 | 0.12 | 9 | |
| | | 7 | ND | | | | |
| | | | D | 0.26 | 0.34 | 8 | |
| ATB | 8 | 4 | ND | 0.52 | 0.57 | 8 | 0.264 |
| | | | D | 0.15 | 0.12 | 8 | |
| | | 7 | ND | 0.16 | 0.18 | 9 | 0.244 |
| | | | D | 0.19 | 0.26 | 8 | |
| | 12 | 4 | ND | 0.04 | 0.11 | 9 | 0.609 |
| | | | D | 0.18 | 0.23 | 8 | |
| | | 7 | ND | 0.22 | 0.24 | 8 | 0.866 |
| | | | D | 0.10 | 0.12 | 9 | |
| | 16 | 4 | ND | | | | |
| | | | D | 0.19 | 0.26 | 8 | |
| | | 7 | ND | | | | |
| | | | D | 0.12 | 0.17 | 9 | |
| ATB/DGAB | 8 | 4 | ND | 0.48 | 0.64 | 8 | |
| | | | D | | | | |
| | | 7 | ND | 0.16 | 0.19 | 9 | |
| | | | D | | | | |
| | 12 | 4 | ND | 0.14 | 0.17 | 9 | |
| | | | D | | | | |
| | | 7 | ND | 0.27 | 0.33 | 8 | |
| | | | D | | | | |

# APPENDIX B1

## Site Summaries for SPS-2 experiment
## (Inventory/construction details, status and data availability)

## Arizona (4)

### Site Description

The site in Arizona is located in the eastbound direction of I-10, approximately 35 miles west of Phoenix between Tonopah and State Spur on route 85, in Maricopa County. The other inventory data for the sections are summarized in Table 1.

**Table 1 Inventory data for AZ (4)**

| | |
|---|---|
| Site code | 4 |
| Climatic zone | Dry No Freeze |
| Average annual precipitation | 232 mm |
| Average annual freezing index | 0.0 $^{o}$C-days |
| Traffic open date | 1st of October 1993 |
| 'Proposed' traffic | 1092 KESALs/year |
| Subgrade soil type | Coarse grained |
| Inside shoulder type | PCC |
| Outside shoulder type | PCC |

### Construction Issues

According to the construction report, no major problems were encountered during construction. The following are the main construction issues encountered at the site:

- In the construction of DGAB, AASHTO No. 57 coarse aggregate was utilized in as the backfill material in the pavement base drain.
- The geotextile wrapped around the PATB edge was short and could have caused intrusion of soil from adjacent DGAB.
- Transverse drains were installed perpendicular rather than in a herringbone fashion.
- Transverse cracking in the LCB layer was observed in sections 4-0217, 4-0218, 4-0219 and 4-0220 prior to the placement of the slab.
- Longitudinal tie bars were placed uncoated and also the bars were smaller (20" long) than specified (30").
- PCC slump variations and segregation occurred in several test sections.

### Site Status

The deviations in the design and/or site features at this site are explained here. No deviations in the site factors have been observed at the site. As planned, the site has coarse-grained roadbed soil and it is situated in the Dry No Freeze climatic zone. A summary of the status of the design features of the site is Table 2. Only one section, 4-0222, has been constructed thicker/thinner by more than 0.5". All the other design features have been constructed as intended in the SPS-2 design.

**Table 2 Summary of status of design features**

| SHRP ID | Slab Thickness, in. | | Base Type | Drainage | Lane Width, ft | As designed? |
|---|---|---|---|---|---|---|
| | Design | Actual | | | | |
| 0213 | 8 | 7.9 | DGAB | No | 14 | Yes |
| 0214 | 8 | 8.3 | DGAB | No | 12 | Yes |
| 0215 | 11 | 11.3 | DGAB | No | 12 | Yes |
| 0216 | 11 | 11.2 | DGAB | No | 14 | Yes |
| 0217 | 8 | 8.1 | LCB | No | 14 | Yes |
| 0218 | 8 | 8.3 | LCB | No | 12 | Yes |
| 0219 | 11 | 10.8 | LCB | No | 12 | Yes |
| 0220 | 11 | 11.3 | LCB | No | 14 | Yes |
| 0221 | 8 | 8.2 | PATB | Yes | 14 | Yes |
| 0222 | 8 | **8.6** | PATB | Yes | 12 | **No** |
| 0223 | 11 | 11.1 | PATB | Yes | 12 | Yes |
| 0224 | 11 | 10.7 | PATB | Yes | 14 | Yes |
| **Flexural Strength, psi** | **Target** | **Std. Dev.** | **Actual (average)** | | **Average Within 10%?** | |
| | 550 | 10 | 572 | | Yes | |
| | 900 | 58 | 837 | | Yes | |

## Data Availability

A summary of the data available for the sections in this site is Table 3. The section 4-0213 is a seasonal monitoring section and that could be the reason for the higher amount of data available for that section.

**Table 3 Summary of monitoring data availability**

| SHRP ID | Monitoring data availability, No. of surveys | | | |
|---|---|---|---|---|
| | Distress | | IRI | FWD |
| | Manual | Faulting | | |
| **0213** | 6 | 6 | 8 | 5 |
| **0214** | 6 | 6 | 8 | 4 |
| **0215** | 18 | 18 | 10 | 40 |
| **0216** | 6 | 6 | 8 | 5 |
| **0217** | 6 | 6 | 8 | 5 |
| **0218** | 6 | 6 | 8 | 5 |
| **0219** | 6 | 6 | 8 | 5 |
| **0220** | 6 | 6 | 8 | 5 |
| **0221** | 6 | 6 | 8 | 5 |
| **0222** | 6 | 6 | 8 | 5 |
| **0223** | 6 | 6 | 8 | 5 |
| **0224** | 6 | 6 | 8 | 4 |

## Arkansas (5)

### Site Description

The site, a four lane divided highway, is located on the westbound lanes of I-30 in Hot Spring County, Arkansas. The other inventory data of the site in Arkansas have been summarized in Table 4. It is to be noted that there is a discrepancy in the notation of the sections between DATAPAVE and the construction reports. The sections were numbered from 5-0213 to 5-0224 in DATAPAVE while the sections were numbered from 5-0201 to 5-0212 in the construction reports. However the notation in DATAPAVE was used during the analysis.

**Table 4 Inventory data for AR (5)**

| | |
|---|---|
| Site code | 5 |
| Climatic zone | Wet No Freeze |
| Average annual precipitation | 1381 mm |
| Average annual freezing index | 38 $^{o}$C-days |
| Traffic open date | 1$^{st}$ of November 1995 |
| ‘Proposed’ traffic | 1903 KESALs/year |
| Subgrade soil type | Coarse grained |
| Inside shoulder type | AC |
| Outside shoulder type | AC |

### Construction Issues

Only a few construction issues occurred during the construction of the section at this site. They are as follows:

- The dowel basket assembly that got “entangled” with the paver had to be removed while the paving operations were halted.
- The longitudinal joints at the site were not sealed until early 1997 and pumping was evident at the joints by that time.

### Site Status

Deviation has been found in the subgrade type at this site. Though as per the design the sections at this site are to be founded on fine-grained soils, most of the sections (i.e. except 0222 and 0223) have been built on coarse-grained subgrade soils.

The subgrade soil type for each test section has been decided based on four different sources of information in the LTPP database- TST_L05B, SPS2_LAYER, TST_SS04_UG08, and TST_SS01_UG01_UG02. The data from SPS2_LAYER has been found to be contradictory with the data from other sources for most of the sections at this site. The construction report has indicated that the site has all the sections on fine-grained subgrade soil. A decision has been made considering all the sources.

But, as planned, the site has been constructed in a Wet No Freeze climatic zone.

Table 5 is a summary of the status of all the design factors. Sections 0213 and 0215 have been constructed with a PCC thickness deviation of at least 0.5 inch. Also the average 14-

day flexural strength of the PCC at the sections with target strength of 900-psi has been found to be lesser by more than 10% the target.

**Table 5 Summary of status of design features**

| SHRP ID | Slab Thickness, in. | | Base Type | Drainage | Lane Width, ft | As designed? |
|---|---|---|---|---|---|---|
| | Design | Actual | | | | |
| 0213 | 8 | **7.4** | DGAB | No | 14 | **No** |
| 0214 | 8 | 8.4 | DGAB | No | 12 | Yes |
| 0215 | 11 | **11.5** | DGAB | No | 12 | **No** |
| 0216 | 11 | 11 | DGAB | No | 14 | Yes |
| 0217 | 8 | 8.3 | LCB | No | 14 | Yes |
| 0218 | 8 | 8.2 | LCB | No | 12 | Yes |
| 0219 | 11 | 11.1 | LCB | No | 12 | Yes |
| 0220 | 11 | 10.7 | LCB | No | 14 | Yes |
| 0221 | 8 | 8.3 | PATB | Yes | 14 | Yes |
| 0222 | 8 | 8.3 | PATB | Yes | 12 | Yes |
| 0223 | 11 | 10.9 | PATB | Yes | 12 | Yes |
| 0224 | 11 | 10.9 | PATB | Yes | 14 | Yes |
| **Flexural Strength, psi** | **Target** | **Std. Dev.** | **Actual (average)** | | **Average Within 10%?** | |
| | 550 | 30 | 545 | | Yes | |
| | 900 | 226 | **666** | | **No** | |

Maintenance construction was done on all the sections at this site. Longitudinal lane-shoulder joints, transverse joints, and cracks were sealed as maintenance. The maintenance work was done in 1997 and 2002, and resulted in the change of ‘construction number’ in the database since those years.

**Data Availability**

Table 6 is the summary of the monitoring data available from the LTPP database. Though the site is more than 8 years old, the data available is only for four or five tests.

**Table 6 Summary of monitoring data availability**

| SHRP ID | Monitoring data availability, No. of surveys | | | |
|---|---|---|---|---|
| | Distress | | IRI | FWD |
| | Manual | Faulting | | |
| **0213** | 5 | 5 | 4 | 4 |
| **0214** | 5 | 5 | 4 | 4 |
| **0215** | 5 | 5 | 4 | 4 |
| **0216** | 5 | 5 | 4 | 4 |
| **0217** | 5 | 5 | 4 | 4 |
| **0218** | 5 | 5 | 4 | 4 |
| **0219** | 5 | 5 | 4 | 4 |
| **0220** | 5 | 5 | 4 | 4 |
| **0221** | 5 | 5 | 4 | 4 |
| **0222** | 5 | 5 | 4 | 4 |
| **0223** | 5 | 5 | 4 | 4 |
| **0224** | 5 | 5 | 4 | 4 |

## California (6)

### Site Description

The project at this site is the youngest of all the sites in the SPS-2 experiment. It is located on the northbound truck lane of SR 99, Delhi (Merced County), California. The test sections were built as part of a realignment of SR 99 and a conversion to a four-lane freeway. The other inventory data are summarized in Table 7.

**Table 7 Summary of inventory data**

| | |
|---|---|
| Site code | 6 |
| Climatic zone | Dry No Freeze |
| Average annual precipitation | 299 mm |
| Average annual freezing index | 0.2 °C-days |
| Traffic open date | 1st October 2000 |
| ‘Proposed’ traffic | 2405 KESALs/year |
| Subgrade soil type | Coarse-grained |
| Inside shoulder type | AC |
| Outside shoulder type | PCC |

### Construction Issues

No major problems were encountered during construction of the pavement sections at the site. The main construction issues are as follows:

- Cracks developed at several places in the LCB layer right after placement because the curing compound was not placed properly.
- Considerable segregation occurred in the LCB layer, due to large aggregate used in mix.
- The PATB layer was bladed, following an inspection, to make the surface uniform.
- The sides of the PATB material were completely covered by the overlaying PCC material and the cement paste rendered the PATB almost ineffective. Later it was cleaned up ‘sufficiently’.
- Unlike in other sites of the SPS-2 experiment, two levels in dowel diameter, 32 mm and 38 mm, exist in sections with target PCC slab thickness of 203 mm and in sections with target PCC slab thickness of 279 mm.

### Site Status

No deviations in the site factors have been observed at the site. As planned, the site has coarse-grained roadbed soil and it is situated in the Dry No Freeze climatic zone. A summary of the status of the design features of the site is Table 8. Only one section, 4-0211, has been constructed thicker by at least 0.5”. The lane width of test section with target of 14 ft was found to be 13 ft (Table: SPS_GENERAL). The data of testing on the PCC of the slab are not available from the database. All the other design features have been constructed as intended in the SPS-2 design.

**Table 8 Summary of status of design features**

| SHRP ID | Slab Thickness, in. | | Base Type | Drainage | Lane Width, ft | As designed? |
|---|---|---|---|---|---|---|
| | Design | Actual | | | | |
| 0201 | 8 | 8.2 | DGAB | No | 12 | Yes |
| 0202 | 8 | 7.7 | DGAB | No | 13 | **No** |
| 0203 | 11 | 11.4 | DGAB | No | 13 | **No** |
| 0204 | 11 | 11.4 | DGAB | No | 12 | Yes |
| 0205 | 8 | 8.3 | LCB | No | 12 | Yes |
| 0206 | 8 | 8.1 | LCB | No | 13 | **No** |
| 0207 | 11 | 11.4 | LCB | No | 13 | **No** |
| 0208 | 11 | 10.8 | LCB | No | 12 | Yes |
| 0209 | 8 | 8.3 | PATB | Yes | 12 | Yes |
| 0210 | 8 | 8.2 | PATB | Yes | 13 | **No** |
| 0211 | 11 | **11.5** | PATB | Yes | **13** | **No** |
| 0212 | 11 | 11.2 | PATB | Yes | 12 | Yes |
| | **Target** | **Std. Dev.** | **Actual (average)** | | **Average Within 10%?** | |
| **Flexural Strength, psi** | 550 | N.A. | N.A. | | - | |
| | 900 | N.A. | N.A. | | - | |

## Data Availability

A summary of the data available for the sections in this site is Table 9.

**Table 9 Summary of status of available data**

| SHRP ID | Monitoring data availability, No. of surveys | | | |
|---|---|---|---|---|
| | Distress | | IRI | FWD |
| | Manual | Faulting | | |
| **0201** | 3 | 3 | 3 | 2 |
| **0202** | 3 | 3 | 3 | 2 |
| **0203** | 3 | 3 | 3 | 2 |
| **0204** | 2 | 2 | 3 | 1 |
| **0205** | 3 | 3 | 3 | 2 |
| **0206** | 3 | 3 | 3 | 2 |
| **0207** | 3 | 3 | 3 | 2 |
| **0208** | 3 | 3 | 3 | 2 |
| **0209** | 3 | 3 | 3 | 2 |
| **0210** | 3 | 3 | 3 | 2 |
| **0211** | 3 | 3 | 3 | 2 |
| **0212** | 3 | 3 | 3 | 2 |

## Colorado (8)

### Site Description

The site in Colorado was constructed on I-76 (east bound) near Adams County in Denver, Colorado. Six sections (0213 through 0216, 0218 and 0219) were a part of reconstruction project and the other six sections were a part of new alignment project. The other inventory data of the site have been summarized in Table 10.

**Table 10 Summary of inventory data**

| | |
|---|---|
| Site code | 8 |
| Climatic zone | Dry Freeze |
| Average annual precipitation | 370 mm |
| Average annual freezing index | 327 $^{o}$C-days |
| Traffic open date | 1st of November 1993 |
| ‘Proposed’ traffic | 400 KESALs/year |
| Subgrade soil type | Fine grained |
| Inside shoulder type | PCC |
| Outside shoulder type | PCC |

### Construction Issues

According to the construction report of the site, six sections each were constructed in ‘cut’ and on ‘fill’. Sections 0213, 0214, 0215, 0216 and 0221 were constructed on fills. The Phase 1 of construction included the construction of the new alignment and the Phase 2 of the construction was reconstruction of I-76. The major construction issues at the site are as follows:

- Subgrade pumping occurred on several sections during Phase 1 construction due to wet weather and high water table at some locations.
- Many PATB sections had too many fines in the mix. The mat in section 0221 was replaced due to this problem.
- In section 0218, construction was stopped sometimes due to delay in delivery of material and equipment. The dowel basket assembly was torn up at station 141+50 but not replaced in this section.

### Site Status

The deviations in the design and/or site features at this site are explained here. The site is one of the three sites in the SPS-2 experiment that have sections on both fine-grained and coarse-grained subgrade soils. The site has five test sections (0214, 0216, 0219, 0223, and 0224) on coarse-grained soils and the other seven sections on fine-grained soils. As a majority of the sections have fine-grained soils, the site has been categorized under fine-grained subgrade soil type (see Table 10). But according to the SPS-2 experiment design, the site was supposed to be having coarse-grained subgrade soils only. This is the major deviation from design at this site. A summary of the status of the design features of the site is Table 10.

**Table 11 Summary of status of design features**

| **SHRP ID** | **Slab Thickness, in.** | | **Base Type** | **Drainage** | **Lane Width, ft** | **As designed?** |
|---|---|---|---|---|---|---|
| | **Design** | **Actual** | | | | |
| 0213 | 8 | **8.7** | DGAB | No | 14 | **No** |
| 0214 | 8 | 8.4 | DGAB | No | 12 | Yes |
| 0215 | 11 | 11.4 | DGAB | No | 12 | Yes |
| 0216 | 11 | **11.8** | DGAB | No | 14 | **No** |
| 0217 | 8 | **8.6** | LCB | No | 14 | **No** |
| 0218 | 8 | 7.7 | LCB | No | 12 | Yes |
| 0219 | 11 | 11.1 | LCB | No | 12 | Yes |
| 0220 | 11 | 11.1 | LCB | No | 14 | Yes |
| 0221 | 8 | 8.3 | PATB | Yes | 14 | Yes |
| 0222 | 8 | **8.7** | PATB | Yes | 12 | **No** |
| 0223 | 11 | **11.8** | PATB | Yes | 12 | **No** |
| 0224 | 11 | **11.7** | PATB | Yes | 14 | **No** |
| **Flexural Strength, psi** | **Target** | **Std. Dev.** | **Actual (average)** | | **Average Within 10%?** | |
| | 550 | 45 | 526 | | Yes | |
| | 900 | 58 | 906 | | Yes | |

Six of the twelve sections have PCC thickness exceeding the respective target PCC thickness by more than 0.5 inch. The target 14-day flexural strength has been met, based on average 14-day flexural strength values.

## Data Availability

A summary of the data available for the sections in this site is Table 12. The initial faulting and distress survey was conducted only in 1996 though the section was opened to traffic in 1993.

**Table 12 Summary of monitoring data availability**

| **SHRP ID** | **Monitoring data availability, No. of surveys** | | | |
|---|---|---|---|---|
| | **Distress** | | **IRI** | **FWD** |
| | **Manual** | **Faulting** | | |
| **0213** | 5 | 5 | 7 | 5 |
| **0214** | 4 | 4 | 7 | 5 |
| **0215** | 5 | 5 | 7 | 5 |
| **0216** | 4 | 4 | 7 | 5 |
| **0217** | 6 | 6 | 8 | 7 |
| **0218** | 7 | 7 | 8 | 7 |
| **0219** | 7 | 7 | 8 | 7 |
| **0220** | 7 | 7 | 8 | 7 |
| **0221** | 7 | 7 | 8 | 7 |
| **0222** | 7 | 7 | 8 | 7 |
| **0223** | 7 | 7 | 8 | 7 |
| **0224** | 7 | 7 | 8 | 7 |

## Delaware (10)

### Site Description

The site is located on US 113 between Milford and Georgetown, Delaware. The site was included in the additional two southbound lanes to an initial to-lane roadway. Within the area of the site, there is an intersecting highway that is assumed to cause only insignificant impact on truck traffic through the test sections. Other inventory data has been summarized in Table 13.

**Table 13 Summary of inventory data**

| | |
|---|---|
| Site code | 10 |
| Climatic zone | Wet Freeze |
| Average annual precipitation | 1144 mm |
| Average annual freezing index | 103 $^{o}$C-days |
| Traffic open date | 1$^{st}$ of May 1996 |
| 'Proposed' traffic | 430 KESALs/year |
| Subgrade soil type | Coarse grained |
| Inside shoulder type | AC |
| Outside shoulder type | AC |

### Construction Issues

A variety of construction issues have been reported in the construction report. Problems were encountered with weather and poor performance of concrete in some test sections. The main issues have been summarized below:

- All the 550-psi PCC has been replaced with the Delaware DOT Type 'B' mix that gives a flexural strength of approximately 650 psi. Extensive cracking (poor performance) prompted the Delaware DOT officials to take this decision.
- Some 900-psi concrete was also replaced (sections 0202 and 0206), with 900-psi mix with 7.5-bag mix, after breaking and removing cracked PCC.
- Also 900-psi mix was found hard finish during paving operations.
- Concrete patching was done at many locations where cracks appeared on the PCC.
- Transverse shrinkage cracks appeared in LCB before PCC was laid.
- During construction of the LCB, depressions occurred due to stoppage of the paver. Transverse cracks were observed at some of these depressions.
- "High spots" were milled before paving was done for some of the sections.
- Edge drains did not extend to the full length of the PATB in section 0211.
- A transverse construction joint was placed within section 0212.
- The road was opened to traffic before all the joints were sealed.

## Site Status

As said above, the 550-psi SHRP mix has been replaced with Delaware DOT Type 'B' mix after the 550-psi SHRP mix was found to be performing poorly (shrinkage cracking). This is the main deviation at this site. A summary of the status of the design factors at this site is in Table 14. Seven of the twelve test sections have been built with PCC layers thicker than their respective target thickness, by at least 0.5 in. Also, the flexural strength of the PCC of the sections are different from the target strength by more than 10%.

**Table 14 Summary of status of design factors**

| SHRP ID | Slab Thickness, in. | | Base Type | Drainage | Lane Width, ft | As designed? |
|---|---|---|---|---|---|---|
| | Design | Actual | | | | |
| 0201 | 8 | 8.3 | DGAB | No | 12 | Yes |
| 0202 | 8 | **8.8** | DGAB | No | 14 | **No** |
| 0203 | 11 | **11.7** | DGAB | No | 14 | **No** |
| 0204 | 11 | 11 | DGAB | No | 12 | Yes |
| 0205 | 8 | **9.2** | LCB | No | 12 | **No** |
| 0206 | 8 | **8.9** | LCB | No | 14 | **No** |
| 0207 | 11 | 11.3 | LCB | No | 14 | Yes |
| 0208 | 11 | **12.1** | LCB | No | 12 | **No** |
| 0209 | 8 | 8.2 | PATB | Yes | 12 | Yes |
| 0210 | 8 | 8.3 | PATB | Yes | 14 | Yes |
| 0211 | 11 | **11.8** | PATB | Yes | 14 | **No** |
| 0212 | 11 | **12.4** | PATB | Yes | 12 | **No** |
| **Flexural Strength, psi** | **Target** | **Std. Dev.** | **Actual (average)** | | **Average Within 10%?** | |
| | 550 | 101 | **657** | | **No** | |
| | 900 | 152 | **757** | | **No** | |

## Data Availability

A summary of the data available for the sections in this site is Table 15.

**Table 15 Summary of data availability**

| SHRP ID | Monitoring data availability, No. of surveys | | | |
|---|---|---|---|---|
| | Distress | | IRI | FWD |
| | Manual | Faulting | | |
| **0201** | 7 | 7 | 7 | 5 |
| **0202** | 6 | 6 | 7 | 4 |
| **0203** | 6 | 6 | 7 | 4 |
| **0204** | 6 | 6 | 7 | 4 |
| **0205** | 5 | 5 | 7 | 4 |
| **0206** | 5 | 5 | 7 | 4 |
| **0207** | 6 | 6 | 7 | 4 |
| **0208** | 6 | 6 | 7 | 4 |
| **0209** | 7 | 7 | 7 | 5 |
| **0210** | 5 | 5 | 7 | 4 |
| **0211** | 5 | 5 | 7 | 4 |
| **0212** | 6 | 6 | 7 | 4 |

## Iowa (19)

### Site Description

The site is located in the northbound lanes of U.S. 65 in central Iowa, northeast of Des Moines. The project was included in the relocation of the U.S. 65 in both the northbound and southbound lanes. A summary of other inventory data is in Table 16.

**Table 16 Summary of inventory data**

| | |
|---|---|
| Site code | 19 |
| Climatic zone | Wet Freeze |
| Average annual precipitation | 901 mm |
| Average annual freezing index | 580 °C-days |
| Traffic open date | 1st of December 1994 |
| 'Proposed' traffic | 377 KESALs/year |
| Subgrade soil type | Fine grained |
| Inside shoulder type | AC |
| Outside shoulder type | AC |

### Construction Issues

No major construction problems have occurred during construction of the report, as per the construction report. Some of the main issues are as follows:

- In six of the twelve sections at the site (0213, 0214, 0215, 0217, 0219, and 0221), underground structures were located. The depth of the structures has a range of 2.4 m to 12.2 m, with reference to the profile grade.
- At least 0.3 m of geotextile was removed from the longitudinal edge of the sections because of the low permeability of the geotextile.
- During placement of the PCC slab for the test section 0222 incorrect dowel baskets were placed. The section was thus relocated to avoid this area.

### Site Status

Five sections (0215, 0216, 0221, 0223, and 0224) have been built with PCC thickness greater than corresponding target PCC thickness by a margin of 0.5 in. Also the average 14-day flexural strength of the sections is lesser than the corresponding target flexural strength by a margin greater than 10% of the target flexural strength. Table 17 is a summary of the status of the design features at the site.

### Table 17 Summary of status of design features

| SHRP ID | Slab Thickness, in. | | Base Type | Drainage | Lane Width, ft | As designed? |
|---|---|---|---|---|---|---|
| | Design | Actual | | | | |
| 0213 | 8 | 8.5 | DGAB | No | 14 | Yes |
| 0214 | 8 | 8.4 | DGAB | No | 12 | Yes |
| 0215 | 11 | **11.8** | DGAB | No | 12 | **No** |
| 0216 | 11 | **11.6** | DGAB | No | 14 | **No** |
| 0217 | 8 | 8.1 | LCB | No | 14 | Yes |
| 0218 | 8 | 8.2 | LCB | No | 12 | Yes |
| 0219 | 11 | 11.2 | LCB | No | 12 | Yes |
| 0220 | 11 | 11.4 | LCB | No | 14 | Yes |
| 0221 | 8 | **9.4** | PATB | Yes | 14 | **No** |
| 0222 | 8 | 8.3 | PATB | Yes | 12 | Yes |
| 0223 | 11 | **11.7** | PATB | Yes | 12 | **No** |
| 0224 | 11 | **11.6** | PATB | Yes | 14 | **No** |
| **Flexural Strength, psi** | **Target** | **Std. Dev.** | **Actual (average)** | | **Average Within 10%?** | |
| | 550 | **31** | 467 | | **No** | |
| | 900 | **47** | 753 | | **No** | |

### Data Availability

A summary of the available monitoring data for the sections at this site is in Table 18. Though the site is almost 10 years old, the deflection data is available only for about 4 tests, on an average.

### Table 18 Summary of monitoring data availability

| SHRP ID | Monitoring data availability, No. of surveys | | | |
|---|---|---|---|---|
| | Distress | | IRI | FWD |
| | Manual | Faulting | | |
| **0213** | 6 | 6 | 8 | 4 |
| **0214** | 5 | 5 | 8 | 3 |
| **0215** | 6 | 6 | 8 | 3 |
| **0216** | 6 | 6 | 8 | 3 |
| **0217** | 6 | 6 | 8 | 4 |
| **0218** | 6 | 6 | 8 | 4 |
| **0219** | 6 | 6 | 8 | 4 |
| **0220** | 6 | 6 | 8 | 4 |
| **0221** | 6 | 5 | 8 | 4 |
| **0222** | 5 | 5 | 7 | 3 |
| **0223** | 5 | 5 | 8 | 3 |
| **0224** | 5 | 5 | 8 | 3 |

## Kansas (20)

### Site Description

The site is located in the westbound driving lane of Interstate 70 near Abilene in Dickinson County. The project was included in the reconstruction of I-70 and was built on fill. The other inventory data are summarized in Table 19.

**Table 19 Summary of inventory data**

| | |
|---|---|
| Site code | 20 |
| Climatic zone | Wet Freeze |
| Average annual precipitation | 820 mm |
| Average annual freezing index | 259 $^{o}$C-days |
| Traffic open date | 1st of August 1992 |
| 'Proposed' traffic | 757 KESALs/year |
| Subgrade soil type | Fine grained |
| Inside shoulder type | PCC |
| Outside shoulder type | PCC |

### Construction Issues

The main construction issues encountered at this site are as follows:

- Underground structures were present at the site in sections 0208 through 0212 and 0204. The drains were at least 1.5 m below the pavement surface.
- Two partial-depth repairs were done to the test section 0204 in the year 1995.
- Vertical curves exist within the limits of the site.
- PATB was difficult to place. Excess PATB was removed with a trimmer.
- Existing subbase and shoulder material was retained.
- Subgrade was dried up prior to construction using Type 'C' Fly Ash.

### Site Status

Table 20 is the summary of the status of design factors at the site. Two sections, 0202 and 0209, have at least 0.5 inches as deviation from target PCC slab thickness. Test section 0202 has been built 0.6" thinner and 0209 has been built 0.5" thicker than corresponding target thicknesses. Also the average 14-day flexural strength of the sections with target 14-day modulus of rupture as 550-psi is more than 10% higher than the target (see Table 20).

Partial depth repairing was performed on section 0201 in the year 2995 resulting in a change in 'construction number' for the section since that year.

### Table 20 Summary of status of the design factors

| SHRP ID | Slab Thickness, in. | | Base Type | Drainage | Lane Width, ft | As designed? |
|---|---|---|---|---|---|---|
| | Design | Actual | | | | |
| 0201 | 8 | 7.7 | DGAB | No | 12 | Yes |
| 0202 | 8 | **7.4** | DGAB | No | 14 | **No** |
| 0203 | 11 | 11.1 | DGAB | No | 14 | Yes |
| 0204 | 11 | 11.3 | DGAB | No | 12 | Yes |
| 0205 | 8 | 7.8 | LCB | No | 12 | Yes |
| 0206 | 8 | 7.9 | LCB | No | 14 | Yes |
| 0207 | 11 | 11.3 | LCB | No | 14 | Yes |
| 0208 | 11 | 11 | LCB | No | 12 | Yes |
| 0209 | 8 | **8.5** | PATB | Yes | 12 | **No** |
| 0210 | 8 | 8.3 | PATB | Yes | 14 | Yes |
| 0211 | 11 | 11.1 | PATB | Yes | 14 | Yes |
| 0212 | 11 | 10.9 | PATB | Yes | 12 | Yes |
| **Flexural Strength, psi** | **Target** | **Std. Dev.** | **Actual (average)** | | **Average Within 10%?** | |
| | 550 | 47 | **613** | | **No** | |
| | 900 | 50 | 843 | | Yes | |

## Data Availability

Table 21 is the summary of the monitoring data availability. Though the site is about 12 years old, the monitoring data available is for less than or equal to six tests for distress and deflection data. Also, unlike in the case most of the sections in the experiment, the faulting data and distress data are not available to the same extent in this site.

### Table 21 Summary of monitoring data availability

| SHRP ID | Monitoring data availability, No. of surveys | | | |
|---|---|---|---|---|
| | Distress | | IRI | FWD |
| | Manual | Faulting | | |
| **0201** | 6 | 4 | 11 | 4 |
| **0202** | 6 | 4 | 12 | 3 |
| **0203** | 6 | 4 | 12 | 3 |
| **0204** | 6 | 4 | 12 | 4 |
| **0205** | 6 | 4 | 12 | 4 |
| **0206** | 6 | 4 | 12 | 4 |
| **0207** | 6 | 4 | 12 | 4 |
| **0208** | 6 | 4 | 12 | 4 |
| **0209** | 5 | 3 | 12 | 3 |
| **0210** | 6 | 4 | 12 | 4 |
| **0211** | 6 | 4 | 12 | 4 |
| **0212** | 6 | 4 | 12 | 4 |

## Michigan (26)

### Site Description

The Michigan SPS-2 site is located on the US 23 (Ottawa Lake, Monroe County), which is a rural principal arterial. The project was included in the reconstruction of US 23. Consear Road bisects the site. Most of the sections were constructed on fills. Some of the sections (0218 and 0219) were constructed on a superelevation. The other inventory data for the site has been summarized in Table 22.

**Table 22 Summary of inventory data**

| | |
|---|---|
| Site code | 26 |
| Climatic zone | Wet Freeze |
| Average annual precipitation | 866 mm |
| Average annual freezing index | 382 °C-days |
| Traffic open date | 1st of November 1993 |
| ‘Proposed’ traffic | 1505 KESALs/year |
| Subgrade soil type | Fine grained |
| Inside shoulder type | AC |
| Outside shoulder type | AC |

### Construction Issues

The major construction issues, from the construction report, at the Michigan site are as follows:

- The traffic flow over all of the test sections is not uniform as Consear road bisects the site.
- Moisture content of the compacted subgrade was not maintained in the range of 85 to 120% of the optimum moisture content on sections 0213 through 0220.
- The DGAB for section 0221 segregated.
- The Geotextile fabric did not extent to the stipulated minimum depth of 1’ under the pavement.
- Rutting (1/2” to 1-3/4”) occurred in PATB due to traffic that was allowed to pass over the outside shoulder area of PATB during construction.
- A transverse construction joint was located in the LCB of section 0218.
- Longitudinal cracking of LCB was observed in 0217 and 0220, which could be due to the paving machines that were allowed to operate from the outside shoulder area.
- LCB in sections 0218, 0219 and 0220 and PCC in sections 0215 and 0219 had lesser than 1” of slump, which is the stipulated value.
- Embankment clay dried out and desiccation cracks appeared
- 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

- Transverse shrinkage cracks appeared in LCB soon after construction
- Extra amount of water entered the pavement structure since this section is located on superelevation, which drains toward the outside shoulder.
- PCC Concreting delayed by a month in 0216

### Site Status

Table 23 is the summary for the status of the design features of the sections at this site. Four of the twelve sections (0213, 0214, 0217, and 0218) were built with PCC thickness deviation of at least 0.5 in. The average 14-day modulus of rupture of PCC of the sections with target 14-day strength of 550-psi is greater than the target by a margin of 10% of the target strength (see Table 23).

**Table 23 Summary of status of design features**

| SHRP ID | Slab Thickness, in. | | Base Type | Drainage | Lane Width, ft | As designed? |
|---|---|---|---|---|---|---|
| | Design | Actual | | | | |
| 0213 | 8 | **8.6** | DGAB | No | 14 | **No** |
| 0214 | 8 | **8.9** | DGAB | No | 12 | **No** |
| 0215 | 11 | 11.2 | DGAB | No | 12 | Yes |
| 0216 | 11 | 11.4 | DGAB | No | 14 | Yes |
| 0217 | 8 | **8.5** | LCB | No | 14 | **No** |
| 0218 | 8 | **7.1** | LCB | No | 12 | **No** |
| 0219 | 11 | 10.9 | LCB | No | 12 | Yes |
| 0220 | 11 | 11.1 | LCB | No | 14 | Yes |
| 0221 | 8 | 8.2 | PATB | Yes | 14 | Yes |
| 0222 | 8 | 8.4 | PATB | Yes | 12 | Yes |
| 0223 | 11 | 11 | PATB | Yes | 12 | Yes |
| 0224 | 11 | 11.2 | PATB | Yes | 14 | Yes |
| **Flexural Strength, psi** | **Target** | **Std. Dev.** | **Actual (average)** | | **Average Within 10%?** | |
| | 550 | 30 | **617** | | **No** | |
| | 900 | 4 | 973 | | Yes | |

Sections 0213, 0215, 0217 and 0218 were de-assigned from the experiment in the years 1999, 2000, 1999, and 1998.

### Data Availability

A summary of the extent of monitoring data available in the LTPP database for the site is Table 24. Though the site is about 11 years old, the deflection data is available for only 3 to 6 tests. Unlike in the case of other sites, this site has high variation in the extent of available data among the test sections. The section 0218 has the least amount of data.

### Table 24 Summary of monitoring data availability

| SHRP ID | Monitoring data availability, No. of surveys | | | |
|---|---|---|---|---|
| | Distress | | IRI | FWD |
| | Manual | Faulting | | |
| **0213** | 5 | 4 | 6 | 5 |
| **0214** | 6 | 6 | 10 | 5 |
| **0215** | 5 | 5 | 7 | 4 |
| **0216** | 8 | 7 | 10 | 5 |
| **0217** | 4 | 3 | 5 | 4 |
| **0218** | 3 | 3 | 4 | 3 |
| **0219** | 7 | 7 | 10 | 5 |
| **0220** | 8 | 7 | 9 | 5 |
| **0221** | 9 | 8 | 9 | 6 |
| **0222** | 7 | 7 | 10 | 5 |
| **0223** | 8 | 8 | 10 | 5 |
| **0224** | 8 | 7 | 10 | 4 |

## Nevada (32)

### Site Description

The site is located in north central Nevada, in the outer eastbound lane of Interstate 80, in Humboldt and Lander Counties. The other inventory data are summarized in Table 25.

**Table 25 Summary of inventory data**

| | |
|---|---|
| Site code | 32 |
| Climatic zone | Dry Freeze |
| Average annual precipitation | 222 mm |
| Average annual freezing index | 276 $^{o}$C-days |
| Traffic open date | 1st of September 1995 |
| 'Proposed' traffic | 800 KESALs/year |
| Subgrade soil type | Fine grained |
| Inside shoulder type | PCC |
| Outside shoulder type | PCC |

### Construction Issues

The Nevada site has many serious construction issues according to the construction report. The PCC layer had a wide range of construction issues. It is highly unlikely, according to the construction report, that any of the sections will last the intended life for the experiment. A majority of the problems with the PCC paving came as a result of the mixes being significantly different from those typically used. Major construction issues, from the construction report, are as follows:

- The site was constructed after removal of an existing AC pavement. After removal of then existing AC layer, cement treated base, and DGAB, it was found that the subgrade was 'unsuitable' as per NDOT specifications. For this, lime stabilization was done to the top one foot of the in-situ subgrade soil.
- Higher deflections were observed in stabilized subgrade soil of sections 0201, 0205, 0207, and 0209, compared to that of other sections
- The PCC consisted of mixes different from the ones stipulated by the SHRP. The sections that were supposed to have PCC of 550-psi 14-day flexural strength have a 475-psi mix and the sections with target 14-day flexural strength of 900-psi have a 750-psi mix. This change was made to the design as it was found difficult to attain the 900-psi strength stipulated by SHRP, with locally available materials.
- Sections 0205, 0207 and 0208 had shrinkage cracking in the LCB before paving operations were carried out.
- Section 0212 had severe cracking following paving and was removed in 1995. The section was replaced with nonconforming materials and thus was removed from the experiment. Also sections 0203, 0205, and 0208 had shrinkage cracks following paving.

## Site Status

Table 26 is the summary of status of the design features at this site. Six of the eleven sections (see Table 25) have been built with PCC slab thicker than target thickness at least by a margin of 0.5 in. Also the average 14-day flexural strength of the sections is more than 10% (of target strength) below the target strength.

Full-depth repairing was conducted on section 0201 in 1999 and 2000. This has been reported in the database as a rehabilitation construction event. In addition sections 0202 and 0206 have been de-assigned from the experiment in 1997.

**Table 26 Summary of status of design features**

| **SHRP ID** | **Slab Thickness, in.** | | **Base Type** | **Drainage** | **Lane Width, ft** | **As designed?** |
|---|---|---|---|---|---|---|
| | **Design** | **Actual** | | | | |
| 0201 | 8 | **9.2** | DGAB | No | 12 | **No** |
| 0202 | 8 | 8.2 | DGAB | No | 14 | Yes |
| 0203 | 11 | **11.9** | DGAB | No | 14 | **No** |
| 0204 | 11 | **11.8** | DGAB | No | 12 | **No** |
| 0205 | 8 | **8.5** | LCB | No | 12 | **No** |
| 0206 | 8 | 7.8 | LCB | No | 14 | Yes |
| 0207 | 11 | 10.9 | LCB | No | 14 | Yes |
| 0208 | 11 | 11 | LCB | No | 12 | Yes |
| 0209 | 8 | **8.9** | PATB | Yes | 12 | **No** |
| 0210 | 8 | **10.1** | PATB | Yes | 14 | **No** |
| 0211 | 11 | 11.3 | PATB | Yes | 14 | Yes |
| 0212 | 11 | - | - | - | - | - |
| **Flexural Strength, psi** | **Target** | **Std. Dev.** | **Actual (average)** | | **Average Within 10%?** | |
| | 550 | 33 | **490** | | **No** | |
| | 900 | 87 | **730** | | **No** | |

## Data Availability

Table 27 is a summary of extent of monitoring data available for the sections at this site.

**Table 27 Summary of monitoring data availability**

| **SHRP ID** | **Monitoring data availability, No. of surveys** | | | |
|---|---|---|---|---|
| | **Distress** | | **IRI** | **FWD** |
| | **Manual** | **Faulting** | | |
| **0201** | 7 | 7 | 7 | 6 |
| **0202** | 2 | 2 | 2 | 2 |
| **0203** | 7 | 7 | 7 | 4 |
| **0204** | 8 | 8 | 7 | 17 |
| **0205** | 7 | 7 | 7 | 6 |
| **0206** | 2 | 2 | 2 | 2 |
| **0207** | 7 | 7 | 7 | 4 |
| **0208** | 7 | 7 | 7 | 4 |
| **0209** | 8 | 8 | 7 | 5 |
| **0210** | 8 | 8 | 7 | 6 |
| **0211** | 7 | 7 | 7 | 4 |
| **0212** | - | - | - | - |

## North Carolina (37)

### Site Description

The site is located in the southbound lanes of U. S. 52 near Lexington, N. C. It is a four lane divided highway. There is an interchange to US 64 on the site and 0204 is on the south of the interchange. The other inventory data are summarized in Table 28.

**Table 28 Summary of inventory data**

| | |
|---|---|
| Site code | 37 |
| Climatic zone | Wet No Freeze |
| Average annual precipitation | 1151 mm |
| Average annual freezing index | 47 $^{o}$C-days |
| Traffic open date | 1st of July 1994 |
| 'Proposed' traffic | 715 KESALs/year |
| Subgrade soil type | Fine grained |
| Inside shoulder type | PCC |
| Outside shoulder type | PCC |

### Construction Issues

No major construction issues have occurred at the site, according to the construction report. The main construction issues are as follows:

- Shrinkage cracks occurred at several locations in LCB before paving was done. Cracks were covered with tar paper before paving. Repairing was done to the PCC slabs that had cracks that reflected from LCB.
- The PATB layer was placed 5" thick instead of 4" thick in 0209 and 0210.
- All sections in the site were constructed with dowels with diameter of 38 mm. The stipulation requires dowels with diameter of 25 mm for sections with 203 mm-thick PCC slab and dowels with diameter of 38 mm for sections with 279 mm-thick PCC slab.
- Cement or lime stabilization was done to top 7 or 8 inches of the subgrade for sections 0204 and 0207.
- The DGAB and LCB extended only to two feet from the pavement edge and not to the shoulder edge as stipulated for SPS-2.
- Edge drains were located at a two-feet offset from the pavement edge instead of at 8-feet, which is an SPS-2 specification. Stone was used as trench backfill instead of PATB.
- Shoulders were made of Econocrete instead of asphalt concrete.
- In section, 0203, a contraction joint was located in LCB.
- No compaction was done around the TDR probes in section 0201. This may cause post construction settlement of the pavement.

## Site Status

A summary of the status of the design features at the site is Table 29. Sections 0201, 0202, 0207, 0209 and 0210 were constructed at least 0.5" thicker than their respective target thickness. The flexural strength data is available only for three sections. Sections with target 14-day flexural strength of 550-psi have average 14-day flexural strength higher than target by a margin of more than 10% (of target strength).

**Table 29 Summary of status of design features**

| SHRP ID | Slab Thickness, in. | | Base Type | Drainage | Lane Width, ft | As designed? |
|---|---|---|---|---|---|---|
| | Design | Actual | | | | |
| 0201 | 8 | **9** | DGAB | No | 12 | **No** |
| 0202 | 8 | **8.9** | DGAB | No | 14 | **No** |
| 0203 | 11 | 11.2 | DGAB | No | 14 | Yes |
| 0204 | 11 | 11.2 | DGAB | No | 12 | Yes |
| 0205 | 8 | 8 | LCB | No | 12 | Yes |
| 0206 | 8 | 8.4 | LCB | No | 14 | Yes |
| 0207 | 11 | **11.6** | LCB | No | 14 | **No** |
| 0208 | 11 | 11.2 | LCB | No | 12 | Yes |
| 0209 | 8 | **8.6** | PATB | Yes | 12 | **No** |
| 0210 | 8 | **9.1** | PATB | Yes | 14 | **No** |
| 0211 | 11 | 11.4 | PATB | Yes | 14 | Yes |
| 0212 | 11 | 10.9 | PATB | Yes | 12 | Yes |
| **Flexural Strength, psi** | **Target** | **Std. Dev.** | **Actual (average)** | | **Average Within 10%?** | |
| | 550 | 61 | **693** | | **No** | |
| | 900 | N/A | 850 | | Yes | |

## Data Availability

A summary of monitoring data availability is Table 30. The large extent of data available for the section 0201 could be because the section is a DLR and SMP section.

**Table 30 Summary of monitoring data availability**

| SHRP ID | Monitoring data availability, No. of surveys | | | |
|---|---|---|---|---|
| | Distress | | IRI | FWD |
| | Manual | Faulting | | |
| **0201** | 8 | 9 | 9 | 47 |
| **0202** | 5 | 6 | 9 | 4 |
| **0203** | 5 | 6 | 9 | 4 |
| **0204** | 5 | 5 | 9 | 4 |
| **0205** | 5 | 6 | 9 | 4 |
| **0206** | 5 | 6 | 9 | 4 |
| **0207** | 5 | 6 | 9 | 4 |
| **0208** | 5 | 5 | 8 | 4 |
| **0209** | 7 | 8 | 9 | 7 |
| **0210** | 5 | 6 | 9 | 4 |
| **0211** | 5 | 6 | 9 | 4 |
| **0212** | 5 | 5 | 9 | 4 |

## North Dakota (38)

### Site Description

The site is located in the eastbound lanes of I-94 in eastern North Dakota, west of Fargo. I-94 is a rural interstate. Table 31 is a summary of other inventory data. The project is reconstruction of an existing PCC pavement.

**Table 31 Summary of inventory data**

| | |
|---|---|
| Site code | 38 |
| Climatic zone | Wet Freeze |
| Average annual precipitation | 545 mm |
| Average annual freezing index | 1313 $^{o}$C-days |
| Traffic open date | 1st of November 1994 |
| 'Proposed' traffic | 420 KESALs/year |
| Subgrade soil type | Fine grained |
| Inside shoulder type | AC |
| Outside shoulder type | AC |

### Construction Issues

The site is located on a flat terrain, which is part of the old Lake Agassiz. The extremely wet clay soils delayed the construction during rains. The project opening was thus delayed by more than a month. The key observations from the construction report are as follows:

- The LCB was hard to place. For this the mix was changed to increase the strength of this layer.
- Shrinkage cracks in LCB reflected on the PCC layer in section 0217 and the cracks were sealed.
- The PATB was difficult to place, as it was very "fluid".

### Site Status

The status of the design features at the site is summarized in Table 32. No data for 14-day flexural strength of PCC is available in the LTPP database (Release 17). All the sections have been constructed with actual PCC thickness deviation (from target thickness) less than 0.5".

Rehabilitation repairing was done to all the sections of the site. AC shoulder restoration was done to all the sections in the year 1997. Partial-depth repairing was done to section 0217 in 1998 and in 1999. Partial-depth repairing was also done in 1999 in 0216.

**Table 32 Summary of status of design features**

| SHRP ID | Slab Thickness, in. | | Base Type | Drainage | Lane Width, ft | As designed? |
|---|---|---|---|---|---|---|
| | Design | Actual | | | | |
| 0213 | 8 | 8.2 | DGAB | No | 14 | Yes |
| 0214 | 8 | 7.9 | DGAB | No | 12 | Yes |
| 0215 | 11 | 11 | DGAB | No | 12 | Yes |
| 0216 | 11 | 11.2 | DGAB | No | 14 | Yes |
| 0217 | 8 | 7.9 | LCB | No | 14 | Yes |
| 0218 | 8 | 7.9 | LCB | No | 12 | Yes |
| 0219 | 11 | 10.9 | LCB | No | 12 | Yes |
| 0220 | 11 | 10.9 | LCB | No | 14 | Yes |
| 0221 | 8 | 8.1 | PATB | Yes | 14 | Yes |
| 0222 | 8 | 8.2 | PATB | Yes | 12 | Yes |
| 0223 | 11 | 11.1 | PATB | Yes | 12 | Yes |
| 0224 | 11 | 10.8 | PATB | Yes | 14 | Yes |
| **Flexural Strength, psi** | **Target** | **Std. Dev.** | **Actual (average)** | | **Average Within 10%?** | |
| | 550 | N/A | N/A | | - | |
| | 900 | N/A | N/A | | - | |

## Data Availability

Table 33 is the summary of the extent of monitoring data available for the sections in this site. Though the site is about 10 years old, the IRI and FWD data is available only for 5 tests each.

**Table 33 Summary of monitoring data availability**

| SHRP ID | Monitoring data availability, No. of surveys | | | |
|---|---|---|---|---|
| | Distress | | IRI | FWD |
| | Manual | Faulting | | |
| **0213** | 7 | 7 | 5 | 5 |
| **0214** | 6 | 6 | 5 | 5 |
| **0215** | 6 | 5 | 5 | 5 |
| **0216** | 6 | 5 | 5 | 5 |
| **0217** | 7 | 7 | 5 | 5 |
| **0218** | 6 | 6 | 5 | 5 |
| **0219** | 6 | 6 | 5 | 5 |
| **0220** | 6 | 6 | 5 | 5 |
| **0221** | 7 | 7 | 5 | 5 |
| **0222** | 6 | 6 | 5 | 5 |
| **0223** | 6 | 6 | 5 | 5 |
| **0224** | 6 | 6 | 5 | 5 |

## Ohio (39)

### Site Description

The Ohio site is located in the northbound lanes of U. S. 23 in Delaware County, central Ohio. The four-lane highway is a rural arterial.

**Table 34 Summary of inventory data**

| | |
|---|---|
| Site code | 39 |
| Climatic zone | Wet Freeze |
| Average annual precipitation | 972 mm |
| Average annual freezing index | 375 °C-days |
| Traffic open date | 1st of October 1996 |
| ‘Proposed’ traffic | 608 KESALs/year |
| Subgrade soil type | Fine grained |
| Inside shoulder type | AC* |
| Outside shoulder type | AC |

*Section 0211 has a PCC shoulder

### Construction Issues

According to the construction report, no major construction problems and/ or deviations have occurred at this site.

### Site Status

Table 35 is summary of the status of design features at the site. A substantial deviation

**Table 35 Summary of status of design features**

| **SHRP ID** | **Slab Thickness, in.** | | **Base Type** | **Drainage** | **Lane Width, ft** | **As designed?** |
|---|---|---|---|---|---|---|
| | **Design** | **Actual** | | | | |
| 0201 | 8 | 7.9 | DGAB | No | 12 | Yes |
| 0202 | 8 | 8.3 | DGAB | No | 14 | Yes |
| 0203 | 11 | 10.9 | DGAB | No | 14 | Yes |
| 0204 | 11 | 11.1 | DGAB | No | 12 | Yes |
| 0205 | 8 | 8 | LCB | No | 12 | Yes |
| 0206 | 8 | 7.9 | LCB | No | 14 | Yes |
| 0207 | 11 | 11.1 | LCB | No | 14 | Yes |
| 0208 | 11 | 11 | LCB | No | 12 | Yes |
| 0209 | 8 | 8.1 | PATB | Yes | 12 | Yes |
| 0210 | 8 | 8 | PATB | Yes | 14 | Yes |
| 0211 | 11 | 11.4 | PATB | Yes | 14 | Yes |
| 0212 | 11 | 10.6 | PATB | Yes | 12 | Yes |
| **Flexural Strength, psi** | **Target** | **Std. Dev.** | **Actual (average)** | | **Average Within 10%?** | |
| | 550 | 56 | **684** | | **No** | |
| | 900 | 153 | **614** | | **No** | |

from the target flexural strengths is to be noted. The average 14-day flexural strength of sections with 550-psi as target strength is much higher than the target and that of the sections with target strength as 900-psi is much lesser than 900-psi. Moreover, the average 14-day flexural strength PCC in sections with target strength of 550-psi is greater than that of PCC of sections with target strength of 900-psi.

## Data Availability

Table 36 is a summary of the extent of monitoring data available for the test sections at this site. Section 0204 is a SMP section. This could be the reason for higher extent of data available for the section.

**Table 36 Summary of monitoring data availability**

| SHRP ID | Monitoring data availability, No. of surveys | | | |
|---|---|---|---|---|
| | Distress | | IRI | FWD |
| | Manual | Faulting | | |
| **0201** | 5 | 5 | 8 | 8 |
| **0202** | 5 | 5 | 8 | 7 |
| **0203** | 5 | 5 | 8 | 8 |
| **0204** | 6 | 6 | 8 | 21 |
| **0205** | 5 | 5 | 8 | 9 |
| **0206** | 4 | 4 | 8 | 7 |
| **0207** | 4 | 4 | 8 | 8 |
| **0208** | 4 | 4 | 8 | 8 |
| **0209** | 5 | 5 | 8 | 8 |
| **0210** | 5 | 5 | 8 | 7 |
| **0211** | 5 | 5 | 8 | 8 |
| **0212** | 5 | 5 | 8 | 6 |

## Ohio (39)

### Site Description

The Ohio site is located in the northbound lanes of U. S. 23 in Delaware County, central Ohio. The four-lane highway is a rural arterial.

**Table 37 Summary of inventory data**

| | |
|---|---|
| Site code | 39 |
| Climatic zone | Wet Freeze |
| Average annual precipitation | 972 mm |
| Average annual freezing index | 375 °C-days |
| Traffic open date | 1st of October 1996 |
| 'Proposed' traffic | 608 KESALs/year |
| Subgrade soil type | Fine grained |
| Inside shoulder type | AC* |
| Outside shoulder type | AC |

*Section 0211 has a PCC shoulder

### Construction Issues

According to the construction report, no major construction problems and/ or deviations have occurred at this site.

### Site Status

Table 35 is summary of the status of design features at the site. A substantial deviation

**Table 38 Summary of status of design features**

| SHRP ID | Slab Thickness, in. | | Base Type | Drainage | Lane Width, ft | As designed? |
|---|---|---|---|---|---|---|
| | Design | Actual | | | | |
| 0201 | 8 | 7.9 | DGAB | No | 12 | Yes |
| 0202 | 8 | 8.3 | DGAB | No | 14 | Yes |
| 0203 | 11 | 10.9 | DGAB | No | 14 | Yes |
| 0204 | 11 | 11.1 | DGAB | No | 12 | Yes |
| 0205 | 8 | 8 | LCB | No | 12 | Yes |
| 0206 | 8 | 7.9 | LCB | No | 14 | Yes |
| 0207 | 11 | 11.1 | LCB | No | 14 | Yes |
| 0208 | 11 | 11 | LCB | No | 12 | Yes |
| 0209 | 8 | 8.1 | PATB | Yes | 12 | Yes |
| 0210 | 8 | 8 | PATB | Yes | 14 | Yes |
| 0211 | 11 | 11.4 | PATB | Yes | 14 | Yes |
| 0212 | 11 | 10.6 | PATB | Yes | 12 | Yes |
| **Flexural Strength, psi** | **Target** | **Std. Dev.** | **Actual (average)** | | **Average Within 10%?** | |
| | 550 | 56 | **684** | | **No** | |
| | 900 | 153 | **614** | | **No** | |

from the target flexural strengths is to be noted. The average 14-day flexural strength of sections with 550-psi as target strength is much higher than the target and that of the sections with target strength as 900-psi is much lesser than 900-psi. Moreover, the average 14-day flexural strength PCC in sections with target strength of 550-psi is greater than that of PCC of sections with target strength of 900-psi.

### Data Availability

Table 36 is a summary of the extent of monitoring data available for the test sections at this site. Section 0204 is a SMP section. This could be the reason for higher extent of data available for the section.

**Table 39 Summary of monitoring data availability**

| SHRP ID | Monitoring data availability, No. of surveys | | | |
|---|---|---|---|---|
| | Distress | | IRI | FWD |
| | Manual | Faulting | | |
| **0201** | 5 | 5 | 8 | 8 |
| **0202** | 5 | 5 | 8 | 7 |
| **0203** | 5 | 5 | 8 | 8 |
| **0204** | 6 | 6 | 8 | 21 |
| **0205** | 5 | 5 | 8 | 9 |
| **0206** | 4 | 4 | 8 | 7 |
| **0207** | 4 | 4 | 8 | 8 |
| **0208** | 4 | 4 | 8 | 8 |
| **0209** | 5 | 5 | 8 | 8 |
| **0210** | 5 | 5 | 8 | 7 |
| **0211** | 5 | 5 | 8 | 8 |
| **0212** | 5 | 5 | 8 | 6 |

## Washington (53)

### Site Description

The site is located in the northbound lanes of SR 395 in eastern Washington. The route is an urban principal arterial.

**Table 40 Summary of other inventory data**

| | |
|---|---|
| Site code | 53 |
| Climatic zone | Dry Freeze |
| Average annual precipitation | 308 mm |
| Average annual freezing index | 265 °C-days |
| Traffic open date | 1st of November 1995 |
| 'Proposed' traffic | 462 KESALs/year |
| Subgrade soil type | Fine grained |
| Inside shoulder type | AC |
| Outside shoulder type | AC |

### Construction Issues

The major observations from the construction report are as follows:

- Average moisture content of the subgrade soil was 5.8% below optimum.
- Construction traffic provided compaction effort.
- The section 0203 that was built on cut has most variation in deflections, as observed from the FWD testing.
- Section 0207 had a high compressive strength of LCB compared to other sections, which could be due to the low water-cement ratio.
- In sections 0209 and 0212, the embankment soil was accidentally placed on shoulder and because of this the PATB voids could have been clogged. Also during paving, the PCC slurry that spilled over the PATB in shoulder, though scrapped off later, could have clogged the PATB voids.
- Patching was done to the fabric of edge drains in 0209 and 0212.
- Surface voids appeared immediately due to the mix being unconsolidated.
- Following paving, shrinkage cracks appeared throughout the section 0206.

### Site Status

The status of the design features has been summarized in Table 41. Five of the twelve sections have deviation of at least 0.5" from the respective target PCC thickness. All the five sections have been built at least 0.5" thicker than the respective target thickness. Also, the average 14-day flexural strength of the sections with target 14-day flexural strength of 550-psi is below the 10% (of target strength) error range.

**Table 41 Summary of status of design factors**

| SHRP ID | Slab Thickness, in. |  | Base Type | Drainage | Lane Width, ft | As designed? |
|---|---|---|---|---|---|---|
|  | Design | Actual |  |  |  |  |
| 0213 | 8 | **8.7** | DGAB | No | 14 | **No** |
| 0214 | 8 | 8.3 | DGAB | No | 12 | Yes |
| 0215 | 11 | 11.1 | DGAB | No | 12 | Yes |
| 0216 | 11 | 11.2 | DGAB | No | 14 | Yes |
| 0217 | 8 | **8.5** | LCB | No | 14 | **No** |
| 0218 | 8 | **8.6** | LCB | No | 12 | **No** |
| 0219 | 11 | 11.1 | LCB | No | 12 | Yes |
| 0220 | 11 | 11.2 | LCB | No | 14 | Yes |
| 0221 | 8 | **9** | PATB | Yes | 14 | **No** |
| 0222 | 8 | 8.3 | PATB | Yes | 12 | Yes |
| 0223 | 11 | **11.8** | PATB | Yes | 12 | **No** |
| 0224 | 11 | 11.3 | PATB | Yes | 14 | Yes |
| **Flexural Strength, psi** | **Target** | **Std. Dev.** | **Actual (average)** |  | **Average Within 10%?** |  |
|  | 550 | 55 | **485** |  | **No** |  |
|  | 900 | 35 | 831 |  | Yes |  |

## Data Availability

Table 42 is the summary of monitoring data availability.

**Table 42 Summary of monitoring data availability**

| SHRP ID | Monitoring data availability, No. of surveys |  |  |  |
|---|---|---|---|---|
|  | Distress |  | IRI | FWD |
|  | Manual | Faulting |  |  |
| **0213** | 8 | 8 | 8 | 6 |
| **0214** | 8 | 8 | 8 | 6 |
| **0215** | 8 | 8 | 8 | 5 |
| **0216** | 8 | 8 | 8 | 6 |
| **0217** | 8 | 8 | 8 | 6 |
| **0218** | 8 | 8 | 8 | 6 |
| **0219** | 8 | 8 | 8 | 6 |
| **0220** | 8 | 8 | 8 | 6 |
| **0221** | 8 | 8 | 8 | 6 |
| **0222** | 8 | 8 | 8 | 6 |
| **0223** | 8 | 8 | 8 | 6 |
| **0224** | 8 | 8 | 8 | 6 |

## Wisconsin (55)

### Site Description

The site is located on the westbound and eastbound STH-29, a rural arterial road, in Marathon County, Wisconsin. The other inventory data are summarized in Table 43.

**Table 43 Summary of inventory data**

| | |
|---|---|
| Site code | 55 |
| Climatic zone | Wet Freeze |
| Average annual precipitation | 815 mm |
| Average annual freezing index | 998 $^{o}$C-days |
| Traffic open date | 1$^{st}$ of November 1997 |
| 'Proposed' traffic | 151 KESALs/year |
| Subgrade soil type | Coarse grained |
| Inside shoulder type | No data |
| Outside shoulder type | No data |

### Construction Issues

No major construction issues exist for the site. The main issues are as follows:

- Undisturbed soil samples could not be obtained for testing, as the project was a replacement of a PCC pavement. The PCC slab was removed and fill was placed.
- A stiff or rigid layer exists below 20 feet.

### Site Status

Table 44 is the summary of the status of the design features of the sections at the site. Section 0222 was constructed 0.5" thicker than the target thickness of 8". The average 14-day flexural strength of the sections with target 14-day strength of 550-psi is higher by 10% of the target strength.

**Table 44 Summary of status of the design features**

| SHRP ID | Slab Thickness, in. | | Base Type | Drainage | Lane Width, ft | As designed? |
|---|---|---|---|---|---|---|
| | Design | Actual | | | | |
| 0213 | 8 | 8.5 | DGAB | No | 14 | Yes |
| 0214 | 8 | 8.4 | DGAB | No | 12 | Yes |
| 0215 | 11 | 11.3 | DGAB | No | 12 | Yes |
| 0216 | 11 | 11.1 | DGAB | No | 14 | Yes |
| 0217 | 8 | 8.2 | LCB | No | 14 | Yes |
| 0218 | 8 | 8.4 | LCB | No | 12 | Yes |
| 0219 | 11 | 11.3 | LCB | No | 12 | Yes |
| 0220 | 11 | 11.2 | LCB | No | 14 | Yes |
| 0221 | 8 | 8.3 | PATB | Yes | 14 | Yes |
| 0222 | 8 | **8.5** | PATB | Yes | 12 | **No** |
| 0223 | 11 | 11.3 | PATB | Yes | 12 | Yes |
| 0224 | 11 | 11.4 | PATB | Yes | 14 | Yes |
| **Flexural Strength, psi** | **Target** | **Std. Dev.** | **Actual (average)** | | **Average Within 10%?** | |
| | 550 | 28 | **633** | | **No** | |
| | 900 | 53 | 884 | | Yes | |

## Data Availability

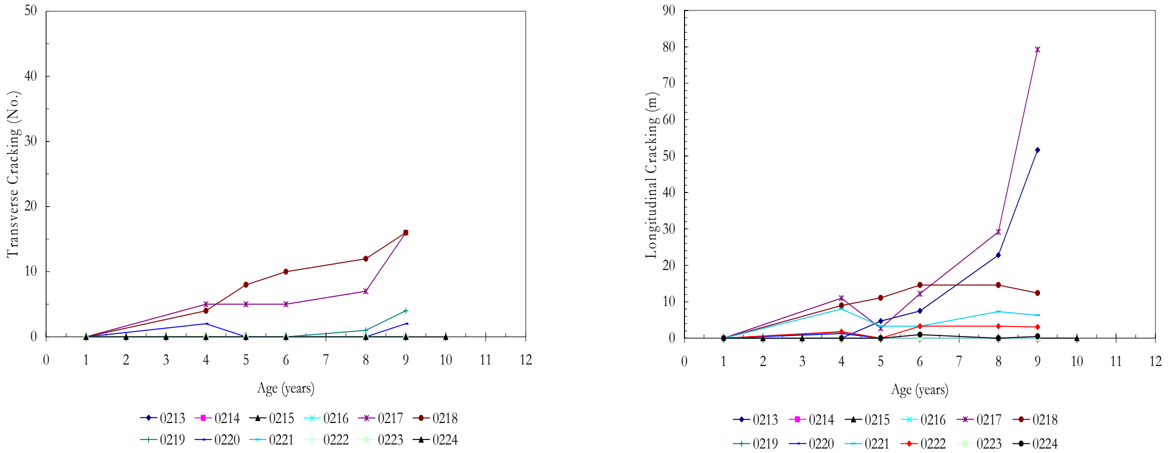
Table 45 is a summary of the monitoring data available for the sections at the site. Though the site is about seven years old, the distress data and FWD data are available for only three tests.

**Table 45 Summary of monitoring data availability**

| SHRP ID | Monitoring data availability, No. of surveys | | | |
|---|---|---|---|---|
| | Distress | | IRI | FWD |
| | Manual | Faulting | | |
| **0213** | 3 | 3 | 7 | 3 |
| **0214** | 3 | 3 | 6 | 3 |
| **0215** | 3 | 3 | 7 | 3 |
| **0216** | 3 | 3 | 7 | 3 |
| **0217** | 3 | 3 | 7 | 3 |
| **0218** | 3 | 3 | 7 | 3 |
| **0219** | 3 | 3 | 7 | 3 |
| **0220** | 3 | 3 | 7 | 3 |
| **0221** | 3 | 3 | 7 | 3 |
| **0222** | 3 | 3 | 7 | 3 |
| **0223** | 3 | 3 | 7 | 3 |
| **0224** | 3 | 3 | 7 | 3 |

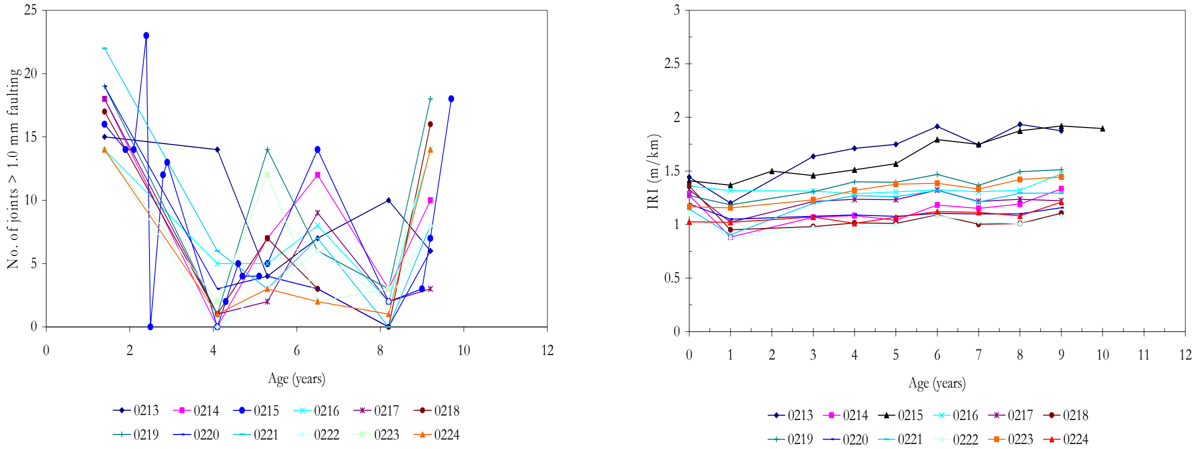
# APPENDIX B2

## Site-wide Performance Data for SPS-2 experiment (Time series plots and tables)



(a) Transverse cracking

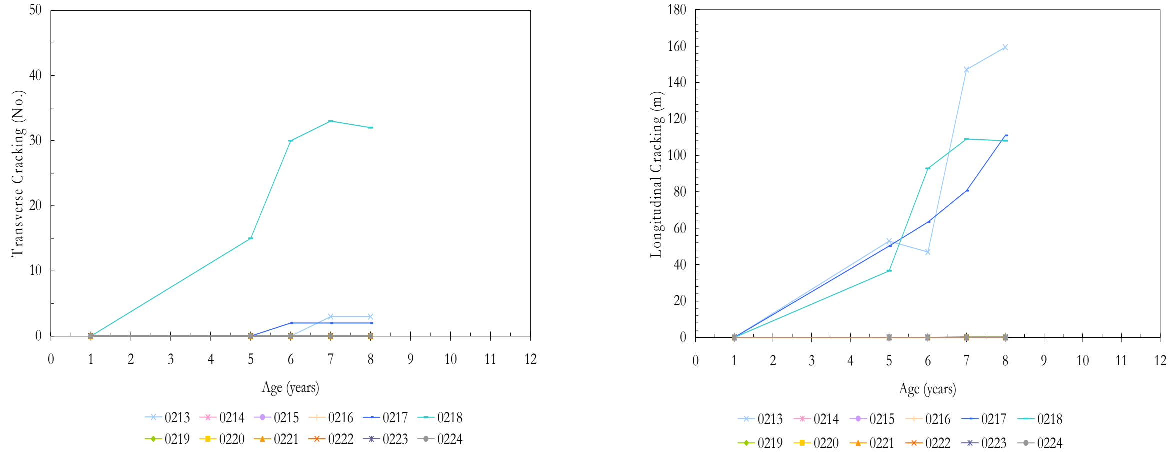
(b) Longitudinal cracking



(c) Wheelpath joint faulting

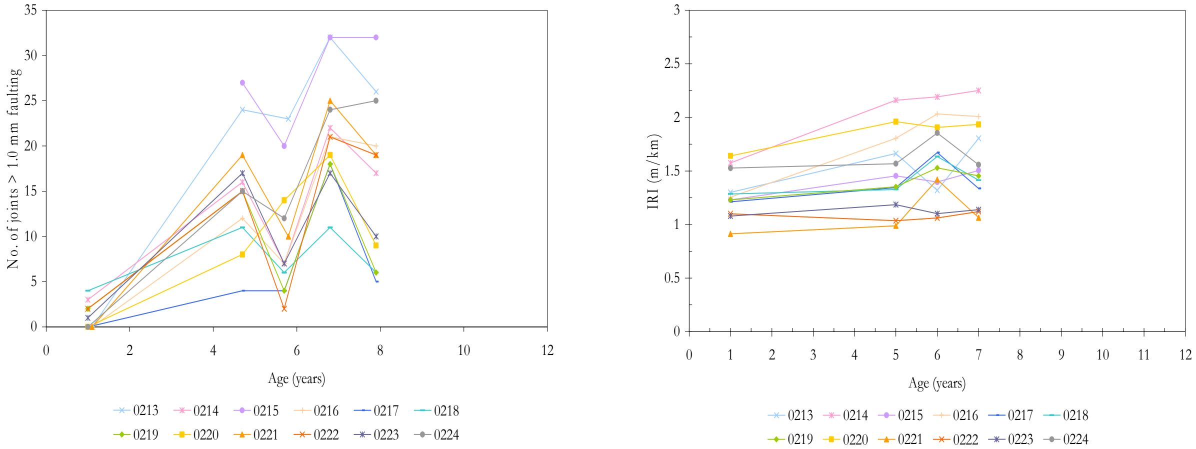
(d) Roughness (IRI)

**Figure B2- 1 Time series trend for various performance measures at the Arizona (4) site**



(a) Transverse cracking

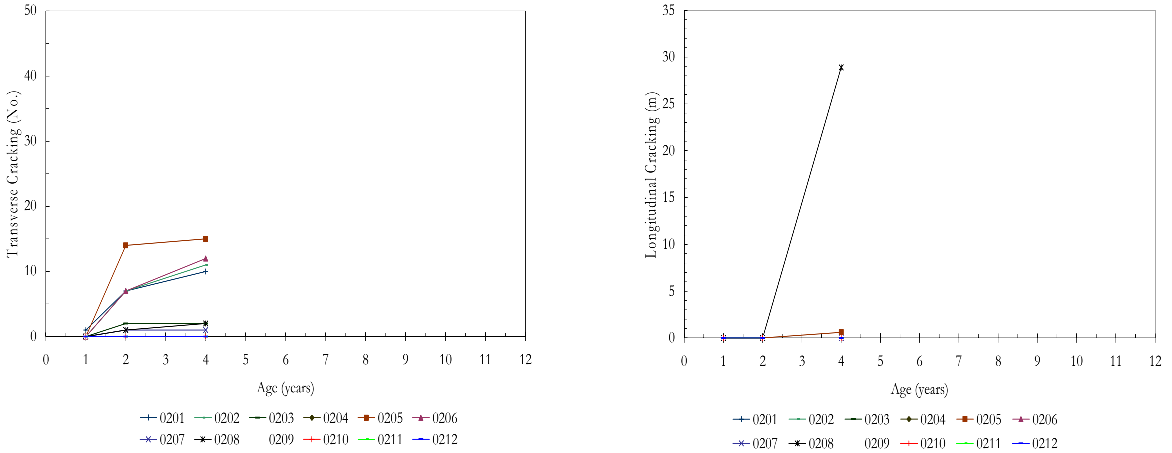
(b) Longitudinal cracking



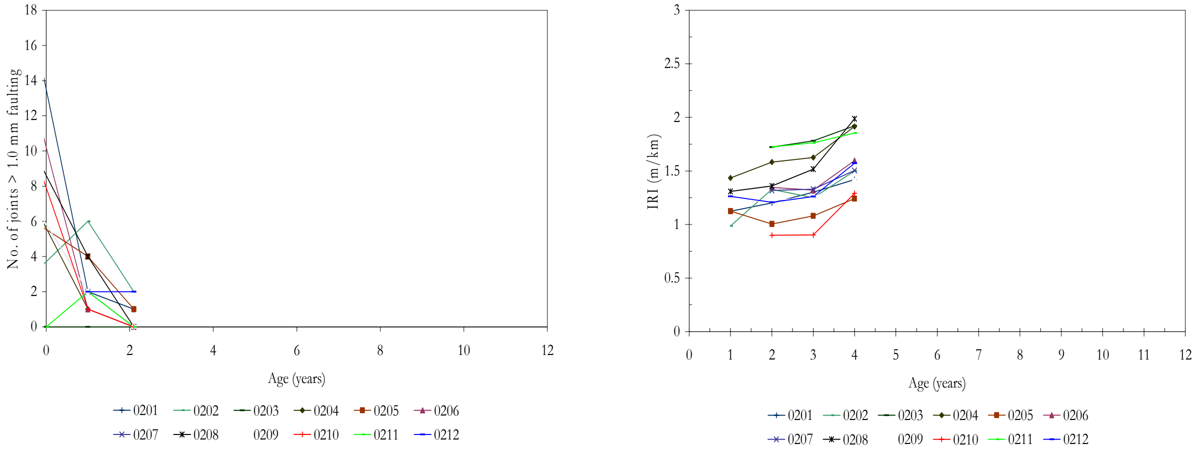
(c) Wheelpath joint faulting

(d) Roughness (IRI)

**Figure B2- 2 Time series trend for various performance measures at the Arkansas (5) site**

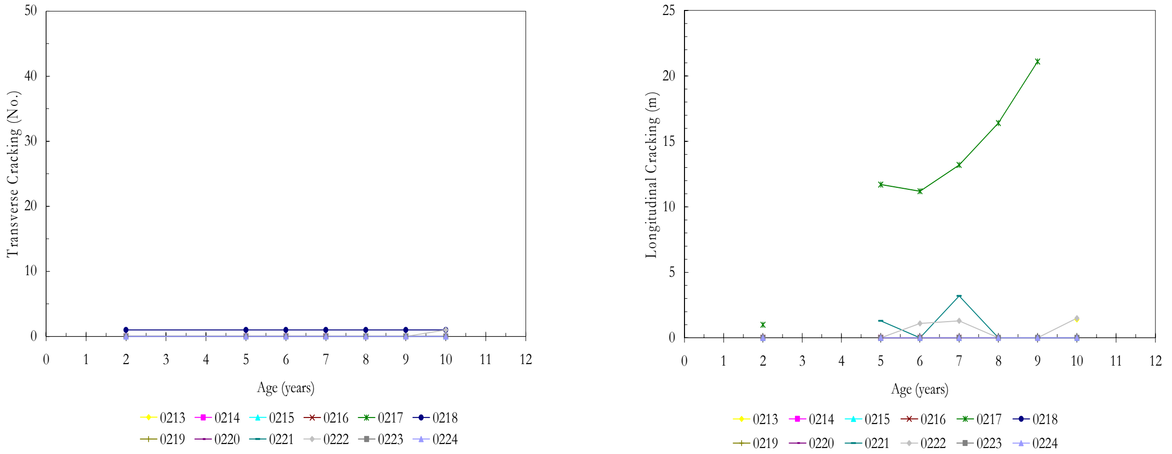


(a) Transverse cracking (b) Longitudinal cracking

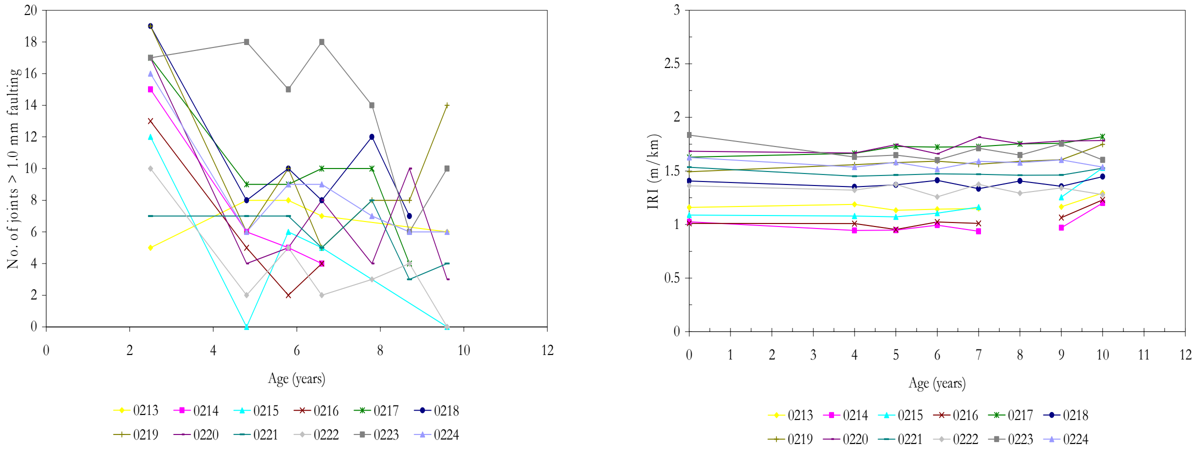


(c) Wheelpath joint faulting (d) Roughness (IRI)

**Figure B2- 3 Time series trend for various performance measures at the California (6) site**

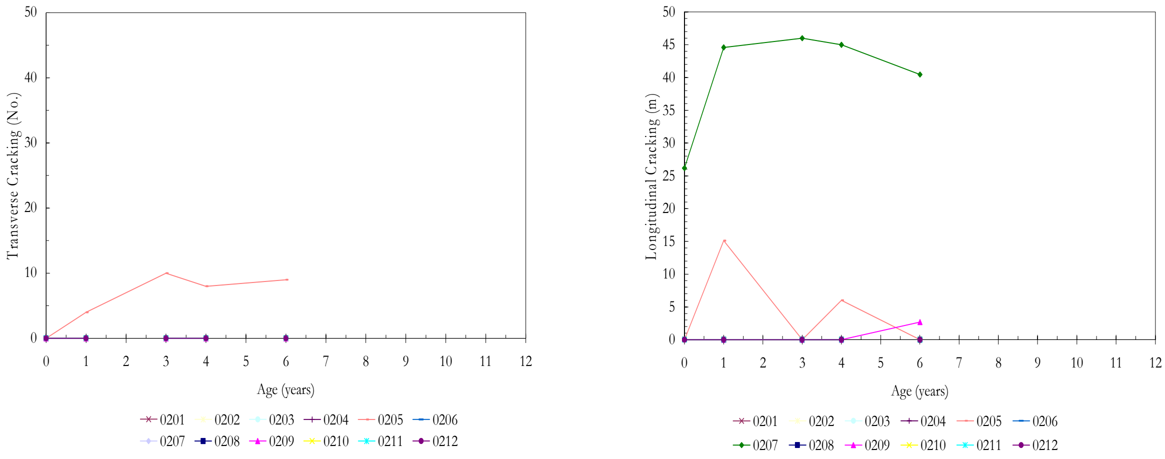


(a) Transverse cracking (b) Longitudinal cracking



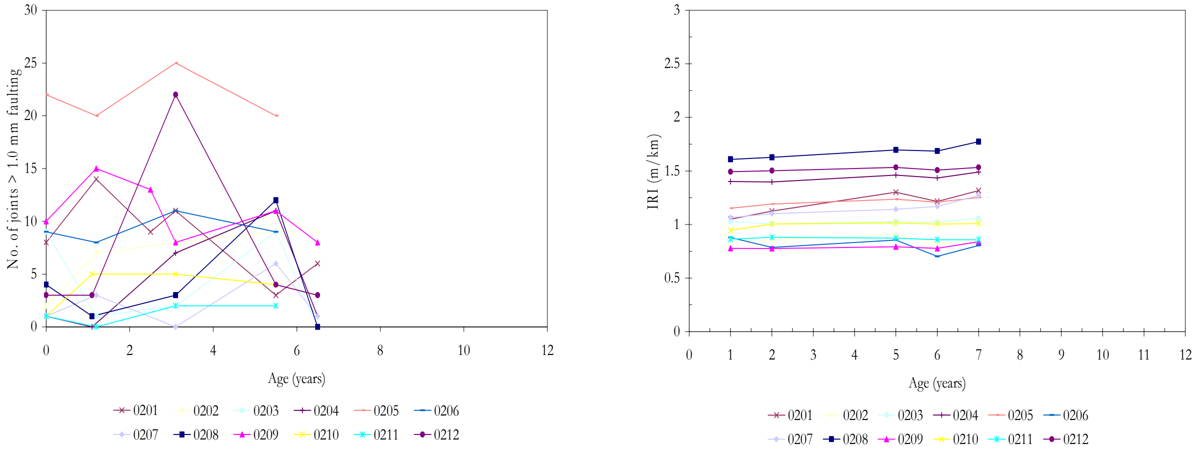
(c) Wheelpath joint faulting (d) Roughness (IRI)

**Figure B2- 4 Time series trend for various performance measures at the Colorado (8) site**



(a) Transverse cracking

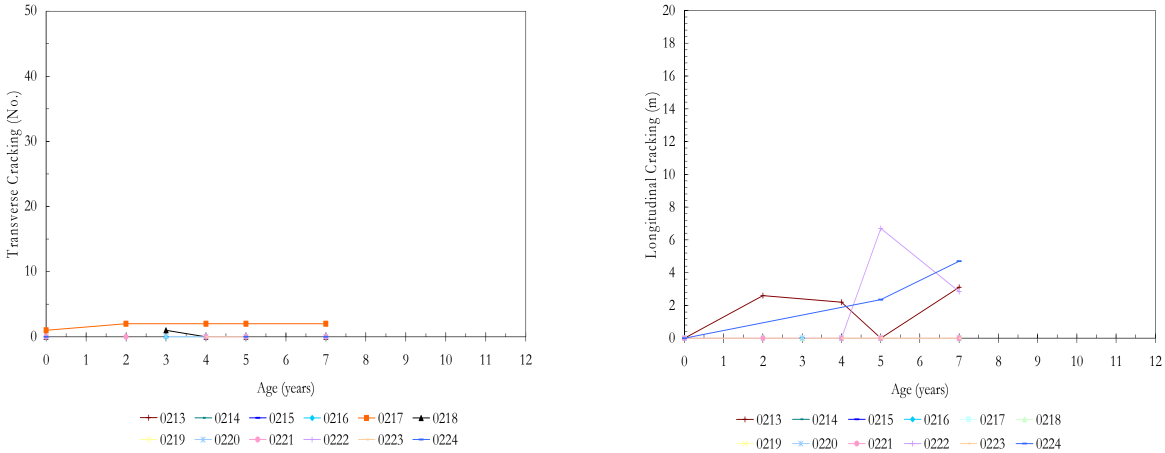
(b) Longitudinal cracking



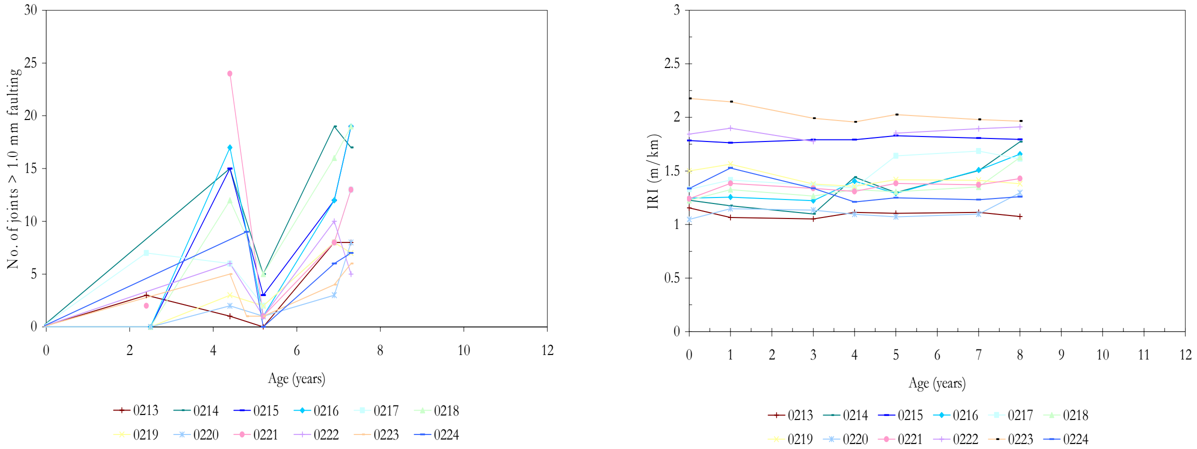
(c) Wheelpath joint faulting

(d) Roughness (IRI)

**Figure B2- 5 Time series trend for various performance measures at the Delaware (10) site**

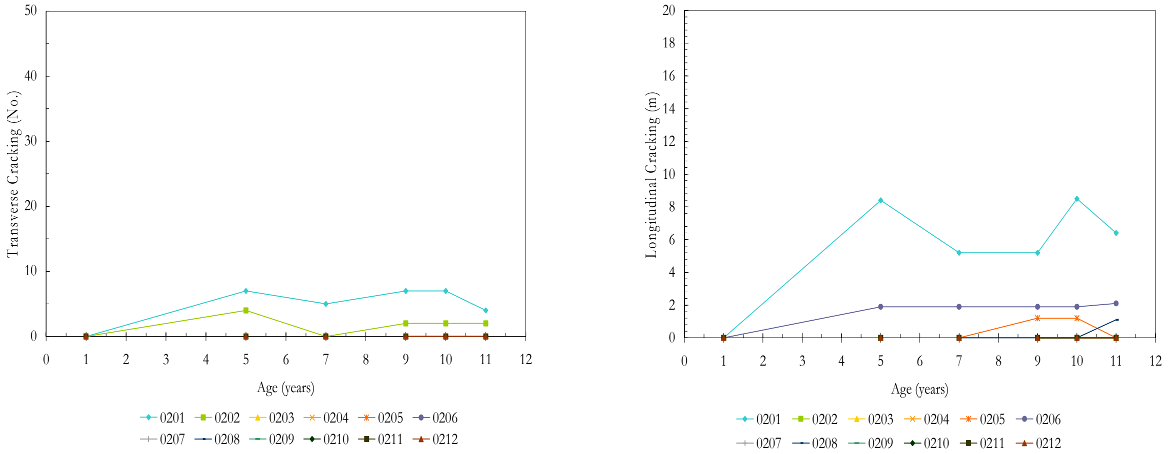


(a) Transverse cracking (b) Longitudinal cracking



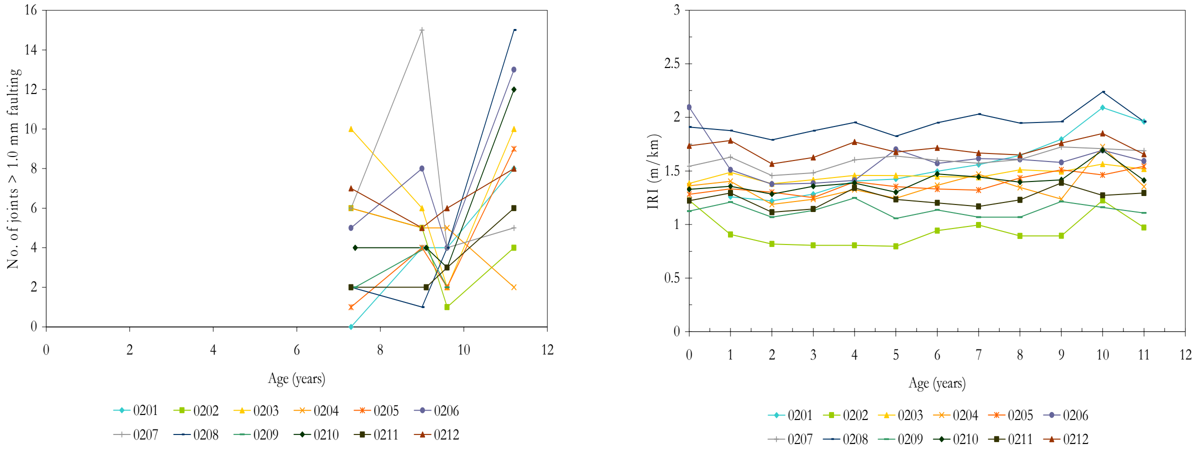
(c) Wheelpath joint faulting (d) Roughness (IRI)

**Figure B2- 6 Time series trend for various performance measures at the Iowa (19) site**



(a) Transverse cracking

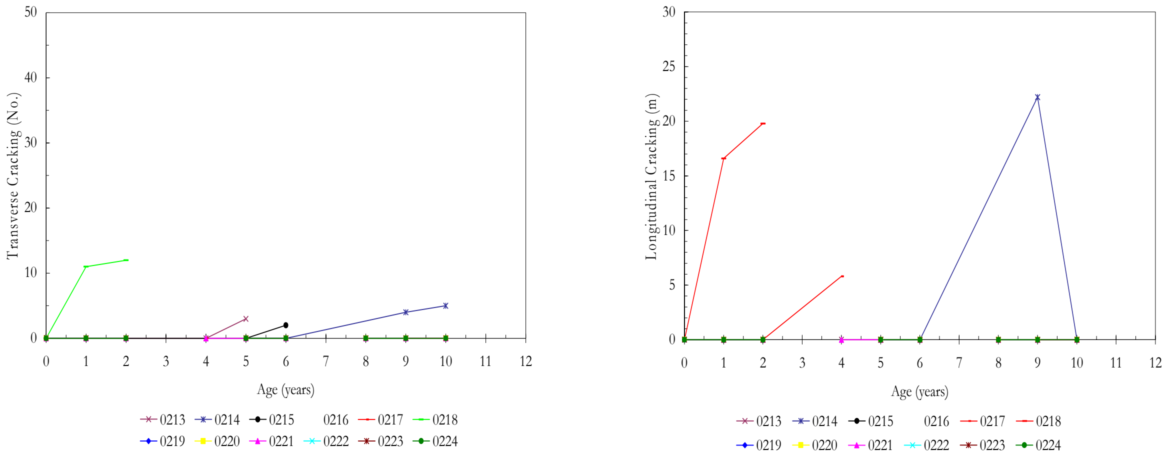
(b) Longitudinal cracking



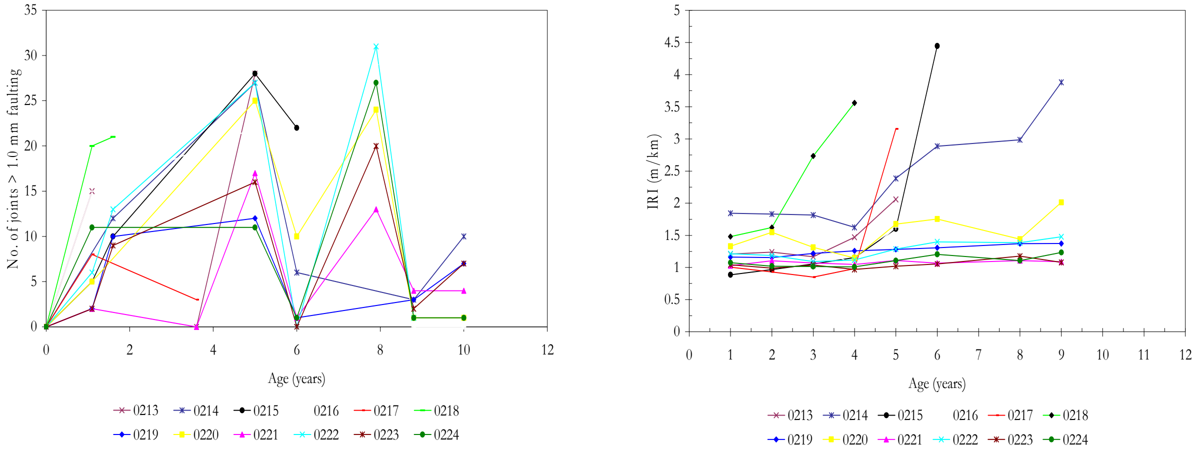
(c) Wheelpath joint faulting

(d) Roughness (IRI)

**Figure B2- 7 Time series trend for various performance measures at the Kansas (20) site**

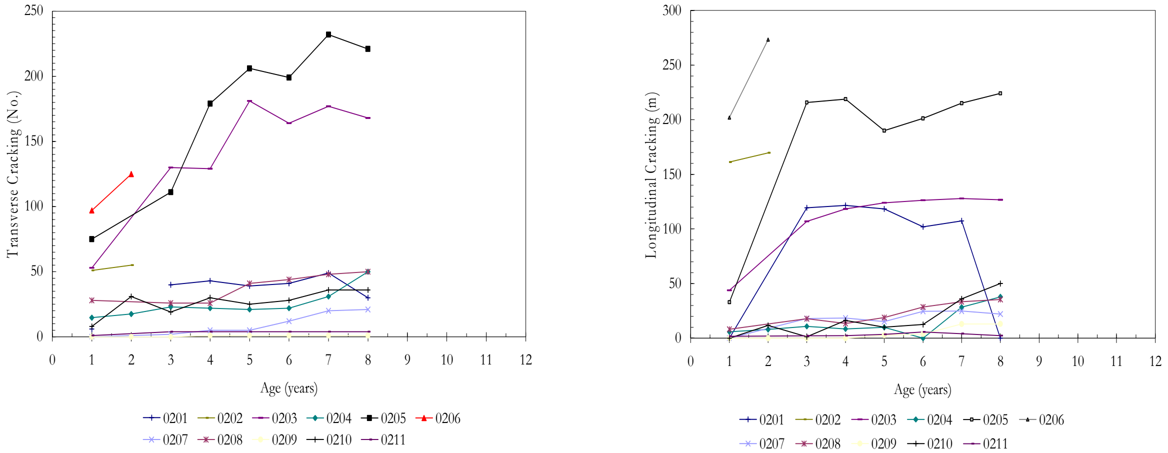


(a) Transverse cracking (b) Longitudinal cracking



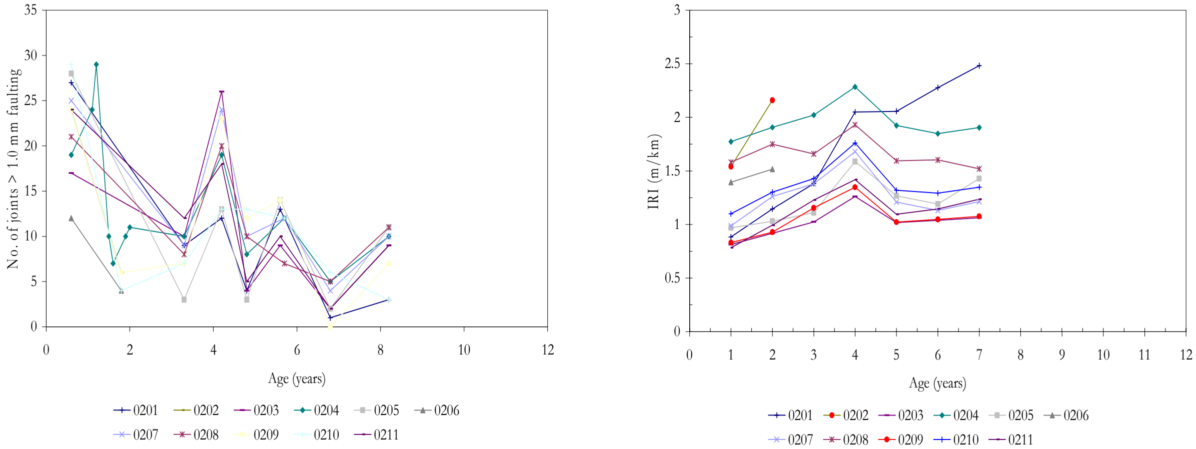
(c) Wheelpath joint faulting (d) Roughness (IRI)

**Figure B2- 8 Time series trend for various performance measures at the Michigan (26) site**



(a) Transverse cracking

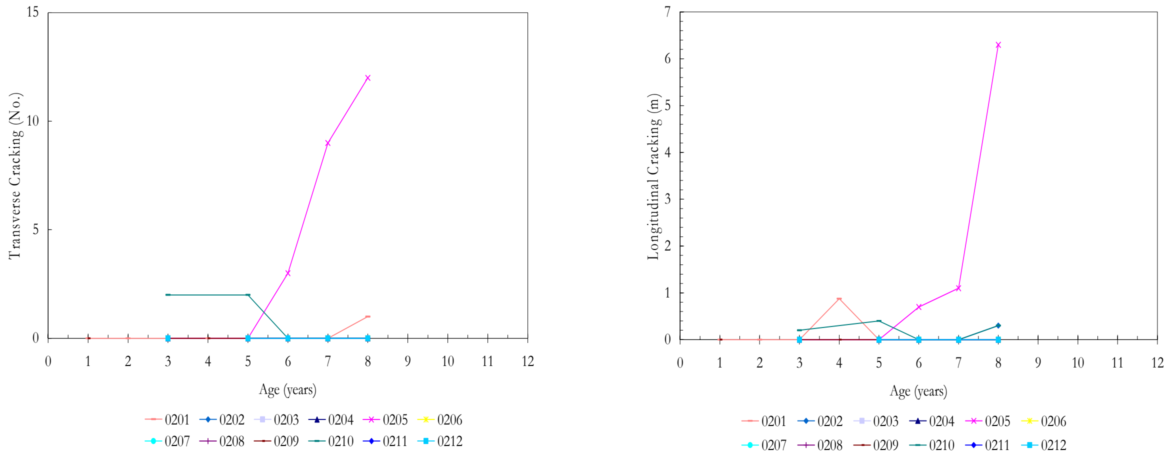
(b) Longitudinal cracking



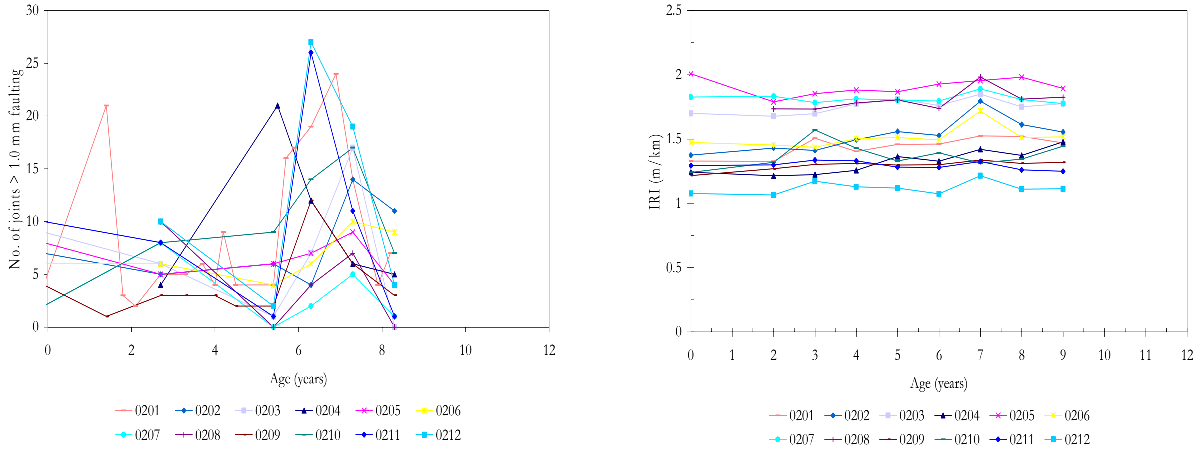
(c) Wheelpath joint faulting

(d) Roughness (IRI)

**Figure B2- 9 Time series trend for various performance measures at the Nevada (32) site**

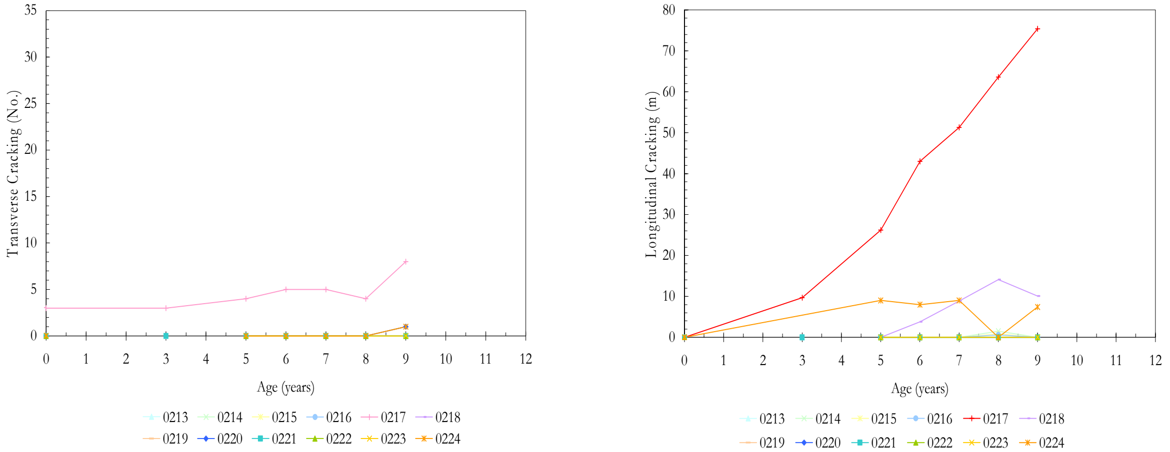


(a) Transverse cracking (b) Longitudinal cracking



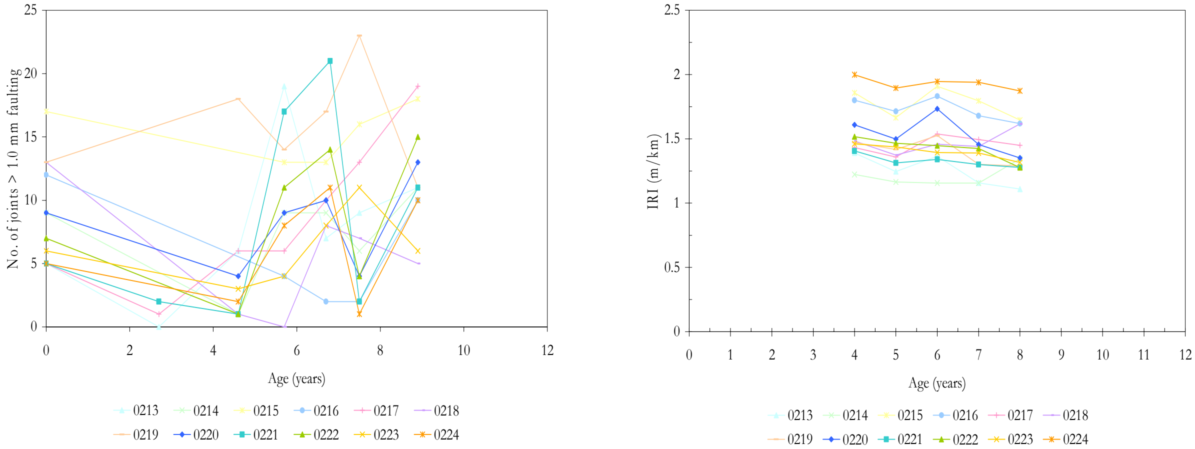
(c) Wheelpath joint faulting (d) Roughness (IRI)

**Figure B2- 10 Time series trend for various performance measures at the North Carolina (37) site**



(a) Transverse cracking

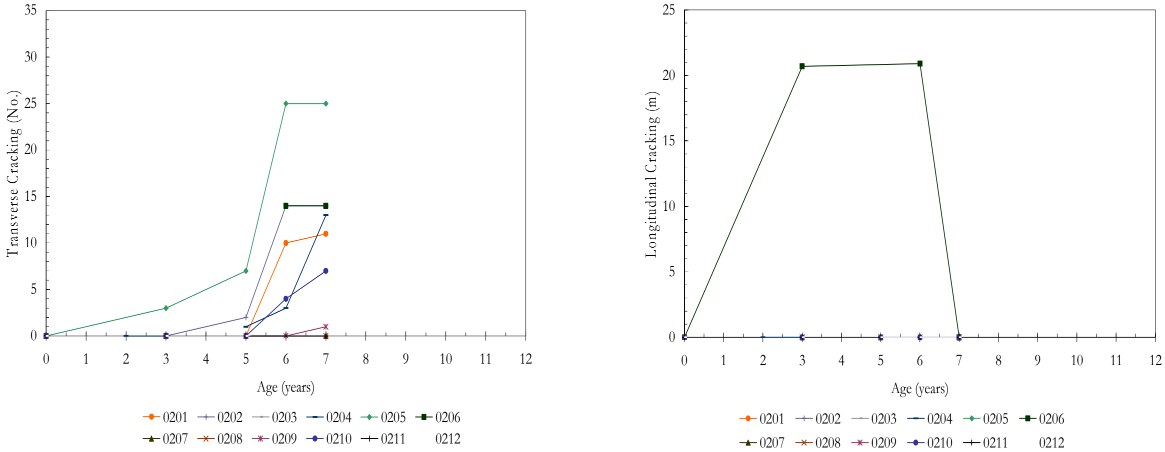
(b) Longitudinal cracking



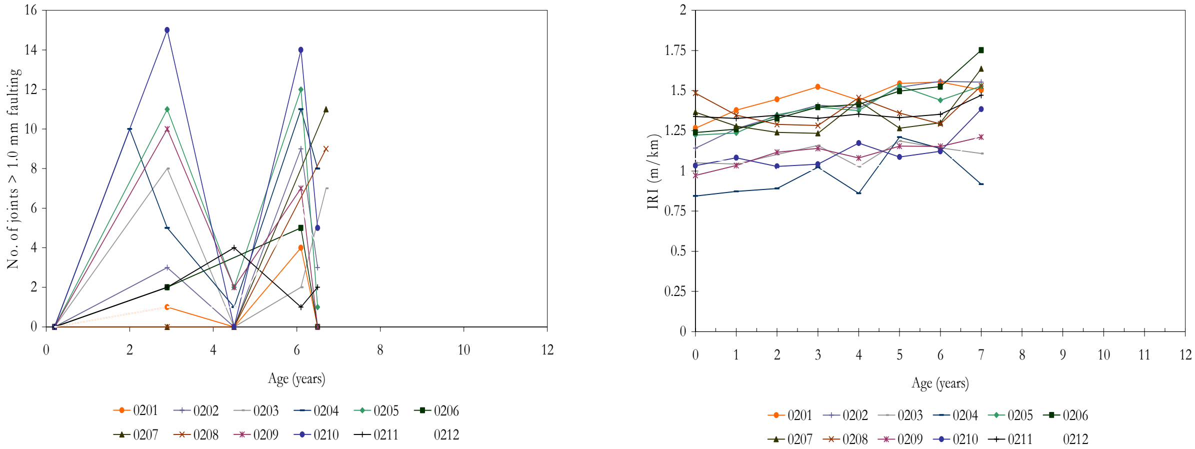
(c) Wheelpath joint faulting

(d) Roughness (IRI)

**Figure B2- 11 Time series trend for various performance measures at the North Dakota (38) site**

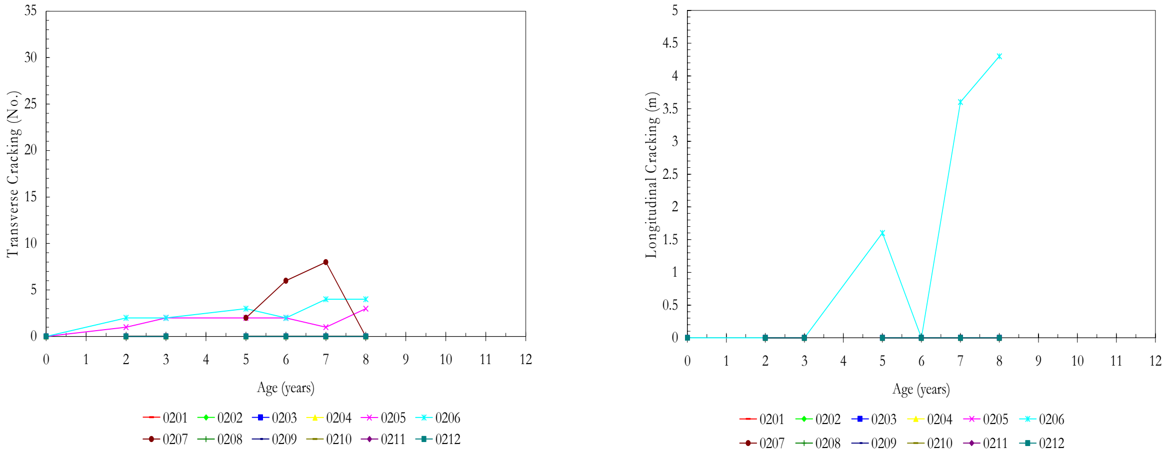


(a) Transverse cracking (b) Longitudinal cracking

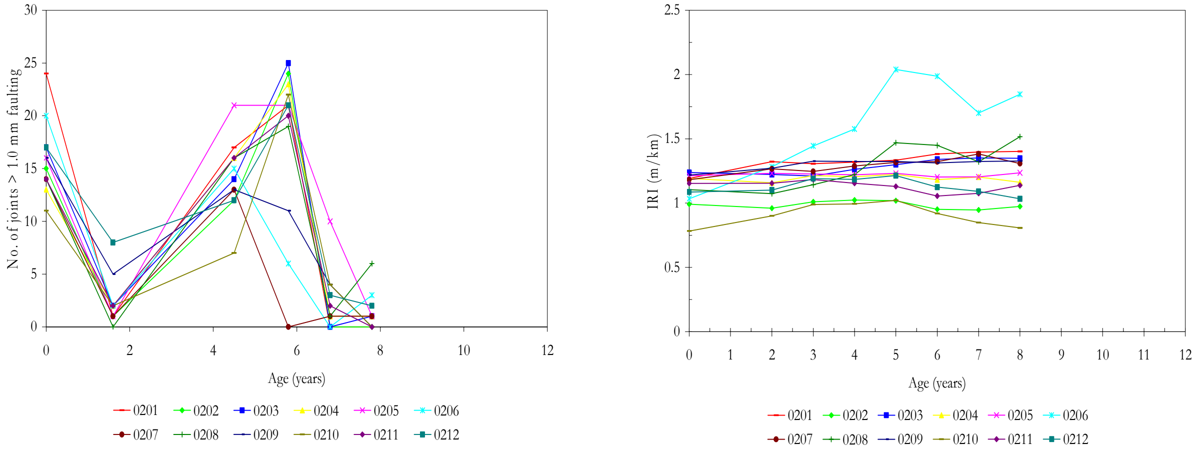


(c) Wheelpath joint faulting (d) Roughness (IRI)

**Figure B2- 12 Time series trend for various performance measures at the Ohio (39) site**

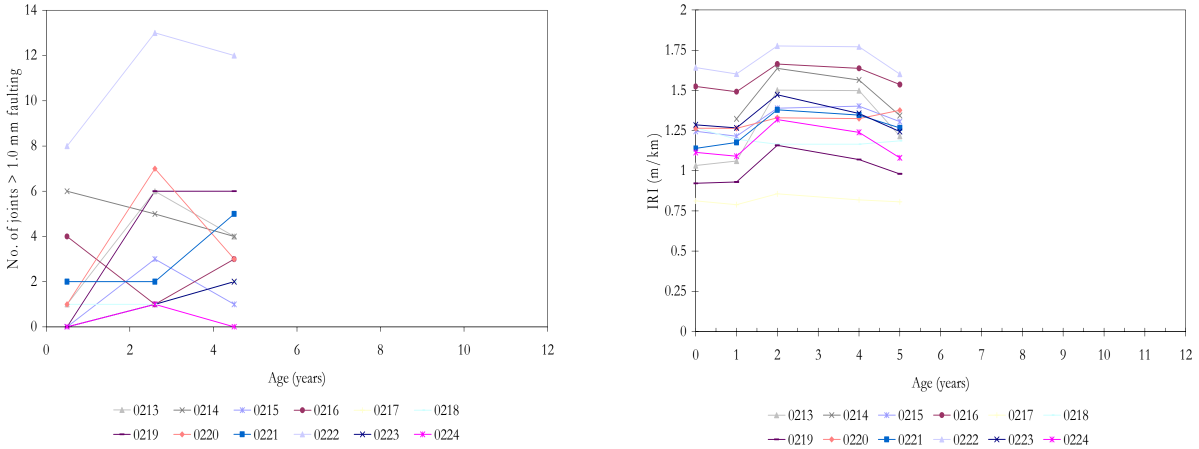


(a) Transverse cracking (b) Longitudinal cracking



(c) Wheelpath joint faulting (d) Roughness (IRI)

**Figure B2- 13 Time series trend for various performance measures at the Washington (53) site**



(c) Wheelpath joint faulting

(d) Roughness (IRI)

Figure B2- 14 Time series trend for various performance measures at the Wisconsin (55) site

Table B2- 1 Roughness Performance for AZ (4)

| State 4 IRI (m/km) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Section ID | Age at time of data collection (years) | | | | | | | | | | |
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 0213 | 1.44 | 1.20 | | 1.64 | 1.71 | 1.75 | 1.92 | 1.74 | 1.93 | 1.87 | |
| 0214 | 1.27 | 0.88 | | 1.07 | 1.08 | 1.04 | 1.18 | 1.15 | 1.19 | 1.33 | |
| 0215 | 1.41 | 1.37 | 1.50 | 1.46 | 1.51 | 1.57 | 1.79 | 1.75 | 1.87 | 1.92 | 1.90 |
| 0216 | 1.36 | 1.32 | | 1.31 | 1.29 | 1.31 | 1.32 | 1.31 | 1.32 | 1.47 | |
| 0217 | 1.33 | 1.02 | | 1.22 | 1.24 | 1.23 | 1.32 | 1.22 | 1.24 | 1.22 | |
| 0218 | 1.36 | 0.95 | | 0.98 | 1.01 | 1.01 | 1.09 | 1.00 | 1.01 | 1.11 | |
| 0219 | 1.27 | 1.18 | | 1.31 | 1.40 | 1.39 | 1.47 | 1.37 | 1.49 | 1.51 | |
| 0220 | 1.19 | 1.05 | | 1.08 | 1.09 | 1.08 | 1.11 | 1.10 | 1.10 | 1.16 | |
| 0221 | 1.15 | 0.90 | | 1.20 | 1.27 | 1.26 | 1.32 | 1.21 | 1.29 | 1.29 | |
| 0222 | 1.10 | 0.88 | | 0.97 | 0.97 | 1.00 | 1.08 | 1.03 | 1.01 | 1.07 | |
| 0223 | 1.17 | 1.16 | | 1.23 | 1.32 | 1.38 | 1.39 | 1.33 | 1.42 | 1.44 | |
| 0224 | 1.03 | 1.02 | | 1.07 | 1.01 | 1.07 | 1.12 | 1.11 | 1.08 | 1.21 | |

Table B2- 2 Roughness Performance for AR (5)

| State 5 IRI (m/km) | | | | |
|---|---|---|---|---|
| Section ID | Age (years) | | | |
| | 1 | 5 | 6 | 7 |
| 0213 | 1.30 | 1.66 | 1.32 | 1.81 |
| 0214 | 1.58 | 2.16 | 2.19 | 2.25 |
| 0215 | 1.23 | 1.45 | 1.40 | 1.50 |
| 0216 | 1.26 | 1.81 | 2.03 | 2.01 |
| 0217 | 1.21 | 1.35 | 1.67 | 1.34 |
| 0218 | 1.29 | 1.33 | 1.63 | 1.41 |
| 0219 | 1.23 | 1.35 | 1.53 | 1.45 |
| 0220 | 1.64 | 1.96 | 1.91 | 1.94 |
| 0221 | 0.91 | 0.99 | 1.42 | 1.06 |
| 0222 | 1.10 | 1.04 | 1.06 | 1.12 |
| 0223 | 1.08 | 1.19 | 1.10 | 1.14 |
| 0224 | 1.53 | 1.57 | 1.86 | 1.56 |

Table B2- 3 Roughness Performance for CA (6)

| State 6 IRI (m/km) | | | | |
|---|---|---|---|---|
| Section ID | Age (years) | | | |
| | 1 | 2 | 3 | 4 |
| 0201 | 1.12 | 1.20 | 1.30 | 1.42 |
| 0202 | 0.99 | 1.33 | 1.25 | 1.50 |
| 0203 | | 1.72 | 1.78 | 1.92 |
| 0204 | 1.44 | 1.58 | 1.63 | 1.92 |
| 0205 | 1.13 | 1.00 | 1.08 | 1.24 |
| 0206 | | 1.35 | 1.32 | 1.60 |
| 0207 | | 1.32 | 1.33 | 1.51 |
| 0208 | 1.31 | 1.36 | 1.52 | 1.99 |
| 0209 | 1.21 | 1.22 | 1.26 | 1.41 |
| 0210 | | 0.90 | 0.90 | 1.29 |
| 0211 | | 1.72 | 1.76 | 1.86 |
| 0212 | 1.26 | 1.21 | 1.26 | 1.57 |

Table B2- 4 Roughness Performance for CO (8)

| State 8 IRI (m/km) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Section ID | Age (years) | | | | | | | |
| | 0 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 0213 | 1.16 | 1.19 | 1.13 | 1.14 | 1.15 | | 1.17 | 1.29 |
| 0214 | 1.03 | 0.95 | 0.95 | 0.99 | 0.94 | | 0.97 | 1.20 |
| 0215 | 1.09 | 1.08 | 1.07 | 1.11 | 1.16 | | 1.26 | 1.53 |
| 0216 | 1.01 | 1.01 | 0.95 | 1.02 | 1.01 | | 1.07 | 1.23 |
| 0217 | 1.63 | 1.67 | 1.73 | 1.72 | 1.73 | 1.75 | 1.76 | 1.82 |
| 0218 | 1.41 | 1.35 | 1.37 | 1.41 | 1.33 | 1.41 | 1.36 | 1.45 |
| 0219 | 1.49 | 1.56 | 1.58 | 1.59 | 1.56 | 1.59 | 1.61 | 1.75 |
| 0220 | 1.68 | 1.67 | 1.75 | 1.66 | 1.82 | 1.76 | 1.78 | 1.78 |
| 0221 | 1.54 | 1.45 | 1.46 | 1.47 | 1.47 | 1.46 | 1.46 | 1.53 |
| 0222 | 1.36 | 1.32 | 1.37 | 1.26 | 1.37 | 1.29 | 1.34 | 1.28 |
| 0223 | 1.84 | 1.63 | 1.65 | 1.60 | 1.71 | 1.65 | 1.75 | 1.60 |
| 0224 | 1.63 | 1.54 | 1.58 | 1.52 | 1.59 | 1.58 | 1.60 | 1.54 |

Table B2- 5 Roughness Performance for DE (10)

| State 10 IRI (m/km) | | | | | |
|---|---|---|---|---|---|
| Section ID | Age (years) | | | | |
| | 1 | 2 | 5 | 6 | 7 |
| 0201 | 1.05 | 1.13 | 1.30 | 1.22 | 1.32 |
| 0202 | 0.85 | 0.85 | 0.91 | 0.83 | 0.85 |
| 0203 | 1.03 | 1.01 | 1.03 | 1.02 | 1.06 |
| 0204 | 1.40 | 1.40 | 1.46 | 1.44 | 1.49 |
| 0205 | 1.15 | 1.19 | 1.24 | 1.21 | 1.25 |
| 0206 | 0.88 | 0.79 | 0.86 | 0.70 | 0.80 |
| 0207 | 1.07 | 1.10 | 1.14 | 1.17 | 1.27 |
| 0208 | 1.61 | 1.63 | 1.70 | 1.69 | 1.77 |
| 0209 | 0.78 | 0.78 | 0.79 | 0.78 | 0.84 |
| 0210 | 0.95 | 1.00 | 1.02 | 1.01 | 1.01 |
| 0211 | 0.86 | 0.88 | 0.87 | 0.86 | 0.86 |
| 0212 | 1.49 | 1.50 | 1.53 | 1.51 | 1.53 |

Table B2- 6 Roughness Performance for IA (19)

| State 19 IRI (m/km) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Section ID | Age (years) | | | | | | |
| | 0 | 1 | 3 | 4 | 5 | 7 | 8 |
| 0213 | 1.15 | 1.07 | 1.05 | 1.11 | 1.10 | 1.11 | 1.07 |
| 0214 | 1.23 | 1.18 | 1.10 | 1.44 | 1.30 | 1.50 | 1.77 |
| 0215 | 1.79 | 1.76 | 1.79 | 1.79 | 1.83 | 1.81 | 1.79 |
| 0216 | 1.25 | 1.26 | 1.22 | 1.41 | 1.29 | 1.51 | 1.66 |
| 0217 | 1.33 | 1.42 | 1.37 | 1.34 | 1.64 | 1.69 | 1.61 |
| 0218 | 1.23 | 1.33 | 1.27 | 1.33 | 1.31 | 1.35 | 1.63 |
| 0219 | 1.50 | 1.56 | 1.38 | 1.36 | 1.42 | 1.41 | 1.38 |
| 0220 | 1.05 | 1.15 | 1.13 | 1.10 | 1.07 | 1.10 | 1.30 |
| 0221 | 1.24 | 1.38 | 1.34 | 1.31 | 1.38 | 1.37 | 1.43 |
| 0222 | 1.84 | 1.90 | 1.78 | | 1.85 | 1.89 | 1.91 |
| 0223 | 2.18 | 2.15 | 1.99 | 1.96 | 2.03 | 1.98 | 1.97 |
| 0224 | 1.34 | 1.53 | 1.34 | 1.21 | 1.25 | 1.23 | 1.26 |

Table B2- 7 Roughness Performance for KS (20)

| State 20 IRI (m/km) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Section ID | Age (years) | | | | | | | | | | | |
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 0201 | | 1.26 | 1.22 | 1.28 | 1.41 | 1.43 | 1.50 | 1.56 | 1.65 | 1.80 | 2.09 | 1.96 |
| 0202 | 1.23 | 0.91 | 0.82 | 0.81 | 0.81 | 0.80 | 0.94 | 1.00 | 0.89 | 0.90 | 1.22 | 0.97 |
| 0203 | 1.38 | 1.49 | 1.38 | 1.42 | 1.46 | 1.46 | 1.45 | 1.44 | 1.51 | 1.49 | 1.57 | 1.52 |
| 0204 | 1.36 | 1.40 | 1.19 | 1.24 | 1.33 | 1.25 | 1.37 | 1.47 | 1.35 | 1.24 | 1.73 | 1.35 |
| 0205 | 1.28 | 1.33 | 1.30 | 1.25 | 1.40 | 1.35 | 1.33 | 1.32 | 1.43 | 1.51 | 1.46 | 1.54 |
| 0206 | 2.09 | 1.51 | 1.38 | 1.39 | 1.41 | 1.70 | 1.57 | 1.62 | 1.61 | 1.58 | 1.69 | 1.59 |
| 0207 | 1.54 | 1.63 | 1.46 | 1.48 | 1.60 | 1.64 | 1.60 | 1.57 | 1.61 | 1.73 | 1.71 | 1.69 |
| 0208 | 1.91 | 1.88 | 1.79 | 1.88 | 1.95 | 1.83 | 1.95 | 2.03 | 1.95 | 1.96 | 2.24 | 1.96 |
| 0209 | 1.13 | 1.21 | 1.07 | 1.13 | 1.25 | 1.06 | 1.14 | 1.07 | 1.07 | 1.22 | 1.16 | 1.11 |
| 0210 | 1.33 | 1.36 | 1.28 | 1.36 | 1.39 | 1.30 | 1.47 | 1.44 | 1.40 | 1.42 | 1.69 | 1.41 |
| 0211 | 1.22 | 1.29 | 1.11 | 1.15 | 1.34 | 1.23 | 1.20 | 1.17 | 1.23 | 1.39 | 1.27 | 1.29 |
| 0212 | 1.74 | 1.78 | 1.57 | 1.63 | 1.77 | 1.68 | 1.72 | 1.67 | 1.65 | 1.76 | 1.85 | 1.66 |

Table B2- 8 Roughness Performance for MI (26)

| State 26 IRI (m/km) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Section ID | Age (years) | | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 8 | 9 |
| 0213 | 1.21 | 1.24 | 1.17 | 1.47 | 2.06 | | | |
| 0214 | 1.84 | 1.83 | 1.82 | 1.62 | 2.39 | 2.89 | 2.99 | 3.88 |
| 0215 | 0.89 | 0.97 | 1.05 | 1.15 | 1.60 | 4.45 | | |
| 0216 | 1.45 | 1.39 | 1.31 | 1.05 | 1.63 | 1.76 | 1.41 | 1.96 |
| 0217 | 1.01 | 0.93 | 0.85 | 0.98 | 3.16 | | | |
| 0218 | 1.48 | 1.62 | 2.74 | 3.56 | | | | |
| 0219 | 1.16 | 1.16 | 1.22 | 1.26 | 1.28 | 1.31 | 1.37 | 1.37 |
| 0220 | 1.33 | 1.55 | 1.31 | 1.15 | 1.68 | 1.75 | 1.44 | 2.01 |
| 0221 | 1.03 | 1.11 | 1.07 | 1.05 | 1.11 | 1.07 | 1.11 | 1.09 |
| 0222 | 1.21 | 1.19 | 1.09 | 1.12 | 1.29 | 1.40 | 1.39 | 1.48 |
| 0223 | 1.04 | 0.99 | 1.04 | 0.97 | 1.02 | 1.05 | 1.18 | 1.08 |
| 0224 | 1.08 | 1.02 | 1.02 | 1.01 | 1.11 | 1.21 | 1.11 | 1.23 |

Table B2- 9 Roughness Performance for NV (32)

| State 32 IRI (m/km) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Section ID | Age (years) | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 0201 | 0.88 | 1.15 | 1.38 | 2.05 | 2.06 | 2.28 | 2.48 |
| 0202 | 1.54 | 2.16 | | | | | |
| 0203 | 0.81 | 0.92 | 1.03 | 1.26 | 1.02 | 1.04 | 1.06 |
| 0204 | 1.77 | 1.91 | 2.02 | 2.28 | 1.92 | 1.85 | 1.91 |
| 0205 | 0.97 | 1.03 | 1.11 | 1.59 | 1.27 | 1.19 | 1.43 |
| 0206 | 1.40 | 1.52 | | | | | |
| 0207 | 0.99 | 1.26 | 1.38 | 1.68 | 1.21 | 1.13 | 1.21 |
| 0208 | 1.58 | 1.75 | 1.66 | 1.93 | 1.59 | 1.60 | 1.52 |
| 0209 | 0.83 | 0.93 | 1.16 | 1.35 | 1.02 | 1.05 | 1.08 |
| 0210 | 1.10 | 1.30 | 1.43 | 1.76 | 1.32 | 1.29 | 1.35 |
| 0211 | 0.78 | 0.99 | 1.23 | 1.42 | 1.10 | 1.15 | 1.24 |

Table B2- 10 Roughness Performance for NC (37)

| State 37 IRI (m/km) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Section ID | Age (years) | | | | | | | | |
| | 0 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 0201 | 1.33 | 1.33 | 1.51 | 1.40 | 1.46 | 1.46 | 1.52 | 1.52 | 1.47 |
| 0202 | 1.38 | 1.43 | 1.41 | 1.49 | 1.56 | 1.53 | 1.79 | 1.61 | 1.56 |
| 0203 | 1.70 | 1.68 | 1.70 | 1.77 | 1.81 | 1.76 | 1.85 | 1.75 | 1.78 |
| 0204 | 1.24 | 1.21 | 1.22 | 1.26 | 1.36 | 1.33 | 1.42 | 1.37 | 1.48 |
| 0205 | 2.01 | 1.79 | 1.85 | 1.88 | 1.87 | 1.93 | 1.96 | 1.98 | 1.89 |
| 0206 | 1.47 | 1.45 | 1.44 | 1.50 | 1.51 | 1.49 | 1.72 | 1.51 | 1.52 |
| 0207 | 1.83 | 1.83 | 1.78 | 1.81 | 1.80 | 1.80 | 1.89 | 1.81 | 1.78 |
| 0208 | | 1.74 | 1.73 | 1.78 | 1.80 | 1.74 | 1.98 | 1.81 | 1.83 |
| 0209 | 1.22 | 1.27 | 1.30 | 1.31 | 1.30 | 1.30 | 1.34 | 1.31 | 1.32 |
| 0210 | 1.24 | 1.32 | 1.57 | 1.43 | 1.33 | 1.39 | 1.31 | 1.34 | 1.44 |
| 0211 | 1.29 | 1.30 | 1.34 | 1.33 | 1.28 | 1.28 | 1.33 | 1.26 | 1.25 |
| 0212 | 1.08 | 1.06 | 1.17 | 1.13 | 1.12 | 1.07 | 1.21 | 1.11 | 1.11 |

Table B2- 11 Roughness Performance for ND (38)

| State 38 IRI (m/km) | | | | | |
|---|---|---|---|---|---|
| Section ID | Age (years) | | | | |
| | 4 | 5 | 6 | 7 | 8 |
| 0213 | 1.39 | 1.25 | 1.36 | 1.16 | 1.11 |
| 0214 | 1.22 | 1.16 | 1.16 | 1.16 | 1.35 |
| 0215 | 1.86 | 1.67 | 1.91 | 1.80 | 1.65 |
| 0216 | 1.80 | 1.71 | 1.83 | 1.68 | 1.62 |
| 0217 | 1.43 | 1.36 | 1.54 | 1.49 | 1.45 |
| 0218 | 1.48 | 1.37 | 1.46 | 1.44 | 1.62 |
| 0219 | 1.47 | 1.42 | 1.53 | 1.30 | 1.29 |
| 0220 | 1.61 | 1.50 | 1.73 | 1.46 | 1.35 |
| 0221 | 1.41 | 1.31 | 1.34 | 1.30 | 1.28 |
| 0222 | 1.52 | 1.47 | 1.45 | 1.43 | 1.28 |
| 0223 | 1.46 | 1.44 | 1.39 | 1.39 | 1.32 |
| 0224 | 2.00 | 1.90 | 1.95 | 1.94 | 1.87 |

Table B2- 12 Roughness Performance for OH (39)

| State 39 IRI (m/km) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Section ID | Age (years) | | | | | | | |
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 0201 | 1.27 | 1.38 | 1.45 | 1.52 | 1.44 | 1.55 | 1.55 | 1.50 |
| 0202 | 1.14 | 1.26 | 1.34 | 1.41 | 1.39 | 1.52 | 1.56 | 1.55 |
| 0203 | 1.05 | 1.04 | 1.10 | 1.16 | 1.03 | 1.19 | 1.14 | 1.11 |
| 0204 | 0.84 | 0.87 | 0.89 | 1.02 | 0.86 | 1.21 | 1.14 | 0.92 |
| 0205 | 1.22 | 1.24 | 1.35 | 1.40 | 1.38 | 1.53 | 1.44 | 1.53 |
| 0206 | 1.24 | 1.26 | 1.33 | 1.40 | 1.41 | 1.50 | 1.52 | 1.75 |
| 0207 | 1.37 | 1.28 | 1.24 | 1.23 | 1.44 | 1.27 | 1.30 | 1.64 |
| 0208 | 1.49 | 1.35 | 1.29 | 1.28 | 1.46 | 1.36 | 1.29 | 1.53 |
| 0209 | 0.97 | 1.03 | 1.12 | 1.14 | 1.08 | 1.15 | 1.15 | 1.21 |
| 0210 | 1.03 | 1.08 | 1.03 | 1.04 | 1.17 | 1.09 | 1.12 | 1.38 |
| 0211 | 1.34 | 1.33 | 1.35 | 1.33 | 1.35 | 1.33 | 1.35 | 1.47 |
| 0212 | 1.07 | 1.06 | 1.01 | 1.00 | 1.04 | 1.03 | 1.01 | 1.23 |

Table B2- 13 Roughness Performance for WA (53)

| State 53 IRI (m/km) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Section ID | Age (years) | | | | | | | |
| | 0 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 0201 | 1.19 | 1.32 | 1.31 | 1.32 | 1.33 | 1.38 | 1.40 | 1.40 |
| 0202 | 0.99 | 0.96 | 1.01 | 1.02 | 1.02 | 0.95 | 0.95 | 0.97 |
| 0203 | 1.24 | 1.22 | 1.21 | 1.26 | 1.30 | 1.34 | 1.35 | 1.35 |
| 0204 | 1.19 | 1.16 | 1.21 | 1.21 | 1.22 | 1.18 | 1.20 | 1.16 |
| 0205 | 1.21 | 1.23 | 1.23 | 1.22 | 1.23 | 1.20 | 1.20 | 1.24 |
| 0206 | 1.04 | 1.28 | 1.45 | 1.58 | 2.04 | 1.99 | 1.70 | 1.85 |
| 0207 | 1.18 | 1.27 | 1.25 | 1.29 | 1.32 | 1.32 | 1.38 | 1.31 |
| 0208 | 1.11 | 1.07 | 1.14 | 1.22 | 1.47 | 1.45 | 1.32 | 1.52 |
| 0209 | 1.22 | 1.27 | 1.33 | 1.32 | 1.32 | 1.31 | 1.32 | 1.33 |
| 0210 | 0.78 | 0.90 | 0.99 | 0.99 | 1.02 | 0.92 | 0.85 | 0.81 |
| 0211 | 1.15 | 1.15 | 1.18 | 1.15 | 1.13 | 1.06 | 1.08 | 1.14 |
| 0212 | 1.09 | 1.10 | 1.19 | 1.18 | 1.21 | 1.12 | 1.09 | 1.03 |

Table B2- 14 Roughness Performance for WI (55)

| State 55 IRI (m/km) | | | | | |
|---|---|---|---|---|---|
| Section ID | Age (years) | | | | |
| | 0 | 1 | 2 | 4 | 5 |
| 0213 | 1.03 | 1.06 | 1.50 | 1.50 | 1.22 |
| 0214 | | 1.32 | 1.64 | 1.56 | 1.34 |
| 0215 | 1.25 | 1.21 | 1.39 | 1.40 | 1.31 |
| 0216 | 1.52 | 1.49 | 1.66 | 1.64 | 1.54 |
| 0217 | 0.81 | 0.79 | 0.86 | 0.82 | 0.81 |
| 0218 | 1.27 | 1.20 | 1.16 | 1.17 | 1.19 |
| 0219 | 0.92 | 0.93 | 1.16 | 1.07 | 0.98 |
| 0220 | 1.26 | 1.26 | 1.33 | 1.32 | 1.38 |
| 0221 | 1.14 | 1.18 | 1.38 | 1.35 | 1.27 |
| 0222 | 1.64 | 1.60 | 1.78 | 1.77 | 1.60 |
| 0223 | 1.29 | 1.27 | 1.47 | 1.36 | 1.24 |
| 0224 | 1.11 | 1.09 | 1.32 | 1.24 | 1.08 |

# APPENDIX B3

## Dynamic Load Response (DLR) Data for SPS-2 experiment (Evaluation of traces, tables for available data)

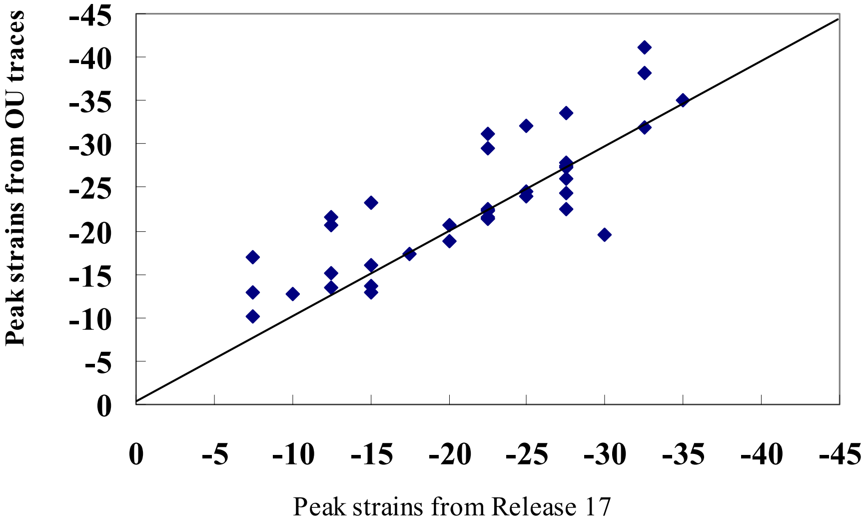


**Figure B3-1 Comparisons between peaks for a sample— OU traces versus LTPP DLR data (top strain gauges)**

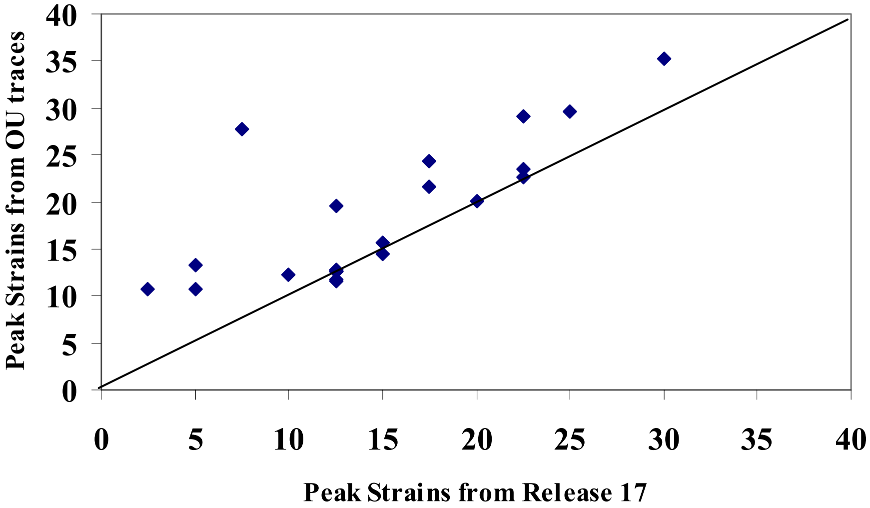


**Figure B3-2 Comparisons between peaks for a sample— OU traces versus LTPP DLR data (bottom strain gauges)**

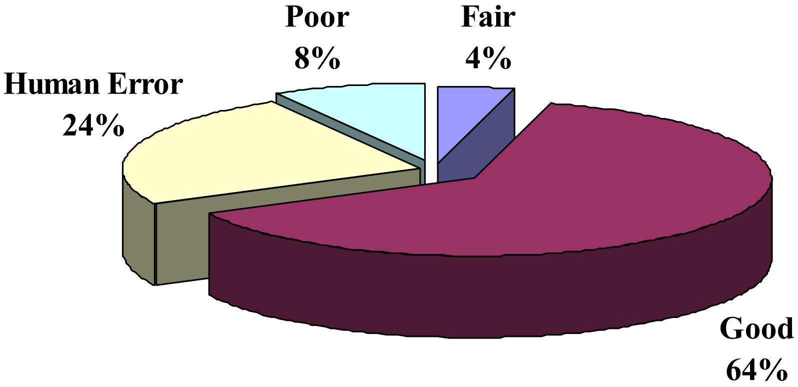


Figure B3-3 Summary of quality check for traces from a random sample

**Table B3-1 Data availability for Ohio DLR experiment (DataPave of Release 17)**

| Date | Test ID | No. of runs | Truck 1 | | Truck 2 | |
|---|---|---|---|---|---|---|
| | | | Speed, km/ h | Load, kN | Speed, km/ h | Load, kN |
| 8/12/1996 | J1a | 107 | 48, 64, 80 | 96.9 | 48, 64, 80 | 186 |
| | J5a | 12 | 64, 80 | 96.9 | 48, 80 | 186 |
| | J8a | 78 | 48, 64, 80 | 96.9 | 48, 64, 80 | 186 |
| | J12a | 91 | 48, 64, 80 | 96.9 | 48, 64, 80 | 186 |
| 8/13/1996 | J5b | 46 | 48, 64, 80 | 96.9 | 48, 64, 80 | 186 |
| | J8b | 82 | 48, 64, 80 | 96.9 | 48, 64, 80 | 186 |
| | J12b | 83 | 48, 64, 80 | 96.9 | 48, 64, 80 | 186 |
| 8/14/1996 | J1c | 49 | 48, 64, 80 | 79.1 | - | - |
| | J5c | 24 | 48, 64, 80 | 79.1 | - | - |
| | J8c | 57 | 48, 64, 80 | 79.1 | - | - |
| | J12c | 52 | 48, 64, 80 | 79.1 | - | - |
| 7/29/1997 | J5j1m | 33 | 30, 40, 50 | 96.9 | 30, 40, 50 | 160.3 |
| | J8s3m | 10 | 48, 80 | 96.9 | 48, 64, 80 | 160.3 |
| | J12j10m | 10 | 48, 64, 80 | 96.9 | 48, 64, 80 | 160.3 |
| 7/30/1997 | J5j1n | 3 | 30 | 96.9 | - | |
| | J5j1o | 33 | 30, 40, 50 | 110.8 | 30, 40, 50 | 199.8 |
| | J8s3n | 3 | 80 | 96.9 | 64 | 160.3 |
| | J8s3o | 3 | 64, 80 | 110.8 | 80 | 199.8 |
| | J12j10n | 21 | 48, 64, 80 | 96.9 | 48, 64, 80 | 160.3 |
| | J12j10o | 15 | 48, 64, 80 | 110.8 | 48, 64, 80 | 199.8 |
| 8/6/1997 | J5j1p | 28 | 30, 40, 50 | 110.8 | 30, 40, 50 | 199.8 |
| | J8s3p | 6 | 48, 64, 80 | 110.8 | 48, 64 | 199.8 |
| | J12j10p | 4 | 80 | 110.8 | 80 | 199.8 |

**Table B3-2 Data availability (No. of runs of data) for section 370201**

| **Test ID** | **DATE** | **Single-axle truck** | | **Tandem-Axle truck** | | |
|---|---|---|---|---|---|---|
| | | **79.1** | **89** | **142.4** | **160.3** | **168.2** |
| t37201a | 10/06/94 | 27 | | 27 | | |
| | 10/07/94 | | 19 | | | 19 |
| t37201b | 05/16/95 | | 27 | | | 27 |
| | 05/17/95 | 27 | | 27 | | |
| t37201c | 08/01/95 | 27 | | 27 | | |
| | 08/02/95 | | 27 | | | 27 |
| t37201d | 11/27/95 | | 27 | | | 28 |
| | 11/28/95 | | 1 | | | 1 |
| | 11/29/95 | 28 | | 27 | | |
| t37201e | 05/07/96 | 18 | | 18 | | |
| | 05/08/96 | | 30 | | 24 | |
| t37201f | 10/29/96 | 26 | 1 | 27 | | |
| | 10/30/96 | | 27 | | | 28 |
| t37201g | 03/17/97 | 23 | | 23 | | |
| | 03/19/97 | | 27 | | | 27 |
| t37201h | 09/23/97 | 27 | | 26 | | |

**Table B3-3 Data availability (No. of runs of data) for section 370205**

| Test ID | DATE | Single-axle truck | | Tandem-Axle truck | | |
|---|---|---|---|---|---|---|
| | | 79.1 | 89 | 142.4 | 160.3 | 168.2 |
| t37205a | 10/06/94 | 27 | | 27 | | |
| | 10/07/94 | | 19 | | | 19 |
| t37205b | 05/16/95 | | 27 | | | 27 |
| | 05/17/95 | 28 | | 27 | | |
| t37205c | 08/01/95 | 28 | | 26 | | |
| | 08/02/95 | | 27 | | | 27 |
| t37205d | 11/28/95 | | 27 | | | 28 |
| | 11/29/95 | | 1 | | | 1 |
| | 11/30/95 | 28 | | 27 | | |
| t37205e | 05/07/96 | 18 | | 17 | | |
| | 05/08/96 | | 29 | 1 | | 24 |
| t37205f | 10/29/96 | 27 | | 27 | | |
| | 10/30/96 | | 27 | | | 27 |
| t37205g | 03/18/97 | 24 | | 24 | | |
| | 03/20/97 | | 27 | | | 27 |
| t37205h | 09/23/97 | 27 | | 26 | | |

## Table B3-4 Data availability (No. of runs of data) for section 370208

| | | Single-axle truck | | Tandem-Axle truck | | |
|---|---|---|---|---|---|---|
| Test ID | DATE | 79.1 | 89 | 142.4 | 160.3 | 168.2 |
| t37208a | 10/11/94 | | 9 | | | 9 |
| | 10/12/94 | 20 | 9 | 17 | | 10 |
| t37208b | 05/09/95 | 28 | | 28 | | |
| | 05/10/95 | | 19 | | | 19 |
| t37208c | 08/08/95 | | 27 | | | 27 |
| | 08/09/95 | 27 | | 27 | | |
| t37208d | 11/14/95 | 18 | | 19 | | |
| | 11/15/95 | 10 | 18 | 10 | | 18 |
| t37208e | 05/14/96 | 27 | | 27 | | |
| | 05/15/96 | | 27 | | | 27 |
| t37208f | 11/05/96 | 27 | | 27 | | |
| | 11/06/96 | | 28 | | | 28 |
| t37208g | 03/10/97 | 27 | 1 | 27 | | |
| | 03/11/97 | | 27 | | | 27 |
| t37208h | 09/30/97 | 27 | | 27 | | |
| | 10/01/97 | | 27 | | | 27 |

## Table B3-5 Data availability (No. of runs of data) for section 370212

| | | Single-axle truck | | Tandem-Axle truck | | |
|---|---|---|---|---|---|---|
| Test ID | DATE | 79.1 | 89 | 142.4 | 160.3 | 168.2 |
| t37212a | 10/11/94 | | 9 | | | 9 |
| | 10/12/94 | 19 | 10 | 18 | | 10 |
| t37212b | 05/09/95 | 28 | | 28 | | |
| | 05/10/95 | | 19 | | | 18 |
| t37212c | 08/08/95 | | 27 | | | 27 |
| | 08/09/95 | 27 | | 27 | | |
| t37212d | 11/14/95 | 18 | | 19 | | |
| | 11/15/95 | | 28 | | | 28 |
| t37212e | 05/14/96 | 27 | | 27 | | |
| | 05/15/96 | | 27 | | | 27 |
| t37212f | 11/05/96 | 27 | | 27 | | |
| | 11/06/96 | | 28 | | | 27 |
| t37212g | 03/11/97 | 27 | 1 | 27 | | |
| | 03/12/97 | | 26 | | | 28 |
| t37212h | 09/30/97 | 27 | | 27 | | |
| | 10/01/97 | | 27 | | | 27 |

# APPENDIX B4

## Site-level Analysis for SPS-2 experiment
## (Tables for site-level analysis)

Table B4- 1 Level-A analysis on transverse cracking

| **Transverse Cracking** | | | | **Drainage** | | **Base type** | | | **PCC slab thickness, in** | | **PCC Flexural Strength, psi** | | **Lane width, feet** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Traffic** | **State** | **Climatic Zone** | **Subgrade** | **Y** | **N** | **DGAB** | **LCB** | **PATB** | **8** | **11** | **550** | **900** | **12** | **14** |
| **400** | **8** | **DF** | **C+F** | 2.0 | 0.0 | 0.0 | 2.5 | 0.5 | 2.0 | 0.0 | 0.0 | 2.0 | 2.0 | 0.0 |
| **800** | **32** | **DF** | **F+C** | 0.3 | 1.7 | 1.2 | 1.6 | 0.2 | 1.2 | 0.8 | 1.1 | 0.9 | 1.0 | 1.0 |
| **462** | **53** | **DF** | **F** | 1.0 | 1.0 | 0.0 | 3.0 | 0.0 | 1.3 | 0.7 | 1.2 | 0.8 | 0.5 | 1.5 |
| **1092** | **4** | **DNF** | **C** | 1.0 | 1.0 | 0.0 | 3.0 | 0.0 | 1.8 | 0.2 | 0.9 | 1.1 | 1.1 | 0.9 |
| **2405** | **6** | **DNF** | **C** | 0.0 | 2.0 | 1.3 | 1.7 | 0.0 | 1.8 | 0.2 | 1.1 | 0.9 | 1.1 | 0.9 |
| **380** | **10** | **WF** | **C** | 1.0 | 1.0 | 0.0 | 3.0 | 0.0 | 2.0 | 0.0 | 2.0 | 0.0 | 2.0 | 0.0 |
| **377** | **19** | **WF** | **F** | 1.0 | 1.0 | 0.0 | 3.0 | 0.0 | 2.0 | 0.0 | 1.9 | 0.1 | 0.1 | 1.9 |
| **757** | **20** | **WF** | **F** | 0.0 | 2.0 | 3.0 | 0.0 | 0.0 | 2.0 | 0.0 | 1.5 | 0.5 | 1.5 | 0.5 |
| **1505** | **26** | **WF** | **F** | 0.0 | 2.0 | 0.9 | 2.1 | 0.0 | 1.9 | 0.1 | 0.3 | 1.7 | 1.8 | 0.2 |
| **420** | **38** | **WF** | **F** | 2.0 | 0.0 | 0.0 | 2.9 | 0.1 | 1.7 | 0.3 | 1.8 | 0.2 | 0.1 | 1.9 |
| **608** | **39** | **WF** | **F** | 0.4 | 1.6 | 1.1 | 1.6 | 0.3 | 1.8 | 0.2 | 0.9 | 1.1 | 1.1 | 0.9 |
| **151** | **55** | **WF** | **C** | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| **1903** | **5** | **WNF** | **C** | 0.0 | 2.0 | 0.2 | 2.8 | 0.0 | 2.0 | 0.0 | 0.2 | 1.8 | 1.8 | 0.2 |
| **715** | **37** | **WNF** | **F** | 1.5 | 0.5 | 0.1 | 2.7 | 0.2 | 2.0 | 0.0 | 1.8 | 0.2 | 1.8 | 0.2 |
| | | **Wet** | **F** | 0.8 | 1.2 | 0.9 | 2.0 | 0.1 | 1.9 | 0.1 | 1.4 | 0.6 | 1.1 | 0.9 |
| | | | **C** | 0.7 | 1.3 | 0.4 | 2.3 | 0.3 | 1.7 | 0.3 | 1.1 | 0.9 | 1.6 | 0.4 |
| | | | **Both** | 0.8 | 1.2 | 0.7 | 2.1 | 0.2 | 1.8 | 0.2 | 1.3 | 0.7 | 1.3 | 0.7 |
| | | **Dry** | **F** | 0.6 | 1.4 | 0.6 | 2.3 | 0.1 | 1.2 | 0.8 | 1.2 | 0.8 | 0.7 | 1.3 |
| | | | **C** | 1.0 | 1.0 | 0.4 | 2.4 | 0.2 | 1.9 | 0.1 | 0.7 | 1.3 | 1.4 | 0.6 |
| | | | **Both** | 0.9 | 1.1 | 0.5 | 2.4 | 0.1 | 1.6 | 0.4 | 0.9 | 1.1 | 1.1 | 0.9 |
| | | **WF** | **C** | 1.0 | 1.0 | 0.5 | 2.0 | 0.5 | 1.5 | 0.5 | 1.5 | 0.5 | 1.5 | 0.5 |
| | | | **F** | 0.7 | 1.3 | 1.0 | 1.9 | 0.1 | 1.9 | 0.1 | 1.3 | 0.7 | 0.9 | 1.1 |
| | | | **Both** | 0.8 | 1.2 | 0.9 | 1.9 | 0.2 | 1.8 | 0.2 | 1.3 | 0.7 | 1.1 | 0.9 |
| | | **DF** | | 1.1 | 0.9 | 0.4 | 2.4 | 0.2 | 1.5 | 0.5 | 0.8 | 1.2 | 1.2 | 0.8 |
| | | **DNF** | | 0.5 | 1.5 | 0.6 | 2.4 | 0.0 | 1.8 | 0.2 | 1.0 | 1.0 | 1.1 | 0.9 |
| | | **WNF** | | 0.7 | 1.3 | 0.1 | 2.8 | 0.1 | 2.0 | 0.0 | 1.0 | 1.0 | 1.8 | 0.2 |
| | | **Overall** | **C** | 0.6 | 1.4 | 0.5 | 2.3 | 0.2 | 1.7 | 0.3 | 1.0 | 1.0 | 1.4 | 0.6 |
| | | | **F** | 0.8 | 1.2 | 0.7 | 2.2 | 0.1 | 1.8 | 0.2 | 1.4 | 0.6 | 1.0 | 1.0 |
| | | | **Both** | 0.8 | 1.2 | 0.6 | 2.2 | 0.2 | 1.7 | 0.3 | 1.1 | 0.9 | 1.2 | 0.8 |

Table B4- 2 Level-A analysis on longitudinal cracking

| Longitudinal Cracking | | | | Drainage | | Base type | | | PCC slab thickness, in | | PCC Flexural Strength, psi | | Lane width, feet | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Traffic** | **State** | **Climatic Zone** | **Subgrade** | **Y** | **N** | **DGAB** | **LCB** | **PATB** | **8** | **11** | **550** | **900** | **12** | **14** |
| **400** | **8** | **DF** | **C+F** | 1.4 | 0.6 | 0.1 | 2.7 | 0.2 | 2.0 | 0.0 | 1.9 | **0.1** | 0.1 | 1.9 |
| **800** | **32** | **DF** | **F+C** | 0.2 | 1.8 | 1.2 | 1.6 | 0.1 | 1.5 | 0.5 | 0.9 | 1.1 | 0.8 | 1.2 |
| **462** | **53** | **DF** | **F** | 1.0 | 1.0 | 0.0 | 3.0 | 0.0 | 2.0 | 0.0 | 0.0 | 2.0 | 0.0 | 2.0 |
| **1092** | **4** | **DNF** | **C** | 0.5 | 1.5 | 0.9 | 1.8 | 0.3 | 2.0 | 0.0 | 1.6 | 0.4 | 0.4 | 1.6 |
| **2405** | **6** | **DNF** | **C** | 1.0 | 1.0 | 0.0 | 3.0 | 0.0 | 0.0 | 2.0 | 0.0 | 2.0 | 2.0 | 0.0 |
| **380** | **10** | **WF** | **C** | 2.0 | 0.0 | 0.0 | 2.9 | 0.1 | 0.2 | 1.8 | 2.0 | 0.0 | 0.2 | 1.8 |
| **377** | **19** | **WF** | **F** | 1.5 | 0.5 | 0.7 | 0.0 | 2.3 | 1.2 | 0.8 | 0.5 | 1.5 | 0.7 | 1.3 |
| **757** | **20** | **WF** | **F** | 0.0 | 2.0 | 2.1 | 0.9 | 0.0 | 1.9 | 0.1 | 1.5 | 0.5 | 1.6 | 0.4 |
| **1505** | **26** | **WF** | **F** | 0.0 | 2.0 | 0.7 | 2.3 | 0.0 | 2.0 | 0.0 | 0.2 | 1.8 | 1.8 | 0.2 |
| **420** | **38** | **WF** | **F** | 1.8 | 0.2 | 0.0 | 2.7 | 0.3 | 1.8 | 0.2 | 1.6 | 0.4 | 0.3 | 1.7 |
| **608** | **39** | **WF** | **F** | 1.0 | 1.0 | 0.0 | 3.0 | 0.0 | 2.0 | 0.0 | 0.0 | 2.0 | 0.0 | 2.0 |
| **151** | **55** | **WF** | **C** | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| **1903** | **5** | **WNF** | **C** | 0.0 | 2.0 | 1.2 | 1.8 | 0.0 | 2.0 | 0.0 | 1.4 | 0.6 | 0.6 | 1.4 |
| **715** | **37** | **WNF** | **F** | 0.8 | 1.2 | 0.3 | 2.5 | 0.2 | 2.0 | 0.0 | 1.8 | 0.2 | 1.8 | 0.2 |
| | | **Wet** | **F** | 0.9 | 1.1 | 0.6 | 1.9 | 0.5 | 1.8 | 0.2 | 0.9 | 1.1 | 1.0 | 1.0 |
| | | | **C** | 1.0 | 1.0 | 0.7 | 1.9 | 0.4 | 1.1 | 0.9 | 1.5 | 0.5 | 0.6 | 1.4 |
| | | | **Both** | 0.9 | 1.1 | 0.7 | 1.9 | 0.4 | 1.6 | 0.4 | 1.1 | 0.9 | 0.9 | 1.1 |
| | | **Dry** | **F** | 0.6 | 1.4 | 0.6 | 2.3 | 0.1 | 1.8 | 0.2 | 0.4 | 1.6 | 0.4 | 1.6 |
| | | | **C** | 1.0 | 1.0 | 0.3 | 2.5 | 0.2 | 1.3 | 0.7 | 1.2 | 0.8 | 0.8 | 1.2 |
| | | | **Both** | 0.8 | 1.2 | 0.4 | 2.4 | 0.1 | 1.5 | 0.5 | 0.9 | 1.1 | 0.7 | 1.3 |
| | | **WF** | **C** | 1.5 | 0.5 | 0.5 | 2.0 | 0.5 | 0.6 | 1.4 | 1.5 | 0.5 | 0.6 | 1.4 |
| | | | **F** | 0.9 | 1.1 | 0.7 | 1.8 | 0.5 | 1.8 | 0.2 | 0.8 | 1.2 | 0.9 | 1.1 |
| | | | **Both** | 1.0 | 1.0 | 0.7 | 1.8 | 0.5 | 1.4 | 0.6 | 1.0 | 1.0 | 0.8 | 1.2 |
| | | **DF** | | 0.9 | 1.1 | 0.4 | 2.4 | 0.1 | 1.8 | 0.2 | 0.9 | 1.1 | 0.3 | 1.7 |
| | | **DNF** | | 0.8 | 1.2 | 0.5 | 2.4 | 0.2 | 1.0 | 1.0 | 0.8 | 1.2 | 1.2 | 0.8 |
| | | **WNF** | | 0.4 | 1.6 | 0.7 | 2.2 | 0.1 | 2.0 | 0.0 | 1.6 | 0.4 | 1.2 | 0.8 |
| | | **Overall** | **C** | 0.9 | 1.1 | 0.6 | 2.1 | 0.3 | 1.0 | 1.0 | 1.2 | 0.8 | 0.8 | 1.2 |
| | | | **F** | 0.9 | 1.1 | 0.6 | 2.1 | 0.4 | 1.8 | 0.2 | 0.8 | 1.2 | 0.9 | 1.1 |
| | | | **Both** | 0.9 | 1.1 | 0.6 | 2.1 | 0.3 | 1.5 | 0.5 | 1.0 | 1.0 | 0.8 | 1.2 |

Table B4- 3 Level-A analysis on IRI

| Roughness (IRI) | | | | Drainage | | Base type | | | PCC slab thickness, in | | PCC Flexural Strength, psi | | Lane width, feet | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Traffic** | **State** | **Climatic Zone** | **Subgrade** | **Y** | **N** | **DGAB** | **LCB** | **PATB** | **8** | **11** | **550** | **900** | **12** | **14** |
| **400** | **8** | **DF** | **C+F** | 1.1 | 0.9 | 0.8 | 1.1 | 1.1 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| **800** | **32** | **DF** | **F+C** | 0.8 | 1.2 | 1.2 | 1.0 | 0.8 | 1.0 | 1.0 | 0.9 | 1.1 | 1.1 | 0.9 |
| **462** | **53** | **DF** | **F** | 1.0 | 1.0 | 1.0 | 1.1 | 0.9 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| **1092** | **4** | **DNF** | **C** | 0.9 | 1.1 | 1.2 | 0.9 | 0.9 | 1.0 | 1.0 | 1.1 | 0.9 | 1.0 | 1.0 |
| **2405** | **6** | **DNF** | **C** | 0.9 | 1.1 | 1.1 | 1.0 | 1.0 | 0.9 | 1.1 | 1.0 | 1.0 | 1.0 | 1.0 |
| **380** | **10** | **WF** | **C** | 1.0 | 1.0 | 1.0 | 1.1 | 0.9 | 0.9 | 1.1 | 0.9 | 1.1 | 1.2 | 0.8 |
| **377** | **19** | **WF** | **F** | 1.1 | 0.9 | 1.0 | 0.9 | 1.1 | 1.0 | 1.0 | 1.0 | 1.0 | 1.1 | 0.9 |
| **757** | **20** | **WF** | **F** | 1.0 | 1.0 | 0.9 | 1.1 | 0.9 | 0.9 | 1.1 | 1.0 | 1.0 | 1.1 | 0.9 |
| **1505** | **26** | **WF** | **F** | 0.7 | 1.3 | 1.2 | 1.1 | 0.7 | 1.1 | 0.9 | 0.9 | 1.1 | 1.1 | 0.9 |
| **420** | **38** | **WF** | **F** | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 | 1.1 | 1.0 | 1.0 | 1.0 | 1.0 |
| **608** | **39** | **WF** | **F** | 1.0 | 1.0 | 1.0 | 1.1 | 0.9 | 1.1 | 0.9 | 1.0 | 1.0 | 1.0 | 1.0 |
| **151** | **55** | **WF** | **C** | 1.0 | 1.0 | 1.1 | 0.9 | 1.1 | 1.0 | 1.0 | 0.9 | 1.1 | 1.0 | 1.0 |
| **1903** | **5** | **WNF** | **C** | 0.8 | 1.2 | 1.2 | 1.0 | 0.8 | 1.0 | 1.0 | 0.9 | 1.1 | 0.9 | 1.1 |
| **715** | **37** | **WNF** | **F** | 0.9 | 1.1 | 1.0 | 1.2 | 0.8 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| | | **Wet** | **F** | 0.9 | 1.1 | 1.0 | 1.1 | 0.9 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| | | | **C** | 0.9 | 1.1 | 1.1 | 1.0 | 0.9 | 0.9 | 1.0 | 0.9 | 1.1 | 1.0 | 1.0 |
| | | | **Both** | 0.9 | 1.1 | 1.0 | 1.0 | 0.9 | 1.0 | 1.0 | 0.9 | 1.0 | 1.0 | 1.0 |
| | | **Dry** | **F** | 0.9 | 1.1 | 1.1 | 1.1 | 0.9 | 1.0 | 1.0 | 0.9 | 1.0 | 1.0 | 1.0 |
| | | | **C** | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 | 1.0 | 1.0 | 0.9 | 1.0 | 1.0 |
| | | | **Both** | 0.9 | 1.1 | 1.0 | 1.0 | 0.9 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| | | **WF** | **C** | 1.0 | 1.0 | 1.1 | 1.0 | 1.0 | 0.9 | 1.1 | 0.9 | 1.1 | 1.1 | 0.9 |
| | | | **F** | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 |
| | | | **Both** | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 | 1.0 | 1.1 | 0.9 |
| | | **DF** | | 1.0 | 1.0 | 1.0 | 1.1 | 0.9 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| | | **DNF** | | 0.9 | 1.1 | 1.1 | 1.0 | 0.9 | 0.9 | 1.1 | 1.1 | 0.9 | 1.0 | 1.0 |
| | | **WNF** | | 0.9 | 1.1 | 1.1 | 1.1 | 0.8 | 1.0 | 1.0 | 0.9 | 1.0 | 1.0 | 1.0 |
| | | **Overall** | **C** | 0.9 | 1.1 | 1.1 | 1.0 | 0.9 | 0.9 | 1.1 | 1.0 | 1.0 | 1.0 | 1.0 |
| | | | **F** | 0.9 | 1.1 | 1.0 | 1.1 | 0.9 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| | | | **Both** | 0.9 | 1.1 | 1.0 | 1.0 | 0.9 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |

Table B4- 4 Level-A analysis on faulting

| Faulting | | | | Drainage | | Base type | | | PCC slab thickness, in | | PCC Flexural Strength, psi | | Lane width, feet | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Traffic | State | Climatic Zone | Subgrade | Y | N | DGAB | LCB | PATB | 8 | 11 | 550 | 900 | 12 | 14 |
| 400 | 8 | DF | C+F | 0.9 | 1.1 | 1.1 | **1.1** | 0.9 | 0.4 | 1.6 | 1.3 | **0.7** | 1.4 | 0.6 |
| 800 | 32 | DF | F+C | 0.6 | 1.4 | 1.8 | 0.4 | 0.8 | 0.9 | 1.1 | 1.2 | 0.8 | 1.1 | 0.9 |
| 462 | 53 | DF | F | 0.6 | 1.4 | 1.4 | **1.0** | 0.6 | 1.6 | 0.4 | 0.6 | 1.4 | 1.1 | 0.9 |
| 1092 | 4 | DNF | C | 1.9 | 0.1 | 0.1 | 1.6 | 1.3 | 0.8 | 1.2 | 0.9 | 1.1 | 1.1 | 0.9 |
| 2405 | 6 | DNF | C | 1.2 | 0.8 | 0.7 | 1.2 | 1.1 | 1.8 | 0.2 | 1.3 | 0.7 | 1.3 | 0.7 |
| 380 | 10 | WF | C | 0.6 | 1.4 | 2.0 | 0.2 | 0.9 | 1.1 | 0.9 | 0.8 | 1.2 | 1.0 | 1.0 |
| 377 | 19 | WF | F | 0.5 | 1.5 | 1.3 | 1.2 | 0.5 | 1.3 | 0.7 | 0.9 | 1.1 | 1.1 | 0.9 |
| 757 | 20 | WF | F | 0.3 | 1.7 | 2.2 | 0.4 | 0.4 | 1.0 | 1.0 | 1.4 | 0.6 | 1.5 | 0.5 |
| 1505 | 26 | WF | F | 0.6 | 1.4 | 1.5 | 0.9 | 0.7 | 1.0 | 1.0 | 1.1 | **0.9** | 0.9 | 1.1 |
| 420 | 38 | WF | F | 1.4 | 0.6 | 0.8 | 0.4 | 1.8 | 0.5 | 1.5 | 0.7 | 1.3 | 1.3 | 0.7 |
| 608 | 39 | WF | F | 0.3 | 1.7 | 1.5 | 1.2 | 0.2 | 0.4 | 1.6 | 1.3 | 0.7 | 1.4 | 0.6 |
| 151 | 55 | WF | C | 1.7 | 0.3 | 0.2 | 1.1 | 1.6 | 1.2 | 0.8 | 1.2 | 0.8 | 1.3 | 0.7 |
| 1903 | 5 | WNF | C | 1.0 | 1.0 | 1.2 | 0.5 | 1.2 | 0.9 | 1.1 | 0.8 | 1.2 | 1.4 | 0.6 |
| 715 | 37 | WNF | F | 1.6 | 0.4 | 0.5 | **0.2** | 2.3 | 1.7 | 0.3 | 0.1 | 1.9 | 1.6 | 0.4 |
| | | Wet | F | 0.8 | 1.2 | 1.3 | 0.7 | 1.0 | 1.0 | 1.0 | 0.9 | 1.1 | 1.3 | 0.7 |
| | | | C | 1.1 | 0.9 | 1.1 | 0.6 | 1.3 | 1.1 | 0.9 | 0.9 | 1.1 | 1.2 | 0.8 |
| | | | Both | 0.9 | 1.1 | 1.3 | 0.7 | 1.1 | 1.0 | 1.0 | 0.9 | 1.1 | 1.3 | 0.7 |
| | | Dry | F | 0.6 | 1.4 | 1.6 | 0.7 | 0.7 | 1.2 | 0.8 | 0.9 | 1.1 | 1.1 | 0.9 |
| | | | C | 1.3 | 0.7 | 0.6 | 1.3 | 1.1 | 1.0 | 1.0 | 1.1 | 0.9 | 1.3 | 0.7 |
| | | | Both | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 | 1.1 | 0.9 | 1.1 | 0.9 | 1.2 | 0.8 |
| | | WF | C | 1.2 | 0.8 | 1.1 | 0.6 | 1.3 | 1.1 | 0.9 | 1.0 | 1.0 | 1.1 | 0.9 |
| | | | F | 0.6 | 1.4 | 1.5 | 0.8 | 0.7 | 0.8 | 1.2 | 1.1 | 0.9 | 1.2 | 0.8 |
| | | | Both | 0.8 | 1.2 | 1.4 | 0.8 | 0.9 | 0.9 | 1.1 | 1.1 | 0.9 | 1.2 | 0.8 |
| | | DF | | 0.7 | 1.3 | 1.4 | 0.8 | 0.8 | 0.9 | 1.1 | 1.0 | 1.0 | 1.2 | 0.8 |
| | | DNF | | 1.5 | 0.5 | 0.4 | 1.4 | 1.2 | 1.3 | 0.7 | 1.1 | 0.9 | 1.2 | 0.8 |
| | | WNF | | 1.3 | 0.7 | 0.9 | 0.3 | 1.8 | 1.3 | 0.7 | 0.5 | 1.5 | 1.5 | 0.5 |
| | | Overall | C | 1.3 | 0.7 | 0.9 | 0.9 | 1.2 | 1.2 | 0.8 | 1.0 | 1.0 | 1.2 | 0.8 |
| | | | F | 0.8 | 1.2 | 1.3 | 0.7 | 0.9 | 1.1 | 0.9 | 0.9 | 1.1 | 1.3 | 0.7 |
| | | | Both | 1.0 | 1.0 | 1.2 | 0.8 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.2 | 0.8 |

## Table B4- 5 Level-B analysis on transverse cracking

| Transverse cracking | | | Effect of PCC thickness | | | | | | | | | | | | Effect of drainage | | | | | | | | Effect of Base type | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | D | | | | ND | | | | | | | | | | | | | | | | 8 | | | | | | 11 | | | | | |
| | | | PATB | | | | DGAB | | | | LCB | | | | 8 | | | | 11 | | | | 12 | | | 14 | | | 12 | | | 14 | | |
| | | | 12 | | 14 | | 12 | | 14 | | 12 | | 14 | | 12 | | 14 | | 12 | | 14 | | D | ND | | D | ND | | D | ND | | D | ND | |
| **Zone** | **State** | **SG** | **8** | **11** | **8** | **11** | **8** | **11** | **8** | **11** | **8** | **11** | **8** | **11** | **D** | **ND** | **D** | **ND** | **D** | **ND** | **D** | **ND** | **PATB** | **DGAB** | **LCB** | **PATB** | **DGAB** | **LCB** | **PATB** | **DGAB** | **LCB** | **PATB** | **DGAB** | **LCB** |
| **DF** | **8** | **C** | | X | | X | X | | | X | | X | | | | X | | | X | | 1.0 | 1.0 | | X | | | | | 1.0 | | 1.0 | 1.0 | 1.0 | |
| | | **F** | X | | X | | | X | X | | X | | 1.0 | 1.0 | X | | 1.0 | 1.0 | | X | | X | 0.3 | | 1.7 | 1.0 | 1.0 | 1.0 | | X | | | | X |
| | **32** | **C** | | | | | X | | | | X | | | | | X | | | | | | | | 0.3 | 1.7 | | | | | | | | | |
| | | **F** | X | | 1.8 | 0.2 | | X | 0.5 | 1.5 | | X | 1.8 | 0.2 | X | | 0.5 | 1.5 | | X | 0.0 | 2.0 | X | | | 0.4 | 0.8 | 1.8 | | 0.8 | 1.2 | 0.1 | 2.7 | 0.2 |
| | **53** | **F** | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 | 0.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 0.0 | 3.0 | 0.0 | 0.0 | 3.0 | 1.0 | 1.0 | 1.0 | 0.0 | 0.0 | 3.0 |
| **DNF** | **4** | **C** | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.8 | 0.2 | 1.8 | 0.2 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 0.0 | 3.0 | 0.0 | 0.0 | 3.0 | 0.0 | 0.0 | 3.0 | 0.0 | 0.0 | 3.0 |
| | **6** | **C** | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 | 0.0 | 1.7 | 0.3 | 1.8 | 0.2 | 1.8 | 0.2 | 0.0 | 2.0 | 0.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 1.1 | 1.9 | 0.0 | 1.5 | 1.5 | 0.0 | 0.0 | 3.0 | 1.0 | 1.0 | 1.0 |
| **WF** | **10** | **C** | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 | 0.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 0.0 | 3.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| | **19** | **F** | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 | 0.0 | 2.0 | 0.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 0.0 | 3.0 | 0.0 | 0.0 | 3.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| | **20** | **F** | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 | 0.0 | 2.0 | 0.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 2.0 | 0.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 3.0 | 0.0 | 0.0 | 3.0 | 0.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| | **26** | **F** | 1.0 | 1.0 | 1.0 | 1.0 | 1.5 | 0.5 | 2.0 | 0.0 | 2.0 | 0.0 | 1.0 | 1.0 | 0.0 | 2.0 | 0.0 | 2.0 | 0.0 | 2.0 | 1.0 | 1.0 | 0.0 | 0.6 | 2.4 | 0.0 | 3.0 | 0.0 | 0.0 | 3.0 | 0.0 | 1.0 | 1.0 | 1.0 |
| | **38** | **F** | 1.0 | 1.0 | 0.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 2.0 | 1.9 | 0.1 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 | 0.0 | 1.0 | 1.0 | 1.0 | 0.0 | 0.0 | 3.0 | 0.0 | 0.0 | 3.0 | 1.5 | 0.0 | 1.5 |
| | **39** | **F** | 0.5 | 1.5 | 2.0 | 0.0 | 1.2 | 0.8 | 2.0 | 0.0 | 2.0 | 0.0 | 2.0 | 0.0 | 0.1 | 1.9 | 0.5 | 1.5 | 0.3 | 1.7 | 1.0 | 1.0 | 0.0 | 0.8 | 2.2 | 0.4 | 1.2 | 1.4 | 0.5 | 2.5 | 0.0 | 1.0 | 1.0 | 1.0 |
| | **55** | **C** | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| **WNF** | **5** | **C** | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 | 0.0 | 2.0 | 0.0 | 2.0 | 0.0 | 1.0 | 1.0 | 0.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 0.0 | 3.0 | 0.0 | 1.6 | 1.4 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| | **37** | **F** | 1.0 | 1.0 | 2.0 | 0.0 | 2.0 | 0.0 | 1.0 | 1.0 | 2.0 | 0.0 | 1.0 | 1.0 | 0.0 | 2.0 | 2.0 | 0.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 0.1 | 2.9 | 3.0 | 0.0 | 0.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| **Average** | **DF** | | X | X | X | X | X | X | X | X | X | X | 1.0 | 1.0 | X | 0.0 | 1.0 | 1.0 | X | 0.0 | 1.0 | 1.0 | X | X | X | X | X | X | 1.0 | X | 1.0 | 1.0 | 1.0 | X |
| | **DNF** | | 1.0 | 1.0 | 1.0 | 1.0 | 1.5 | 0.5 | 1.3 | 0.7 | 1.8 | 0.2 | 1.8 | 0.2 | 0.5 | 1.5 | 0.5 | 1.5 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 0.6 | 2.4 | 0.0 | 0.7 | 2.3 | 0.0 | 0.0 | 3.0 | 0.5 | 0.5 | 2.0 |
| | **WF** | **C** | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.5 | 0.5 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.5 | 0.5 | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| | | **F** | 0.9 | 1.1 | 1.0 | 1.0 | 1.3 | 0.7 | 1.6 | 0.4 | 1.4 | 0.6 | 1.6 | 0.4 | 0.4 | 1.6 | 0.5 | 1.5 | 0.7 | 1.3 | 1.2 | 0.8 | 0.2 | 1.1 | 1.7 | 0.1 | 1.4 | 1.5 | 0.5 | 1.5 | 1.0 | 1.1 | 0.8 | 1.1 |
| | | Both | 0.9 | 1.1 | 1.0 | 1.0 | 1.2 | 0.8 | 1.4 | 0.6 | 1.4 | 0.6 | 1.4 | 0.6 | 0.6 | 1.4 | 0.6 | 1.4 | 0.8 | 1.2 | 1.1 | 0.9 | 0.3 | 0.9 | 1.8 | 0.3 | 1.3 | 1.3 | 0.6 | 1.4 | 1.0 | 1.1 | 0.9 | 1.1 |
| | **WNF** | | 1.0 | 1.0 | 1.5 | 0.5 | 1.5 | 0.5 | 1.5 | 0.5 | 2.0 | 0.0 | 1.5 | 0.5 | 0.5 | 1.5 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 0.0 | 3.0 | 1.5 | 0.8 | 0.7 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| | **Overall** | **C** | 1.0 | 1.0 | 1.0 | 1.0 | 1.2 | 0.8 | 1.3 | 0.7 | 1.7 | 0.3 | 1.5 | 0.5 | 0.8 | 1.2 | 0.6 | 1.4 | #VALUE! | 0.8 | 1.0 | 1.0 | 0.2 | 0.4 | 2.4 | 0.4 | 1.0 | 1.6 | 0.6 | 0.6 | 1.7 | 0.8 | 0.8 | 1.4 |
| | | **F** | 1.0 | 1.0 | 1.0 | 1.0 | 1.4 | 0.6 | 1.3 | 0.7 | 1.5 | 0.5 | 1.3 | 0.7 | #VALUE! | 1.3 | 0.9 | 1.1 | 0.8 | 1.2 | 1.2 | 0.8 | 0.2 | 0.8 | 2.0 | 0.6 | 1.0 | 1.4 | 0.7 | 1.2 | 1.2 | 0.9 | 0.7 | 1.4 |
| | | **Both** | 1.0 | 1.0 | 1.1 | 0.9 | 1.3 | 0.7 | 1.3 | 0.7 | 1.6 | 0.4 | 1.5 | 0.5 | 0.6 | 1.4 | 0.7 | 1.3 | 0.9 | 1.1 | 1.0 | 1.0 | 0.2 | 0.6 | 2.1 | 0.5 | 1.0 | 1.5 | 0.7 | 1.0 | 1.3 | 0.8 | 0.9 | 1.3 |

## Table B4- 6 Level-B analysis on IRI

| IRI | | | Effect of PCC thickness | | | | | | | | | | | | Effect of drainage | | | | | | | | Effect of Base type | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | D | | | | ND | | | | | | | | | | | | | | | | 8 | | | | | | 11 | | | | | |
| | | | PATB | | | | DGAB | | | | LCB | | | | 8 | | | | 11 | | | | 12 | | | 14 | | | 12 | | | 14 | | |
| | | | 12 | | 14 | | 12 | | 14 | | 12 | | 14 | | 12 | | 14 | | 12 | | 14 | | D | ND | | D | ND | | D | ND | | D | ND | |
| **Zone** | **State** | **SG** | **8** | **11** | **8** | **11** | **8** | **11** | **8** | **11** | **8** | **11** | **8** | **11** | **D** | **ND** | **D** | **ND** | **D** | **ND** | **D** | **ND** | **PATB** | **DGAB** | **LCB** | **PATB** | **DGAB** | **LCB** | **PATB** | **DGAB** | **LCB** | **PATB** | **DGAB** | **LCB** |
| **DF** | **8** | **C** | | X | | X | X | | | X | | X | | | | X | | | X | | 1.2 | 0.8 | | X | | | | | 1.0 | | 1.0 | 1.2 | 0.8 | |
| | | **F** | X | | X | | | X | X | | X | | 1.0 | 1.0 | X | | 1.1 | 0.9 | | X | | X | 1.0 | | 1.0 | 1.0 | 0.8 | 1.2 | | X | | | | X |
| | **32** | **C** | | | | | X | | | | X | | | | | X | | | | | | | | 1.2 | 0.8 | | | | | | | | | |
| | | **F** | X | | 1.1 | 0.9 | | X | 1.3 | 0.7 | | X | 1.1 | 0.9 | X | | 0.8 | 1.2 | | X | 1.1 | 0.9 | X | | | 0.9 | 1.2 | 0.9 | | 1.1 | 0.9 | 1.0 | 0.9 | 1.1 |
| | **53** | **F** | 1.1 | 0.9 | 0.9 | 1.1 | 1.1 | 0.9 | 0.9 | 1.1 | 0.9 | 1.1 | 1.1 | 0.9 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 | 1.1 | 1.0 | 1.0 | 0.9 | 0.7 | 0.8 | 1.5 | 0.9 | 1.0 | 1.1 | 0.9 | 1.1 | 1.1 |
| **DNF** | **4** | **C** | 0.9 | 1.1 | 1.1 | 0.9 | 0.8 | 1.2 | 1.1 | 0.9 | 0.8 | 1.2 | 1.1 | 0.9 | 0.9 | 1.1 | 0.8 | 1.2 | 0.9 | 1.1 | 0.9 | 1.1 | 1.0 | 1.1 | 1.0 | 0.9 | 1.3 | 0.9 | 0.9 | 1.2 | 0.9 | 0.9 | 1.1 | 0.9 |
| | **6** | **C** | 1.0 | 1.0 | 0.8 | 1.2 | 0.9 | 1.1 | 0.9 | 1.1 | 0.8 | 1.2 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 | 1.1 | 0.9 | 1.1 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 | 0.9 | 1.0 | 1.1 | 0.9 | 1.1 | 1.1 | 1.0 | 1.0 | 1.0 |
| **WF** | **10** | **C** | 0.7 | 1.3 | 1.1 | 0.9 | 0.9 | 1.1 | 0.9 | 1.1 | 0.8 | 1.2 | 0.8 | 1.2 | 0.8 | 1.2 | 1.1 | 0.9 | 1.0 | 1.0 | 0.9 | 1.1 | 0.7 | 1.1 | 1.1 | 1.1 | 1.0 | 0.9 | 1.0 | 0.9 | 1.1 | 0.8 | 1.0 | 1.2 |
| | **19** | **F** | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 | 1.1 | 0.9 | 1.1 | 1.0 | 1.0 | 1.2 | 0.8 | 1.1 | 0.9 | 1.1 | 0.9 | 1.1 | 0.9 | 0.9 | 1.1 | 1.2 | 0.9 | 0.9 | 1.0 | 0.8 | 1.2 | 1.2 | 1.0 | 0.8 | 1.0 | 1.1 | 0.9 |
| | **20** | **F** | 0.8 | 1.2 | 1.1 | 0.9 | 1.1 | 0.9 | 0.8 | 1.2 | 0.8 | 1.2 | 1.0 | 1.0 | 0.8 | 1.2 | 1.2 | 0.8 | 1.1 | 0.9 | 0.9 | 1.1 | 0.8 | 1.2 | 1.0 | 1.1 | 0.7 | 1.2 | 1.0 | 0.8 | 1.2 | 0.9 | 1.0 | 1.1 |
| | **26** | **F** | 1.1 | 0.9 | 1.0 | 1.0 | 1.2 | 0.8 | 1.0 | 1.0 | 1.3 | 0.7 | 1.0 | 1.0 | 0.6 | 1.4 | 0.8 | 1.2 | 0.7 | 1.3 | 0.8 | 1.2 | 0.6 | 1.3 | 1.1 | 0.8 | 1.1 | 1.1 | 0.8 | 1.3 | 0.9 | 0.8 | 1.1 | 1.1 |
| | **38** | **F** | 1.0 | 1.0 | 0.8 | 1.2 | 0.8 | 1.2 | 0.8 | 1.2 | 1.0 | 1.0 | 1.0 | 1.0 | 1.1 | 0.9 | 1.0 | 1.0 | 0.9 | 1.1 | 1.1 | 0.9 | 1.0 | 0.9 | 1.1 | 1.0 | 0.9 | 1.1 | 0.9 | 1.2 | 0.9 | 1.1 | 1.0 | 0.9 |
| | **39** | **F** | 1.0 | 1.0 | 0.9 | 1.1 | 1.2 | 0.8 | 1.1 | 0.9 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 | 1.1 | 0.9 | 1.1 | 1.0 | 1.0 | 1.1 | 0.9 | 0.8 | 1.1 | 1.1 | 0.8 | 1.1 | 1.1 | 0.9 | 0.9 | 1.2 | 1.1 | 0.9 | 1.1 |
| | **55** | **C** | 1.1 | 0.9 | 1.1 | 0.9 | 1.0 | 1.0 | 0.9 | 1.1 | 1.1 | 0.9 | 0.8 | 1.2 | 1.1 | 0.9 | 1.0 | 1.0 | 1.0 | 1.0 | 0.8 | 1.2 | 1.2 | 1.0 | 0.8 | 1.1 | 1.1 | 0.7 | 1.0 | 1.0 | 1.0 | 0.8 | 1.2 | 1.0 |
| **WNF** | **5** | **C** | 1.0 | 1.0 | 0.8 | 1.2 | 1.2 | 0.8 | 0.9 | 1.1 | 1.0 | 1.0 | 0.9 | 1.1 | 0.7 | 1.3 | 0.8 | 1.2 | 0.9 | 1.1 | 0.9 | 1.1 | 0.7 | 1.4 | 0.9 | 0.8 | 1.1 | 1.0 | 0.8 | 1.1 | 1.1 | 0.9 | 1.0 | 1.0 |
| | **37** | **F** | 1.1 | 0.9 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 | 1.1 | 1.0 | 1.0 | 0.9 | 1.1 | 0.9 | 1.1 | 0.9 | 1.1 | 0.9 | 1.1 | 0.8 | 1.2 | 0.8 | 0.9 | 1.2 | 0.9 | 1.1 | 1.0 | 0.8 | 0.9 | 1.3 | 0.8 | 1.1 | 1.1 |
| **Average** | **DF** | | X | X | X | X | X | X | X | X | X | X | 1.0 | 1.0 | X | 0.0 | 1.1 | 0.9 | X | 0.0 | 1.2 | 0.8 | X | X | X | X | X | X | 1.0 | X | 1.0 | 1.2 | 0.8 | X |
| | **DNF** | | 0.9 | 1.1 | 0.9 | 1.1 | 0.8 | 1.2 | 1.0 | 1.0 | 0.8 | 1.2 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 | 1.1 | 0.9 | 1.1 | 1.0 | 1.0 | 1.0 | 1.1 | 0.9 | 0.9 | 1.1 | 1.0 | 0.9 | 1.1 | 1.0 | 1.0 | 1.1 | 1.0 |
| | **WF** | **C** | 0.9 | 1.1 | 1.1 | 0.9 | 1.0 | 1.0 | 0.9 | 1.1 | 1.0 | 1.0 | 0.8 | 1.2 | 0.9 | 1.1 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 | 1.1 | 1.0 | 1.1 | 1.0 | 1.1 | 1.1 | 0.8 | 1.0 | 1.0 | 1.0 | 0.8 | 1.1 | 1.1 |
| | | **F** | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 | 1.1 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 | 1.1 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 | 1.1 | 1.0 | 0.9 | 0.9 | 1.1 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| | | Both | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 | 1.1 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 | 1.1 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 | 1.1 | 0.9 | 1.1 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 | 1.0 | 1.0 |
| | **WNF** | | 1.0 | 1.0 | 0.9 | 1.1 | 1.1 | 0.9 | 0.9 | 1.1 | 1.0 | 1.0 | 0.9 | 1.1 | 0.8 | 1.2 | 0.9 | 1.1 | 0.9 | 1.1 | 0.9 | 1.1 | 0.8 | 1.2 | 1.1 | 0.9 | 1.1 | 1.0 | 0.8 | 1.0 | 1.2 | 0.8 | 1.1 | 1.1 |
| | **Overall** | **C** | 0.9 | 1.1 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 | 1.1 | 0.9 | 1.1 | 0.9 | 1.1 | 0.9 | 1.1 | 0.9 | 1.1 | #VALUE! | 0.9 | 1.0 | 1.0 | 0.9 | 1.1 | 1.0 | 1.0 | 1.1 | 0.9 | 0.9 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| | | **F** | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 | 1.1 | 1.0 | 1.0 | 1.0 | 1.0 | #VALUE! | 0.9 | 1.0 | 1.0 | 0.9 | 1.1 | 0.9 | 1.1 | 0.9 | 1.0 | 1.0 | 0.9 | 0.9 | 1.2 | 0.9 | 1.0 | 1.0 | 0.9 | 1.1 | 1.0 |
| | | **Both** | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 | 1.1 | 1.0 | 1.0 | 0.9 | 1.1 | 1.0 | 1.0 | 0.9 | 1.1 | 1.0 | 0.9 | 1.0 | 1.1 | 0.9 | 1.0 | 1.0 | 0.9 | 1.0 | 1.0 |

## Table B4- 7 Level-B analysis on longitudinal cracking

| Longitudinal Cracking | | | Effect of PCC thickness | | | | | | | | | | | | Effect of drainage | | | | | | | | Effect of Base type | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | D | | | | ND | | | | | | | | | | | | | | | | 8 | | | | | | 11 | | | | | |
| | | | PATB | | | | DGAB | | | | LCB | | | | 8 | | | | 11 | | | | 12 | | | 14 | | | 12 | | | 14 | | |
| | | | 12 | | 14 | | 12 | | 14 | | 12 | | 14 | | 12 | | 14 | | 12 | | 14 | | D | ND | | D | ND | | D | ND | | D | ND | |
| **Zone** | **State** | **SG** | **8** | **11** | **8** | **11** | **8** | **11** | **8** | **11** | **8** | **11** | **8** | **11** | **D** | **ND** | **D** | **ND** | **D** | **ND** | **D** | **ND** | **PATB** | **DGAB** | **LCB** | **PATB** | **DGAB** | **LCB** | **PATB** | **DGAB** | **LCB** | **PATB** | **DGAB** | **LCB** |
| **DF** | **8** | **C** | | X | | X | X | | | X | | X | | | | X | | | X | | 1.0 | 1.0 | | X | | | | | 1.0 | | 1.0 | 1.0 | 1.0 | |
| | | **F** | X | | X | | | X | X | | X | | 2.0 | 0.0 | X | | 1.1 | 0.9 | | X | | X | 2.0 | | 0.0 | 0.1 | 0.1 | 2.0 | | X | | | | X |
| | **32** | **C** | | | | | X | | | | X | | | | | X | | | | | | | | 0.6 | 1.4 | | | | | | | | | |
| | | **F** | X | | 1.8 | 0.2 | | X | 1.2 | 0.8 | | X | 1.8 | 0.2 | X | | 0.3 | 1.7 | | X | 0.1 | 1.9 | X | | | 0.2 | 1.1 | 1.7 | | 0.8 | 1.2 | 0.1 | 2.5 | 0.4 |
| | **53** | **F** | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 | 0.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 0.0 | 3.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| **DNF** | **4** | **C** | 2.0 | 0.0 | 1.9 | 0.1 | 1.0 | 1.0 | 2.0 | 0.0 | 2.0 | 0.0 | 2.0 | 0.0 | 2.0 | 0.0 | 0.4 | 1.6 | 1.0 | 1.0 | 2.0 | 0.0 | 0.5 | 0.0 | 2.5 | 0.3 | 1.1 | 1.6 | 0.0 | 0.0 | 3.0 | 2.0 | 0.0 | 1.0 |
| | **6** | **C** | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 0.0 | 3.0 | 1.0 | 1.0 | 1.0 | 0.0 | 0.0 | 3.0 | 1.0 | 1.0 | 1.0 |
| **WF** | **10** | **C** | 2.0 | 0.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 | 0.0 | 0.0 | 2.0 | 2.0 | 0.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 0.0 | 3.0 |
| | **19** | **F** | 2.0 | 0.0 | 0.0 | 2.0 | 1.0 | 1.0 | 2.0 | 0.0 | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 | 0.0 | 0.0 | 2.0 | 1.0 | 1.0 | 2.0 | 0.0 | 3.0 | 0.0 | 0.0 | 0.0 | 3.0 | 0.0 | 1.0 | 1.0 | 1.0 | 3.0 | 0.0 | 0.0 |
| | **20** | **F** | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 | 0.0 | 1.0 | 1.0 | 1.3 | 0.7 | 2.0 | 0.0 | 0.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 2.8 | 0.2 | 0.0 | 0.0 | 3.0 | 0.0 | 0.0 | 3.0 | 1.0 | 1.0 | 1.0 |
| | **26** | **F** | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 | 0.0 | 1.0 | 1.0 | 2.0 | 0.0 | 2.0 | 0.0 | 0.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 0.8 | 2.2 | 0.0 | 0.0 | 3.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| | **38** | **F** | 1.0 | 1.0 | 0.0 | 2.0 | 1.3 | 0.7 | 0.0 | 2.0 | 2.0 | 0.0 | 2.0 | 0.0 | 0.0 | 2.0 | 1.0 | 1.0 | 0.0 | 2.0 | 2.0 | 0.0 | 0.0 | 0.1 | 2.9 | 0.0 | 0.0 | 3.0 | 0.0 | 3.0 | 0.0 | 2.9 | 0.1 | 0.0 |
| | **39** | **F** | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 | 0.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 0.0 | 3.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| | **55** | **C** | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| **WNF** | **5** | **C** | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 | 0.0 | 2.0 | 0.0 | 2.0 | 0.0 | 1.0 | 1.0 | 0.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 0.0 | 3.0 | 0.0 | 1.7 | 1.3 | 0.0 | 0.0 | 3.0 | 1.0 | 1.0 | 1.0 |
| | **37** | **F** | 1.0 | 1.0 | 2.0 | 0.0 | 2.0 | 0.0 | 2.0 | 0.0 | 2.0 | 0.0 | 1.0 | 1.0 | 0.0 | 2.0 | 1.4 | 0.6 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 0.2 | 2.8 | 2.0 | 1.0 | 0.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| **Average** | **DF** | | X | X | X | X | X | X | X | X | X | X | 2.0 | 0.0 | X | 0.0 | 1.1 | 0.9 | X | 0.0 | 1.0 | 1.0 | X | X | X | X | X | X | 1.0 | X | 1.0 | 1.0 | 1.0 | X |
| | **DNF** | | 1.5 | 0.5 | 1.4 | 0.6 | 1.0 | 1.0 | 1.5 | 0.5 | 1.0 | 1.0 | 1.5 | 0.5 | 1.5 | 0.5 | 0.7 | 1.3 | 1.0 | 1.0 | 1.5 | 0.5 | 0.2 | 0.0 | 2.8 | 0.6 | 1.0 | 1.3 | 0.0 | 0.0 | 3.0 | 1.5 | 0.5 | 1.0 |
| | **WF** | **C** | 1.5 | 0.5 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.5 | 0.5 | 0.5 | 1.5 | 1.5 | 0.5 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.5 | 1.5 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.5 | 0.5 | 2.0 |
| | | **F** | 1.2 | 0.8 | 0.6 | 1.4 | 1.5 | 0.5 | 1.0 | 1.0 | 1.5 | 0.5 | 1.8 | 0.2 | 0.6 | 1.4 | 0.8 | 1.2 | 0.8 | 1.2 | 1.4 | 0.6 | 0.8 | 0.9 | 1.3 | 0.0 | 0.6 | 2.4 | 0.6 | 1.2 | 1.2 | 1.8 | 0.6 | 0.6 |
| | | Both | 1.3 | 0.7 | 0.7 | 1.3 | 1.3 | 0.7 | 1.0 | 1.0 | 1.5 | 0.5 | 1.4 | 0.6 | 0.9 | 1.1 | 0.9 | 1.1 | 0.9 | 1.1 | 1.3 | 0.7 | 0.9 | 0.8 | 1.3 | 0.3 | 0.7 | 2.0 | 0.7 | 1.1 | 1.1 | 1.4 | 0.6 | 1.0 |
| | **WNF** | | 1.0 | 1.0 | 1.5 | 0.5 | 1.5 | 0.5 | 2.0 | 0.0 | 2.0 | 0.0 | 1.5 | 0.5 | 0.5 | 1.5 | 0.7 | 1.3 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 0.1 | 2.9 | 1.0 | 1.4 | 0.6 | 0.5 | 0.5 | 2.0 | 1.0 | 1.0 | 1.0 |
| | **Overall** | **C** | 1.4 | 0.6 | 1.2 | 0.8 | 1.0 | 1.0 | 1.4 | 0.6 | 1.4 | 0.6 | 1.2 | 0.8 | 1.4 | 0.6 | 0.7 | 1.3 | #VALUE! | 0.8 | 1.2 | 0.8 | 0.5 | 0.2 | 2.3 | 0.7 | 1.2 | 1.2 | 0.4 | 0.4 | 2.0 | 1.0 | 0.7 | 1.4 |
| | | **F** | 1.2 | 0.8 | 0.8 | 1.2 | 1.6 | 0.4 | 1.2 | 0.8 | 1.5 | 0.5 | 1.7 | 0.3 | #VALUE! | 1.3 | 0.9 | 1.1 | 0.8 | 1.2 | 1.3 | 0.7 | 0.9 | 0.8 | 1.3 | 0.3 | 0.6 | 2.0 | 0.7 | 1.2 | 1.2 | 1.7 | 0.7 | 0.7 |
| | | **Both** | 1.3 | 0.8 | 1.0 | 1.0 | 1.3 | 0.7 | 1.2 | 0.8 | 1.4 | 0.6 | 1.6 | 0.4 | 0.9 | 1.1 | 0.8 | 1.2 | 0.9 | 1.1 | 1.1 | 0.9 | 0.7 | 0.6 | 1.6 | 0.4 | 0.8 | 1.8 | 0.6 | 0.8 | 1.5 | 1.2 | 0.8 | 1.0 |

## Table B4- 8 Level-B analysis on faulting

| Faulting | | | Effect of PCC thickness | | | | | | | | | | | | Effect of drainage | | | | | | | | Effect of Base type | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | D | | | | ND | | | | | | | | | | | | | | | | 8 | | | | | | 11 | | | | | | | | | | | |
| | | | PATB | | | | DGAB | | | | LCB | | | | 8 | | | | 11 | | | | 12 | | | 14 | | | 12 | | | 14 | | | | | | | | |
| | | | 12 | | 14 | | 12 | | 14 | | 12 | | 14 | | 12 | | 14 | | 12 | | 14 | | D | ND | | D | ND | | D | ND | | D | ND | | | | | | | |
| Clim. Zone | State | subgrade type | 8 | 11 | 8 | 11 | 8 | 11 | 8 | 11 | 8 | 11 | 8 | 11 | D | ND | D | ND | D | ND | D | ND | PATB | DGAB | LCB | PATB | DGAB | LCB | PATB | DGAB | LCB | PATB | DGAB | LCB | | | | | | |
| DF | 8 | C | | X | | X | X | | | X | | X | | | | X | | | X | | 1.9 | 0.1 | | X | | | | | 1.2 | | 0.8 | 1.9 | 0.1 | | | | | | | |
| | | F | X | | X | | | X | X | | X | | 1.2 | 0.8 | X | | 0.9 | 1.1 | | X | | X | 0.1 | | 1.9 | 0.3 | 0.4 | 2.0 | | X | | | | X | | | | | | |
| | 32 | C | | | | | X | | | | X | | | | | X | | | | | | | | 0.9 | 1.1 | | | | | | | | | | | | | | | |
| | | F | X | | 1.1 | 0.9 | | X | 1.2 | 0.8 | | X | 0.0 | 2.0 | X | | 0.5 | 1.5 | | X | 0.5 | 1.5 | X | | | 0.7 | 2.3 | 0.0 | | 1.2 | 0.8 | 0.4 | 1.2 | 1.4 | | | | | | |
| | 53 | F | 0.4 | 1.6 | 0.9 | 1.1 | 1.1 | 0.9 | 1.2 | 0.8 | 1.0 | 1.0 | 2.0 | 0.0 | 0.5 | 1.5 | 0.9 | 1.1 | 1.3 | 0.7 | 1.2 | 0.8 | 0.5 | 1.8 | 0.7 | 1.0 | 1.2 | 0.8 | 1.6 | 0.9 | 0.5 | 1.8 | 1.2 | 0.0 | | | | | | |
| DNF | 4 | C | 0.0 | 2.0 | 2.0 | 0.0 | 0.6 | 1.4 | 0.0 | 2.0 | 0.5 | 1.5 | 0.3 | 1.7 | 0.0 | 2.0 | 2.0 | 0.0 | 1.3 | 0.7 | 0.0 | 2.0 | 0.0 | 1.3 | 1.7 | 2.5 | 0.0 | 0.5 | 1.2 | 0.7 | 1.1 | 0.0 | 2.3 | 0.7 | | | | | | |
| | 6 | C | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 | 0.0 | 2.0 | 0.0 | 1.0 | 1.0 | 2.0 | 0.0 | 1.0 | 1.0 | 0.0 | 2.0 | 2.0 | 0.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 2.3 | 0.7 | 1.5 | 0.0 | 1.5 | 1.0 | 1.0 | 1.0 | | | | | | |
| WF | 10 | C | 1.4 | 0.6 | 2.0 | 0.0 | 2.0 | 0.0 | 1.5 | 0.5 | 2.0 | 0.0 | 2.0 | 0.0 | 1.1 | 0.9 | 1.3 | 0.7 | 2.0 | 0.0 | 0.0 | 2.0 | 0.8 | 0.7 | 1.5 | 1.4 | 0.8 | 0.8 | 3.0 | 0.0 | 0.0 | 0.0 | 3.0 | 0.0 | | | | | | |
| | 19 | F | 1.0 | 1.0 | 1.6 | 0.4 | 1.2 | 0.8 | 0.0 | 2.0 | 2.0 | 0.0 | 1.0 | 1.0 | 0.0 | 2.0 | 2.0 | 0.0 | 0.0 | 2.0 | 0.4 | 1.6 | 0.0 | 2.5 | 0.5 | 3.0 | 0.0 | 0.0 | 0.0 | 3.0 | 0.0 | 0.6 | 2.4 | 0.0 | | | | | | |
| | 20 | F | 0.0 | 2.0 | 2.0 | 0.0 | 1.7 | 0.3 | 0.7 | 1.3 | 0.7 | 1.3 | 1.7 | 0.3 | 0.0 | 2.0 | 1.0 | 1.0 | 1.5 | 0.5 | 0.0 | 2.0 | 0.0 | 2.6 | 0.4 | 0.4 | 0.4 | 2.2 | 1.4 | 0.5 | 1.0 | 0.0 | 2.0 | 1.0 | | | | | | |
| | 26 | F | 1.5 | 0.5 | 2.0 | 0.0 | 0.2 | 1.8 | 2.0 | 0.0 | 2.0 | 0.0 | 0.0 | 2.0 | 1.2 | 0.8 | 0.1 | 1.9 | 0.1 | 1.9 | 1.0 | 1.0 | 1.1 | 0.7 | 1.2 | 0.1 | 2.9 | 0.0 | 0.2 | 2.8 | 0.0 | 0.0 | 0.0 | 3.0 | | | | | | |
| | 38 | F | 0.0 | 2.0 | 0.0 | 2.0 | 0.6 | 1.4 | 0.3 | 1.7 | 0.0 | 2.0 | 0.6 | 1.4 | 0.0 | 2.0 | 0.0 | 2.0 | 0.1 | 1.9 | 0.9 | 1.1 | 0.0 | 3.0 | 0.0 | 0.0 | 0.9 | 2.1 | 0.1 | 1.5 | 1.4 | 0.8 | 1.0 | 1.2 | | | | | | |
| | 39 | F | 0.4 | 1.6 | 1.0 | 1.0 | 0.0 | 2.0 | 1.0 | 1.0 | 2.0 | 0.0 | 1.0 | 1.0 | 2.0 | 0.0 | 2.0 | 0.0 | 1.3 | 0.7 | 2.0 | 0.0 | 0.3 | 0.0 | 2.7 | 3.0 | 0.0 | 0.0 | 2.0 | 1.0 | 0.0 | 3.0 | 0.0 | 0.0 | | | | | | |
| | 55 | C | 2.0 | 0.0 | 1.0 | 1.0 | 2.0 | 0.0 | 0.7 | 1.3 | 1.0 | 1.0 | 0.0 | 2.0 | 2.0 | 0.0 | 0.0 | 2.0 | 1.0 | 1.0 | 0.0 | 2.0 | 2.9 | 0.1 | 0.0 | 0.0 | 3.0 | 0.0 | 1.0 | 1.0 | 1.0 | 0.0 | 1.9 | 1.1 | | | | | | |
| WNF | 5 | C | 1.6 | 0.4 | 0.4 | 1.6 | 0.5 | 1.5 | 1.7 | 0.3 | 0.3 | 1.7 | 0.1 | 1.9 | 1.0 | 1.0 | 0.3 | 1.7 | 0.2 | 1.8 | 1.6 | 0.4 | 1.5 | 1.4 | 0.1 | 0.4 | 2.6 | 0.1 | 0.2 | 2.4 | 0.4 | 1.6 | 0.4 | 0.9 | | | | | | |
| | 37 | F | 0.1 | 1.9 | 0.3 | 1.7 | 0.7 | 1.3 | 0.9 | 1.1 | 2.0 | 0.0 | 2.0 | 0.0 | 0.6 | 1.4 | 0.5 | 1.5 | 1.8 | 0.2 | 1.1 | 0.9 | 0.3 | 0.6 | 2.1 | 0.5 | 1.9 | 0.6 | 2.7 | 0.3 | 0.0 | 1.6 | 1.4 | 0.0 | | | | | | |
| Average | DF | | X | X | X | X | X | X | X | X | X | X | 1.2 | 0.8 | X | 0.0 | 0.9 | 1.1 | X | 0.0 | 1.9 | 0.1 | X | X | X | X | X | X | 1.2 | X | 0.8 | 1.9 | 0.1 | X | | | | | | |
| | DNF | | 0.5 | 1.5 | 1.5 | 0.5 | 1.3 | 0.7 | 1.0 | 1.0 | 0.7 | 1.3 | 1.2 | 0.8 | 0.5 | 1.5 | 1.0 | 1.0 | 1.6 | 0.4 | 0.5 | 1.5 | 0.5 | 1.1 | 1.4 | 1.3 | 1.1 | 0.6 | 1.3 | 0.3 | 1.3 | 0.5 | 1.7 | 0.8 | | | | | | |
| | WF | C | 1.7 | 0.3 | 1.5 | 0.5 | 2.0 | 0.0 | 1.1 | 0.9 | 1.5 | 0.5 | 1.0 | 1.0 | 1.5 | 0.5 | 0.6 | 1.4 | 1.5 | 0.5 | 0.0 | 2.0 | 1.8 | 0.4 | 0.8 | 0.7 | 1.9 | 0.4 | 2.0 | 0.5 | 0.5 | 0.0 | 2.4 | 0.6 | | | | | | |
| | | F | 0.6 | 1.4 | 1.3 | 0.7 | 0.8 | 1.2 | 0.8 | 1.2 | 1.3 | 0.7 | 0.8 | 1.2 | 0.6 | 1.4 | 1.0 | 1.0 | 0.6 | 1.4 | 0.9 | 1.1 | 0.3 | 1.8 | 1.0 | 1.3 | 0.9 | 0.8 | 0.7 | 1.8 | 0.5 | 0.9 | 1.1 | 1.0 | | | | | | |
| | | Both | 0.9 | 1.1 | 1.4 | 0.6 | 1.1 | 0.9 | 0.9 | 1.1 | 1.4 | 0.6 | 0.9 | 1.1 | 0.9 | 1.1 | 0.9 | 1.1 | 0.9 | 1.1 | 0.6 | 1.4 | 0.7 | 1.4 | 0.9 | 1.1 | 1.1 | 0.7 | 1.1 | 1.4 | 0.5 | 0.6 | 1.5 | 0.9 | | | | | | |
| | WNF | | 0.8 | 1.2 | 0.4 | 1.6 | 0.6 | 1.4 | 1.3 | 0.7 | 1.2 | 0.8 | 1.1 | 0.9 | 0.8 | 1.2 | 0.4 | 1.6 | 1.0 | 1.0 | 1.3 | 0.7 | 0.9 | 1.0 | 1.1 | 0.5 | 2.2 | 0.3 | 1.5 | 1.4 | 0.2 | 1.6 | 0.9 | 0.5 | | | | | | |
| | Overall | C | 1.2 | 0.8 | 1.3 | 0.7 | 1.4 | 0.6 | 1.2 | 0.8 | 1.0 | 1.0 | 0.9 | 1.1 | 1.0 | 1.0 | 0.7 | 1.3 | #VALUE! | 0.6 | 0.7 | 1.3 | 1.2 | 0.9 | 0.9 | 0.9 | 1.7 | 0.4 | 1.4 | 0.8 | 0.8 | 0.8 | 1.5 | 0.7 | | | | | | |
| | | F | 0.5 | 1.5 | 1.1 | 0.9 | 0.9 | 1.1 | 0.8 | 1.2 | 1.3 | 0.7 | 1.2 | 0.8 | #VALUE! | 1.4 | 0.8 | 1.2 | 0.8 | 1.2 | 0.8 | 1.2 | 0.3 | 1.9 | 1.0 | 0.8 | 1.1 | 1.1 | 1.0 | 1.5 | 0.5 | 0.8 | 1.3 | 0.9 | | | | | | |
| | | Both | 0.8 | 1.2 | 1.2 | 0.8 | 1.1 | 0.9 | 1.0 | 1.0 | 1.2 | 0.8 | 1.0 | 1.0 | 0.8 | 1.2 | 0.8 | 1.2 | 1.0 | 1.0 | 0.8 | 1.2 | 0.7 | 1.3 | 1.1 | 1.0 | 1.3 | 0.7 | 1.2 | 1.2 | 0.6 | 0.9 | 1.3 | 0.8 | | | | | | |

# APPENDIX B5

## Data Analysis for SPS-2 experiment
(Standard deviate summary tables for various performance measures-Level A & Level B)

Table B5- 1 Standard deviate summary – Change in IRI

| Design Factors | Overall | SG | | Zone | | | | DF | | DNF | WF | | WNF | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | C | F | DF | DNF | WF | WNF | C | F | C | C | F | C | F |
| ND | 0.32 | 0.47 | 0.21 | 0.17 | 0.56 | 0.14 | 0.86 | 0.22 | 0.15 | 0.56 | 0.12 | 0.15 | 1.12 | 0.60 |
| D | -0.36 | -0.35 | -0.37 | -0.84 | -0.16 | -0.32 | -0.26 | -1.41 | -0.65 | -0.16 | -0.16 | -0.38 | -0.83 | -0.07 |
| DGAB | 0.32 | 0.47 | 0.21 | 0.17 | 0.56 | 0.14 | 0.86 | 0.22 | 0.15 | 0.56 | 0.12 | 0.15 | 1.12 | 0.60 |
| LCB | 0.04 | -0.13 | 0.16 | 0.67 | -0.40 | 0.17 | -0.60 | 1.37 | 0.57 | -0.40 | 0.04 | 0.23 | -0.33 | -0.87 |
| PATB | -0.36 | -0.35 | -0.37 | -0.84 | -0.16 | -0.32 | -0.26 | -1.41 | -0.65 | -0.16 | -0.16 | -0.38 | -0.83 | -0.07 |
| 8" | 0.09 | -0.09 | 0.20 | 0.06 | -0.24 | 0.19 | 0.10 | 0.33 | 0.03 | -0.24 | -0.07 | 0.30 | 0.17 | 0.05 |
| 11" | -0.09 | 0.09 | -0.23 | -0.06 | 0.24 | -0.19 | -0.10 | -0.34 | 0.08 | 0.24 | 0.07 | -0.30 | 0.13 | -0.26 |
| 550-psi | 0.00 | 0.09 | -0.07 | 0.04 | -0.11 | 0.08 | -0.24 | -0.08 | 0.07 | -0.11 | 0.37 | -0.03 | -0.02 | -0.41 |
| 900-psi | 0.00 | -0.07 | 0.06 | -0.04 | 0.11 | -0.08 | 0.24 | -0.28 | 0.04 | 0.11 | -0.37 | 0.03 | 0.31 | 0.20 |
| 12' | 0.04 | 0.07 | 0.02 | 0.00 | 0.09 | 0.07 | -0.06 | 0.06 | -0.02 | 0.09 | 0.02 | 0.09 | 0.16 | -0.17 |
| 14' | -0.04 | -0.05 | -0.03 | 0.00 | -0.09 | -0.07 | 0.06 | -0.59 | 0.11 | -0.09 | -0.02 | -0.09 | 0.14 | -0.02 |

Table B5- 2 Standard deviate summary – Wheelpath Faulting

| Design Factors | Overall | SG | | Zone | | | | DF | | DNF | WF | | WNF | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | C | F | DF | DNF | WF | WNF | C | F | C | C | F | C | F |
| ND | 0.15 | 0.06 | 0.20 | -0.25 | 0.20 | 0.19 | 0.34 | -0.88 | -0.04 | 0.20 | -0.21 | 0.35 | 0.82 | -0.14 |
| D | 0.00 | 0.15 | -0.10 | 0.31 | -0.21 | -0.08 | 0.18 | 1.34 | -0.04 | -0.21 | 0.29 | -0.23 | -0.15 | 0.29 |
| DGAB | 0.15 | 0.06 | 0.20 | -0.25 | 0.20 | 0.19 | 0.34 | -0.88 | -0.04 | 0.20 | -0.21 | 0.35 | 0.82 | -0.14 |
| LCB | -0.14 | -0.12 | -0.16 | -0.05 | 0.02 | -0.11 | -0.53 | 0.55 | -0.14 | 0.02 | -0.08 | -0.12 | -0.63 | -0.42 |
| PATB | 0.00 | 0.15 | -0.10 | 0.31 | -0.21 | -0.08 | 0.18 | 1.34 | -0.04 | -0.21 | 0.29 | -0.23 | -0.15 | 0.29 |
| 8" | 0.00 | 0.11 | -0.06 | -0.17 | -0.06 | 0.14 | -0.22 | -0.95 | -0.10 | -0.06 | 0.50 | -0.01 | -0.19 | -0.24 |
| 11" | 0.00 | -0.04 | 0.03 | 0.17 | 0.06 | -0.14 | 0.22 | 0.60 | -0.04 | 0.06 | -0.50 | 0.01 | 0.28 | 0.17 |
| 550-psi | -0.01 | 0.09 | -0.07 | -0.19 | -0.01 | 0.04 | 0.00 | 0.82 | -0.39 | -0.01 | -0.05 | 0.07 | 0.35 | -0.25 |
| 900-psi | 0.01 | -0.02 | 0.03 | 0.19 | 0.01 | -0.04 | 0.00 | -0.06 | 0.27 | 0.01 | 0.05 | -0.07 | -0.25 | 0.18 |
| 12' | 0.22 | 0.25 | 0.20 | 0.30 | 0.22 | 0.21 | 0.16 | 0.23 | 0.33 | 0.22 | 0.27 | 0.19 | 0.29 | 0.09 |
| 14' | -0.22 | -0.18 | -0.25 | -0.30 | -0.22 | -0.21 | -0.16 | 0.39 | -0.44 | -0.22 | -0.27 | -0.19 | -0.11 | -0.20 |

Table B5- 3 Effect of lane width on faulting - Level B

| Base type | Target PCC th | Flex Strength | Lane Width | std. Deviate | Mean | Std. Deviation | N | p-value |
|---|---|---|---|---|---|---|---|---|
| DGAB | 8 | 550 | 12 | 3.2 | 0.9 | 1.0 | 6 | 0.299 |
| | | | 14 | -0.7 | 2.6 | 4.3 | 7 | |
| | | 900 | 12 | 0.4 | 1.3 | 1.7 | 7 | 0.79 |
| | | | 14 | 3.4 | 0.6 | 0.5 | 6 | |
| | 11 | 550 | 12 | 7.1 | 4.5 | 6.4 | 7 | 0.037 |
| | | | 14 | -1.8 | 0.4 | 0.5 | 6 | |
| | | 900 | 12 | -1.8 | 0.3 | 0.3 | 6 | 0.42 |
| | | | 14 | 0.4 | 0.7 | 0.5 | 7 | |
| LCB | 8 | 550 | 12 | 4.8 | 1.5 | 2.0 | 6 | 0.034 |
| | | | 14 | -3.8 | 0.3 | 0.4 | 7 | |
| | | 900 | 12 | -0.7 | 0.9 | 1.3 | 7 | 0.805 |
| | | | 14 | -1.4 | 0.6 | 0.7 | 6 | |
| | 11 | 550 | 12 | 1.7 | 1.1 | 1.2 | 7 | 0.042 |
| | | | 14 | -4.0 | 0.1 | 0.1 | 6 | |
| | | 900 | 12 | -3.1 | 0.2 | 0.2 | 6 | 0.595 |
| | | | 14 | -2.0 | 0.9 | 1.2 | 7 | |
| PATB | 8 | 550 | 12 | -1.9 | 0.6 | 1.0 | 6 | 0.937 |
| | | | 14 | -2.0 | 0.4 | 0.6 | 7 | |
| | | 900 | 12 | 0.1 | 1.9 | 2.4 | 7 | 0.817 |
| | | | 14 | -1.3 | 0.7 | 0.9 | 6 | |
| | 11 | 550 | 12 | -0.1 | 0.8 | 0.8 | 7 | 0.602 |
| | | | 14 | -2.5 | 0.4 | 0.6 | 6 | |
| | | 900 | 12 | 6.5 | 1.5 | 1.9 | 6 | 0.079 |
| | | | 14 | -0.5 | 1.3 | 2.2 | 7 | |

Table B5- 4 Effect of PCC flexural strength on faulting - Level B

| Base type | Target PCC th | Lane Width | Flex Strength | std. Deviate | Mean | Std. Deviation | N | p-value |
|---|---|---|---|---|---|---|---|---|
| DGAB | 8 | 12 | 550 | 3.2 | 0.9 | 1.0 | 6 | 0.397 |
| | | | 900 | 0.4 | 1.3 | 1.7 | 7 | |
| | | 14 | 550 | -0.7 | 2.6 | 4.3 | 7 | 0.619 |
| | | | 900 | 3.4 | 0.6 | 0.5 | 6 | |
| | 11 | 12 | 550 | 7.1 | 4.5 | 6.4 | 7 | 0.059 |
| | | | 900 | -1.8 | 0.3 | 0.3 | 6 | |
| | | 14 | 550 | -1.8 | 0.4 | 0.5 | 6 | 0.252 |
| | | | 900 | 0.4 | 0.7 | 0.5 | 7 | |
| LCB | 8 | 12 | 550 | 4.8 | 1.5 | 2.0 | 6 | 0.202 |
| | | | 900 | -0.7 | 0.9 | 1.3 | 7 | |
| | | 14 | 550 | -3.8 | 0.3 | 0.4 | 7 | 0.157 |
| | | | 900 | -1.4 | 0.6 | 0.7 | 6 | |
| | 11 | 12 | 550 | 1.7 | 1.1 | 1.2 | 7 | 0.204 |
| | | | 900 | -3.1 | 0.2 | 0.2 | 6 | |
| | | 14 | 550 | -4.0 | 0.1 | 0.1 | 6 | 0.009 |
| | | | 900 | -2.0 | 0.9 | 1.2 | 7 | |
| PATB | 8 | 12 | 550 | -1.9 | 0.6 | 1.0 | 6 | 0.692 |
| | | | 900 | 0.1 | 1.9 | 2.4 | 7 | |
| | | 14 | 550 | -2.0 | 0.4 | 0.6 | 7 | 0.73 |
| | | | 900 | -1.3 | 0.7 | 0.9 | 6 | |
| | 11 | 12 | 550 | -0.1 | 0.8 | 0.8 | 7 | 0.109 |
| | | | 900 | 6.5 | 1.5 | 1.9 | 6 | |
| | | 14 | 550 | -2.5 | 0.4 | 0.6 | 6 | 0.634 |
| | | | 900 | -0.5 | 1.3 | 2.2 | 7 | |

Table B5- 5 Effect of PCC slab thickness on faulting - Level B

| Base type | Lane Width | Flex Strength | Target PCC th | std. Deviate | Mean | Std. Deviation | N | p-value |
|---|---|---|---|---|---|---|---|---|
| DGAB | 12 | 550 | 8 | 3.2 | 0.9 | 1.0 | 6 | 0.506 |
| | | | 11 | 7.1 | 4.5 | 6.4 | 7 | |
| | | 900 | 8 | 0.4 | 1.3 | 1.7 | 7 | 0.407 |
| | | | 11 | -1.8 | 0.3 | 0.3 | 6 | |
| | 14 | 550 | 8 | -0.7 | 2.6 | 4.3 | 7 | 0.492 |
| | | | 11 | -1.8 | 0.4 | 0.5 | 6 | |
| | | 900 | 8 | 3.4 | 0.6 | 0.5 | 6 | 0.793 |
| | | | 11 | 0.4 | 0.7 | 0.5 | 7 | |
| LCB | 12 | 550 | 8 | 4.8 | 1.5 | 2.0 | 6 | 0.478 |
| | | | 11 | 1.7 | 1.1 | 1.2 | 7 | |
| | | 900 | 8 | -0.7 | 0.9 | 1.3 | 7 | 0.442 |
| | | | 11 | -3.1 | 0.2 | 0.2 | 6 | |
| | 14 | 550 | 8 | -3.8 | 0.3 | 0.4 | 7 | 0.18 |
| | | | 11 | -4.0 | 0.1 | 0.1 | 6 | |
| | | 900 | 8 | -1.4 | 0.6 | 0.7 | 6 | 0.396 |
| | | | 11 | -2.0 | 0.9 | 1.2 | 7 | |
| PATB | 12 | 550 | 8 | -1.9 | 0.6 | 1.0 | 6 | 0.634 |
| | | | 11 | -0.1 | 0.8 | 0.8 | 7 | |
| | | 900 | 8 | 0.1 | 1.9 | 2.4 | 7 | 0.192 |
| | | | 11 | 6.5 | 1.5 | 1.9 | 6 | |
| | 14 | 550 | 8 | -2.0 | 0.4 | 0.6 | 7 | 0.998 |
| | | | 11 | -2.5 | 0.4 | 0.6 | 6 | |
| | | 900 | 8 | -1.3 | 0.7 | 0.9 | 6 | 0.863 |
| | | | 11 | -0.5 | 1.3 | 2.2 | 7 | |

Table B5- 6 Effect of base type on faulting - Level B

| Lane Width | Flex Strength | Target PCC th | Base type | std. Deviate | Mean | Std. Deviation | N | p-value |
|---|---|---|---|---|---|---|---|---|
| 12 | 550 | 8 | DGAB | 3.2 | 0.9 | 1.0 | 6 | 0.267 |
| | | | LCB | 4.8 | 1.5 | 2.0 | 6 | |
| | | | PATB | -1.9 | 0.6 | 1.0 | 6 | |
| | | 11 | DGAB | 7.1 | 4.5 | 6.4 | 7 | 0.263 |
| | | | LCB | 1.7 | 1.1 | 1.2 | 7 | |
| | | | PATB | -0.1 | 0.8 | 0.8 | 7 | |
| | 900 | 8 | DGAB | 0.4 | 1.3 | 1.7 | 7 | 0.963 |
| | | | LCB | -0.7 | 0.9 | 1.3 | 7 | |
| | | | PATB | 0.1 | 1.9 | 2.4 | 7 | |
| | | 11 | DGAB | -1.8 | 0.3 | 0.3 | 6 | 0.015 |
| | | | LCB | -3.1 | 0.2 | 0.2 | 6 | |
| | | | PATB | 6.5 | 1.5 | 1.9 | 6 | |
| 14 | 550 | 8 | DGAB | -0.7 | 2.6 | 4.3 | 7 | 0.555 |
| | | | LCB | -3.8 | 0.3 | 0.4 | 7 | |
| | | | PATB | -2.0 | 0.4 | 0.6 | 7 | |
| | | 11 | DGAB | -1.8 | 0.4 | 0.5 | 6 | 0.186 |
| | | | LCB | -4.0 | 0.1 | 0.1 | 6 | |
| | | | PATB | -2.5 | 0.4 | 0.6 | 6 | |
| | 900 | 8 | DGAB | 3.4 | 0.6 | 0.5 | 6 | 0.814 |
| | | | LCB | -1.4 | 0.6 | 0.7 | 6 | |
| | | | PATB | -1.3 | 0.7 | 0.9 | 6 | |
| | | 11 | DGAB | 0.4 | 0.7 | 0.5 | 7 | 0.654 |
| | | | LCB | -2.0 | 0.9 | 1.2 | 7 | |
| | | | PATB | -0.5 | 1.3 | 2.2 | 7 | |

Table B5- 7 Effect of lane width on ΔIRI - Level B

| Base type | Target PCC th | Flex Strength | Lane Width | Std. Deviate | Mean | Std. Deviation | N | p-value |
|---|---|---|---|---|---|---|---|---|
| DGAB | 8 | 550 | 12 | 6.7 | 0.3 | 0.2 | 6 | 0.534 |
| | | | 14 | 1.8 | 0.3 | 0.5 | 7 | |
| | | 900 | 12 | 6.0 | 0.6 | 0.8 | 7 | 0.123 |
| | | | 14 | 1.2 | 0.1 | 0.3 | 6 | |
| | 11 | 550 | 12 | 4.5 | 0.7 | 1.3 | 7 | 0.066 |
| | | | 14 | -2.9 | 0.1 | 0.1 | 6 | |
| | | 900 | 12 | 0.9 | 0.2 | 0.2 | 6 | 0.99 |
| | | | 14 | 1.3 | 0.3 | 0.4 | 7 | |
| LCB | 8 | 550 | 12 | -2.1 | 0.1 | 0.2 | 6 | 0.27 |
| | | | 14 | 1.9 | 0.4 | 0.8 | 7 | |
| | | 900 | 12 | -0.7 | 0.3 | 0.8 | 7 | 0.98 |
| | | | 14 | -1.5 | 0.1 | 0.5 | 6 | |
| | 11 | 550 | 12 | 1.0 | 0.1 | 0.2 | 7 | 0.99 |
| | | | 14 | 0.4 | 0.2 | 0.1 | 6 | |
| | | 900 | 12 | 1.6 | 0.2 | 0.3 | 6 | 0.35 |
| | | | 14 | -0.9 | 0.2 | 0.4 | 7 | |
| PATB | 8 | 550 | 12 | -1.1 | 0.1 | 0.1 | 6 | 0.97 |
| | | | 14 | -0.8 | 0.1 | 0.1 | 7 | |
| | | 900 | 12 | -5.5 | 0.0 | 0.2 | 7 | 0.001 |
| | | | 14 | 2.9 | 0.2 | 0.2 | 6 | |
| | 11 | 550 | 12 | -4.6 | 0.0 | 0.2 | 7 | 0.98 |
| | | | 14 | -3.7 | 0.0 | 0.1 | 6 | |
| | | 900 | 12 | -2.4 | 0.1 | 0.1 | 6 | 0.52 |
| | | | 14 | -4.0 | 0.0 | 0.2 | 7 | |

Table B5- 8 Effect of PCC flexural strength on ΔIRI - Level B

| Base type | Target PCC th | Lane Width | Flex Strength | Std. Deviate | Mean | Std. Deviation | N | p-value |
|---|---|---|---|---|---|---|---|---|
| DGAB | 8 | 12 | 550 | 6.7 | 0.3 | 0.2 | 6 | 0.64 |
| | | | 900 | 6.0 | 0.6 | 0.8 | 7 | |
| | | 14 | 550 | 1.8 | 0.3 | 0.5 | 7 | 0.79 |
| | | | 900 | 1.2 | 0.1 | 0.3 | 6 | |
| | 11 | 12 | 550 | 4.5 | 0.7 | 1.3 | 7 | 0.48 |
| | | | 900 | 0.9 | 0.2 | 0.2 | 6 | |
| | | 14 | 550 | -2.9 | 0.1 | 0.1 | 6 | 0.21 |
| | | | 900 | 1.3 | 0.3 | 0.4 | 7 | |
| LCB | 8 | 12 | 550 | -2.1 | 0.1 | 0.2 | 6 | 0.75 |
| | | | 900 | -0.7 | 0.3 | 0.8 | 7 | |
| | | 14 | 550 | 1.9 | 0.4 | 0.8 | 7 | 0.65 |
| | | | 900 | -1.5 | 0.1 | 0.5 | 6 | |
| | 11 | 12 | 550 | 1.0 | 0.1 | 0.2 | 7 | 0.67 |
| | | | 900 | 1.6 | 0.2 | 0.3 | 6 | |
| | | 14 | 550 | 0.4 | 0.2 | 0.1 | 6 | 0.5 |
| | | | 900 | -0.9 | 0.2 | 0.4 | 7 | |
| PATB | 8 | 12 | 550 | -1.1 | 0.1 | 0.1 | 6 | 0.005 |
| | | | 900 | -5.5 | 0.0 | 0.2 | 7 | |
| | | 14 | 550 | -0.8 | 0.1 | 0.1 | 7 | 0.15 |
| | | | 900 | 2.9 | 0.2 | 0.2 | 6 | |
| | 11 | 12 | 550 | -4.6 | 0.0 | 0.2 | 7 | 0.42 |
| | | | 900 | -2.4 | 0.1 | 0.1 | 6 | |
| | | 14 | 550 | -3.7 | 0.0 | 0.1 | 6 | 0.79 |
| | | | 900 | -4.0 | 0.0 | 0.2 | 7 | |

Table B5- 9 Effect of PCC slab thickness on ΔIRI - Level B

| Base type | Lane Width | Flex Strength | Target PCC th | Std. Deviate | Mean | Std. Deviation | N | p-value |
|---|---|---|---|---|---|---|---|---|
| DGAB | 12 | 550 | 8 | 6.7 | 0.3 | 0.2 | 6 | 0.98 |
| | | | 11 | 4.5 | 0.7 | 1.3 | 7 | |
| | | 900 | 8 | 6.0 | 0.6 | 0.8 | 7 | 0.19 |
| | | | 11 | 0.9 | 0.2 | 0.2 | 6 | |
| | 14 | 550 | 8 | 1.8 | 0.3 | 0.5 | 7 | 0.28 |
| | | | 11 | -2.9 | 0.1 | 0.1 | 6 | |
| | | 900 | 8 | 1.2 | 0.1 | 0.3 | 6 | 0.85 |
| | | | 11 | 1.3 | 0.3 | 0.4 | 7 | |
| LCB | 12 | 550 | 8 | -2.1 | 0.1 | 0.2 | 6 | 0.36 |
| | | | 11 | 1.0 | 0.1 | 0.2 | 7 | |
| | | 900 | 8 | -0.7 | 0.3 | 0.8 | 7 | 0.49 |
| | | | 11 | 1.6 | 0.2 | 0.3 | 6 | |
| | 14 | 550 | 8 | 1.9 | 0.4 | 0.8 | 7 | 0.8 |
| | | | 11 | 0.4 | 0.2 | 0.1 | 6 | |
| | | 900 | 8 | -1.5 | 0.1 | 0.5 | 6 | 0.99 |
| | | | 11 | -0.9 | 0.2 | 0.4 | 7 | |
| PATB | 12 | 550 | 8 | -1.1 | 0.1 | 0.1 | 6 | 0.14 |
| | | | 11 | -4.6 | 0.0 | 0.2 | 7 | |
| | | 900 | 8 | -5.5 | 0.0 | 0.2 | 7 | 0.007 |
| | | | 11 | -2.4 | 0.1 | 0.1 | 6 | |
| | 14 | 550 | 8 | -0.8 | 0.1 | 0.1 | 7 | 0.14 |
| | | | 11 | -3.7 | 0.0 | 0.1 | 6 | |
| | | 900 | 8 | 2.9 | 0.2 | 0.2 | 6 | 0.015 |
| | | | 11 | -4.04373867 | 0.0 | 0.2 | 7 | |

Table B5- 10 Effect of base type on ΔIRI - Level B

| Lane Width | Flex Strength | Target PCC th | Base type | Std. Deviate | Mean | Std. Deviation | N | p-value |
|---|---|---|---|---|---|---|---|---|
| 12 | 550 | 8 | DGAB | 6.7 | 0.3 | 0.2 | 6 | 0.067 |
| | | | LCB | -2.1 | 0.1 | 0.2 | 6 | |
| | | | PATB | -1.1 | 0.1 | 0.1 | 6 | |
| | | 11 | DGAB | 4.5 | 0.7 | 1.3 | 7 | 0.051 |
| | | | LCB | 1.0 | 0.1 | 0.2 | 7 | |
| | | | PATB | -4.6 | 0.0 | 0.2 | 7 | |
| | 900 | 8 | DGAB | 6.0 | 0.6 | 0.8 | 7 | 0.006 |
| | | | LCB | -0.7 | 0.3 | 0.8 | 7 | |
| | | | PATB | -5.5 | 0.0 | 0.2 | 7 | |
| | | 11 | DGAB | 0.9 | 0.2 | 0.2 | 6 | 0.338 |
| | | | LCB | 1.6 | 0.2 | 0.3 | 6 | |
| | | | PATB | -2.4 | 0.1 | 0.1 | 6 | |
| 14 | 550 | 8 | DGAB | 1.8 | 0.3 | 0.5 | 7 | 0.726 |
| | | | LCB | 1.9 | 0.4 | 0.8 | 7 | |
| | | | PATB | -0.8 | 0.1 | 0.1 | 7 | |
| | | 11 | DGAB | -2.9 | 0.1 | 0.1 | 6 | 0.096 |
| | | | LCB | 0.4 | 0.2 | 0.1 | 6 | |
| | | | PATB | -3.7 | 0.0 | 0.1 | 6 | |
| | 900 | 8 | DGAB | 1.2 | 0.1 | 0.3 | 6 | 0.715 |
| | | | LCB | -1.5 | 0.1 | 0.5 | 6 | |
| | | | PATB | 2.9 | 0.2 | 0.2 | 6 | |
| | | 11 | DGAB | 1.3 | 0.3 | 0.4 | 7 | 0.187 |
| | | | LCB | -0.9 | 0.2 | 0.4 | 7 | |
| | | | PATB | -4.0 | 0.0 | 0.2 | 7 | |

# APPENDIX C

## Site Summaries for SPS-8 experiment (Inventory/construction details and performance of flexible and rigid pavements)

# Site summaries for flexible pavements in SPS-8 experiment

## Arkansas (5)

### Site Description

The site is located on US-65 Frontage Road in Jefferson County. The ADT at the site is 30 ADT for both the lanes, which is less than stipulated traffic of 100 vehicles per day. The inventory data for the sections are summarized in Table C-1.

**Table C- 1 Inventory data for AR (5)**

| | |
|---|---|
| Site code | 5 |
| Climatic zone | Wet-No-Freeze |
| Average annual precipitation | 1374 mm |
| Average annual freezing index | 46.2 $^{o}$C-days |
| Traffic open date | 1st December 1997 |
| Subgrade soil type | Fine grained |
| Inside shoulder type | AC |
| Outside shoulder type | AC |

### Construction Issues

According to the construction report (December 1998), 'minor deviations' were observed in construction. The following are the main construction issues encountered at the site:

- WIM equipment was not installed and traffic monitoring data was not submitted.
- Thickness exceeded the target thickness at localized areas but the average thickness confirms with specifications.
- Post construction coring was done only on the 18th day after casting, instead of 14th day, because of harsh weather and equipment issues.

### Performance Summary

The pavement performance for this site has been monitored for 5 years. Both flexible pavement sections have not shown any sign of cracking except longitudinal cracking-NWP has just started in section 0804. High initial roughness of 1.14 and 1.39 m/km were observed for sections 0803 and 0804 respectively.

## California (6)

### Site Description

The site California is located on the northbound lane of Sycamore Street which is a low volume traffic frontage road to US-99 at Delhi, about 18 miles south of Modesto, California. The two-way AADT at the site, as per the construction report, is 1240 vehicles. The inventory data for the sections are summarized in Table C-2.

**Table C- 2 Inventory data for CA (6)**

| | |
|---|---|
| Site code | 6 |
| Climatic zone | Dry-No-Freeze |
| Average annual precipitation | 316 mm |
| Average annual freezing index | - $^{o}$C-days |
| Traffic open date | 1st November 1999 |
| Subgrade soil type | Fine grained |
| Inside shoulder type | AC |
| Outside shoulder type | AC |

### Construction Issues

According to the construction report (August 2001), minor deviations occurred at the site. The following are the main construction issues encountered at the site:

- All sections at site are located on gently curving alignment.
- In section 06-A806 shoulder auger probe drilling was performed at the beginning of test section instead of the mid point of the test section.

### Performance Summary

The pavement performance for this site has been monitored only for 3 years. Both flexible pavement sections have not shown any signs of cracking. Initial roughness of 1.0 and 0.94 m/km were observed for sections A805 and A806 respectively.

## Mississippi (28)

### Site Description

The site at Mississippi is located on SR-315 in Panola County. The two flexible sections were laid out on the east and west side of a bridge. The inventory data for the sections are summarized in Table C-3.

**Table C- 3 Inventory data for MS (28)**

| | |
|---|---|
| Site code | 28 |
| Climatic zone | Wet-No-Freeze |
| Average annual precipitation | 1427 mm |
| Average annual freezing index | 57 °C-day |
| Traffic open date | 1st November 1996 |
| Subgrade soil type | Coarse grained |
| Inside shoulder type | AC |
| Outside shoulder type | AC |

### Construction Issues

According to the construction report (Feb 1998), minor deviations occurred at these sites, as summarized below:

- Extra fill material, consisting entirely of base material was dumped on top of subgrade before subgrade sampling and testing.
- Binder mix was substituted for the asphalt concrete base layer.
- Contractor had to cut portions of the test sections to fix some soft spots in base layer.
- Nuclear density and moisture content tests were not obtained on the subgrade layer. No FWD testing was conducted on the subgrade.
- Quantities of the binder in asphalt layer were less than what was called for in the material sampling test plan.

### Performance Summary

The pavement performance for this site has been monitored for 6 years. Fatigue (1.6%) and longitudinal-WP (11 m) cracking are observed on section 0806. Also section 0805 has shown high level of longitudinal cracking-NWP (91 m). A rut depth of more than 5mm is also observed for section 0806. High change in roughness is observed for thin asphalt section (0805) as compared to thick asphalt section (0806). These values are 1 m/km and 0.38 m/km respectively.

## Missouri (29)

### Site Description

Two projects were constructed in Missouri at two different locations. The sections at the first site (site 290800) are 290801 and 290802 while the sections at the second project (site 29A800) are 29A801 and 29A802. Site 290800 is located on the frontage road to the west of US-65 in Christian County. Site 29A800 is located on the frontage road, west of US-61 in Ralls County. The inventory data for the sections are summarized in Table C-4.

**Table C- 4 Inventory data for MO (29)**

| Site code | 290800 | 29A800 |
|---|---|---|
| Climatic zone | Wet-Freeze | Wet-Freeze |
| Average annual precipitation | 1079 mm | 945mm |
| Average annual freezing index | 167 $^{o}$C-days | 334 $^{o}$C-day |
| Traffic open date | 1st July 1998 | December 1998 |
| Subgrade soil type | Fine grained | Fine grained (Active) |
| Inside shoulder type | AC | No shoulder |
| Outside shoulder type | AC | AC |

### Construction Issues

According to the construction report (June 1998), no deviations occurred at any of the sites.

### Performance Summary

The pavement performance for this site has been monitored for 5 years. There are two sites for SPS-8 experiment in this state. Overall the site 0800 has shown better performance than site A800. Low levels of fatigue cracking are observed in both section A801 and A802. Also, both of these sections have exhibited high levels of longitudinal cracking both WP and NWP. Transverse cracking is also observed in these two sections with section A802 showing higher length of cracking. High change in roughness is observed for thin asphalt section (A901) as compared to thick asphalt section (A802). These values are 0.71 m/km and 0.38 m/km respectively.

## Montana (30)

### Site Description

The Montana site was constructed in Deer Lodge County on State Route 273 in the vicinity of Anaconda. The average annual daily traffic in two directions for this section of the roadway was 660 in 1994. The inventory data for the sections are summarized in Table C-5.

**Table C- 5 Inventory data for MT (30)**

| | |
|---|---|
| Site code | 39 |
| Climatic zone | Dry-Freeze |
| Average annual precipitation | 371 mm |
| Average annual freezing index | 574 $^{o}$C-days |
| Traffic open date | 1st June 1994 |
| Subgrade soil type | Coarse grained |
| Inside shoulder type | AC |
| Outside shoulder type | AC |

### Construction Issues

According to the construction report (August 1996), “minor deviations’ occurred at the site. The main construction issues encountered at the site are as follows:

- One section was cut and the other was on a fill. The cut section was undercut during the construction and same fill material was used in both sections.
- In section 30-0805 the average DGAB thickness was 7.1” which is less than the target thickness of 8” for this section.
- Significant deflection difference between sections was found between both the subgrade and base layers.

### Performance Summary

The pavement performance for this site has been monitored for 8 years. Low levels of fatigue cracking are observed in both sections 0805 and 0806 with thinner section showing higher cracking. Also, both of these sections have exhibited high levels (> 50 m) of longitudinal cracking-WP. Higher change in roughness is observed for thin asphalt section (0805) as compared to thick asphalt section (0806). These values are 0.18 m/km and 0.10 m/km respectively.

## New Jersey (34)

### Site Description

The New Jersey site was undertaken by the Port Authority of NY/NJ. These projects are located at JFK airport. The project is inside JFK airport west of taxiway "O" and east of the restricted service road. The two main SHRP SPS sections and two Port Authority supplemental sections are laid in parallel next to each other. This layout is unlike other GPS and SPS section which come in series following each other. The inventory data for the sections are summarized in Table C-6.

**Table C- 6 Inventory data for NJ (34)**

| | |
|---|---|
| Site code | 34 |
| Climatic zone | Wet-Freeze |
| Average annual precipitation | 1071 mm |
| Average annual freezing index | 127 $^{o}$C-days |
| Traffic open date | August 1993 |
| Subgrade soil type | Fine grained |
| Inside shoulder type | AC |
| Outside shoulder type | AC |

### Construction Issues

The construction issues and deviations report is not available for this site.

### Performance Summary

The pavement performance for this site has been monitored for 6 years. No cracking is observed on both the sections at this site. A raveling of 72 sq-m is observed in section 0801. Both the SPS-8 sections at this site were constructed with a very higher initial roughness, with thin asphalt section (0801) showing higher initial roughness as compared to thick asphalt section (0806). These values are 3.22 m/km and 1.54 m/km respectively. However, the change in roughness is not high for both sections.

## New Mexico (35)

### Site Description

The New Mexico site is located on I-10 Frontage Road in Grant County. The inventory data for the sections are summarized in Table C-7.

**Table C- 7 Inventory data for NM (35)**

| | |
|---|---|
| Site code | 35 |
| Climatic zone | Dry-No-Freeze |
| Average annual precipitation | 346 mm |
| Average annual freezing index | 9 $^{o}$C-days |
| Traffic open date | 1st November 1996 |
| Subgrade soil type | Fine grained |
| Inside shoulder type | AC |
| Outside shoulder type | AC |

### Construction Issues

According to the construction report (May 1997), "minor deviations' occurred at the site. The main construction issues encountered at the site are as follows:

- The thickness of DGAB layer varies more than 1-inch which is greater than the allowable in the construction guideline.
- The site was opened to traffic during the construction of the test section. The subgrade showed the signs of rutting and was re-graded before laying DGAB layer.

### Performance Summary

The pavement performance for this site has been monitored for 6 years. Fatigue cracking has just started in both the sections at this site. High levels (> 50 m) of longitudinal cracking-NWP are observed in both sections with thicker section exhibiting higher cracking. Raveling is also observed on both sections. Both the SPS-8 sections at this site were constructed with an initial roughness of 1.07 m/km and 0.91 m/km respectively.

## New York (36)

### Site Description

The New York site is located on Lake Ontario State Parkway, Route 947A and LOSP 49-1, from Yanty Creek to route 260 near the town of Hamlin, Monroe County. The inventory data for the sections are summarized in Table C-8.

**Table C- 8 Inventory data for NY (36)**

| | |
|---|---|
| Site code | 36 |
| Climatic zone | Wet-Freeze |
| Average annual precipitation | 891 mm |
| Average annual freezing index | 437 °C-days |
| Traffic open date | 1st November 1994 |
| Subgrade soil type | Fine grained (Active) |
| Inside shoulder type | AC |
| Outside shoulder type | AC |

### Construction Issues

The construction issues and deviations report is not available for this site.

### Performance Summary

The pavement performance for this site has been monitored for 8 years. Fatigue cracking is observed in both the sections at this site with thinner section exhibiting higher cracking than the thicker. The percentages of fatigue craking are 20% and 5% respectively. High levels (> 50 m) of longitudinal cracking-NWP are observed in both sections with thicker section exhibiting higher cracking. Both the SPS-8 sections at this site were constructed with an initial roughness of 1.0 m/km and 1.07 m/km respectively.

## North Carolina (37)

### Site Description

The North Carolina site is located on the north bound lane of SR 124, off SR 1209 in Onslow County which is 10 km from the Albert J. Ellis Airport and 30 km from Jacksonville. The inventory data for the sections are summarized in Table C-9.

**Table C- 9 Inventory data for NC (37)**

| | |
|---|---|
| Site code | 37 |
| Climatic zone | Wet-No-Freeze |
| Average annual precipitation | 1342 mm |
| Average annual freezing index | 14 $^oC$-days |
| Traffic open date | 1st December 1997 |
| Subgrade soil type | Fine grained (Active) |
| Inside shoulder type | AC |
| Outside shoulder type | AC |

### Construction Issues

According to the construction report (Dec 1998), “minor deviations’ occurred at the site. The main construction issues encountered at the site are as follows:

- The finished elevations of the DGAB layer did not meet the 12 mm tolerance in all the sections.
- No prime coat was used on the DGAB layer before paving.
- The lane width of 3.05 was constructed at this site, which is the minimum width allowed as compared to a standard lane width of 3.66 m.
- The shoulder width was also reduced to 0.61 m as compared to the minimum 1.22 m specified in the SPS-8 construction guidelines.

### Performance Summary

The pavement performance for this site has been monitored for 5 years. No fatigue cracking is observed in both the sections at this site. Raveling is also observed on both sections. Both the SPS-8 sections at this site were constructed with an initial roughness of 1.21 m/km and 1.33 m/km respectively. Higher change in the roughness is shown by thicker section as it was constructed rougher than the thinner section.

## Ohio (39)

### Site Description

The site is a reconstruction project located on a ramp that carries traffic from SR-229 onto southbound US-23, in Delaware County. The inventory data for the sections are summarized in Table C-10.

**Table C- 10 Inventory data for OH (39)**

| | |
|---|---|
| Site code | 39 |
| Climatic zone | Wet-Freeze |
| Average annual precipitation | 972 mm |
| Average annual freezing index | 374 $^{o}$C-days |
| Traffic open date | 1$^{st}$ November 1994 |
| Subgrade soil type | Fine grained (Active) |
| Inside shoulder type | AC |
| Outside shoulder type | AC |

### Construction Issues

According to the construction report (June 1998), “minor deviations’ occurred at the site. The main construction issues encountered at the site are as follows:

- Underground structures were located within the sections. The under ground structure in section 39-0804 has shown abnormal settlement.
- Compaction problems were encountered during the placement of the intermediate AC leveling course. These problems were solved but premature cracking developed in the shoulder at these locations.
- Surface irregularities, from rod and level survey, exceeded the tolerance of 6.4 mm.

### Performance Summary

The pavement performance for this site has been monitored for only 2 years. No cracking is observed on both the sections at this site. Section 0803 (thin section) has shown a severe rutting (>20 mm) in the second year of its service life. Both the SPS-8 sections at this site were constructed with an initial roughness of 1.23 m/km and 1.18 m/km respectively. Very high change in the roughness is observed by both the sections at this site. These values of change in IRI for thin and thick sections are 2.24 m/km and 1.69 m/km respectively.

## South Dakota (46)

### Site Description

The project is located in North Central South Dakota on State Highway 1804. The site is about 1 mile south of t he North Dakota border and about 7 miles northwest of Pollock, South Dakota. . The two-way AADT at this site is 73 with an estimated 14000 ESAL per year. The inventory data for the sections are summarized in Table C-11.

**Table C- 11 Inventory data for SD (46)**

| | |
|---|---|
| Site code | 46 |
| Climatic zone | Dry-Freeze |
| Average annual precipitation | 423 mm |
| Average annual freezing index | 978 °C-days |
| Traffic open date | 1st Jun 1993 |
| Subgrade soil type | Fine grained (Active) |
| Inside shoulder type | AC |
| Outside shoulder type | AC |

### Construction Issues

According to the construction report (June 1996), “minor deviations’ occurred at the site. The main issues encountered at the site are as follows:

- The earthwork and base material was completed in 1992 and the asphalt layer was placed in 1993. During this time, the base was completely sealed with a tack coat to hold the material in place and to limit the amount of moisture going in the un-bound layer.

### Performance Summary

The pavement performance for this site has been monitored for 9 years. High levels of transverse cracking are observed on both the sections at this site with thinner section showing higher cracking. Both the SPS-8 sections at this site were constructed with an initial roughness of 0.81 m/km and 0.82 m/km respectively. A change in IRI of 0.18 m/km and 0.39 m/km is observed in both the sections at this site.

## Texas (48)

### Site Description

The Texas site is located on FM-2223 in Brazos County. The inventory data for the sections are summarized in Table C-12.

**Table C- 12 Inventory data for TX (48)**

| | |
|---|---|
| Site code | 48 |
| Climatic zone | Wet-No-Freeze |
| Average annual precipitation | 1015 mm |
| Average annual freezing index | 10 $^{o}$C-days |
| Traffic open date | 1st July 1996 |
| Subgrade soil type | Fine grained |
| Inside shoulder type | AC |
| Outside shoulder type | AC |

### Construction Issues

According to the construction report (July 2000), “minor deviations’ occurred at the site. The main issues encountered at the site are as follows:

- Construction of the DGAB layer showed a wide variation in the layer thickness.
- Also surface thickness contained high variations.

### Performance Summary

The pavement performance for this site has been monitored for 7 years. No cracking distresses are observed on both the sections at this site. Both the SPS-8 sections at this site were constructed with an initial roughness of 0.76 m/km and 1.05 m/km respectively. A negligible change in IRI is observed in both the sections at this site.

## Utah (49)

### Site Description

This SPS-8 project was constructed in Wasatch County on State Route 35 (Wolf Creek Road) near Francis, Utah. The design annual average daily traffic (AADT) for this roadway was 390 vehicles per day with 2% trucks. The inventory data for the sections are summarized in Table C-13.

**Table C- 13 Inventory data for UT (49)**

| | |
|---|---|
| Site code | 49 |
| Climatic zone | Dry-Freeze |
| Average annual precipitation | 473 mm |
| Average annual freezing index | 498 °C-days |
| Traffic open date | 1st October 1997 |
| Subgrade soil type | Coarse grained |
| Inside shoulder type | AC |
| Outside shoulder type | AC |

### Construction Issues

According to the construction report (September 1998), "minor deviations' occurred at the site. The main issues encountered at the site are as follows:

- Some of the base material was finer than specified.
- The variation in DGAB and AC layer thickness was higher than allowed. However the mean thicknesses were within specifications.
- The AC aggregates were finer than specified.
- Subgrade deflections for FWD were outside the allowable range of FWD sensors.

### Performance Summary

The pavement performance for this site has been monitored for 5 years. No cracking distresses are observed on both the sections at this site. Both the SPS-8 sections at this site were constructed with an initial roughness of 1.0 m/km and 0.93 m/km respectively. A negligible change in IRI is observed in both the sections at this site.

## Washington (53)

### Site Description

This SPS-8 project was constructed in Columbia County on the North Touchet Road in Dayton, Washington. These sections are located in the northbound lane near milepost 4. The design annual average daily traffic (AADT) for this roadway in 1994 was 600 vehicles per day with 3% trucks. Other inventory data for the sections are summarized in Table C-14.

**Table C- 14 Inventory data for WA (53)**

| | |
|---|---|
| Site code | 53 |
| Climatic zone | Wet-Freeze |
| Average annual precipitation | 510 mm |
| Average annual freezing index | 169 $^{o}$C-days |
| Traffic open date | 1st November 1995 |
| Subgrade soil type | Fine grained (Active) |
| Inside shoulder type | AC |
| Outside shoulder type | AC |

### Construction Issues

According to the construction report (September 1997), no major deviations occurred at the site. The constructions issues which were highlighted for this project are:

- Sections are located on a side hill. The initial estimate was that no excavation would be required; however, excavation was required which made both sections over a fill.
- Over-excavation was replaced by the shot rock and a barrow selected material. This can affect the subgrade type i.e. it may not behave as active subgrade.

### Performance Summary

The pavement performance for this site has been monitored for 7 years. High levels (> 50 m) of longitudinal cracking-NWP are observed on both the sections at this site with thinner section showing higher length of cracking. Both the SPS-8 sections at this site were constructed with an initial roughness of 0.9 m/km and 1.26 m/km respectively. A negligible change in IRI is observed in both the sections at this site.

## Wisconsin (55)

### Site Description

The Wisconsin SPS-8 project is located on Apple Lane (frontage road) on the north side of Wisconsin State Highway 29 (STH-29) in Marathon County. This site is about 0.8 km east of Hatley, Wisconsin and adjacent to the SPS-1 site. The design annual average daily traffic (AADT) for this roadway in 1994 was 100 vehicles per day with 7.4% trucks. Other inventory data for the sections are summarized in Table C-15.

**Table C- 15 Inventory data for WI (55)**

| | |
|---|---|
| Site code | 55 |
| Climatic zone | Wet-Freeze |
| Average annual precipitation | 814 mm |
| Average annual freezing index | 1015 $^{o}$C-days |
| Traffic open date | 1$^{st}$ November 1997 |
| Subgrade soil type | Coarse grained |
| Inside shoulder type | AC |
| Outside shoulder type | AC |

### Construction Issues

According to the construction report (September 1997), no major deviations occurred at this site. The constructions issues which were highlighted for these projects are:

- Section 55-0805 was relocated 198 m (650 ft) to the west of the original alignment because old Portland cement concrete was found 152 mm to 203 mm below the surface.
- Shoulders were constructed with a minimum width of 1 m instead of the required 1.2 m.

### Performance Summary

The pavement performance for this site has been monitored for 5 years. No cracking distress is observed on both of the sections at this site. Both the SPS-8 sections at this site were constructed with an initial roughness of 1.01 m/km and 1.04 m/km respectively. A negligible change in IRI is observed in both the sections at this site.

## Site summaries for rigid pavements in SPS-8 experiment

## Arkansas (5)

### Site Description

The site is located on US-65 Frontage Road in Jefferson County. The ADT at the site is 30 ADT for both the lanes, which is less than stipulated traffic of 100 vehicles per day. The inventory data for the sections are summarized in Table C-16.

**Table C- 16 Inventory data for AR (5)**

| | |
|---|---|
| Site code | 5 |
| Climatic zone | Wet No Freeze |
| Average annual precipitation | 1339 mm |
| Average annual freezing index | 41 °C-days |
| Traffic open date | 1st of December 1997 |
| Subgrade soil type | Fine grained |
| Inside shoulder type | PCC |
| Outside shoulder type | PCC |

### Construction Issues

According to the construction report (December 1997), ‘minor deviations’ were observed in construction. The following are the main construction issues encountered at the site:

- WIM equipment was not installed and traffic monitoring data was not submitted.
- Thickness exceeded the target thickness at localized areas but the average thickness confirms with specifications.
- Post construction coring was done only on the 18th day after casting, instead of 14th day, because of harsh weather and equipment issues.

### Performance

This site is located in the Wet No Freeze zone and was opened to traffic in December 1997. The AADT (two-way), from construction report that was used for calculation of design ESAL is 38 vehicles/day. The sections at this site are about 5 years old.

Low severity longitudinal spalling was observed at the sections at this site. 46 m and 38 m of low-severity spalling occurred at sections 0809 and 0810, respectively. 30 and 24% of joints in sections 0809 and 0810 have exhibited faulting of 1.0 mm. None of the joints have faulted greater than 1.0 mm. The initial roughness of the sections was 1.7 m/km and it unchanged after 4 years of service.

## Colorado (8)

### Site Description

The site Colorado is located on Chestnut Street in Adams County. The two-way AADT at the site, as per the construction report, is 2500 in 1992. The inventory data for the sections are summarized in Table C-17.

**Table C- 17 Inventory data for CO (8)**

| | |
|---|---|
| Site code | 8 |
| Climatic zone | Dry Freeze |
| Average annual precipitation | 379 mm |
| Average annual freezing index | 306 $^{o}$C-days |
| Traffic open date | 1$^{st}$ of January 1994 |
| Subgrade soil type | Coarse grained |
| Inside shoulder type | AC |
| Outside shoulder type | AC |

### Construction Issues

According to the construction report (June 1998), “several deviations” occurred at the site. The following are the main construction issues encountered at the site:

- The amount of fly ash used was 25% which is more than15% that is stipulated by guidelines.
- According to the LTPP personnel present at the site during construction, “very poor” climatic conditions prevailed during construction that caused the construction to happen at a faster rate.

### Performance

This site is located in the Dry Freeze zone and was opened to traffic in January 1994. The AADT (two-way), from construction report that was used for calculation of design ESAL is 2500 vehicles/ day. All types of distresses were observed by sections at this site.

Section 0812 did not exhibit cracking, spalling, scaling or corner breaking. One occurrence each of corner break and scaling has been observed in section 0811. Longitudinal cracking of 7.7 m (all of medium severity) and 5 transverse cracks (4 of medium and 1 of low severity) have been observed in the section apart from 2 occurrences (0.8 m long of medium severity) of transverse spalling. Though 24% and 39% of joints in sections 0811 and 0812 have measurable faulting, 12% of joints in section 0811 have faulting >1.0 mm or more while 1 joint in 0812 has faulting >1.0mm. Though the initial roughness of both the sections was 1.6 m/ km, according to the latest survey (November 2003), 0811 has roughness of 2.3 m/ km and 0812 has roughness of 1.8 m/ km, after 9 years of service.

# Missouri (29)

## Site Description

Two projects were constructed in Missouri at two different locations. The sections at the first site (site 290800) are 290807 and 290808 while the sections at the second project (site 29A800) are 29A807 and 29A808. Site 290800 is located on the frontage road to the west of US-65 in Christian County. Site 29A800 is located on the frontage road, west of US-61 in Ralls County. The inventory data for the sections are summarized in Table C-18.

**Table C- 18 Inventory data for MO (29)**

| Site code | 290800 | 29A800 |
|---|---|---|
| Climatic zone | Wet Freeze | Wet Freeze |
| Average annual precipitation | 1076 mm | 947 mm |
| Average annual freezing index | 163 $^{o}$C-days | 325 $^{o}$C-day |
| Traffic open date | 1st of July 1998 | December 1998* |
| Subgrade soil type | Fine grained | Fine grained (Active) |
| Inside shoulder type | AC | No shoulder |
| Outside shoulder type | AC | AC |

* Construction completion date, from construction report

According to the construction report (June 1998), no deviations occurred at any of the sites.

## Performance

Two projects were constructed in Missouri at two different locations. The sections at the first site (site 290800) are 290807 and 290808 while the sections at the second project (site 29A800) are 29A807 and 29A808. The sites are located in Wet Freeze zone. The AADT (two-way) at sites 290800 and 29A800 is 50 (4000 ESALs/yr) and 118 vehicles/day (7200 ESALs/yr), respectively. Traffic was opened on sites 290800 and 29A800 in July and December of 1998, respectively.

No distress was observed at site 29A800 while sections at site 290800 exhibited cracking and spalling. Section 0808 exhibited longitudinal spalling of 4.5 m (low severity) while section 0807 exhibited longitudinal and transverse spalling of 37 and 0.5 m (low severity) apart from 0.5 m of longitudinal cracking (low severity) and 3 transverse cracks (medium severity).

At the site 290800, sections 0807 and 0808 had measurable faulting at 30% and 24 % of joints. One joint each at these sites faulted 2.0 mm. At the site 29A800, faulting occurred only in section A807. 21% of joints had faulting of 1.0mm at the section. No change in roughness was observed in any of the sections in Missouri after 5 years of service. The average initial roughness of the 4 sections is 1.6 m/ km.

## Ohio (39)

### Site Description

The site is a reconstruction project located on a ramp that carries traffic from SR-229 onto southbound US-23, in Delaware County. The inventory data for the sections are summarized in Table C-19.

**Table C- 19 Inventory data for OH (39)**

| | |
|---|---|
| Site code | 39 |
| Climatic zone | Wet Freeze |
| Average annual precipitation | 976 mm |
| Average annual freezing index | 339 $^{o}$C-days |
| Traffic open date | 1st of November 1994 |
| Subgrade soil type | Fine grained (Active) |
| Inside shoulder type | AC |
| Outside shoulder type | AC |

### Construction Issues

According to the construction report (June 1998), "minor deviations' occurred at the site. The main construction issues encountered at the site are as follows:

- Underground structures were located within the sections.
- Compaction was not done to 95% of Maximum Proctor Density in section 390809. Segregation was also observed at the location where target compaction was not achieved.
- Surface irregularities, from rod and level survey, exceeded the tolerance of 6.4 mm.
- Air content in PCC exceeded the limit of 7.5 % and slumps were below the recommendation of 38 mm.

### Performance

This site is located in the Wet Freeze zone and was opened to traffic in November 1994. The AADT (two-way), from construction report that was used for calculation of design ESAL is 500 vehicles/day. Spalling and cracking occurred at this site.

While section 0810 had 79 m of longitudinal spalling (low severity), section 0809 exhibited 1 transverse crack (medium severity) and 0.7 m of longitudinal spalling (low severity).

23% of joints at each of the sections have measurable faulting and one joint in 0809 had faulting of 2.0 mm. A change in roughness of 0.1 m/km was observed at both the sections after 8 years of service, though sections 0809 and 0810 had initial roughness of 1.9 and 1.6 m/ km.

## Texas (48)

### Site Description

The site is located in Bell County, Texas. The inventory data for the sections are summarized in Table C-20.

**Table C- 20 Inventory data for TX (48)**

| | |
|---|---|
| Site code | 48 |
| Climatic zone | Wet No Freeze |
| Average annual precipitation | 871 mm |
| Average annual freezing index | 17 $^{o}$C-days |
| Traffic open date | 1st of July 1996 |
| Subgrade soil type | Active |
| Inside shoulder type | No Shoulder |
| Outside shoulder type | PCC |

### Construction Issues

According to the construction report (July 2000), “minor deviations’ occurred at the site. The main issues encountered at the site are as follows:

- The lane width of the sections is 3.3 m instead of 3.7 m.
- The base layer thickness for the initial 62 m is not known for section 48A808 as subgrade elevations were not available.
- Longitudinal tie bars were 1016 mm long and were placed 990 mm center-to-center. The guidelines require 762 mm long tie bars at 762 mm center-to-center distance.
- Dowel bars were of 44.5 mm diameter while the guidelines require bars of 38 mm diameter.

### Performance

This site is located in the Wet No Freeze zone and was opened to traffic in July 1996. The design traffic is 2.2 KESAL/yr. None of the distresses occurred at this site. 73% of joints at each of the sections have measurable faulting. While 15% of joints faulted greater than 3.0 mm in section A808, 15% of joints faulted 2.0 mm in section A807. Roughness of sections A807 and A808 changed to 3.5 and 3.7 m/ km from 3.4 and 3.6 m/ km, respectively, after 6 years of service.

## Washington (53)

### Site Description

The site is located on Smith Springs Road, Walla Walla County. Other inventory data for the sections are summarized in Table C-21.

**Table C- 21 Inventory data for WA (53)**

| | |
|---|---|
| Site code | 53 |
| Climatic zone | Dry Freeze |
| Average annual precipitation | 384 mm |
| Average annual freezing index | 152 °C-days |
| Traffic open date | 1st of November 1995 |
| Subgrade soil type | Fine grained |
| Inside shoulder type | No Shoulder |
| Outside shoulder type | AC |

### Construction Issues

According to the construction report (July 2000), “no deviations’ occurred at the site. The base layer thickness for the initial 62 m is not known for section 48A808 as subgrade elevations were not available.

### Performance

This site is located in the Dry Freeze zone and was opened to traffic in November 1995. According to the construction report, the design traffic is 9.1 KESAL/yr, calculated using AADT (two-way) of 60 vehicles/day. None of the distresses occurred at A809. Transverse spalling of 0.4 m length (low severity) occurred in section A810.
No measurable faulting occurred at the sections. Roughness of sections remained unchanged, after 7 years of service, from average initial roughness of 1.0 m/ km.