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Implementation of AASHTOWare Pavement ME Design Software for the Kansas Department of Transportation

Xingdong Wu
Ya Gao
Syedarmin Motaharitabari
Stacey Kulesza, Ph.D., P.E.
Mustaque Hossain, Ph.D., P.E

Kansas State University Transportation Center

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16 Abstract

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Engineering judgment is critical in the calibration process. The AASHTO (1993) design guide yielded higher slab thicknesses for projects with high truck traffic than the PMED software did when no friction is assumed between the jointed plain concrete pavement (JPCP) slab and the portland cement-treated base (PCTB). For sections with medium truck traffic, PMED produced a higher thickness than that specified in the 1993 AASHTO design guide. An assumption of full friction between the JPCP slab and PCTB had a discernible effect on the JPCP slab thickness obtained from PMED. When the distress predictions from Level 1 and Level 3 HMA dynamic moduli inputs were compared, the effect was pronounced in some projects, particularly for fatigue-cracking distresses. Level 1 creep test inputs affect the predicted AC thermal cracking, which may reach the failure criteria. The total transverse cracking values increased sharply with Level 1 inputs but not with Level 3 inputs. A stiffer mix resulted in higher thermal and total transverse cracking for Level 1 inputs. On the other hand, the mixtures with softer binders produce less thermal cracking on asphalt overlays over existing asphalt pavements.

Lower subgrade moduli resulted in higher IRI and a higher percentage of AC bottom-up fatigue cracking in HMA pavements, but other distresses remained practically unchanged. Lower subgrade modulus also resulted in a slight increase in slab thickness for projects with higher truck traffic.

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Prepared by

Xingdong Wu
Ya Gao
Syedarmin Motaharitabari
Stacey Kulesza, Ph.D., P.E.*
Mustaque Hossain, Ph.D., P.E

Kansas State University Transportation Center

**Currently affiliated with Texas State University*

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PREFACE

The Kansas Department of Transportation's (KDOT) Kansas Transportation Research and New-Developments (K-TRAN) Research Program funded this research project. It is an ongoing, cooperative, and comprehensive research program addressing transportation needs of the state of Kansas utilizing academic and research resources from KDOT, Kansas State University and the University of Kansas. Transportation professionals in KDOT and the universities jointly develop the projects included in the research program.

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Abstract

The AASHTOWare Pavement ME Design (PMED) software uses the mechanistic-empirical pavement design approach. PMED prediction models need to be calibrated to local conditions to produce accurate, reliable pavement performance predictions. Previously, multiple efforts were made to locally calibrate performance models in Kansas across various AASHTOWare versions. This study was initiated to revise the local calibration factors for version 2.6.2, released in September 2022. Another objective was to find any significant changes between the two versions that might affect the performance prediction. Also, several issues related to input material characteristics were studied. The results show that the re-calibration process is pretty straightforward. The local calibration process depends on measured performance data. Not all global coefficients need to be changed during calibration or recalibration.

Engineering judgment is critical in the calibration process. The AASHTO (1993) design guide yielded higher slab thicknesses for projects with high truck traffic than the PMED software did when no friction is assumed between the jointed plain concrete pavement (JPCP) slab and the portland cement-treated base (PCTB). For sections with medium truck traffic, PMED produced a higher thickness than that specified in the 1993 AASHTO design guide. An assumption of full friction between the JPCP slab and PCTB had a discernible effect on the JPCP slab thickness obtained from PMED. When the distress predictions from Level 1 and Level 3 HMA dynamic moduli inputs were compared, the effect was pronounced in some projects, particularly for fatigue-cracking distresses. Level 1 creep test inputs affect the predicted AC thermal cracking, which may reach the failure criteria. The total transverse cracking values increased sharply with Level 1 inputs but not with Level 3 inputs. A stiffer mix resulted in higher thermal and total transverse cracking for Level 1 inputs. On the other hand, the mixtures with softer binders produce less thermal cracking on asphalt overlays over existing asphalt pavements.

Lower subgrade moduli resulted in higher IRI and a higher percentage of AC bottom-up fatigue cracking in HMA pavements, but other distresses remained practically unchanged. Lower subgrade modulus also resulted in a slight increase in slab thickness for projects with higher truck traffic.

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Chapter 1: Introduction

1.1 Background

The American Association of State Highway and Transportation Officials (AASHTO) Guide for Design of Pavement Structures is the primary document state highway agencies use to design new and rehabilitated highway pavements. The Federal Highway Administration's 1995-97 National Pavement Design Review found that approximately 80% of states used the 1972, 1986, or 1993 AASHTO Pavement Design Guide. All those versions were empirically based on the performance equations developed using the American Association of State Highway Officials (AASHO) Road Test data from the late 1950s. The AASHTO (1993) guide also included state-of-the-practice refinements to materials, input parameters, and rehabilitation design procedures.

The National Cooperative Highway Research Program (NCHRP) developed a Mechanistic-Empirical Pavement Design Guide (MEPDG) that can perform mechanistic-empirical design while accounting for local environmental conditions, highway materials, and actual traffic (AASHTO, 2008). AASHTO has adopted this MEPDG procedure as the new AASHTO design method for pavement structures.

The Kansas Department of Transportation (KDOT) is also keen on fully adopting MEPDG (and the associated software, AASHTOWare Pavement ME Design [PMED]) to replace the 1993 AASHTO design guide currently in use. However, local calibration of the AASHTOWare PMED software needs to be completed, and results need to be verified with the performance of in-service pavements in Kansas. It should be noted that all mechanistic design approaches produce "theoretical structural designs" that require adjustment or "calibration" to actual conditions using data originating from in-service pavement structures. Although it is recommended that calibration be incorporated in the new AASHTOWare PMED, it is to be remembered that it was intended to be a procedure with (i) national correlations to estimate selected inputs, (ii) national default values, and (iii) national calibration factors developed from the LTPP sites (Von Quintus & Scofield, 2003). It is recommended that all national correlations, default values, and calibration factors be validated and/or calibrated for the specific state and/or region. Without region/state-specific calibration, the new guide will be of limited use for design purposes.

An emphasis on calibration has also been emphasized at the national level, as shown by two NCHRP research projects closely related to local calibration of AASHTOWare PMED predictions (Von Quintus et al., 2005; Brown et al., 2006; Darter et al., 2006; Von Quintus et al., 2009). They are: (1) NCHRP 9-30 project, "Experimental Plan for Calibration and Validation of Hot Mix Asphalt Performance Models for Mix and Structural Design," and (2) NCHRP 1-40B "User Manual and Local Calibration Guide for the Mechanistic-Empirical Pavement Design Guide and Software."

The current version of AASHTOWare PMED is numbered 2.6.2. The technical report of the AASHTO Pavement ME national user group meeting in Illinois in 2022 stated that three state highway agencies implemented PMED in 2013, 14 in 2016, and 18 in 2021 (AASHTO, 2022). However, only nine state agencies use PMED as the primary method, and the other nine use it parallel with another procedure. The report also noted that implementation trends in recent years have stagnated, with several "implemented" agencies reverting to the previous system or using PMED alongside another method. The same forum report from 2017 highlighted several challenges for state highway agencies implementing the PMED software (AASHTO, 2017). Local calibration and verification of PMED performance models was the top challenge on the list. The other challenges included the availability of performance data, characterizing bound and unbound layer material properties, and the compatibility of performance measures and threshold criteria.

The Kansas Department of Transportation (KDOT) is transitioning from using the 1993 AASHTO Pavement Design Guide to implementing PMED. Previously, multiple efforts were made to calibrate performance models locally in Kansas. The first local calibration was performed on several in-service rigid and flexible pavements using AASHTOWare version 2.2 (Sun et al., 2015; Sufian, 2016). Then, the process was repeated in a second effort for the rehabilitation projects using AASHTOWare version 2.5 (Islam, 2019). Local calibration was carried out for the flexible pavements' permanent deformation or rutting, top-down fatigue cracking, International Roughness Index (IRI), and transverse cracking distress models. In addition, IRI and mean joint faulting models were also locally calibrated for the rigid pavements.

As mentioned earlier, one of the most challenging issues in implementing the PMED software is the need for periodic calibration using updated performance data or when the models are updated. Since the latest version of AASHTOWare PMED is 2.6, the performance models must be evaluated to see if further calibration is needed. Thus, the main objective of this study was to determine whether the local calibration factors developed using version 2.5 remain valid for version 2.6.2, released in September 2022. Another objective was to see any significant changes between the two versions that might affect performance prediction. This could be done by analyzing selected projects and evaluating those against the failure criteria. Also, several issues related to input types were studied.

1.2 Objective

The primary objectives of this project were (i) to provide continuous technical support to the KDOT Pavement Design Unit for proper implementation of the AASHTOWare PMED software, especially on comparative runs with the AASHTOWare DARWin (1993 AASHTO design guide), (ii) to improve the quality of inputs for local calibration of software for KDOT that can be verified and compared with historical performance of existing pavements throughout the state, and (iii) to implement the AASHTOWare PMED software in day-to-day design of new pavement sections.

1.3 Report Outline

This report is divided into four chapters. Chapter 1 states the background and objective of the research. Chapter 2 describes the recalibration of distress models in the AASHTOWare PMED software (version 2.6.2). Chapter 3 discusses the effect of selected material inputs on the PMED results. Chapter 4 presents the correlation between FWD-back-calculated subgrade modulus and DCP/CBR value. Finally, Chapter 5 summarizes the conclusions and presents the recommendations based on this study.

Chapter 2: Recalibration of Distress Models in AASHTOWare PMED Software

2.1 Introduction

One of the principal goals of distress and IRI model calibration/recalibration in the AASHTOWare Pavement ME Design (PMED) software is to reduce or eliminate bias. A biased model will produce over-designed or under-designed pavements (AASHTO, 2010). Increasing prediction precision is another objective of model calibration. Lack of precision in the model will result in ineffective pavement section design, potentially leading to premature failures. The local calibration guide for AASHTOWare PMED outlines a 10-step procedure (AASHTO, 2010). These steps are listed below:

1. Select a hierarchical input level for each input parameter;
2. Develop a local experimental plan and sampling template;
3. Estimate sample size for specific distress prediction model;
4. Select roadway segments;
5. Extract and evaluate distress and project data;
6. Conduct field and forensic investigations;
7. Assess local bias by implementing globally calibrated values to local conditions, policies, and materials;
8. Eliminate local bias of distress and IRI prediction models;
9. Assess the standard error of estimate (S_e); and
10. Reduce the standard error of estimate (S_e).

The predicted pavement distresses and the IRI from AASHTOWare PMED software need to be compared with the measured data from the KDOT Pavement Information System (PMIS) database. The bias and standard error of the estimate can then be determined. The local calibration guide for PMED defines the standard error of estimate (S_e) as the standard deviation of the residuals for pavement sections included in the calibration dataset for each prediction model. The standard error is usually obtained by taking the positive square root of the variance of the statistic. The local calibration guide for PMED (AASHTO, 2010) lists four components of the standard error of the estimate. The first component concerns measurement errors in distress or smoothness measurements in the field. The second source of error is an input error related to underestimating or overestimating specific input parameters required by the MEPDG. The third source of error is related to deficiencies in the transfer functions within the AASHTOWare PMED software. The fourth source of error is defined as pure error. Pure error depends on the input level, distress type, and prediction equation.

A t-test is needed to assess the initial bias between the actual distress and the PMED-predicted data (using globally calibrated coefficients). In this report, a paired t-test was conducted at the 95% confidence level. The null hypothesis is stated below:

Hypothesis, H_0: $\sum$(Measured-Predicted) = 0

At a 95% confidence level, the p-value (probability of occurrence of a given event) generated from the paired t-test should be greater than or equal to 0.05 for the null hypothesis to be accepted. If the null hypothesis is rejected, the distress model in the AASHTOWare PMED software needs to be calibrated to eliminate local bias. S_y has denoted this study's standard deviation of the measured distress data. The S_e/S_y ratio was calculated for each distress model calibration to assess the variability between predicted and measured performance. A S_e/S_y ratio greater than one indicates that the variability in the residual error between predicted and measured performance is larger than the variability in the measured data. A S_e/S_y ratio smaller than one indicates that the variability in the residual error is smaller than the variability in the measured data. The second scenario is preferred for each distress model calibration (Kim et al., 2011).

After eliminating local bias, the standard error of the estimate from the sampling template should be compared with that derived from the global dataset.

2.2 Jointed Plain Concrete Pavements (JPCP)

A general description of selected rigid pavement projects for local calibration is given in Table 2.1. Most of the projects are located on Interstate and US routes.

Table 2.1: Selected PCCP Projects for Local Calibration

No.	Project Name	Route	County	Begin milepost	End milepost	Length (mile)
1	018K0036000-EB	K-360	Cowley	0	2.95	2.95
2	018U0007700-NB	US-77	Cowley	4.62	8.51	3.89
3	031I0007000-EB	I-70	Geary	18.82	26.53	7.71
4	040I0013500-NB-1	I-135	Harvey	7.47	13.39	5.92
5	040I0013500-NB-2	I-135	Harvey	13.39	20.83	7.44
6	043U0007500-NB-1	US-75	Jackson	0	8.02	8.02
7	043U0007500-NB-2	US-75	Jackson	8.02	17.33	9.31
8	046K0000700-SB	K-7	Johnson	12.47	15.14	2.67
9	056I0003500-SB-1	I-35	Lyon	11.51	16.60	5.09
10	056U0005000-EB-1	US-50	Lyon	0	4.89	4.89
11	059I0013500-NB	I-135	McPherson	6.29	14.30	8.01
12	061I0003500-NB	I-35	Miami	0	2.56	2.56
13	063U0040000-EB	US-400	Montgomery	2.06	11.86	9.80
14	067U0016900-NB	US-169	Neosho	7.14	13.31	6.17
15	079U0008100-NB	US-81	Republic	13.29	17.46	4.17
16	085I0007000-EB	I-70	Saline	14.72	24.02	9.30
17	103U0040000-EB	US-400	Wilson	3.56	11.75	8.19

2.2.1 Input Parameters

2.2.1.1 Climatic Stations

Climatic stations used in this study were selected from the software's default locations. Brief descriptions of the climatic stations and other inputs, such as latitude, longitude, and elevation used in this study for the JPCP projects, are presented in Table 2.2. The water table depth for all segments was set at 50 ft.

Table 2.2: Site-specific Climatic for JPCP Sections

Project Name	Climate Station	Latitude (degree)	Longitude (degree)	Elevation (ft)
018U0007700-NB	Winfield/Arkansas City	37.168	-97.037	1,156
018K0036000-EB	Winfield/Arkansas City	37.168	-97.037	1,156
019U0006900-EB	Joplin, MO	37.149	-94.498	972
029U0006900-NB	Dodge City	37.773	-99.970	2,576
030I0003500-NB-3	Franklin	38.831	-94.890	1,066
031I0007000-EB	Junction City	39.134	-96.679	1,048
040I0013500-NB-1	Newton	38.831	-94.890	1,066
040I0013500-NB-2	Newton	38.831	-94.890	1,066
043U0007500-NB	Topeka/Manhattan	39.073	-95.626	884
043U0007500-NB-2	Topeka/Manhattan	39.073	-95.626	884
046K0000700-SB	Olathe	38.831	-94.890	1,066
055U0004000-WB	Goodland	39.376	-99.830	2,194
056I0003500-SB-1	Emporia	38.331	-96.190	1,205
056U005000-EB	Emporia	38.331	-96.190	1,205
059I0013500-NB	McPherson	38.813	-97.661	1,269
061I0003500-NB	North Mulberry	38.331	-96.190	1,205
063U0040000-EB	Sycamore	37.328	-95.504	869
067U0016900-EB	Chanute	37.67	-95.484	985
079U008100-NB	Belleville	39.549	-97.652	1,469
085I0007000-EB	Salina	38.813	-97.661	1,269
099I0007000-EB-2	Manhattan	39.134	-96.679	1,048
103U0040000-EB	Fredonia	37.328	-95.504	869

2.2.1.2 Traffic Data

The AASHTOWare PMED software allows the designer to input traffic parameters in three levels: Level 1 being project-specific with extensive traffic volume and load data, Level 2 being regional input parameters derived from weigh-in-motion (WIM) and automatic vehicle classifier (AVC) stations across the state, and Level 3 based on global default values included in the software.

In addition to traffic volume, the AASHTOWare PMED software requires monthly distribution factors (MDF), hourly distribution factors (HDF), truck classification distribution, axle load distribution factors, and several other traffic inputs. These inputs are:

- Initial two-way Average Annual Daily Truck Traffic (AADTT)
- Percentage of trucks in the design direction and design lane
- Traffic growth factors
- Vehicle operation speed
- Axle and wheelbase configurations

In this study, truck classification distributions were developed from 11 AVC stations in Kansas. Also, axle load spectra have been developed from 10 WIM stations to use as inputs for the design analysis of pavement structures in Kansas. These derived traffic parameters can be considered as statewide Level 2 traffic inputs. Tables 2.3 and 2.4 list this study's AVC and WIM sites.

Table 2.3: Kansas WIM Stations

WIM Station	County	Route	Functional Classification
2WOA86	Seward	US-54	Rural Principal Arterial
3MXC22	Meade	US-54	Rural Principal Arterial
4LGSU3	Thomas	I-70	Rural Interstate/Principal Arterial
9M4PS3	Saline	I-70	Rural Interstate/Principal Arterial
9ORQP1	Sedgwick	I-135	Urban Interstate/Principal Arterial
9Q9OK1	Sedgwick	I-135	Urban Interstate/Principal Arterial
BWGAA6	Lyon	I-35	Urban Interstate/Principal Arterial
DVMSP3	Douglas	I-70	Urban Interstate/Principal Arterial
F07WC7	Wyandotte	I-70	Urban Interstate/Principal Arterial
2OPUF5	Logan	US-83	Rural Principal Arterial

Table 2.4: Kansas AVC Stations

AVC Station	County	Route	Functional Classification
7HOM63	Russel	I-70	Urban Principal Arterial
7XRME7	Kingman	US-54	Rural Principal Arterial
9LON61	Sedgwick	I-235	Urban Principal Arterial
9Q9OK1	Sedgwick	I-135	Urban Principal Arterial
61ILI3	Kiowa	US-54	Rural Principal Arterial
91TFY5	Republic	US-81	Rural Principal Arterial
AW9N83	Butler	US-400	Rural Principal Arterial
CTQ1D1	Brown	US-36	Rural Principal Arterial
CV64B3	Montgomery	I-166	Rural Principal Arterial
F10VD5	Bourbon	US-69	Rural Principal Arterial
0DT453	Sherman	I-70	Rural Principal Arterial

2.2.1.2.1 Vehicle Class Factors

Vehicle class factors (VCF) determine the frequency of trucks in each vehicle class from Class 4 to Class 13. Figure 2.1 shows the different vehicle classes.

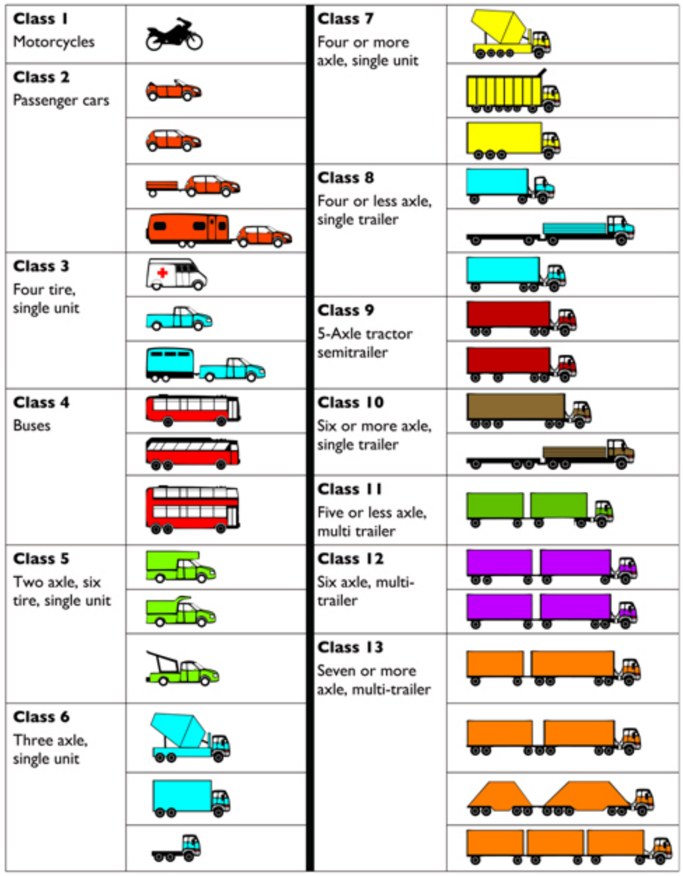


Figure 2.1: Federal Highway Administration (FHWA) Vehicle Classification
Source: FHWA (2014)

The Level 3 vehicle class factors provided in the AASHTOWare PMED software are based on the roadway function, classification, and Truck Traffic Classification groups for that roadway.

This study generated vehicle class factors (VCFs), or truck classification distributions, from the AVC data at eight stations on rural principal arterials in Kansas. The averages of these VCF values were then compared with the software's global default values for this functional class. The statewide average VCF values are close to the global default values determined using the LTPP traffic data. The VCF values were also computed for three AVC stations located on urban principal arterials in Kansas. A comparison of these average values with the default values for the particular functional class is also shown in Figure 2.2. This figure shows that the average VCF values for urban principal arterials in Kansas significantly vary from the AASHTOWare PMED global default values. Class 4 and Class 9 vehicles have higher frequencies on Kansas urban principal arterials.

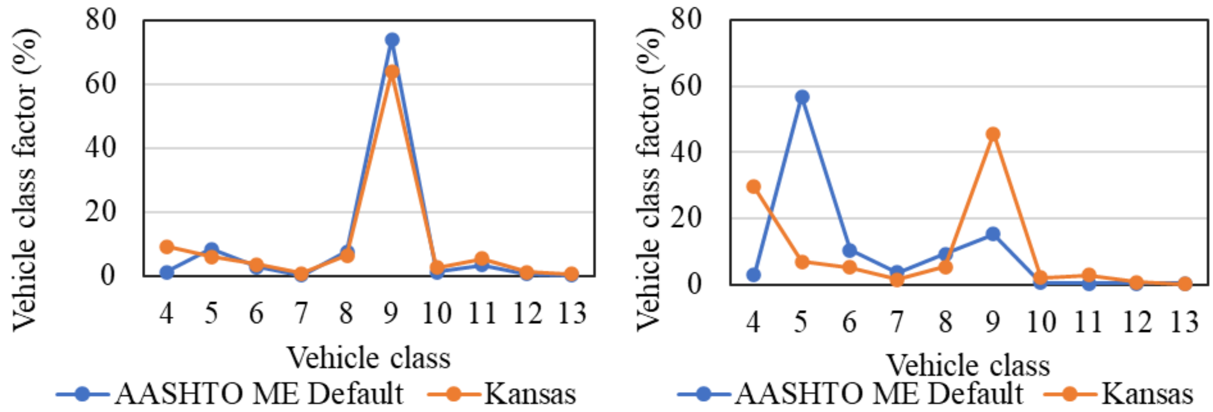


Figure 2.2: Average Vehicle Class Factors for Rural (Left) and Urban (Right) Principal Arterials

2.2.1.2.2 Monthly Adjustment/Distribution Factors

Truck traffic monthly adjustment or distribution factors are defined as the proportion of the annual truck traffic for a particular truck class for a specific month (Applied Research Associates, Inc., 2004). These factors determine the monthly variation in truck traffic within the base year. MAFs are influenced by several factors, such as adjacent land use, industrial location, and roadway location (Khanum et al., 2005).

This study used a two-dimensional clustering analysis of MA/DF values from 11 AVC stations across Kansas, with Class 9 as the predominant vehicle class. Cluster analysis identified two distinct patterns in the rural and urban principal arterials. The average MAF values of vehicle Class 9 for the rural and urban AVC stations are shown in Figure 2.3. Both rural and urban sites show higher MA/DF values in spring and summer than in winter. However, MA/DF values are higher for AVC stations on urban principal arterials than on rural principal arterials during eight months of a typical year. The nationally calibrated design software does not account for monthly variation in the traffic stream, and it is recommended that MAF values for the respective state be derived during calibration.

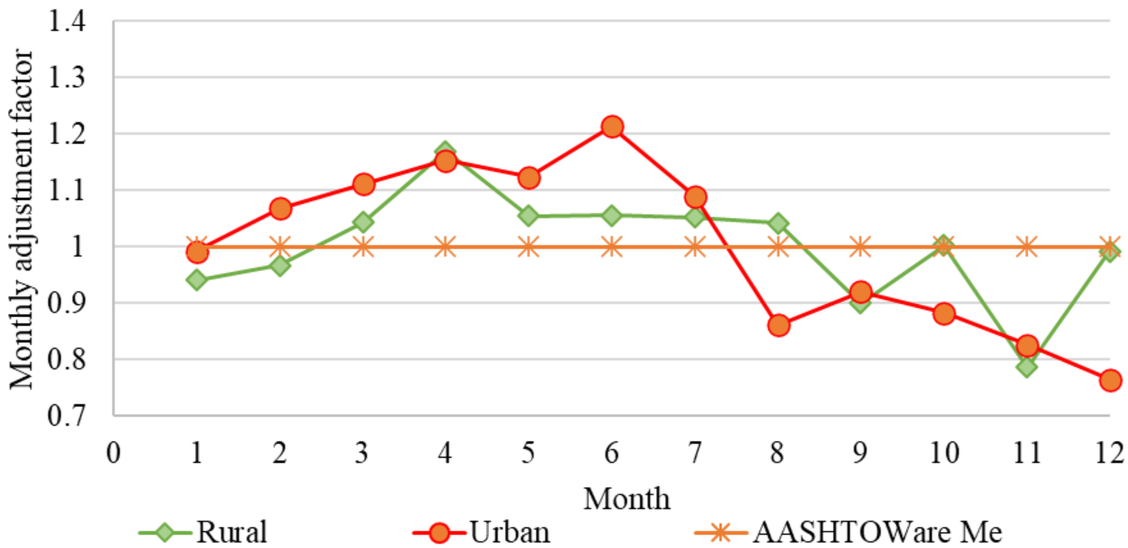


Figure 2.3: Monthly Adjustment/Distribution Factor for Rural and Urban Principal Arterials in Kansas

2.2.1.2.3 Hourly Distribution Factors

The hourly distribution factors (HDF) are derived from the percentage of AADTT at each hour of the day (Applied Research Associates, Inc., 2004). The hourly distribution of truck traffic is required to compute incremental damage to the pavement structure under different thermal gradients over 24 hours (Khanum et al., 2005).

In this study, HDF values were generated from 11 AVC stations along urban and rural principal arterials in Kansas and then classified by roadway functional class. The average HDF values for rural and urban principal arterials are presented in Figure 2.4. Both rural and urban principal arterials show higher HDF values in the afternoon, evening, and night periods than the AASHTOWare PMED software-recommended values. More truck travel appears in Kansas during the afternoon, evening, and night hours than during the early morning and morning hours. This is expected to significantly affect JPCP slab mean joint faulting calculations and, in turn, the predicted distresses.

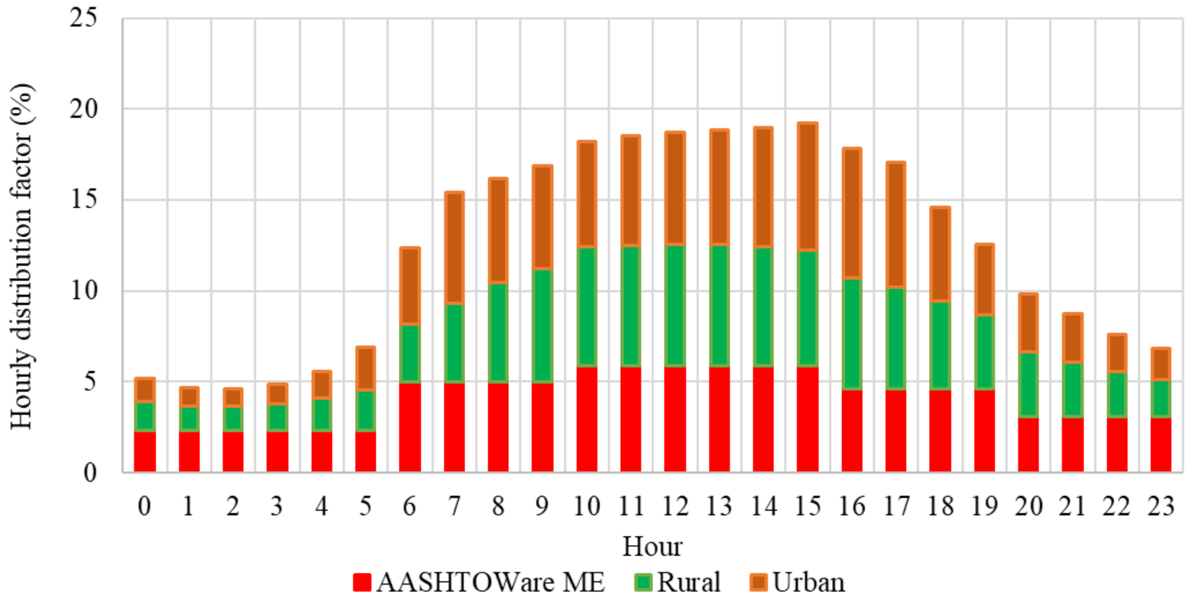


Figure 2.4: Hourly Distribution Factor for Rural and Urban Principal Arterials in Kansas

2.2.1.2.4 Axle Load Spectra

The AASHTOWare PMED software requires the frequency of total axle-load applications within each load-class interval for a specific axle type (single, tandem, tridem, or quad) and vehicle class (Classes 4 through 13, shown in Figure 2.1) for each month. For single axles, load distribution is from 3,000 to 40,000 lb. at 1,000-lb intervals; for tandem axles, distribution ranges from 6,000 to 80,000 lb. at 2,000-lb intervals; and for tridem and quad axles, distribution varies from 12,000 to 102,000 lb. at 3,000-lb intervals.

This study's axle load spectra were derived manually using KDOT-provided WIM data. For all these WIM stations, "W" card data were processed for 48 hours. Although AASHTOWare ME Design requires a normalized axle load distribution for each month, truck weight data were unavailable at any site for any month. However, previous researchers have reported variations in axle load spectra within a year but not across years (Tam & Von Quintus, 2003; Khanum et al., 2005). Thus, this study uses axle load spectra derived from 48 hours of WIM data for each month.

Axle load spectra were developed for 10 WIM stations: five rural and five urban. Statewide distributions of axle loads for rural and urban roadways have been developed by averaging data from the respective WIM sites. Figure 2.5 and Figure 2.6 show the distribution of single- and tandem-axle loads for truck Class 9 on rural and urban roadways in Kansas, compared with the default AASHTOWare PMED values.

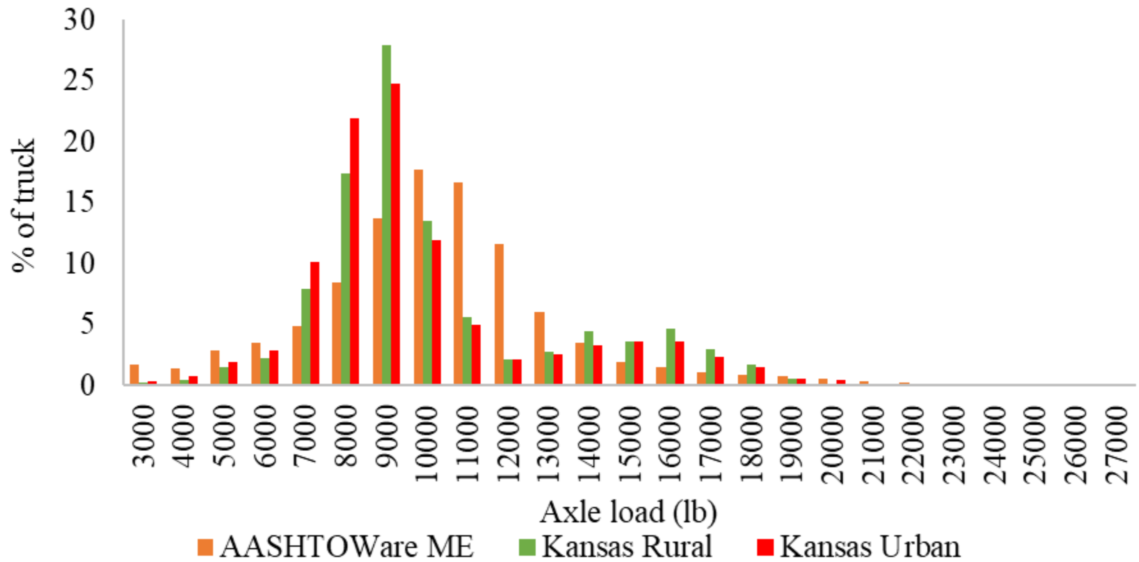


Figure 2.5: Single Axle Load for Truck Class 9 for Kansas

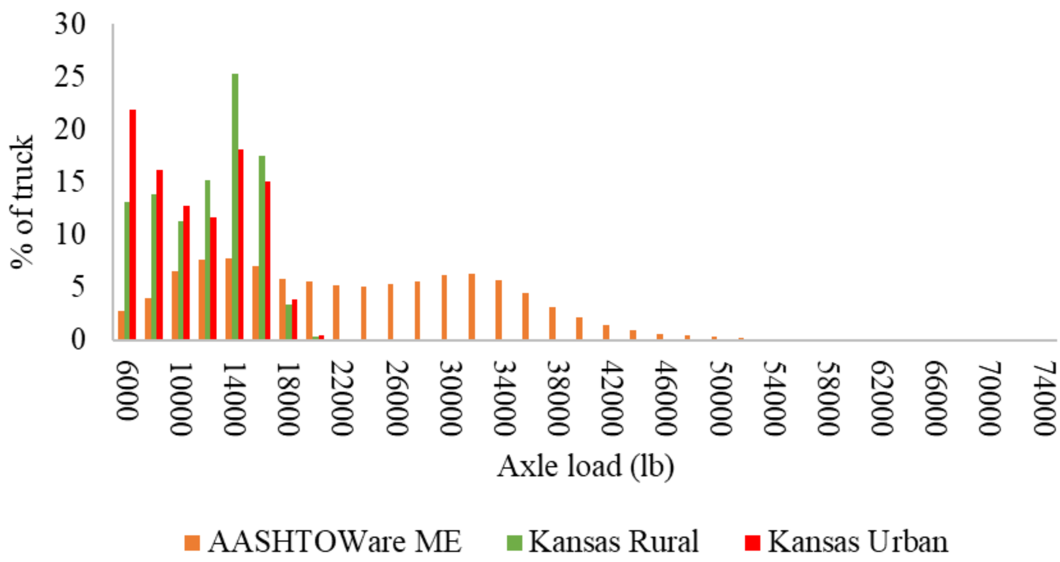


Figure 2.6: Tandem Axle Load for Truck Class 9 for Kansas

For single axle load distribution, Kansas rural traffic shows a frequency between 7,000 and 16,000 lb., whereas urban traffic shows a frequency between 7,000 and 14,000 lb. Kansas traffic shows low frequency above 20,000 lb. in both cases compared to the AASHTOWare default value.

For tandem axle load distribution, Kansas rural traffic shows a higher frequency between 6,000 and 18,000 lb., whereas Kansas urban traffic shows a higher frequency between 6,000 and 16,000 lb. Kansas traffic shows low frequency above 20,000 lb. in both cases compared to the AASHTOWare default value.

The percentage of tridem and quad axles in Kansas is less than one percent of the total axles for rural and urban traffic streams.

2.2.1.2.5 Axle Group per Vehicle

The average number of axle groups per vehicle (AGPV) is another crucial traffic input for the AASHTOWare ME Design software. The software requires AGPV and axle-load spectra to compute the average damage to the pavement structure caused by truck traffic for each vehicle class (Romanoschi et al., 2011).

In this study, the average AGPV values for rural and urban roadways in Kansas were computed from WIM data and presented in Table 2.5. For each vehicle class, AGPV is obtained by dividing the total number of axles (single/tandem/tridem/quad) by the number of trucks.

Table 2.5: Axle Group per Vehicle for Rural and Urban Roadways in Kansas

Vehicle Class	Kansas Rural				Kansas Urban				AASHTO ME Default			
	Single	Tandem	Tridem	Quad	Single	Tandem	Tridem	Quad	Single	Tandem	Tridem	Quad
4	1.90	0.28	-	-	2.21	0.57	0.00	-	1.62	0.39	-	-
5	2.16	0.68	0.08	-	2.08	0.50	0.06	-	2.00	-	-	-
6	1.32	1.70	-	-	1.35	1.65	-	-	1.02	0.99	-	-
7	2.20	0.80	0.10	0.13	1.87	0.96	0.92	0.45	1.00	0.26	0.83	-
8	2.19	1.52	-	-	2.30	1.49	-	-	2.38	0.67	-	-
9	1.54	3.45	0.01	0.00	1.53	3.46	0.02	-	1.13	1.93	-	-
10	2.64	2.00	1.23	0.01	2.21	2.06	1.59	0.29	1.19	1.09	0.89	-
11	4.00	0.00	-	-	5.00	0.00	-	-	4.29	0.26	0.06	-
12	3.84	1.75	-	-	3.99	2.01	-	-	3.52	1.14	0.06	-
13	2.53	0.82	0.55	-	3.70	1.07	-	-	2.15	2.13	0.35	-

2.2.1.3 Dowel Diameter

Dowel bar diameters for all JPCP pavements are shown in Table 2.6.

Table 2.6: KDOT Standard Dowel Bar Diameters

Pavement Depth, D (in.)	Dowel Diameter (in.)
6 < D < 9	1
9 ≤ D < 11	1.25
D ≥ 11	1.5

2.2.1.4 Coefficient of Thermal Expansion (CTE)

CTE values used to calibrate the PCCP models are shown in Table 2.7.

Table 2.7: CTE Values

Coarse Aggregate Type	Adjusted CTE x 10^{-6} (in./in./°F)
Limestone	5.5
Non-Limestone	6.0

2.2.1.5 Base Layer Properties

The unit weight for the chemically stabilized base was 140 pcf for all projects per KDOT recommendation. The base layer modulus has been adjusted for all JPCP pavements, as shown in Table 2.8.

Table 2.8: Modulus of Base Layer Values

Base Layer Type	Modulus (psi)
Cement-treated Base (PCTB)	1,000,000
Granular/Aggregate Base (GB/AB-3)	31,000
Bound Drainable Base (BDB)	650,000

2.2.1.6 Subgrade Soil Properties

2.2.1.6.1 Lime-treated Subgrade Layer (LTSG)

- Poisson's ratio was set to 0.2 per KDOT recommendation.
- Resilient modulus was modified according to the formula below:
    - LTSG M_R (psi) = (2.03 × untreated subgrade M_R, psi) + 225
- Liquid Limit and Plasticity Index were taken as 30 and 5 for the LTSG layer, respectively.

2.2.1.6.2 Compacted Subgrade Layer

Beneath the LTSG layer, a 12-in. compacted subgrade layer was added for all projects. KDOT provided a list of average county-wide soil resilient modulus values used in the calibration. Subgrade soil gradation values were obtained from soil survey reports of the Soil Conservation Service for each county. The extracted engineering properties of subgrade soils are shown in Table 2.9.

Table 2.9: Subgrade Soil Properties for Selected Pavement Sections

Project No.	County	Soil Type	Gradation (% Passing)				Atterberg Limits	
			#4 Sieve	#10 Sieve	#40 Sieve	#200 Sieve	Liquid Limit	Plasticity Index
018K0036000-EB	Cowley	Labette silty clay loam	60-100	60-100	60-95	60-95	40-60	20-35
018U0007700-NB	Cowley	Labette silty clay loam	60-100	60-100	60-95	60-95	40-60	20-35
031I0007000	Geary	Chase silty clay loam	100	100	95-100	90-100	-	-
040I0013500-NB-1	Harvey	Ladysmith silty clay loam	-	100	95-100	90-100	-	-
040I0013500-NB-2	Harvey	Ladysmith silty clay loam	-	100	95-100	90-100	-	-
043U0007500-NB-1	Jackson	Pawnee clay loam	95-100	95-100	85-100	70-85	50-70	25-45
043U0007500-NB-2	Jackson	Pawnee clay loam	95-100	95-100	85-100	70-85	50-70	25-45
046K0000700-SB	Johnson	Grundy silty clay loam	100	100	95-100	95-100	45-55	30-40
055U0004000-WB	Logan	Keith silty clay loam	100	100	-	90-100	-	-
085I0007000-EB	Saline	Detroit silty clay Loam	95-100	95-100	85-100	70-85	50-70	25-45
056I0003500-SB-1	Lyon	Kenoma silty loam	85-100	85-100	85-100	85-100	50-65	30-45
056U0005000-EB-1	Lyon	Osage silty clay	100	100	100	95-100	50-80	30-55
059I0013500-NB	McPherson	Crete silty clay loam	100	100	100	95-100	50-65	25-38
061I0003500-NB	Miami	Woodson silty clay loam	100	95-100	95-100	90-100	50-65	30-45
063U0040000-EB	Montgomery	Dennis silty clay loam	98-100	98-100	94-100	75-98	33-48	13-25
067U0016900-NB	Neosho	Kenoma silty clay loam	85-100	85-100	85-100	85-100	50-75	30-48
079U0008100-NB	Republic	Crete silty clay loam	100	100	-	90-100	50-75	30-48
030I0003500-NB-3	Franklin	Kenoma silty loam	85-100	85-100	85-100	85-100	50-75	30-48
099I0007000-EB-2	Wabaunsee	Martin silt clay loam	100	100	95-100	80-100	40-70	25-40
103U0040000-EB	Wilson	Mason silty clay loam	98-100	98-100	96-100	65-98	40-60	24-34

2.2.2 Calibration of the JPCP Distress Models

Since measured cracking data for the JPCP pavements were unavailable, the cracking model could not be calibrated, and the global calibration values shown in Table 2.10 were treated as local values in the original work. These coefficients remain unchanged during the recalibration work of this study.

Table 2.10: Coefficients for PCC Cracking Model

C1	C2	C3	C4
2	1.22	0.52	-2.17

2.2.3 Calibration of Transverse Joint Faulting Model

2.2.3.1 Assess Local Bias and Standard Error of the Estimate from Global Calibration Factors

Local bias was assessed using hypothesis testing for the transverse joint-faulting model with globally calibrated coefficients. The measured versus predicted faulting is shown in Figure 2.7. A paired t-test at a 95% confidence level resulted in a p-value lower than 0.05, indicating the presence of significant bias in the transverse joint faulting model. The statistical analysis results are shown in Table 2.11. The results show that at a 95% confidence level, there was a significant difference between the measured and predicted faulting. The standard error of the estimate was 0.0115 in. AASHTO recommends that the standard error of estimate be within 0.05 in.

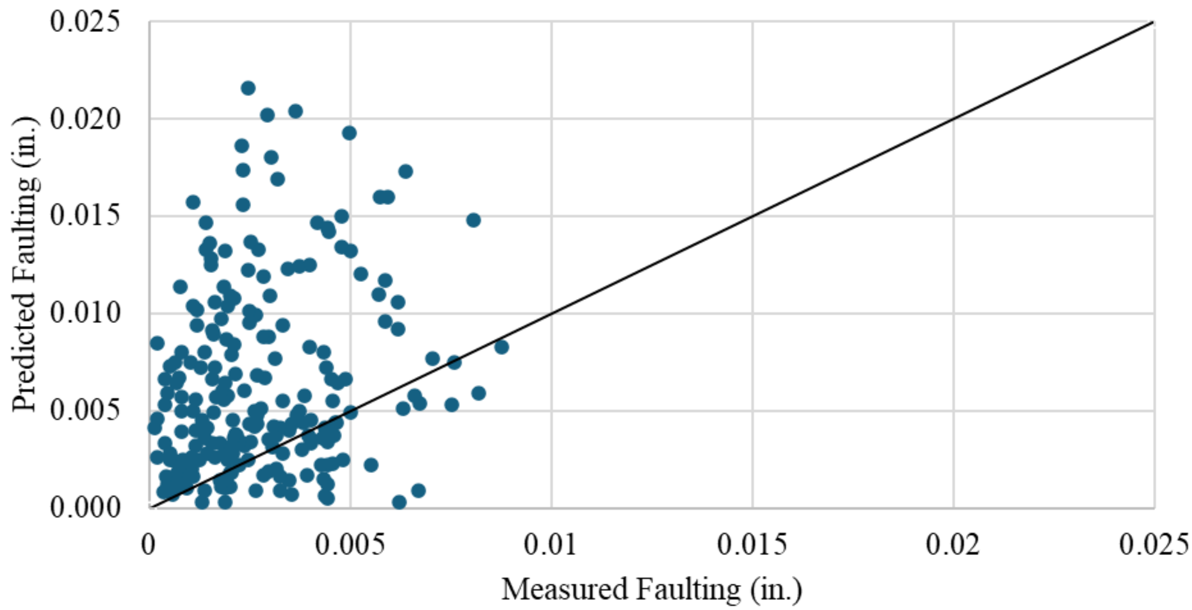


Figure 2.7: Predicted versus Measured Faulting with Nationally Calibrated Factors

Table 2.11: Statistical Analysis Summary Results for Nationally Calibrated Factors

Bias	S_e	S_e/S_y	R^2	P-value	Hypothesis, H_0: ∑(Meas.-Pred.) = 0
0.7748	0.0115	6.43	poor	<0.0001	Rejected

2.2.3.2 Elimination of Local Bias

Islam et al. (2019) performed an initial sensitivity analysis with two randomly selected projects (031I0007000-EB & 019U0006900-NB) to calibrate the faulting model. Since the faulting model contains eight calibration factors, it was essential to identify the most sensitive coefficients to adjust during calibration.

The sensitivity analysis was performed by computing the least-squares sum of errors (LSSE) from the regression model of measured and actual distress data, varying only one calibration factor at a time while keeping all other input parameters constant. Table 2.12 and Table 2.13 present the sum of squared errors (SSE) for varying faulting model coefficients for projects 031I0007000-EB and 019U0006900-NB, respectively.

Table 2.12: Sensitivity Analysis for Faulting Model Coefficients for Project 031I0007000-EB

Coefficient	SSE for Global Coefficient	SSE, after increasing the global coefficient by				SSE, after decreasing the global coefficient by			
		5%	10%	20%	50%	5%	10%	20%	50%
C1	6.90E-05	7.60E-05	8.10E-05	9.50E-05	1.50E-04	6.30E-05	5.90E-05	4.90E-05	2.70E-05
C2	6.90E-05	7.60E-05	8.60E-05	1.10E-04	1.80E-04	6.20E-05	5.50E-05	4.40E-05	1.90E-05
C3	6.90E-05	7.30E-05	7.50E-05	8.20E-05	1.00E-04	6.60E-05	6.30E-05	5.70E-05	4.00E-05
C4	6.90E-05	7.30E-05	7.60E-05	8.20E-05	1.00E-04	6.60E-05	6.30E-05	5.60E-05	4.20E-05
C5	6.90E-05	7.00E-05	7.00E-05	7.20E-05	7.60E-05	6.80E-05	6.70E-05	6.60E-05	6.00E-05
C6	6.90E-05	8.20E-05	9.80E-05	1.40E-04	3.90E-04	5.80E-05	4.80E-05	3.40E-05	1.20E-05
C7	6.90E-05	6.90E-05	6.90E-05	6.90E-05	6.90E-05	6.90E-05	6.90E-05	6.90E-05	6.90E-05

Table 2.13: Sensitivity Analysis for Faulting Model Coefficients for Project 019U0006900-NB

Coefficient	SSE for Global Coefficient	SSE, after increasing global coefficient by				SSE, after decreasing the global coefficient by			
		5%	10%	20%	50%	5%	10%	20%	50%
C1	9.60E-06	1.10E-05	1.20E-05	1.30E-05	2.20E-05	8.40E-06	7.80E-06	6.40E-06	3.20E-06
C2	9.60E-06	1.10E-05	1.10E-05	1.40E-05	2.30E-05	8.20E-06	7.60E-06	6.30E-06	2.80E-06
C3	9.60E-06	1.00E-05	1.10E-05	1.20E-05	1.50E-05	8.80E-06	8.30E-06	7.80E-06	5.00E-06
C4	9.60E-06	1.00E-06	1.00E-05	1.10E-05	1.40E-05	9.10E-06	8.60E-06	8.00E-06	5.90E-06
C5	9.60E-06	9.60E-06	9.80E-06	1.00E-06	1.00E-05	9.10E-06	9.10E-06	9.10E-06	7.70E-06
C6	9.60E-06	1.10E-05	1.40E-05	1.20E-05	6.10E-05	8.00E-06	6.40E-06	4.50E-06	1.50E-06
C7	9.60E-06	9.60E-06	9.60E-06	9.60E-06	9.60E-06	9.60E-06	9.60E-06	9.60E-06	9.60E-06

From Table 2.12 and Table 2.13, it can be seen that coefficient C6 is the most sensitive. LSSE gets reduced by 83% when C6 is 50% lower than the global value. Coefficient C6 correlates the influence of overburden on the subgrade, the percent of subgrade material passing the No. 200 sieve, and the average annual number of wet days with the faulting potential (AASHTO, 2010).

The sensitivity analysis shows that C1, C2, C3, and C4 are also sensitive. The local calibration guide suggests adjusting coefficients C1 and C2 to influence the magnitude of mid-range and long-range faulting. In contrast, coefficients C3 and C4 must be adjusted to account for initial faulting.

The sensitivity analysis shows that coefficient C7 is insensitive. The coefficient C5 was found to be a little sensitive. This coefficient relates a change in erodibility to a change in the rate of predicted faulting, and coefficient C7 represents the increase in the rate of long-term faulting.

Based on faulting data from the PMIS database, it was determined that the initially measured faulting was less than the AASHTOWare PMED (with globally calibrated coefficients) predicted. The measured faulting for all calibration and validation projects is available elsewhere (Sufian, 2016). Also, AASHTOWare PMED software over-predicts mid-range faulting. To address this issue, coefficient C1 was decreased to lower initial predicted faulting, and coefficient C3 was reduced to decrease predicted faulting in the mid-range. Also, coefficient C6 was reduced to eliminate bias as it was the most sensitive. The coefficient C6 was the only change in the recalibration process.

To calibrate the faulting model, the AASHTOWare PMED analysis was performed multiple times using a large factorial of C1, C3, and C6 to reduce bias between the measured and predicted data. Figure 2.8 shows the measured versus predicted faulting after local calibration. Table 2.14 shows that the bias between predicted and measured faulting decreased from 0.775 in. to 0.0049 in. after local calibration, indicating an improvement.

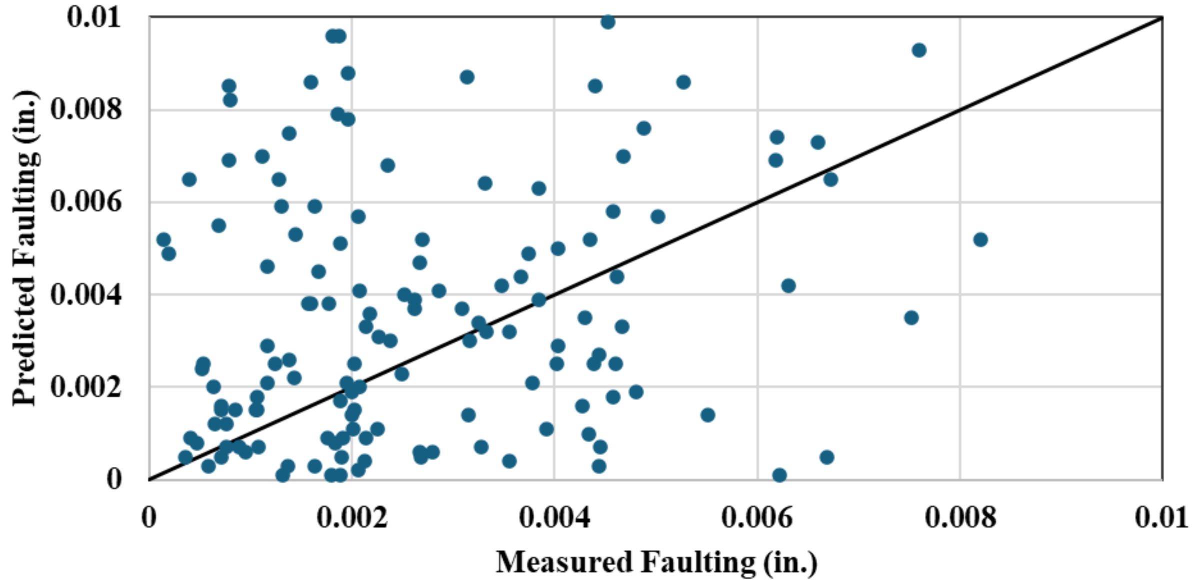


Figure 2.8: Predicted versus Measured Faulting with Local Calibration Factors

The summary parameters of the statistical analysis after local calibration are listed in Table 2.14. A paired t-test at the 95% confidence level yielded a p-value greater than 0.05, indicating that the bias between predicted and measured distress has been significantly reduced. The standard error of the estimate is 0.0097 in., which is lower than AASHTO's recommended limiting criteria (0.05 in.). Thus, no further refinement was needed.

Table 2.14: Statistical Analysis Summary for Locally Calibrated Factors

Bias	S_e	S_e/S_y	R^2	P-value	Hypothesis, H_0: ∑(Meas.-Pred.) = 0
0.0490	0.0097	1.516	poor	0.4683	Accepted

* R^2 value poor implies a value less than 0.01

2.2.3.3 Validation of Transverse Joint Faulting Model

The projects listed in Table 2.15 were used for validation. Note that all projects considered for local calibration are pavement sections with a Portland cement-treated base (PCTB). However, four out of five projects selected for validation contained bound drainable bases (BDB). Since KDOT does not design PCCP pavements with BDB and consequently did not include projects with BDB bases for calibration, four projects with BDB bases were selected for validation. The projects with BDB bases were chosen carefully with minimal IRI increase over time.

Table 2.15: General Description of the Projects for Validation

No.	Project Name	Route	Base Layer Type	County	Begin milepost	End milepost	Length (mile)
1	019U0006900-NB	US-69	BDB	Crawford	15.71	23.90	8.19
2	029U0005600-EB	US-56	BDB	Ford	12.17	15.60	3.43
3	030I0003500-NB-3	I-35	BDB	Franklin	19.87	26.85	6.97
4	055U0004000-WB	US-40	PCTB	Logan	35.69	38.65	2.96
5	099I0007000-EB-2	I-70	BDB	Wabaunsee	5.19	8.02	2.83

The parameters describing the success of the statistical analysis for the transverse joint faulting model after validation are shown in Table 2.16. The bias and standard error are low with locally calibrated coefficients. A paired t-test at the 95% confidence level yielded a p-value greater than 0.05, indicating that the bias between predicted and measured distress is insignificant.

Table 2.16: Summary of Statistical Analysis for Local Calibrated Factors for Validation

Bias	S_e	S_e/S_y	R^2	P-value	Hypothesis, H_0: ∑(Meas.-Pred.) = 0
0.0143	0.0029	1.257	0.434	0.195	Accepted

2.2.3.4 Final Calibration Results

After completion of local calibration, the coefficients shown in Table 2.17 were selected.

Table 2.17: Calibration Coefficient Transverse Joint Faulting Model

C1	C2	C3	C4	C5	C6	C7	C8
0.565	1.636	0.00235	0.00444	250	0.08554	7.3	400

2.2.4 Calibration of IRI Model

AASHTOWare Pavement ME Design software predicts the International Roughness Index (IRI) based on the following equation:

$$IRI = IRI_I + C1 \times CRK + C2 \times SPALL + C3 \times TFAULT + C4 \times SF$$

Equation 2.1

where:

IRI = Predicted IRI (in./mile);

IRII = Initial smoothness measured as IRI (in./mile);

CRK = Percent slabs with transverse cracks (all severities);

SPALL = Percentage of joints with spalling (medium and high severities);

TFAULT = Total joint faulting cumulated per mile (in.), and

C1, C2, C3, C4 = Calibration factors.

Site factor (SF) is based on the following equation:

$$SF = AGE\ [(1+0.5556\times FI)\ (1+P_{200})\ \times 10^{-6}]$$

Equation 2.2

where:

AGE = Pavement age (year);

FI = Freezing index (°F-days); and

P_{200} = Percent subgrade material passing #200 sieve

The local bias was determined using the globally calibrated factors for the IRI model. Table 2.15 lists the global calibration results. The result shows a 500-inch/mile bias between predicted and measured IRI for the globally calibrated model. Thus, the globally calibrated model showed significant bias in the paired t-test, and the null hypothesis was rejected at a 95% confidence interval. The measured versus predicted IRI (globally calibrated) relationship is shown in Figure 2.9.

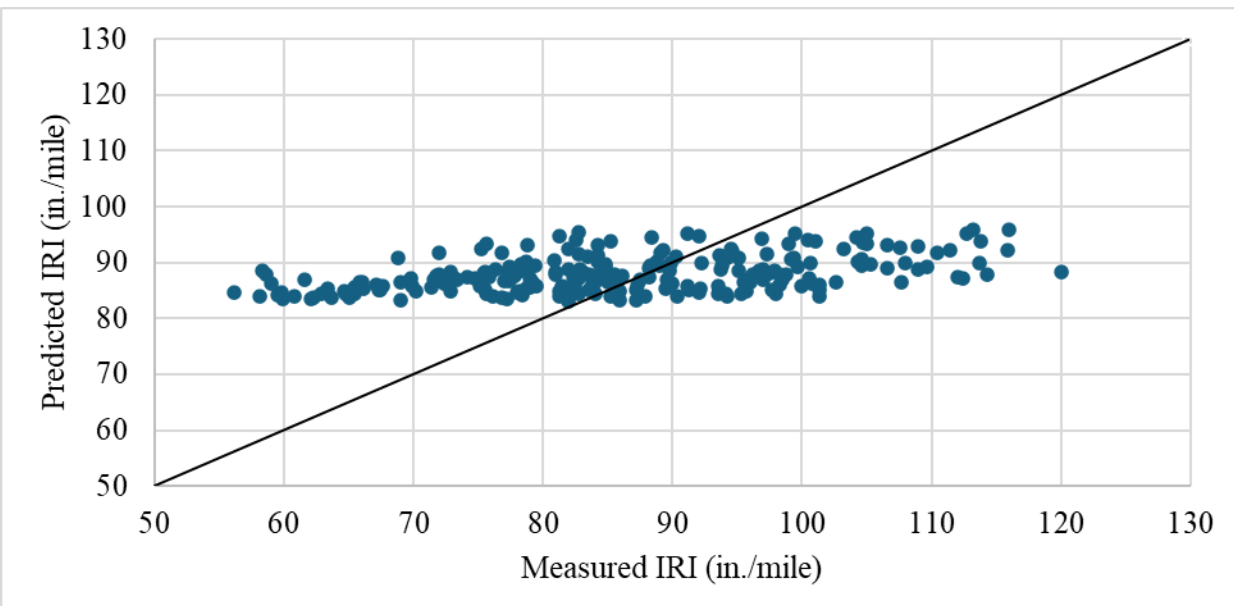


Figure 2.9: Predicted versus Measured IRI with Globally Calibrated Factors

2.2.4.1 Elimination of Local Bias for the IRI Model

The Generalized Reduced Gradient (GRG) nonlinear optimization technique was applied in Microsoft Excel Solver to reduce local bias in the IRI model. The following steps were followed in this process (Islam et al., 2019):

1. Equation (i) was defined in the Excel spreadsheet as a summation of cracking, spalling, faulting, and site factor multiplied by coefficients C1, C2, C3, and C4, respectively.
2. The residual errors for the complete data set were obtained as the difference between the measured and predicted IRI.
3. The SSE was obtained from the residuals. The sum of SSE was then computed.
4. Microsoft Solver was used to adjust the coefficients to minimize SSE for the whole data.
5. These adjusted coefficients were used as the calibrated coefficients of the IRI model in the AASHTOWare Pavement ME Design software, and a paired t-test was conducted between the measured data and the predicted data.

2.2.4.2 Influence of Initial IRI in Calibration

While calibrating the IRI model, the initial IRI was set to 60 in./mile based on the earlier KU study. With that value, calibration coefficient C4 was found to be 136 (global value is 25.24). The statistical parameters were satisfactory for both calibration and validation. However, researchers noted that many KDOT projects were failing on IRI. Since the AASHTOWare PMED software predicted minor cracking, spalling, and faulting, the critical parameters in the IRI model were the site factor and initial IRI. The PMIS database did not contain the initial IRI values for these projects since, in KDOT, construction specifications for smoothness are based on the profilograph measurements. Thus, 83 in./mile was used as the initial IRI in the calibration project per KDOT recommendation.

The optimization process was repeated with the modified initial IRI, and the optimized coefficients are listed in Table 2.18. In this recalibration process, only C4 was adjusted.

Table 2.18: Calibration Coefficient Values for the IRI Model

C1	C2	C3	C4
0.8203	0.4417	1.4929	18.75

The paired t-test results after local calibration are shown in Table 2.19. The results show that the bias was significantly reduced. The measured versus predicted IRI (locally calibrated) relationship is shown in Figure 2.10.

Table 2.19: Summary of Statistical Analysis for Global and Local Calibrated Factors for Validation

	Bias	S_e	S_e/S_y	R^2	P-value	Hypothesis, H_0: ∑(Meas.-Pred.) = 0
Global	504.155	13.003	0.919	0.209	0.010	Rejected
Local	227.132	10.926	1.078	0.069	0.051	Accepted

It can be seen from Table 2.16 that the standard error of estimate has decreased slightly after calibration. The Guide for Local Calibration of Mechanistic-Empirical Pavement Design recommends recalibrating the model to reduce the standard error of estimate if the agency believes the standard error is too large and results in an overly conservative design at higher reliability levels. As noted earlier, there are four components of the total standard error. According to the design guide, only the "input error" component can be reduced through calibration. The guide further states that measurement error in distress/IRI significantly contributes to these error components. The agency needs to decide whether to incur additional costs and effort to reduce the total standard error. Nonetheless, the design guide recommends that the standard error of estimate of the JPCP IRI model should be within 17 in./mile.

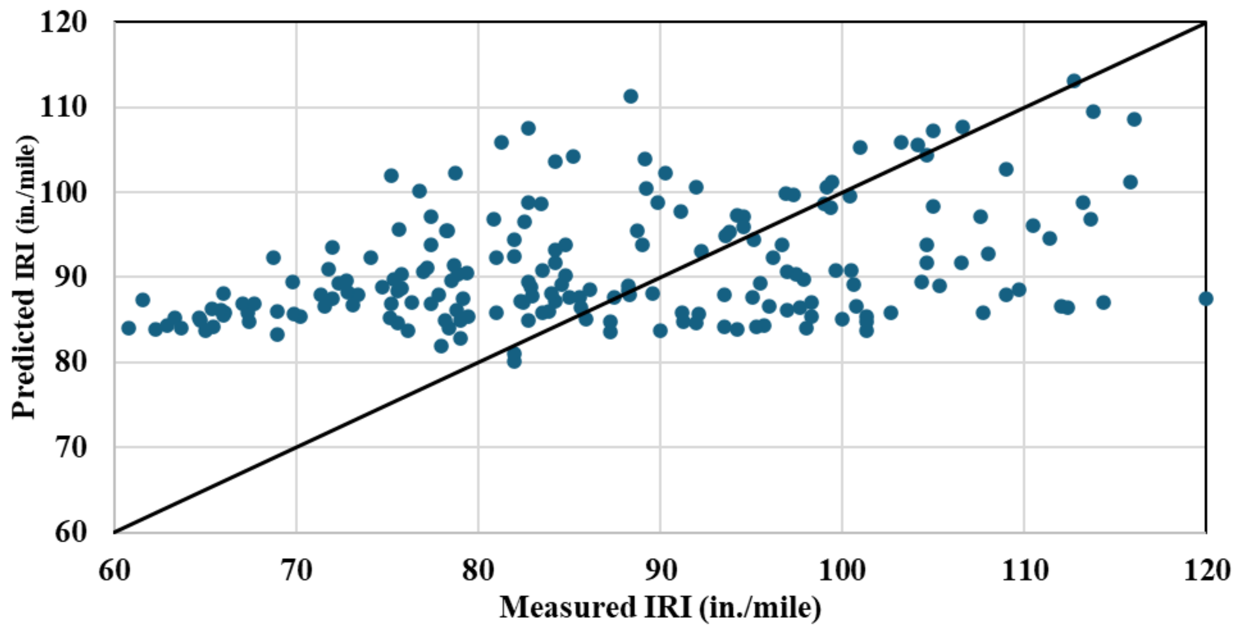


Figure 2.10: Predicted versus Measured IRI with Locally Calibrated Factors

The statistical analysis results for the IRI model after validation are shown in Table 2.20. The bias and standard error are low with locally calibrated factors.

Table 2.20: Summary of Statistical Analysis for IRI for Locally Calibrated Factors for Validation

	Bias	S_e/S_y	R^2	P-value	Hypothesis, H_0: ∑(Meas.-Pred.) = 0
Local	8.819	0.931	0.134	<0.0001	Rejected

In Table 2.20, the p-value from the paired t-test for the IRI model is very small, indicating rejection of the null hypothesis. This is because the projects selected for IRI model validation were intentionally chosen to show minimal increases in IRI over time. Nonetheless, the bias and standard error are relatively small with locally calibrated coefficients.

2.2.4.3 Calibration Results

After local calibration, the IRI model coefficients for the JPCP in Kansas are shown in Table 2.21. The adjusted coefficients are shown in bold text.

Table 2.21: Calibration Coefficients of the JPCP IRI Model

C1	C2	C3	C4
0.8203	0.4417	1.4929	**18.75**

Table 2.22 shows how the recalibrated coefficients for local materials, traffic, and climatic conditions compare with those in the national models. Changes are shown in bold.

Table 2.22: JPCP Performance Model Calibration Parameters

Model	Calibration coefficient	National default (Ver. 2.5.0)	National default (Ver. 2.6.2)	Kansas
Transverse cracking	C1	-	2	2
	C2	-	1.22	1.22
	C4	0.52	0.52	0.52
	C5	−2.17	−2.17	−2.17
Faulting	C1	0.595	0.595	0.595
	C2	1.636	1.636	1.636
	C3	0.00217	0.00217	**0.0024**
	C4	0.00444	0.00444	0.0044
d	C5	250	250	250
	C6	0.47	0.47	**0.0855**
	C7	7.3	7.3	7.3
	C8	400	400	400
IRI	J1	0.8203	0.8203	0.8203
	J2	0.4417	0.4417	0.4417
	J3	1.4929	1.4929	1.4929
	J4	25.24	25.24	**18.75**

2.3 Flexible Pavements

Twenty-seven (27) flexible pavement projects were selected for local calibration and validation by Sufian (2016). The traditional splitting data method was used to determine the accuracy of the calibrated model and verify the goodness-of-fit statistics during calibration. Twenty-one (21) projects were used for calibration, and six were used for validation. Table 2.23 provides a general description of the projects used for local calibration. Table 2.24 lists the projects used for validation.

Table 2.23: Selected Projects for New Flexible Pavement Local Calibration

No.	Project Name	Route	County	Begin milepost	End Milepost	Length (mile)
1	007U0007500-NB	US-75	Brown	13.05	19.68	6.63
2	008U0005400-EB	US-54	Butler	17.47	25.69	8.22
3	008U0007700-NB-1	US-77	Butler	0	12.71	12.71
4	008U0007700-NB-2	US-77	Butler	33.88	43.44	9.56
5	008U0007700-NB-3	US-77	Butler	43.44	50.67	7.23
6	011U0006900-NB	US-69	Cherokee	8.45	11.44	2.99
7	019K0000700-NB-1	K-7	Crawford	0	4.97	4.97
8	019K0000700-NB-2	K-7	Crawford	4.97	10.99	6.02
9	019U0016000-EB	US-160	Crawford	9.69	14.54	4.85
10	023U0004000-EB	US-40	Douglas	11.24	12.44	1.20
11	025K0009900-NB	K-99	Elk	12.92	21.72	8.80
12	027K0015600-EB	K-156	Ellsworth	5.63	18.40	12.77
13	028U0005000-EB	US-50	Finney	19.88	29.37	9.48
14	031K0001800-WB	K-18	Geary	15.55	17.55	2.00
15	033U0028300-NB	US-283	Graham	16.96	30.36	13.40
16	052U0007300-NB	US-73	Leavenworth	18.45	20.92	2.47
17	065K0002700-NB	K-27	Morton	0	2.67	2.67
18	065U0005600-EB	US-56	Morton	19.76	21.87	2.12
19	069U0028300-NB	US-283	Norton	21.55	32.05	10.50
20	082U0018300-NB	US-183	Rooks	0	5.92	5.92
21	095U0005600-EB	US-56	Stevens	8.57	11.12	2.55

Table 2.24: Selected Projects for New Flexible Pavement Validation of Calibration Process

No.	Project Name	Route	County	Begin milepost	End milepost	Length (mile)
1	003U0007300-NB	US-73	Atchison	0	4.14	4.14
2	022K0000700-NB	K-7	Doniphan	5.92	11.71	5.79
3	088U0005400-WB	US-54	Seward	0	3.87	3.87
4	091K0002700-NB	K-27	Sherman	0	4.19	4.19
5	098U0028300-NB	US-283	Trego	10.03	21.49	11.46
6	103K0003900-NB	K-39	Wilson	14.47	16.43	1.96

2.3.1 Input Parameters

2.3.1.1 HMA Layer Properties

The AASHTOWare PMED software requires the asphalt mix's dynamic modulus (E*), creep compliance, and indirect tensile strength for level 1 input. Dynamic shear modulus (G*) and the asphalt binder's phase angle (δ) values are also required to generate dynamic modulus master curves for asphalt mixes. Since these data were not available for the selected projects, the researchers extracted level 3 input values (aggregate gradation, binder grade, and mix volumetric properties) from KDOT's mix design database for surface, intermediate, and base layers. However, for one project (065K0002700-NB), no data was available. For this project, KDOT suggested using aggregate gradation as the midpoint values for the BM-1T mix for the surface course and the BM-2C mix (KDOT 1990 standard specification) for the binder and base courses. The latter mixes contained an AC-10 asphalt cement equivalent to a PG 58-28 binder. The level 3 inputs for all the projects are listed in Table 2.25. For level 3 inputs, aggregate gradation and mixture volumetric properties were used in the modified Witczak model to compute the dynamic modulus (E*) of the hot-mix asphalt (HMA) layer.

The unit weight of the HMA mix for all projects was 140 pcf, per KDOT's recommendation. The air void of the surface course mixture was 8%, while the air void for the binder and base course mixtures was 7%. The Poisson's ratio for the HMA mix was assumed to be 0.35.

Table 2.25: Inputs of AC Properties

Input Parameters		Source	Value Used	Input Level
Mixture Volumetrics	Thickness (in.)	APD	As in APD	1
	Unit weight (pcf)	Default	140	3
	Poisson's ratio	Default	0.35	3
	Air voids (%)	Default	7	3
	Effective binder content (%)	KDOT suggestion	KDOT suggestion	3
Mechanical Properties	Preference temperature (°F)	Default	70	3
	Indirect tensile strength at 14 °F (psi)	Default	Default value	3
	Creep compliance (1/psi)	Default	Default value	3
Thermal	Thermal conductivity (BTU/hr-ft-°F)	Default	0.67	3
	Heat capacity (BTU/lb-°F)	Default	0.23	3
	Thermal contraction	Default	1.30E-05	3
AC Layer Properties	AC surface shortwave absorptivity	Default	0.85	3
	Is endurance limit applied?	Default	No	3
	Endurance limit (microstrain)	Default	100	3
	Layer interface	Default	Full friction interface	3

2.3.1.2 Unbound Layer Properties

Two of the 27 projects selected for this study were designed with an unbound base course layer (AB-3). KDOT suggested the base course layer's resilient modulus (M_R) to be 31,000 psi. The gradation and the Atterberg limits data were collected from previous projects for this layer.

All projects except one (019U0016000-EB) selected for local calibration and validation were built with a 6-inch treated subgrade layer on top of the natural subgrade. In most cases, this 6-inch layer was treated with lime. In a few projects, fly ash and mechanically stabilized layers were used. The resilient modulus of the mechanically stabilized layer was set to 25,000 psi (KDOT recommended). For the lime/fly-ash treated layers, the M_R was calculated using the following equation:

$$\text{LTSG } M_R \text{ (psi)} = (2.03 \times \text{untreated subgrade } M_R\text{, psi}) + 225$$

Equation 2.3

The AASHTOWare PMED software requires resilient modulus and soil gradation data for the unbound layers. KDOT provided the resilient modulus data for these projects. Subgrade soil gradation values were obtained from county soil survey reports of the Soil Conservation Service.

2.3.1.3 Climate

The climatic stations used in this recalibration study were chosen from the AASHTOWare PMED software and are shown in Table 2.26.

Table 2.26: Site-specific Climate Inputs for Flexible Pavement Projects

Project Name	Climate Station	Latitude (deg)	Longitude (deg)	Elevation (ft)
003U0007300-NB	De Soto	39.000	-95.000	781
007U0007500-NB	Brown	39.500	-95.625	1069
008U0007700-NB-1	El Dorado	37.500	-96.875	1342
008U0007700-NB-2	Burns	38.000	-96.875	1407
008U0007700-NB-3	El Dorado	38.000	-96.875	1407
008U0005400-EB	Wichita	37.500	-96.250	1043
011U0006900-NB	Cherokee	37.500	-95.000	951
019K0000700-NB-1	Beulah	37.500	-95.000	951
019K0000700-NB-2	Beulah	37.500	-95.000	951
019U0016000-EB	Beulah	37.500	-95.000	951
022K0000700-NB	Doniphan	39.500	-95.000	997
023U0004000-EB	Lawrence	39.000	-95.000	781
025K0009900-NB	Longton	37.500	-96.250	1043
027K0015600-EB	Lawrence	38.000	-98.125	1633
028U0005000-EB	Garden City	38.000	-100.625	2834
031K0001800-WB	Manhattan	39.000	-96.875	1138
033U0028300-NB	Junction City	39.500	-99.375	2034
052U0007300-NB	Fairmount	39.500	-95.000	997
065K0002700-NB	Wilburton	37.500	-101.875	3496
065U0005600-EB	Wilburton	37.500	-101.875	3496
069U0028300-NB	Norton	40.000	-100.000	2260
082U0018300-NB	Rooks	39.500	-99.375	2034
088U0005400-WB	Seward	38.000	-98.750	1922
091K0002700-NB	Goodland	39.500	-101.875	3739
095U0005600-EB	Hugoton	37.500	-101.250	2939
098U0028300-NB	Ogalala	39.000	-100.000	2467
103K0003900-NB	Wilson	39.000	-98.750	1597

2.3.1.4 Pavement Performance Data

KDOT measures the extent of fatigue cracking in the wheel path, in feet per 100 ft of sample, by severity. Three 100-ft samples are taken from a one-mile segment of a particular project. Rutting and roughness are measured on the left wheel path of the outer lane. The measured distress data for all the projects were extracted from the KDOT Pavement Management Information System (PMIS) database. The following distress data were extracted from the database:

- Total rutting
- Top-down longitudinal cracking
- HMA/Asphalt Concrete (AC) thermal cracking
- International Roughness Index (IRI)

2.3.2 Calibration of the Flexible Distress

2.3.2.1 Permanent Deformation/Rutting Model

The AASHTOWare software uses the incremental damage approach to predict total rutting. Rutting is estimated as the summation of rut depths accumulated in all bound and unbound layers. The software assumes no rutting occurs in the stabilized base and sub-base layers (Kim et al., 2011).

For HMA mixtures, the permanent deformation model is shown in Equation 2.4.

$$\Delta p(\text{HMA}) = \beta_{1r k_z} \varepsilon r(\text{HMA}) 10^{k_{3r}\beta_{3r}} T^{k_{2r}\beta_{2r}}$$

Equation 2.4

where:

$\Delta p(\text{HMA})$ = Accumulated permanent or plastic vertical deformation in the HMA layer (in.);

$\varepsilon r(\text{HMA})$ = Resilient or elastic strain calculated by the structural response model at the mid-depth of each HMA layer (in.);

n = of axle-load repetitions;

T = Mix or pavement temperature (°F);

kz = Depth confinement factor;

$k_{1r,2r,3r}$ = Global calibration factors (material-specific coefficients that are determined from the repeated load tri-axial tests for permanent deformation); and

β1r, β2r, β3r = Local calibration coefficients.

For unbound layers, the rut depth model is shown in Equation 2.5.

$$\Delta_{p(soil)} = \beta_{s1} k_{s1} \varepsilon_v h_{soil} \left(\frac{\varepsilon_o}{\varepsilon_r}\right) e^{-\left(\frac{p}{n}\right)^{\beta}}$$

Equation 2.5

where:

$\Delta p(\text{soil})$ = Permanent or plastic vertical deformation in the unbound layer (in.);

εo = Intercept determined from laboratory repeated load permanent deformation tests (in./in.);

εr = Resilient strain imposed in laboratory tests to obtain material properties (in./in.);

εv = Average vertical resilient or elastic strain in the unbound layer calculated by the structural response model (in./in.);

$h$soil = thickness of the unbound layer (in./in.);

ks1 = Global calibration coefficients (ks1 = 2.03 for granular materials and 1.35 for fine-grained materials); and

βs1 = Local calibration coefficients.

2.3.2.2 Assess Local Bias and Standard Error of the Estimate from Global Calibration Factors

Local bias was determined by hypothesis testing for the total permanent deformation model with globally calibrated coefficients. The globally calibrated model showed significant bias in the paired t-test, and the null hypothesis was rejected at a 95% confidence interval (Table 2.27).

Table 2.27: Summary Statistical Analysis for Global Calibrated Factors for the Rutting Model

Bias	S_e	S_e/S_y	R^2	P-value	Hypothesis, H_0: ∑(Meas.-Pred.) = 0
-17.86	0.06	1.20	0.25	<0.0001	Rejected

The measured versus predicted total rutting for global calibration factors is shown in Figure 2.11. These values differ across all projects.

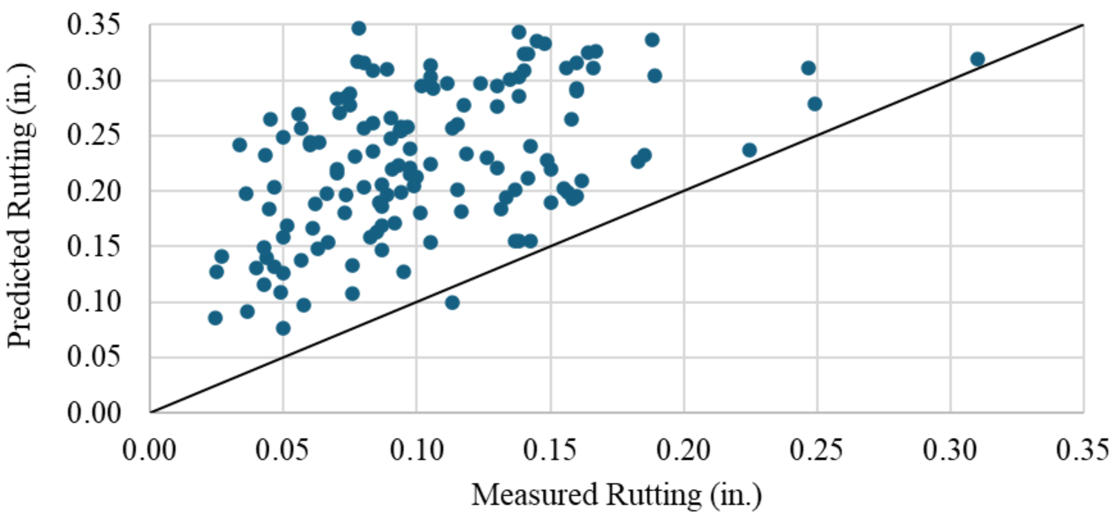


Figure 2.11: Predicted versus Measured Total Rut Depth with Globally Calibrated Factors

2.3.2.3 Elimination of Local Bias for the Rutting Model

From Equations 2.4 and 2.5, it can be observed that the calibration parameter $\beta 1r$ and $\beta s1$ can be optimized outside AASHTOWare to reduce bias and standard error. The Generalized Reduced Gradient (GRG) nonlinear optimization technique was performed using Microsoft Excel Solver to optimize $\beta 1r$ and $\beta s1$.

However, $\beta 2r$ and $\beta 3r$ are not direct multipliers and cannot be optimized outside AASHTOWare. These two calibration coefficients denote the effects of temperature and loading cycles on the HMA layers, respectively (Kim et al., 2011). The AASHTOWare PMED software was run numerous times using a large factorial of $\beta 2r$ and $\beta 3r$. The combination that resulted in the smallest sum of the squares of error (SSE) was selected for $\beta 2r$ and $\beta 3r$.

These adjusted coefficients were used as the locally calibrated coefficients in the permanent deformation model in the AASHTOWare PMED software. A paired t-test was conducted between the measured and predicted data; the results after local calibration are shown in Table 2.28. The results show that the bias was significantly reduced.

Table 2.28: Summary Statistical Analysis of Local Calibrated Factors for the Rutting Model

Bias	S_e	S_e/S_y	R^2	p-value	Hypothesis, H_0: $\sum$(Meas.-Pred.) = 0
8.78	0.091	0.907	0.128	0.058	Accepted

The measured vs predicted total rutting for local calibration factors is shown in Figure 2.12. The values nicely wrap around the 45° line as expected.

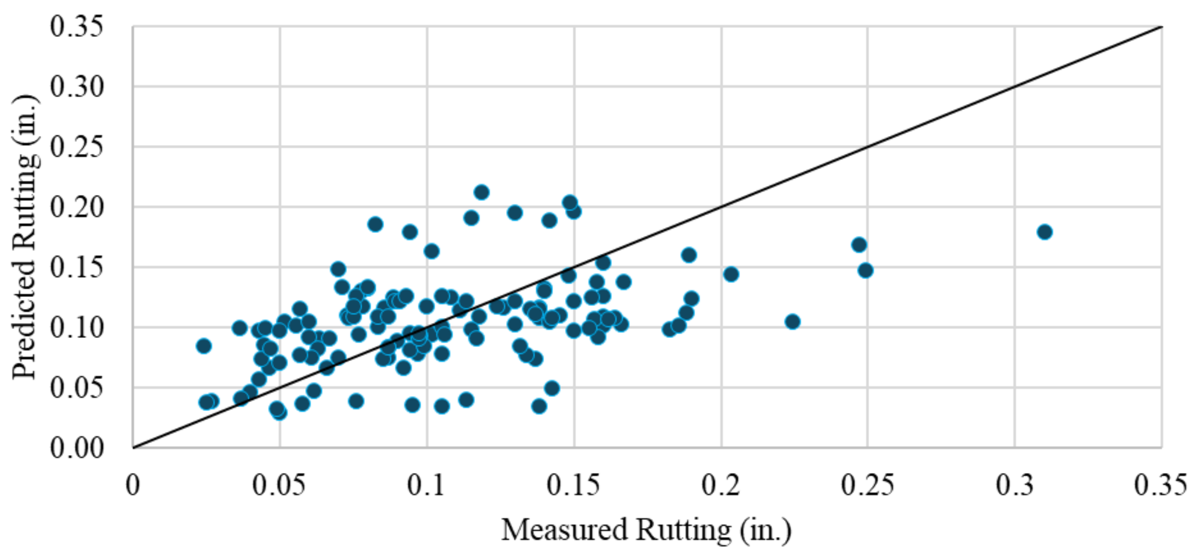


Figure 2.12: Predicted versus Measured Total Rut Depth with Local Calibrated Factors

The results in Table 2.24 show that the standard error of the estimate (S_e) has decreased slightly after calibration (0.05 in.). The local calibration guide for the AASHTOWare software recommends that the standard error of estimate of the permanent deformation model should be within 0.10 in. (AASHTO, 2010).

The statistical analysis results for the permanent deformation model after validation are shown in Table 2.29. The bias and standard errors are low with locally calibrated factors.

Table 2.29: Summary of Statistical Analysis for a Rutting Model for Local Coefficients for Validation

Bias	S_e	S_e/S_y	R^2	p-value	Hypothesis, H_0: $\sum$(Meas.-Pred.) = 0
-1.224	0.057	1.191	0.001	0.574	Accepted

2.3.2.4 Calibration Results

After completion of local calibration, the coefficients shown in Tables 2.30 and 2.31 were selected for the permanent deformation model. The adjusted coefficients are shown in bold.

Table 2.30: Calibrated AC Rutting Model Coefficients

Br_1	Br_2	Br_3
0.75	1.0	**0.85**

Table 2.31: Calibrated Subgrade Rutting Model Coefficients

Bs_1 (fine)	Bs_1 (granular)
0.4	1.0

2.3.3 Load-Related Cracking Model

The AASHTOWare PMED software predicts two types of fatigue- or load-related cracking: bottom-up (alligator) and top-down (longitudinal). Fatigue damage prediction is based on the incremental damage approach, and the allowable number of axle-load applications ($N_{f\text{-}HMA}$) is required to calculate the damage indices. The AASHTOWare software uses the Asphalt Institute (MS-1) model to determine $N_{f\text{-}HMA}$. This model is shown in Equation 2.6.

$$N_{f-HMA} = k_{f1}(C)(C_H)\beta_{f1}(\varepsilon_t)^{k_{f2}\beta_{f2}(E_{AC})k_{f3}\beta_{f3}}$$

Equation 2.6

where:

ε_t = Tensile strain at critical location calculated by the structural response model (in./in.);

E_{AC} = Dynamic modulus of HMA measured in compression (psi);

k_{f1}, k_{f2} and k_{f3} = Global calibration factor (material-specific coefficients);

β_{f1}, β_{f2} and β_{f3} = Local calibration coefficients;

C = 10M

$M = 4.84 \times (\frac{Vbe}{Va+Vbe} - 0.69)$

V_{be} = Effective asphalt content by volume (%);

V_a = Percent air voids in HMA mixture; and

C_H = Thickness correction factor.

AASHTOWare calculates the cumulative damage (DI) by summing the incremental damage indices over time as:

$$DI = \sum (\frac{n}{N_{f-HMA}})_{j,m,l,p,T}$$

Equation 2.7

The fatigue damage transfer functions for top-down ($FC_{Top\text{-}down}$) and bottom-up ($FC_{Bottom\text{-}up}$) cracking are:

$$FC_{Top-down} = 10.56 \times \frac{1000}{1+e^{C1-C2*logD}})$$

Equation 2.8

where:

C1 & C2 = Local calibration coefficients.

$$FC_{Top-down} = \frac{6000}{1+e^{(C1C'1+C2C'2Log(DI*100))}}$$

Equation 2.9

C'1 = 2* C'2

$C'2 = -2.40874-39.748(1+H_{HMA})^{-2.856}$

H_{HMA} = Asphalt layer thickness, and

C1 & C2 = Local calibration coefficients.

2.3.3.1 Bottom-up Fatigue Cracking Model

The KDOT PMIS database showed no bottom-up cracks for the projects considered for calibration and validation. Moreover, KDOT recognizes all load-related cracking as top-down cracking. Since the measured data for this distress model were unavailable, the bottom-up fatigue cracking model was not calibrated.

2.3.3.2 Top-down Fatigue Cracking Model

Figure 2.13 shows the measured vs predicted top-down cracking for global calibration factors. The figure indicates that the local calibration of this model is essential.

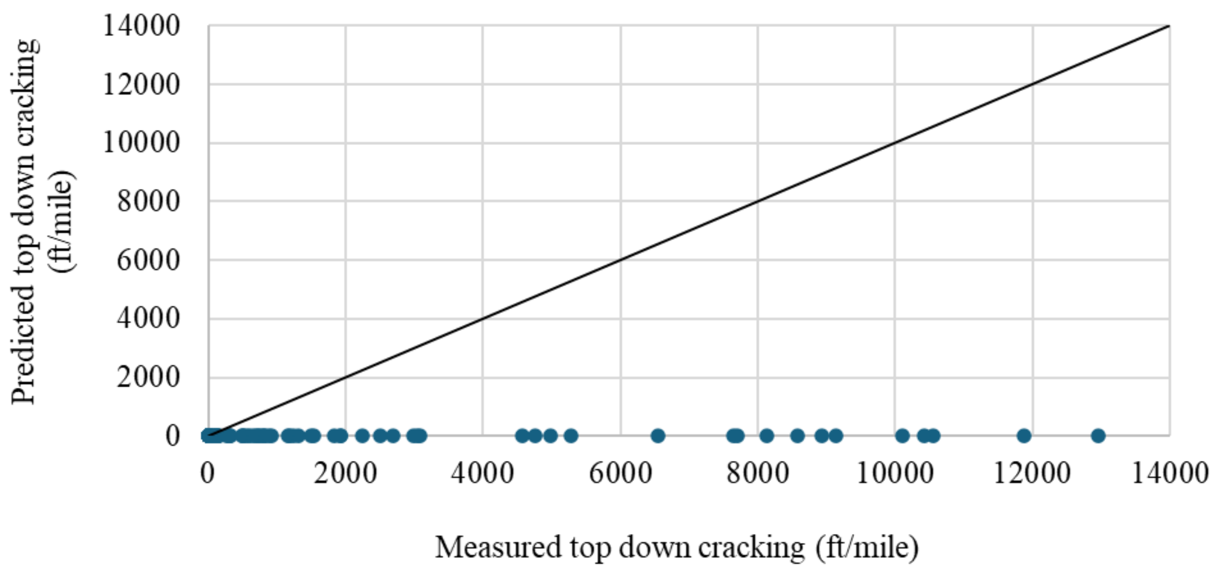


Figure 2.13: Predicted versus Measured Top-Down Cracking with Locally Calibrated Factors

2.3.3.3 Assess Local Bias and Standard Error of the Estimate from Global Calibration Factors

Local bias was assessed using hypothesis testing for the top-down cracking model with globally calibrated coefficients. The globally calibrated model showed significant bias in the paired t-test, and the null hypothesis was rejected at a 95% confidence interval (Table 2.32).

Table 2.32: Calibrated Subgrade Rutting Model Coefficients

Bias	S_e	R^2	p-value	Hypothesis, H_0: $\sum$(Meas.-Pred.) = 0
174395	2899	N/A	<0.0001	Rejected

2.3.3.4 The Variability in Measured Data

The extracted top-down cracking data from the PMIS database showed high variability (Figure 2.14). The average top-down cracking on the projects varied from 13,000 ft/mile to zero. To reduce this variability, the researchers decided to calibrate the top-down cracking model without including the projects with "zero" measured values.

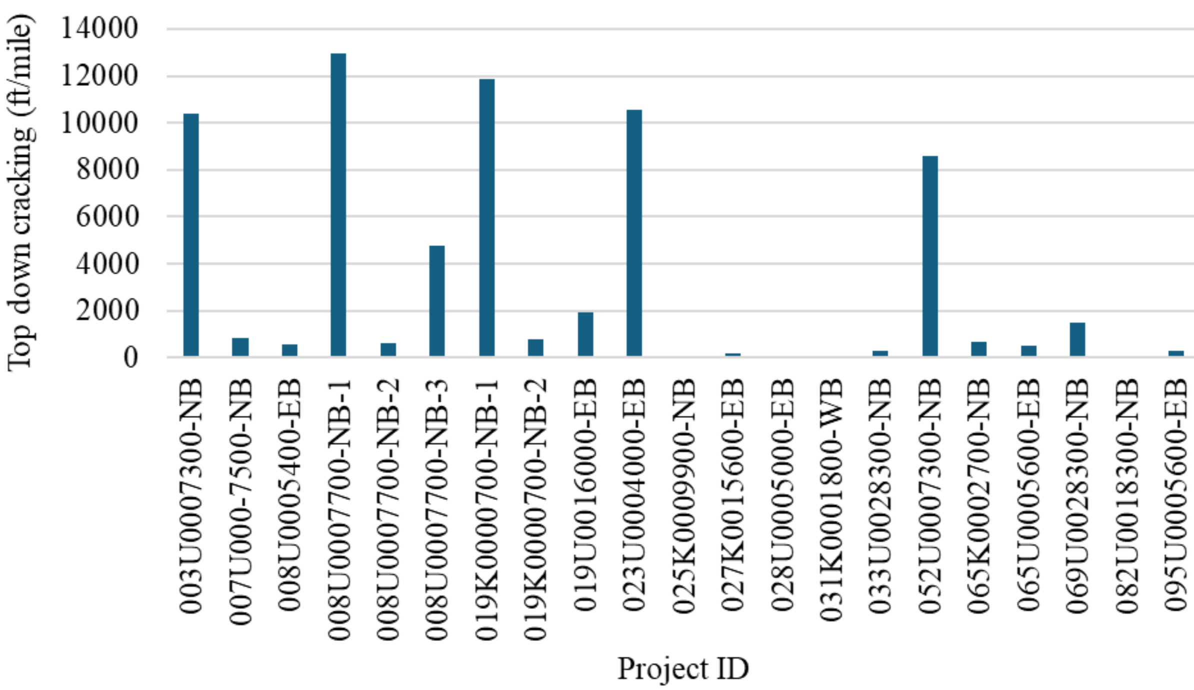


Figure 2.14: Variability in Measured Top-Down Cracking Data

2.3.3.5 Elimination of Local Bias for the Top-down Cracking Model

The local bias in the top-down cracking model was eliminated following the steps listed below:

- The local bias elimination process involved calibrating the $N_{f\text{-}HMA}$ model (Equation 2.6) and the top-down cracking model's transfer function.

- Calibration parameters βf1, C1, and C2 were optimized outside of the AASHTOWare software environment using Microsoft Excel Solver.
- The AASHTOWare PMED software was run numerous times using a large factorial of βf2 and βf3 since these two parameters are not direct multipliers and cannot be optimized outside the AASHTOWare software environment.

Following these steps, the top-down cracking model was calibrated, and the bias was reduced from 174,395 to 59,986 in./mile. The calibrated model still showed a high standard error of 2,750 in./mile. The local calibration guide for the AASHTOWare software recommends that the standard error estimate of the top-down cracking model should be within 600 in./mile (AASHTO, 2010). However, the null hypothesis in the t-test was accepted. The summary statistics are shown in Table 2.33.

Table 2.33: Summary of Statistical Analysis for Top-down Cracking Model for Local Calibration

Bias	S_e	R^2	P-value	Hypothesis, H_0: ∑(Meas.-Pred.) = 0
59,986	2,750	N/A	0.051	Accepted

Since all projects with "zero" measured values were excluded from calibration, the top-down cracking model was not further validated. However, it should be noted that the resulting calibrated model showed high top-down cracking across all projects, and all projects exceeded the KDOT-recommended trigger value of 500 ft/mile for a 10-year design life.

2.3.3.6 Calibration Results

After completion of local calibration, the coefficients shown in Tables 2.34 and 2.35 were selected. The adjusted coefficients are shown in bold.

Table 2.34: Calibrated AC Fatigue Model Coefficients

B_{f1}	B_{f2}	B_{f3}
1	1	**1.60**

Table 2.35: Calibrated AC Top-down Fatigue Cracking Model Coefficients

C1	C2	C3	C4
0.90	**0.45**	0	1000

2.3.4 Top-Down Cracking Enhancement

In the PMED software (after version 2.5.5), a fracture mechanics-based cracking model was developed under NCHRP project 1-52 and added (AASHTO, 2021). The top-down cracking model in NCHRP 1-52 replaces the older bending-beam-based model in the PMED software and outputs. In addition, longitudinal cracks in the wheel paths and/or alligator cracks have been confirmed in cores to originate at the surface and propagate through the asphalt layers. The top-down cracking transfer function was modified to account for longitudinal and alligator cracks in the wheel paths, expressed as the percentage of the total lane area cracked.

In this study, all 26 asphalt projects were rerun using PMED version 2.6.2. Significant differences/anomalies in predicted and measured values were observed. In most cases, there was no predicted or measured cracking. The earlier calibration effort described in Section 2.3.3.5 involved four model parameters, but the newer top-down cracking models have five coefficients, K1, K2, K3, K4, and K5; and three other parameters, C_1, C_2, and C_3. The default values of these are shown in Table 2.36.

Table 2.36: Default Values of Top-Down Cracking Parameters

C1	2.5219
C2	0.8069
C3	1
K_1	64271618
K_2	0.2855
K_3	0.011
K_4	0.01488
K_5	3.266

Also, several more years of performance data were collected until the first rehabilitation of the projects. Preliminary PMED runs were made with varying C1, C2, K_3, and K_4 values. The other coefficients were kept at the PMED default values. The comparison of predicted and measured top-down cracking showed a low correlation coefficient (r). Finally, a trial was conducted with K3, K4, and K5 varied, resulting in a marginal improvement in r values. Further trials were conducted with K5 and C2 values. Again, a marginal improvement of r values was observed, as shown in Table 2.37.

Table 2.37: Summary of Trial Analysis for Top-down Cracking Model for Local Calibration

Calibration Trial	Calibration Coefficients & Parameters	r	R^2
1	C1=0.19; C2=0.019	0.13	0.02
2	C1=1.9; C2=0.1	0.11	0.01
3	K3=0.055; K4=0.074	0.23	0.05
4	K3=0.033; K4=0.044	0.22	0.05
5	K3=0.022; K4=0.044	0.11	0.01
6	K3=0.022; K4=0.0296; K5=3.466	0.15	0.03
7	K5=4.566	0.18	0.03
8	K5=5.266	0.22	0.05
9	K5=5.266; C2=1.0	0.24	0.06
10	K5=5.266; C2=0.9	0.23	0.05
11	K5=5.266; C2=1.2	0.25	0.06

An examination of a few individual projects showed good r values (≥ 0.5), but in the majority of projects, the values were on one side of the 45-degree line. Figure 2.15 shows a case in which 15 projects were used in trial 11 (with changes to K_5 and C2). The summary statistics for the comparison of the predicted and observed parameters are shown in Table 2.38. Still, in most projects, the values were on the same side of the line. The statistical results indicate that the calibration process failed for this set of projects.

Table 2.38: Statistics Summary of the Comparison between Predicted and Observed Top-Down Cracking Data

Bias	99.8574
SEE (S_e)	2.2116
S_y	2.4627
SSE	711.9672
r	0.3913
R^2	0.1531
S_e/S_y	0.8980

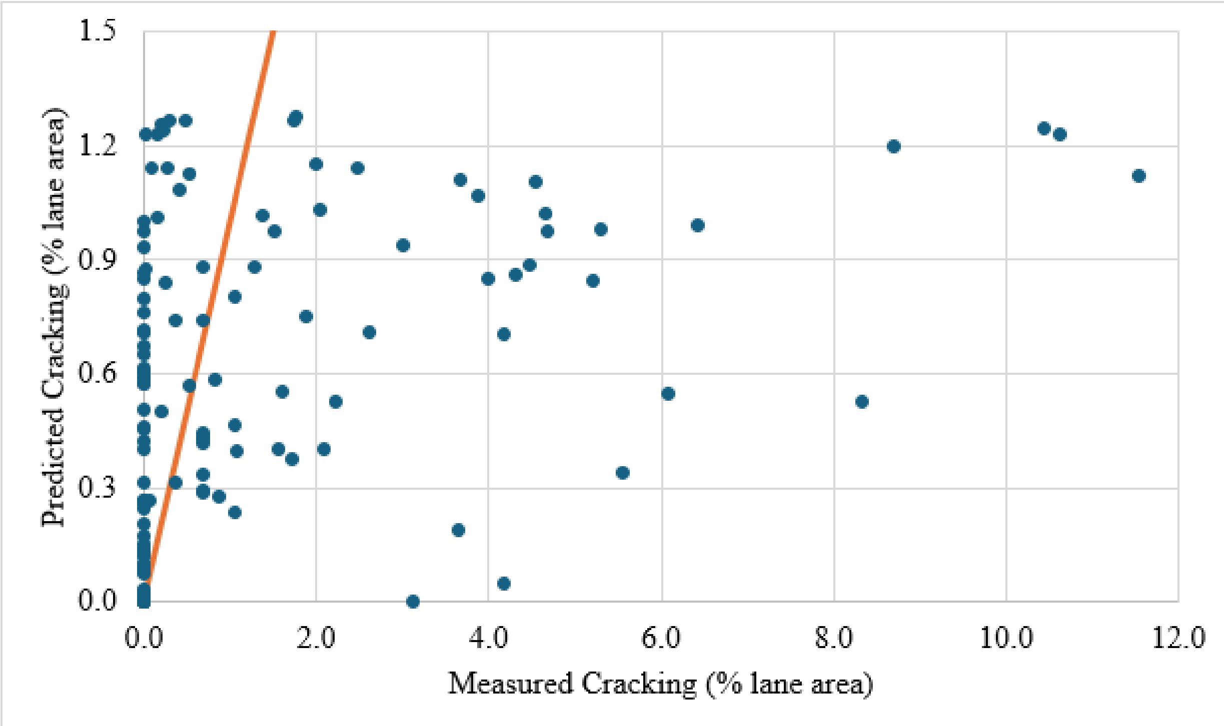


Figure 2.15: Predicted versus Measured Top-Down Cracking with Locally Calibrated Factors

2.3.5 Calibration of AC Thermal Cracking Model

2.3.5.1 Assess Local Bias and Standard Error of the Estimate from Global Calibration Factors

Local bias was assessed using hypothesis testing for the AC thermal cracking model with globally calibrated coefficients. The measured versus predicted thermal cracking is shown in Figure 2.16. A paired t-test at the 95% confidence level yielded a P-value < 0.05, indicating significant bias in the thermal fracture model. The statistical analysis is shown in Table 2.39. The results showed that at a 95% confidence level, there is a significant difference between the measured and predicted transverse cracking. The standard error of the estimate was 98.6 ft/mile.

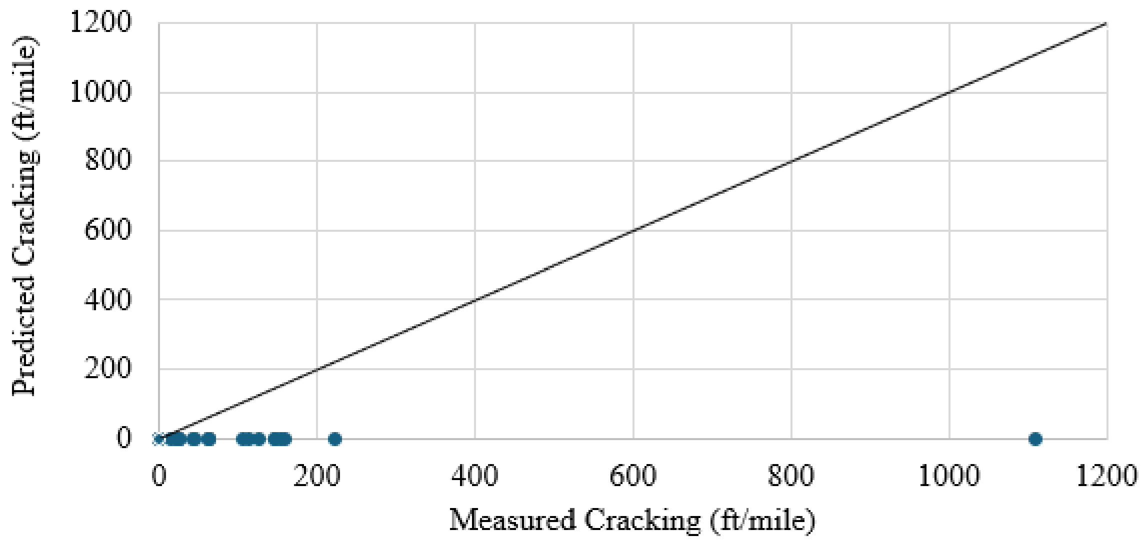


Figure 2.16: Predicted versus Measured Transverse Cracking with Globally Calibrated Factors

Table 2.39: Summary of Statistical Analysis for Thermal Cracking Model for Local Calibration

Bias	S_e	S_e/S_y	R^2	P-value	Hypothesis, H_0: ∑(Meas.-Pred.) = 0
2,724	98.6	1.00	N/A	<0.0001	Rejected

2.3.5.2 Elimination of Local Bias

The AC thermal cracking model has only one calibration coefficient. The globally adjusted value derived from LTPP sites is provided below:

Level 1 = 1.5

Level 2 = 0.5

Level 3 = 1.5

In this study, only 13 of 27 projects exhibited transverse cracking. Also, the study's level 1 input data (creep compliance and indirect tensile strength) were unavailable. Thus, the researchers attempted to calibrate the AC thermal cracking model for level 3 inputs. Since the AASHTOWare software did not predict transverse cracking for any project with the global values, calibration of the model to force the predicted data to match the measured data yielded a model that generates high AC thermal cracking for all projects.

Thus, the researchers felt that the AC thermal cracking model should be calibrated district-wise, and only the districts showing AC transverse cracking would be calibrated in the future. No further attempt to calibrate the model was made during this project phase.

2.3.6 IRI Model

The AASHTOWare PMED software predicts the International Roughness Index (IRI) based on the following Equation 2.10:

$$IRI = IRI_O + C_1(RD) + C_2(FC_{total}) + C_3(TC) + C_4(SF)$$

Equation 2.10

where:

IRI = Predicted IRI (in./mile);

IRI_o = Initial IRI after construction (in./mile);

RD = Average rut depth (in.);

FC_{total} = Area of fatigue cracking (combined alligator, longitudinal, and reflection cracking in the wheel path), percent lane area. All load-related cracks are combined on an area basis;

TC = Length of transverse cracking (ft/mile);

TFAULT = Total joint faulting cumulated per mile (in.); and

C_1, C_2, C_3, C_4 = Calibration factors.

Site factor (SF) is based on the following Equation 2.11:

$$SF = Age^{1.5}\left[\ln\left((Precip + 1)(FI + 1)p_{02}\right) + \ln\left((Precip + 1)(PI + 1)p_{200}\right)\right]$$

Equation 2.11

where:

AGE = Pavement age (year);

PI = Percent plasticity index of the soil;

Precip = Average annual precipitation (in.);

FI = Average annual freezing index (°F-days);

P_{02} = Percent passing the 0.02 mm sieve; and

P_{200} = Percent passing the 0.075 mm sieve.

The local bias was determined using the globally calibrated factors for the IRI model. The globally calibrated model showed significant bias in the paired t-test, and the null hypothesis was rejected at a 95% confidence interval (Table 2.40). The measured versus predicted IRI (globally calibrated) relationship is shown in Figure 2.17.

Table 2.40: Statistical Analysis Summary Parameters for Local Calibration

Bias	S_e	S_e/S_y	R^2	P-value	Hypothesis, H_0: $\sum$(Meas.-Pred.) = 0
-1487.6	9.72	0.871	0.24	0.053	Rejected

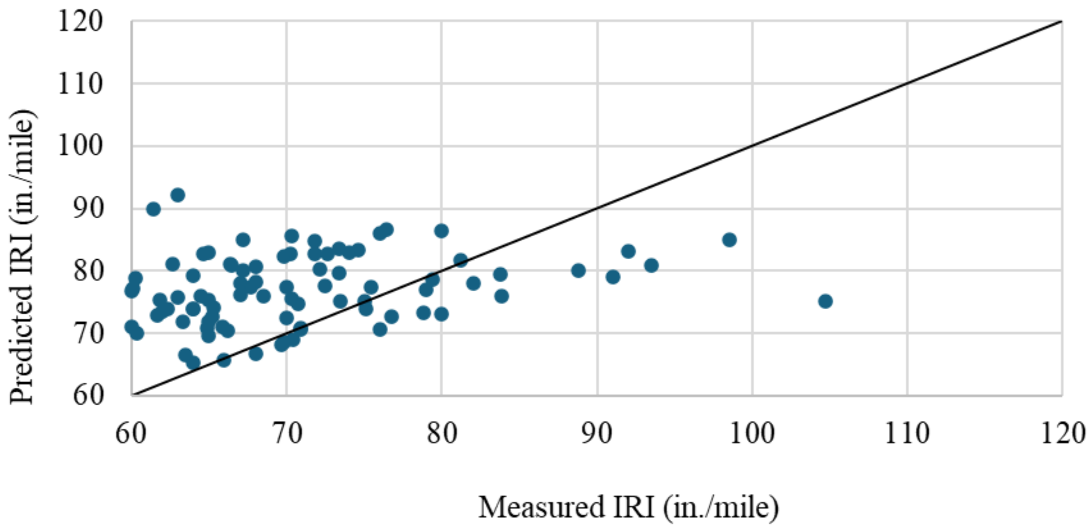


Figure 2.17: Predicted versus Measured IRI with Globally Calibrated Factors

2.3.6.1 Elimination of Local Bias for the IRI Model

From Equation 2.10, it is clear that data on the percentage of subgrade soil passing the 0.02 mm sieve are required to calculate the size factor parameter. Since this data was unavailable, it was not possible to optimize the calibration coefficients. The AASHTOWare software was run multiple times using a full factorial design of C1, C2, and C4 to reduce bias between measured and predicted data. Since the transverse cracking model was not calibrated, it was decided to keep the coefficient C3 at the global value. Figure 2.18 shows the measured versus predicted IRI after local calibration.

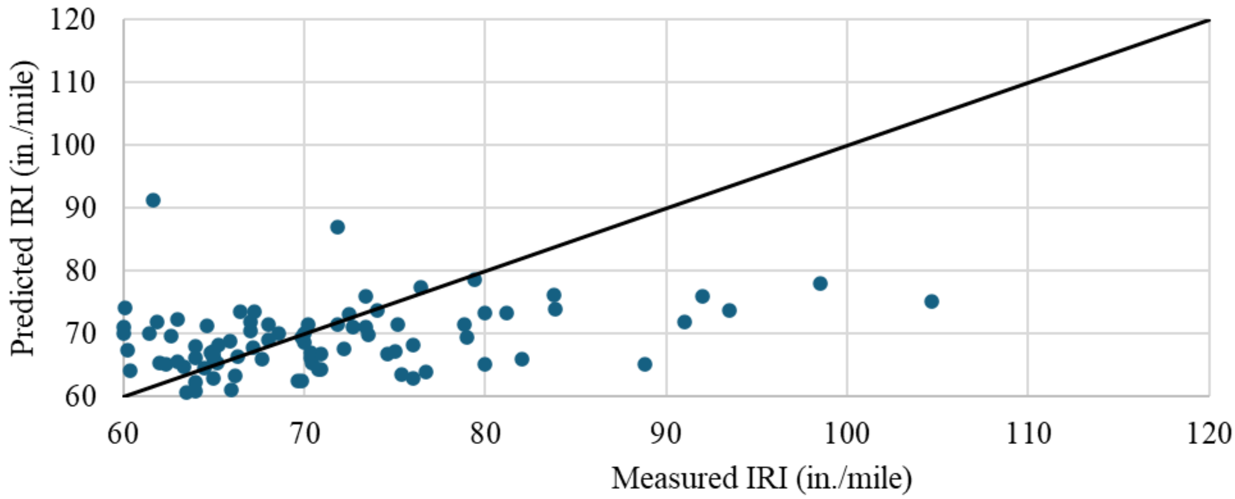


Figure 2.18: Predicted versus Measured IRI with Local Calibration Factors

The summary parameters of the statistical analysis after local calibration are listed in Table 2.41. Both bias and standard errors have been significantly reduced.

Table 2.41: Statistical Analysis Summary Parameters for Local Calibration

Bias	S_e	S_e/S_y	R^2	P-value	Hypothesis, H_0: ∑(Meas.-Pred.) = 0
-122.254	9.486	1.027	0.059	0.171	Accepted

The statistical analysis results for the IRI model after validation are shown in Table 2.33. The bias and standard error are low with the locally calibrated factors. However, Table 2.36 shows that the standard error of the estimate has increased slightly after calibration. The four components of standard error were previously discussed in this report. It was noted that measurement errors in distress/IRI are a significant source of error, and the agency needs to decide whether to incur additional costs and effort to reduce total standard errors. Nonetheless, the design guide recommends that the standard error of the IRI model's estimate be within 17 in./mile.

The statistical analysis results for the IRI model after validation are shown in Table 2.42. The bias and standard error are low with locally calibrated factors.

Table 2.42: Summary of Statistical Analysis for IRI for Local Calibrated Factors for Validation

Bias	S_e	S_e/S_y	R^2	P-value	Hypothesis, H_0: ∑(Meas.-Pred.) = 0
-116.753	14.006	0.868	0.270	0.190	Accepted

2.3.6.2 Calibration Results

After local calibration, the IRI model coefficients for the new flexible pavements in Kansas are shown in Table 2.43. The adjusted coefficients are shown in bold text.

Table 2.43: Calibration Coefficients of the Flexible IRI Model

C1	C2	C3	C4
33	0.4	0.008	**0.01**

Chapter 3: Effect of Material Inputs on the PMED Results

3.1 Base Course

The base/subbase is between the concrete slab and the foundation layer or subgrade. Past experimental work indicated that subbases played only a minor role in increasing the structural capacity of a concrete pavement, which derived its load-carrying capacity from the slab's flexural capacity. Experiments also have indicated that one inch of concrete equals about six in. of subbase. However, it is usually more economical to increase the slab thickness to increase the load-carrying capacity (Sharp, 1970). In practice, a subbase is used under a concrete slab mainly to expedite construction or facilitate paving operations.

For pavements with repetitive heavy traffic and water ingress, clayey and silty subgrades tend to exhibit “pumping.” In such cases, a subbase, especially a treated one, is essential to prevent pumping. Soil cement has been used in the United States since the mid-1930s (Sharp, 1970). However, a lean concrete base (LCB) is more suitable for concrete pavements carrying heavy traffic. Lean concrete is similar to paving concrete but contains less cement (typically about 200 lbs./yd^3). Thus, it is lower (about 20–50%) in strength than conventional paving concrete. The most significant structural contribution of an LCB is achieved with a high degree of friction between the slab and the base. However, there have been performance issues related to excessive curling due to LCB in the LTPP SPS-2 sections in Kansas (Khanum et al., 2005) and reflection cracking in general (Pavement Interactive, n.d.).

KDOT uses several base course types directly over the subgrade. Base courses are used as a structural layer, a separation layer, or as an economic pavement course, depending on the design requirements. Table 3.1 lists the base courses currently in use.

Table 3.1: Base Courses and Uses

Base Type	Designation	Pavement Type
Aggregate Base 3	AB-3	Flexible
Granular Base	GB	Rigid
Portland Cement Treated Base	PCTB	Rigid
Asphalt Treated Base	ATB	Rigid
Bound Drainable Base	BDB	Rigid

AB-3 is a dense graded base course a minimum of six in. thick and uses water as a binder. When 20-year design lane ESALs are less than 3,000,000, then a flexible design with an aggregate base (6.0" AB-3) can be considered, as well as the full-depth flexible pavement. AB-3 is not used under concrete pavement.

GB, ATB, PCTB, and BDB, constructed under mainline rigid pavements, are four in. thick. The base type is selected based on traffic. For 30-year traffic with more than 9 million ESALs, ATB, PCTB, or BDB is used. For less than 9 million ESALs, GB is selected.

3.1.1 Effect of PCTB on AASHTOWare PMED Results

Cement-bound granular material is a further development from lean concrete where some relaxation of gradation of the constituent aggregates is permitted (Croney & Croney, 1991). Cement-treated bases consist of conventional dense-graded aggregates mixed with portland cement (typically about 3 to 8 percent). PIARC studies have shown that 6 to 8 percent cement is required for the base to be erosion-resistant (FHWA, 1999). However, some cement-treated bases with high cement contents have been responsible for increased slab cracking, where the base and slab were not bonded and the slab experienced high curling stresses. In such cases, shorter joint spacing is needed. An excellent review of the effect of PCTB on concrete pavement design, analysis, and behavior was given by Khazanovich and Tompkins (2017).

Currently, KDOT standard specifications require that the PCTB mixture have a 7-day strength between 650 psi and 1600 psi (KDOT, 2015). Any test correlating to the maximum value or higher requires "scoring" or sawing joints in the base that fall within the failing test section. This is done to prevent reflection cracking. PCTB mixture is commonly produced by stabilizing a crushed limestone aggregate product AB-3 in Kansas. Figure 3.1 shows the AB-3 gradation. A review of recent PCTB mixtures in Kansas shows that cement content ranging from 5% to about 15% is needed to meet the 7-day strength requirements. The PCTB is constructed two feet wider than the pavement surface. This provides the contractor with the surface for the paver's track line. PCTB curing is performed using a curing compound expected to serve as a bond breaker. If the paving is done after 30 days, the curing compound must be reapplied and should serve as the bond breaker between PCTB and the JPCP slab.

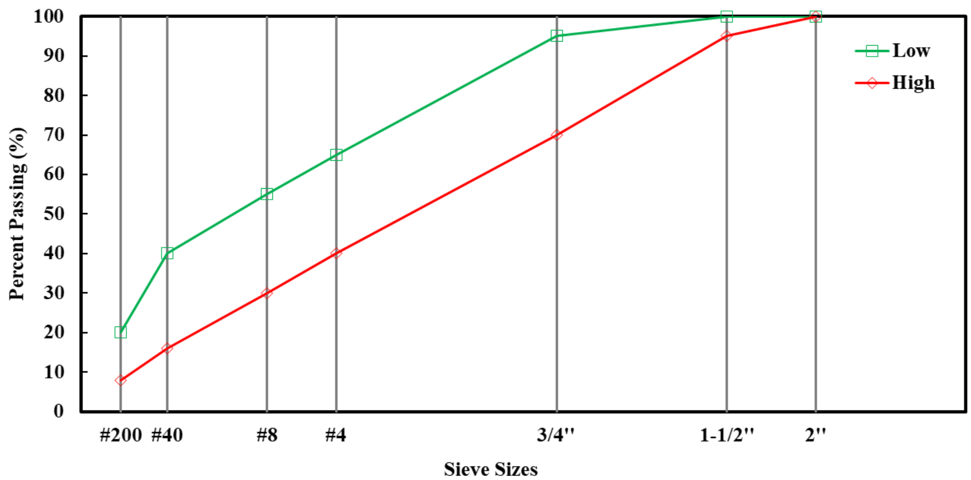


Figure 3.1: AB-3 Gradation

In this study, after local recalibration of the AASHTOWare PMED software models, four JPCP projects with PCTB were reanalyzed. Two projects are located on Interstate 70; others are on US and Kansas state routes. The 1993 AASHTO design guide was also used for side-by-side comparison. The general features of the projects analyzed are tabulated in Table 3.2. In Kansas, based on the range of 20-year cumulative equivalent single axle loads (ESALs), projects are divided into three traffic categories – high (greater than 18 million ESALs), medium (3–18 million ESALs), and low (less than 3 million ESALs). Only the sections with high traffic, as reported by Islam et al. (2019), were studied, since these sections showed a greater slab thickness discrepancy between the two methods.

Table 3.2: General Features of the Projects for Thickness Comparison

Project No.	Route	County	Year Built	Subgrade Soil Type	Subgrade Modulus (psi)	Initial AADT	% Truck	Traffic Level
1	I-70	Thomas	2016*	A-6	5,000	11,400	34.7	High
2	US-54	Seward	2018	A-2-4	4,638	6,700	38	High
3	K-10	Douglas	2018	A-7-6	2,600	3,620	60	High
4	I-70	Gove	2018	A-6	5,400	11,400	35	High

*in-service

3.1.2 Characterization of the PCTB Mixture

As mentioned earlier, KDOT standard specification requires that the PCTB mixture have a 7-day strength of a minimum of 650 psi and a maximum of 1200 psi (KDOT, 2015). A review of the KDOT PCTB database identified various combinations of aggregates stabilized with Portland cement or Portland cement-fly ash. However, the most commonly used aggregate was crushed limestone, and its gradation is shown in Figure 3.1. Recent PCTB mixtures showed cement contents ranging from 5 percent to about 15 percent to meet the 7-day strength requirements. In this study, three PCTB mixtures with AB-3 gradation and 5, 7, and 15% Portland cement were tested in the laboratory to determine the modulus of elasticity.

3.1.3 Sample Preparation

PCTB modulus tests were done on cylindrical samples six in. diameter and six in. height. The procedure for sample preparation is detailed in the KT-37 Kansas Test Method (2018). The loose CTB mixture at a certain cement content was first tested to establish the moisture-density relationship. The optimum moisture content and the maximum dry density were then found. The slump of the mixture was also determined. The modulus test samples were then compacted into three layers, with each layer receiving 56 blows of the rammer (5.5 lb. and 12 in. drop), distributed uniformly over the layer's surface. After the final layer had been compacted, the collar was removed, and the excess material level with the top of the mold was trimmed. The compacted sample was then cured for seven days.

3.1.4 Testing

When curing was complete, the specimens were removed from the moist room, measured for diameter, capped, weighed, measured for height after capping, and broken. The load was applied continuously with a constant rate of 10–12 psi/sec. Load and deformation readings were taken periodically to establish the stress-strain curve. The tests were completed using the setup shown in Figure 3.2.

Figure 3.2: CTB Elastic Modulus Test Setup

3.1.5 Pavement Design Inputs

The input parameters must be equivalent to enable better comparison of the two design procedures. Standard inputs for both design procedures are design traffic, reliability, design period, and subgrade properties. Specific design inputs for the JPCP design using the 1993 AASHTO design guide are the effective modulus of subgrade reaction, concrete modulus of rupture, concrete modulus of elasticity, load transfer coefficient, and drainage coefficient. PMED-specific input parameters include traffic, climate, structural details, and miscellaneous inputs such as thermo-hydraulic properties.

3.1.5.1 Design Traffic

The 1993 AASHTO design guide estimates traffic based on the expected cumulative 18-kip equivalent single axle loads (ESALs) on the design lane over the design period.

For AASHTOWare PMED, site-specific (Level 1) traffic inputs included average annual daily truck traffic (AADTT), operational speed, number of lanes, traffic growth rate, and the percentage of trucks in the design direction or lane. KDOT-supplied truck class distribution and hourly distribution factors (HDF) were also project-specific input parameters. Kansas regional traffic inputs (Level 2) used monthly distribution factors (MDFs), axles per truck, and axle load spectra. Islam et al. (2019) have detailed the PMED traffic inputs used in this study. All other traffic inputs were chosen from the AASHTOWare PMED default values.

3.1.5.2 Serviceability

The present serviceability index (PSI) quantifies pavement performance using the 1993 AASHTO design method. An initial PSI of 4.5 is typically used for JPCP in Kansas. The terminal PSI was set to 2.5 for all projects in this study, since the routes are primary.

3.1.5.3 Reliability

The AASHTO Guide reliability level depends on the roadway's functional classification and intended use. It is applied in the design by selecting a standard deviation value. This study used a standard deviation value of 0.35 for all projects.

3.1.5.4 Design Period

KDOT-recommended design period of 20 years was used in this study.

3.1.5.5 Subgrade Properties

No seasonal variation was considered. The effective modulus of subgrade reaction (k) values was used for this study.

3.1.5.6 Elastic Modulus of Concrete

This study used the 1993 AASHTO guide-recommended typical value of 4 million psi for the elastic modulus.

3.1.5.7 Concrete Modulus of Rupture

KDOT-suggested 28-day modulus of rupture value of 600 psi was used to design the projects in this study.

3.1.5.8 Load Transfer Coefficient

This is the ability of the loaded slab to transfer a portion of the traffic load across the joint to the adjacent slab, incorporated in the design by the load transfer coefficient (J). Since all JPCP sections are dowel jointed and have tied shoulders, a typical J factor of 2.8 was used for all sections in this study.

3.1.5.9 PCTB Layer Elastic Modulus

Four different PCTB layer moduli were used in this study. The lowest and the highest moduli were derived from the ACI relationship of moduli and compressive strength, as shown in Equation 3.1.

$$E_c\ (psi) = 57000\sqrt{f_c}$$

Equation 3.1

where:

f_c = 7-day unconfined compressive strength of cylinder (6-in. diameter).

The moduli computed from the KDOT-specified PCTB strength of 650 and 1200 psi were used. The two other PCTB moduli were calculated from the stress-strain relationships developed during the KT-37 tests described earlier. Table 3.3 shows those values.

Table 3.3: Elastic Modulus of the PCTB Layer

Mixture	**Elastic Modulus**	**C.O.V**
	ksi	%
Std. Spec. - 650 psi	14.53*	-
Std. Spec - 1600 psi	22.80*	-
Lab Mix (AB-3 + 5% Cement)	18.77	5.7
Lab Mix (AB-3 + 7% Cement)	19.46	5.5
Lab Mix (AB-3 + 15% Cement)	20.60	6.3

*Obtained from the ACI relationship

3.1.5.10 Contact Friction

The MEPDG manual (AASHTO, 2020) describes this parameter as the interface condition between the JPCP slab and the base layer. The input specifies the months during which full contact friction exists between the two layers. Full friction at the interface produces a monolithic slab or base and significantly affects JPCP slab cracking. The MEPDG manual (AASHTO, 2020) contends that assuming full friction yields accurate cracking predictions, except for CTB or LCB, when "extraordinary" efforts are made to ensure no bonding between the JPCP slab and the cementitious base. This input was studied in detail.

3.1.5.11 Drainage Coefficient

Depending on whether the subsurface drainage is present, a value of 1.0 or 1.2 is typically used as the drainage coefficient (C_d) in Kansas. A value of 1.0 was used in this study since the base layer was treated.

3.1.5.12 General Information

In AASHTOWare PMED, the general information inputs include design life, construction month, traffic opening month, pavement type, and more. For this study, all sections were JPCP and analyzed for 20-year design lives.

3.1.5.13 Failure Criteria

For JPCP, PMED design predicts distress faulting, transverse cracking, and smoothness (in the International Roughness Index (IRI)). The MEPDG reliability concept, which is more sophisticated than the 1993 AASHTO design guide's reliability approach, allows a designer to specify an acceptable level of distress for each predicted distress type at the end of the design life. This study used the KDOT-recommended reliability based on traffic level and highway functional class. The IRI failure criteria were set at 164 in./mile. Joint faulting and transverse slab cracking were selected at 0.125 in. and 5 percent, respectively. KDOT established the failure criteria.

3.1.5.14 Climate

Among all climatic inputs for the MEPDG design, the coordinates (latitude and longitude) and elevations for all pavement sections were input as site-specific values. The water table depth for all sections was set at 50 ft. Climatic stations used in this study were selected from the nearest weather stations in the NARR database to more accurately depict the effect of climate on pavement structure.

3.1.5.15 Structural Details

In this study, the baseline JPCP structure for the new pavement design was a four-layer construction consisting of a Portland cement concrete (PCC) slab over a Portland cement-treated base (PCTB) for high-traffic sections. The third layer is a lime-treated subgrade (LTSG) or fly-ash-treated subgrade (FATSG). The last layer is the compacted subgrade. Structural inputs for the AASHTOWare PMED software are summarized in Table 3.4.

Table 3.4: Specific Input Parameters of JPCP Analysis by PMED

Input	I-70 TH	US-54 SW	K-10 DG	I-70 GO
General Information				
Pavement construction date	Mar-16	May-18	May-18	May-18
Traffic				
Initial two-way AADTT	3,956	2,546	2,170	3,990
No. of lanes in design direction	2	2	2	2
Traffic growth factor (%)	1.48	0.63	3.44	1.4
PCC Layer				
PCC layer thickness (in.)	TBD	TBD	TBD	TBD
Cement content (lb./yd^3)	540	540	540	540
Aggregate type	Lime-stone	Lime-stone	Granite	Granite
Water-cement ratio (w/c)	0.42	0.42	0.42	0.42
Base Material				
Base type	PCTB	PCTB	PCTB	PCTB
Base thickness (in.)	4	4	4	4
Base material unit wt. (pcf)	140	140	140	140
Base modulus (psi)	Variable	Variable	Variable	Variable
Treated Subgrade				
Subgrade type	FATSG	LTSG	LTSG	FATSG
Subgrade modulus (psi)	10375	9640	5503	11185
Unit weight (pcf)	140	110	110	140
Compacted Subgrade				
Subgrade soil type	A-6	A-2-4	A-7-6	A-6
Subgrade Modulus (psi)	5000	4638	2600	5400
Plasticity index, PI	16	2	30	16
Percent Passing # 200 sieve	63.2	22.4	79.1	63.2
% passing # 4 sieve	93.5	87.2	94.9	93.5

3.1.6 Analysis Methodology

Initially, the JPCP sections were designed using the 1993 AASHTO design guide. Then, those were reanalyzed using AASHTOWare PMED. Thickness design in AASHTOWare PMED was performed using a strategy: if a section met all criteria for smoothness (IRI) and other distresses (faulting and slab cracking), the slab thickness would be reduced by 0.5 in., and a reanalysis would be performed. This process was repeated until the section failed to pass one of the failure criteria. The section with the resultant slab thickness (the trial thickness just before failure) was then accepted as the design thickness by AASHTOWare PMED. Only the local calibration coefficients for Kansas were used. Slab thicknesses of the JPCP sections derived from the 1993 design were used as inputs in the AASHTOWare PMED software.

Since this study was initiated to assess the effect of PCTB on the PMED JPCP design analysis, two factors were studied: (1) PCTB modulus and (2) interface condition between the JPCP slab and the PCTB, comparing the PMED JPCP slab thicknesses with the 1993 AASHTO design guide values.

3.1.7 Design Thickness Comparison between 1993 AASHTO Guide and AASHTOWare PMED

The thicknesses of the projects obtained from the 1993 AASHTO guide and AASHTOWare PMED for varying PCTB base thickness are presented in Figure 3.3. The design analysis using PMED (ver. 2.6.2) assumed no friction between the JPCP slab and the PCTB, consistent with KDOT's "expectation" of no bonding. In Figure 3.3, PCTB-E low and PCTB-E high denote experimental elastic modulus results for the PCTB mixture with 5% and 15% cement, respectively. The PCTB-KDOT low and PCTB-KDOT high represent moduli obtained from the ACI correlation in Equation 3.1 corresponding to KDOT PCTB specifications of minimum 7-day UCS of 650 psi and maximum 7-day UCS of 1600 psi.

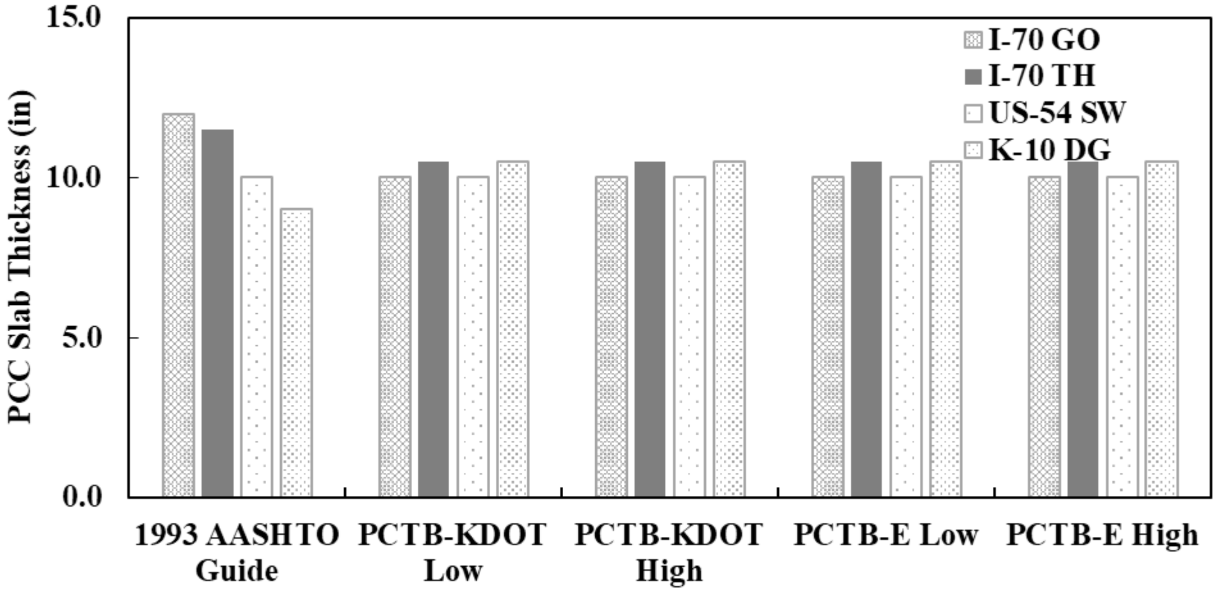


Figure 3.3: Comparison of Slab Thicknesses using AASHTO 1993 and AASHTOWare PMED

Figure 3.3 shows that the high-traffic test sections had higher slab thickness in the 1993 AASHTO guide design than the AASHTOWare PMED design. This trend was evident for the I-70 Gove County and I-70 Thomas County projects. The 1993 AASHTO design guide thicknesses were 1 to 2 in. higher. The PMED thickness did not change due to the PCTB modulus range used. Both methods showed similar thicknesses for US-54 in Seward County. The K-10 in Douglas County had the lowest AADTT among all four sections, and PMED showed a 1.5-inch-thicker slab than the 1993 AASHTO design guide. Islam et al. (2019) attributed this discrepancy to PMED's truck-traffic and damage-prediction capability, compared with the empirical nature of the 1993 AASHTO design guide, which describes traffic in a single number—cumulative ESALs.

PMED runs were also made assuming full friction between the JCCP slab and PCTB, but with friction loss after 240 months (for the design life of 20 years) and 120 months (halfway through the design life of 20 years). In both cases, unreasonably thinner slabs were obtained for all projects. Figure 3.4 shows the PMED design outs for I-70 Thomas County. Previously, almost all failures during PMED design analysis were due to slab cracking. Even with 2 in.

For a JPCP slab over 4 in. PCTB with full friction for the design life, slab cracking was less than 1%. Similar results were obtained for other projects and cases when friction is lost after 10 years. As mentioned earlier, the MEPDG manual (AASHTO, 2020) contends that assuming full friction will yield accurate cracking predictions and, presumably, better design. Figure 3.4 does not show any reasonable output. A sensitivity analysis shows that when the PCTB modulus exceeds 1 million psi, the JPCP slab thickness decreases dramatically under full friction. This phenomenon needs further study.

Design Structure

Layer type	Material Type	Thickness (in)
PCC	JPCP	2.0
Cement_Base	PCTB	4.0
Subgrade	FA modified	6.0
Subgrade	A-6	10.0
Subgrade	A-6	Semi-infinite

Joint Design:	
Joint spacing (ft)	15.0
Dowel diameter (in)	1.25
Slab width (ft)	12.0

Traffic

Age (year)	Heavy Trucks (cumulative)
2016 (initial)	3,956
2026 (10 years)	7,702,530
2036 (20 years)	16,473,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	164.00	117.62	90.00	99.89	Pass
Mean joint faulting (in)	0.12	0.02	90.00	100.00	Pass
JPCP transverse cracking (percent slabs)	5.00	0.96	90.00	100.00	Pass

Figure 3.4: PMED Output for I-70 Thomas County for PCC-Base Friction Loss at 240 Months

3.2 Flexible Pavement Inputs/HMA Layer

Dynamic modulus and creep compliance of hot-mix asphalt (HMA) are primary mechanical property inputs for the PMED analysis of flexible pavements. The AASHTOWare PMED can calculate pavement responses and predict the long-term performance of flexible pavement structures using required HMA input data. Laboratory-measured values, which are Level 1 inputs, can represent the best available knowledge of local materials or a specific project. However, this also requires extensive testing and data collection, which are time-consuming and expensive (AASHTO, 2020). When laboratory-measured data are not available, predictive models are used to estimate asphalt properties. However, the reliability of PMED input prediction should be evaluated. When Level 2 or 3 inputs are used, the predictive models may need to be more accurate and consistent for different mixes in all regions since they were globally calibrated (Esfandiarpour, 2017).

Ali (2005) found that pavement performance predicted by the MEPDG software (predecessor to AASHTOWare PMED) was sensitive to material type when using laboratory-measured material properties as inputs (Tashman & Elangovan, 2007). Tashman and Elangovan (2007) concluded that the MEPDG methodology overpredicted longitudinal cracking but reasonably predicted alligator cracking. IRI predicted by Levels 1 and 3 matched well but was not sensitive to mix type. Level 3 predicted distress higher than Level 1.

Abdo et al. (2009) developed a model to predict the dynamic modulus of asphalt mix. MEPDG runs were conducted under actual dynamic modulus (E*), proposed model E*, Level 3 E* from Witczak's 1996 model, and Witczak's 2006 revised model. The predicted distresses showed that the proposed model E* yielded results closer to the actual E* values.

Solanki et al. (2014) conducted a creep compliance test on four mixtures with different RAP content. They compared the laboratory test results to the MEPDG-predicted values. They confirmed that the MEPDG Level 3 creep compliance estimates are significantly higher than tested values. Using MEPDG Level 3 predicted creep values could lead to nonconservative pavement design for HMA thermal cracking resistance.

Esfandiarpour and Shalaby (2018) investigated the impact of local calibration of dynamic modulus and creep compliance models on the long-term performance of mixes containing RAP and the sensitivity of the predicted distresses to RAP content. Three asphalt mixes, Mix-0, Mix-15, and Mix-50, were tested, and three Levels of asphalt input data, including Level 1, Level 3, and calibrated Level 3, were used in PMED. The results showed that higher distress levels were predicted with Level 3 inputs. Level 3 noticeably overpredicted the distress of the asphalt mix compared to Levels 1 and 2, which were calibrated. The results of calibrated Level 3 inputs were comparable to those of Level 1 inputs, indicating that calibrated Level 3 input data can be used for design and analysis. It was also found that increasing RAP did not significantly affect the predictions, even though the mechanical properties of each mix differed.

Worthey (2020) made a similar conclusion. Worthey concluded that, based on terminal IRI, permanent deformation, and AC thermal cracking performance indicators, notable differences were observed across different levels of dynamic modulus and creep compliance inputs. Compared with Level 3 inputs, Level 1 dynamic modulus inputs increased the total permanent deformation of the pavement and AC fatigue cracking. The terminal IRI and AC thermal cracking outputs increased noticeably with Level 2 creep-compliance inputs. The highest distresses of terminal IRI and AC thermal cracking were achieved at the combination of Level 1 dynamic modulus and Level 2 creep compliance.

In this research, the impact of these two mechanical properties on the performance of hot-mix asphalt (HMA) layers with reclaimed asphalt pavement (RAP) was investigated on new pavements and overlays in Kansas.

3.2.1 Dynamic Modulus

Dynamic modulus is a fundamental property of HMA mixtures. It characterizes the viscoelastic nature of HMA mixtures and describes stiffness across a wide range of temperatures and loading frequencies (Witczak & Bari, 2004; Awed et al., 2011). Furthermore, the dynamic modulus is an essential input in the MEPDG, it determines load-related distresses such as longitudinal cracking (top-down cracking), alligator cracking (bottom-up cracking), and pavement rutting (Worthey, 2020). Therefore, evaluating this property for HMA is essential to mix and structural design of asphalt pavements (Abdo et al., 2009).

PMED software predicted two load-related cracks associated with the dynamic modulus: longitudinal (top-down) cracking and alligator (bottom-up) cracking. The predicted models were described in Equations 2.6-2.9 in Chapter 2.

In this research, dynamic modulus inputs were used in PMED for the design analysis of newly constructed asphalt surface projects to predict asphalt pavement performance and to compare Level 1 and Level 3 inputs.

This study performed dynamic modulus tests to obtain Level 1 inputs in accordance with the AASHTO T 342-22 (2022) Standard Method of Test for Determining Dynamic Modulus of Hot Mix Asphalt (HMA). Compacted samples with a diameter of 6 in. and a height of 6.7 in. were prepared. For each mixture, three samples were fabricated, cored, and trimmed to a 4-in. diameter and 6-in. height, with a target air void of 7 ± 0.5%. Six metal studs were glued to the sides of the samples to attach the LVDTs. The tests were conducted at temperatures of 40 °F, 70 °F, and 100 °F, and frequencies of 25, 10, 5, 1, 0.5, and 0.1 Hz. The samples were preconditioned in an environmental chamber before being set up in the Asphalt Mixture Performance Tester (AMPT) machine. Test results were automatically collected and recorded by the AMPT data acquisition system. The AMPT software computed the dynamic modulus and phase angle.

3.2.1.1 Project Information

Twenty-one new flexible pavement projects used in the calibration/recalibration described earlier were selected and divided into two groups: minor arterial (10 projects) and principal arterial (11 projects), based on the road category. Minor arterial roads provide inter-county travel, linking cities, larger towns, and other major traffic generators. Principal arterials provide statewide and interstate travel with high speeds and limited access. The group information is listed in Table 3.5, and a general description of these projects is provided in Tables 2.20 and 2.21.

Table 3.5: Project Group Information

Minor Arterial	Principal Arterial
011U0006900-NB, 019K0000700-NB-1, 019K0000700-NB-2, 019U0016000-EB, 025K0009900-NB, 033U0028300-NB, 065K0002700-NB, 065U0005600-EB, 069U0028300-NB, 095U0005600-EB.	007U0007500-NB, 008U0007700-NB-1, 008U0007700-NB-2, 008U0007700-NB-3, 008U0005400-EB, 023U0004000-EB, 027K0015600-EB, 028U0005000-EB, 031K0001800-WB, 052U0007300-NB, 082U0018300-NB.

3.2.1.2 Materials Selection

In this study, eight HMA mixtures with varying nominal maximum aggregate size (NMAS), binder grade, and RAP content were tested for dynamic modulus. Table 3.6 lists the details of the eight asphalt mixes.

Table 3.6: Test Materials Information

Mix ID	Mix Designation	Binder Grade	% RAP
1	SR-12.5A	PG 70-28	25
2	SR-19A	PG 64-28	15
3	SR-9.5A	PG 58-28	25
4	SR-12.5A	PG 58-28	25
5	SR-19A	PG 70-28	15
6	SR-9.5A	PG 70-28	15
7	SR-19A	PG 58-28	25
8	SR-19A	PG 58-34	25

However, not all mixture results were applicable as inputs to the dynamic modulus. KDOT requires that the binder performance grade (PG) for each asphalt layer be determined based on cumulative equivalent single axle loads (ESALs), and the percentage of RAP in the mixtures as shown in Table 3.7.

Table 3.7: KDOT Criteria for Superpave Mixtures

Asphalt Layer	Percent RAP	<3 Million ESALs	>3 Million ESALs
Top 1.5” (Surface)	0	SR-9.5A (PG 64-28)	SR-9.5A (PG 70-28)
	1-15	SR-9.5A (PG 64-28)	SR-9.5A (PG 70-28)
Top 2.5” of Base (Intermediate)	0	SR-19A (PG 64-28)	SR-19A (PG 70-28)
	1-15	SR-19A (PG 64-28)	SR-19A (PG 70-28)
	16-25	SR-19A (PG 64-34)	SR-19A (PG 70-34)
Rest of Base (Base)	0	SR-19A (PG 64-22)	SR-19A (PG 64-22)
	1-15	SR-19A (PG 64-22)	SR-19A (PG 64-22)
	16-25	SR-19A (PG 58-28)	SR-19A (PG 58-28)

All selected projects carried fewer than three million ESALs. Based on the test results, Mix 2, containing 15% RAP, 19 mm NMAS, and a PG 64-28 binder, was selected for the intermediate course, and Mix 7 of SR-19A, with a PG 58-28 binder and 25% RAP, was used for the base course. Due to limitations in the tested materials, there was no laboratory-measured data for a surface mixture with 9.5 mm NMAS and a binder grade of PG 64-28. Therefore, Mix 6, which uses a higher binder grade of PG 70-28 and is applicable to surface mixtures larger than 3 million ESALs, was selected instead. The selection results are shown in Table 3.8.

Table 3.8: Mixture Selection

Asphalt Layer	Mix ID	Percent RAP	<3 Million ESALs
Surface	6	15	SR-9.5A (PG 70-28)
Intermediate	2	15	SR-19A (PG 64-28)
Base	7	25	SR-19A (PG 58-28)

3.2.1.3 Input Parameters

3.2.1.3.1 HMA Layer Properties

The aggregate gradation and volumetric properties of each selected mixture were entered into the PMED software for Level 1 and 3 predictions. All required inputs are listed in Table 3.9.

Table 3.9: Aggregate Gradation and Volumetric Properties Inputs

Asphalt Layer	Mix ID	Volumetric Properties			Aggregate Gradation			
		Asphalt Content	Effective Binder Content (%)	Unit Weight	Passing 3/4	Passing 3/8	Passing #4	Passing #200
Surface	6	5.9	13.15	142.72	100	96	77	4.7
Intermediate	2	5.72	11.05	144.65	93	75	62	4.7
Base	7	5.2	11.15	147.2	99	77	61	4.4

The air void for all courses was 7%. Poisson's ratio for the HMA mix was assumed to be 0.35.

3.2.1.3.2 Dynamic Modulus Inputs

The PMED software requires the dynamic modulus of the asphalt mix for level 1 input. A minimum of three frequencies were needed. Therefore, the dynamic modulus results at 0.1, 1, and 10 Hz were used as inputs. Dynamic moduli at a minimum of three temperatures, containing 130 °F, were needed for the temperature. However, the dynamic modulus test was conducted under 40, 70, and 100 °F. A master curve can be developed from dynamic modulus data at a single temperature. Therefore, the dynamic modulus data at 130 °F can be obtained from the master curve. All dynamic modulus results are listed in Table 3.10.

Table 3.10: Level 1 Dynamic Modulus Inputs

Temp. (°F)	Surface – Mix 6			Intermediate – Mix 2			Base – Mix 7		
	Frequency (Hz)			Frequency (Hz)			Frequency (Hz)		
	0.1	1	10	0.1	1	10	0.1	1	10
40	551,870	956,058	1,370,395	814,997	1,136,075	1,474,263	495,610	861,735	1,306,813
70	107,764	272,310	573,330	255,732	441,477	713,013	86,297	223,010	473,933
100	16,595	40,825	113,941	45,951	98,223	201,260	16,175	45,740	126,890
130	5,100	9,800	22,000	14,300	25,400	48,600	5,500	11,100	26,000

Besides the laboratory-measured dynamic modulus data, dynamic shear modulus (G*) and phase angle (δ) values of the asphalt binder are also required in the AASHTOWare PMED software. Since data for the binders were unavailable, G* and δ can be calculated from the binder grade. The calculated results are shown in Table 3.11.

Table 3.11: Dynamic Shear Modulus (G*) and Phase Angle (δ) Inputs

		Surface – Mix 6		Intermediate – Mix 2		Base – Mix 7	
Binder Grade		PG 70-28		PG 64-28		PG 58-28	
		G*	Delta	G*	Delta	G*	Delta
Temp. (°F)	40	9.69E+06	44.14	1.03E+07	46.02	1.08E+07	48.42
	70	8.51E+05	59.11	7.16E+05	62.08	5.60E+05	65.66
	100	7.25E+04	68.94	5.06E+04	72.23	3.20E+04	76.06

For Level 3 inputs, aggregate gradation and mixture volumetric properties were used in the modified Witczak model to compute the dynamic modulus (E*) of the HMA layer. Performance binder grade can be directly used for Level 3 inputs.

3.2.1.3.3 Criterial Inputs for Each Category of Road

This study applied KDOT performance criteria based on road type. The detailed values are listed in Table 3.12.

Table 3.12: KDOT Performance Criteria for Each Road Category

Road Type	Minor Arterial		Principle Arterial	
Performance Criteria	Target Value	Reliability	Target Value	Reliability
Initial IRI (in./mile)	30	-	30	-
Terminal IRI (in./mile)	200	65	180	75
AC top-down fatigue cracking (% lane area) *	25	75	25	85
AC bottom-up fatigue cracking (% lane area)	30	75	20	85
AC thermal cracking (ft/mile)	750	65	750	75
Permanent deformation – total pavement (in.)	0.65	75	0.55	85
Permanent deformation – AC only (in.)	0.55	75	0.45	85

*Top-down fatigue cracking changed the unit from ft/mile to % lane area in version 2.6.2. The value of the new criteria was unavailable; therefore, the default value was used.

3.2.1.4 Level 1 and Level 3 Dynamic Modulus Inputs Prediction Results

3.2.1.4.1 Minor Arterial Projects Results

Figure 3.5 shows an example of the distress results of minor arterial project 011U0006900-NB. As shown in Figure 3.5, the project failed in AC bottom-up fatigue cracking at both input levels. KDOT usually does not consider the bottom-up fatigue cracking results and thinks all fatigue cracking to be top-down. Thus, bottom-up fatigue-cracking data are not available. Comparing Level 1 to Level 3 distress prediction, the AC top-down fatigue cracking drastically increased but did not exceed the target value. Similar results were also observed on Project 033U0028300-NB, 065U0005600-EB, 069U0028300-NB, and 095U0005600-EB. The other five projects did not change the AC top-down fatigue cracking values between Level 1 and Level 3 inputs. The other predicted distresses were similar for Level 1 and 3 inputs. The detailed results are shown in Appendix A.

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	69.06	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.11	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	56.47	75.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	65.73	65.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	2.47	75.00	100.00	Pass
Permanent deformation - AC only (in)	0.35	0.04	75.00	100.00	Pass

(a) Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	66.53	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.09	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	52.07	75.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	65.73	65.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	22.16	75.00	83.53	Pass
Permanent deformation - AC only (in)	0.35	0.03	75.00	100.00	Pass

(b) Level 3 Prediction Results

Figure 3.5: Project 011U0006900-NB Distress Prediction Comparison

3.2.1.4.2 Principal Arterial Projects Results

Figure 3.6 illustrates an example of distress output for the principal arterial project 007U0007500-NB. As shown in Figure 3.5, the AC top-down fatigue cracking value increased significantly for Level 3 input and reached the failure criterion. Similar results were also observed for projects 027K0015600-EB, 028U0005000-EB, 031K0001800-WB, and 082U0018300-NB. The remaining six projects showed no change in AC top-down fatigue-cracking values between Level 1 and Level 3 inputs. The other distress predictions were similar for the Level 1 and 3 inputs. The detailed results are shown in Appendix A.

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	44.12	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.11	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	1.22	85.00	100.00	Pass
AC thermal cracking (ft/mile)	750.00	114.31	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.79	85.00	100.00	Pass
Permanent deformation - AC only (in)	0.45	0.04	85.00	100.00	Pass

(a) Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	52.78	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.09	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	1.21	85.00	100.00	Pass
AC thermal cracking (ft/mile)	750.00	114.32	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	27.10	85.00	79.49	Fail
Permanent deformation - AC only (in)	0.45	0.03	85.00	100.00	Pass

(b) Level 3 Prediction Results

Figure 3.6: Project 007U0007500-NB Distress Prediction Comparison

3.2.1.5 Impact of HMA Thickness

In addition to the dynamic modulus, a thickness investigation was conducted for new flexible pavement projects. The thickness of the HMA layer base course was reduced by 2 in. for the predictions, and the results were compared with those obtained using the original thickness. Figure 3.7 shows the distress predictions for a minor arterial (Project 011U0006900-NB) with decreased thickness. Appendix A shows the detailed results for all the remaining minor arterial projects.

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	79.80	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.12	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	78.87	75.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	65.73	65.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	2.47	75.00	100.00	Pass
Permanent deformation - AC only (in)	0.35	0.04	75.00	100.00	Pass

(a) Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	77.76	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.11	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	75.47	75.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	65.73	65.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	22.29	75.00	83.17	Pass
Permanent deformation - AC only (in)	0.35	0.03	75.00	100.00	Pass

(b) Level 3 Prediction Results

Figure 3.7: Project 011U0006900-NB Distress Prediction Comparison with 2” Reduced Thickness

As shown in Figure 3.7 and compared to Figure 3.5, bottom-up fatigue cracking and terminal IRI increased simultaneously for all minor arterial projects. The top-down fatigue cracking increased slightly at Level 3 and showed no change at Level 1 for Projects 011U0006900-NB, 033U0028300-NB, 065U0005600-EB, 069U0028300-NB, and 095U0005600-EB. The remaining distress predictions were similar. The comparison of predictions of reduced thickness between Level 1 and Level 3 was the same as the original thickness.

For principal arterial projects, Project 007U0007500-NB with reduced thickness showed predictions similar to those for the original thickness across all distress levels, as shown in Figure 3.8 and compared with Figure 3.6. In the remaining projects, bottom-up fatigue cracking and terminal IRI increased at the same rate, and the remaining distress was similar to the original thickness predictions. The detailed results are shown in Appendix A. The comparison of predictions of reduced thickness between Level 1 and Level 3 was similar to those using the original thickness.

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	44.48	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.12	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	1.30	85.00	100.00	Pass
AC thermal cracking (ft/mile)	750.00	114.31	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.79	85.00	100.00	Pass
Permanent deformation - AC only (in)	0.45	0.03	85.00	100.00	Pass

(a) Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	53.08	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.10	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	1.25	85.00	100.00	Pass
AC thermal cracking (ft/mile)	750.00	114.32	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	27.10	85.00	79.49	Fail
Permanent deformation - AC only (in)	0.45	0.03	85.00	100.00	Pass

(b) Level 3 Prediction Results

Figure 3.8: Project 007U0007500-NB Distress Prediction Comparison with 2” Reduced Thickness

3.2.2 Creep Compliance

Creep describes the relationship between the time-dependent strain and applied stress for viscoelastic materials (Gong et al., 2012; Worthey, 2020). Creep test results are used to determine the master relaxation modulus curve and fracture parameters, which control thermal crack development and define asphalt mixture fracture resistance (Gao et al., 2018). In the creep test, a static load is applied along the test specimen's axis and held constant. Horizontal and vertical deformations near the center of the specimen are measured and used to calculate creep compliance as a function of time. Creep compliance is calculated as follows (AASHTO T 322-07, 2020):

$$D(t) = \frac{\Delta X_{tm,t} \times D_{avg} \times b_{avg}}{P_{avg} \times GL} \times C_{cmpl}$$

Equation 3.2

where:

D(t) = creep compliance at time t, (psi^{-1});

$\Delta X_{tm,t}$ = trimmed value of horizontal deformation, (in.);

D_{avg} = average diameter of the three replicates, (in.);

b_{avg} = average thickness of the three replicates, (in.);

P_{avg} = average creep load of the three replicates, (lb.);

GL = gauge length, (in.); and

C_{cmpl} = 0.6354 × $(\frac{X}{Y})^{-1}$ – 0.332 is the creep compliance coefficient, and X/Y is the ratio of horizontal deformations to vertical deformations.

Transverse cracking is a non-load-related cracking associated with creep compliance that the PMED software can predict. The transverse cracking prediction model and the transfer function are based on fracture mechanics and are shown in the following equations (AASHTO, 2020).

$$\Delta C = A(\Delta K)^n$$

Equation 3.3

where:

ΔC = Change in the crack depth due to a cooling cycle;

ΔK = Change in the stress intensity factor due to a cooling cycle; and

A, n = Fracture parameters for the AC mixture.

A reasonable estimate of A and n can be obtained from the AC's indirect tensile creep compliance and strength, as shown in Equation 3.4 (AASHTO, 2020).

$$A = k_t \beta_t 10^{[4.389 - 2.51 \log(E_{HMA} \sigma_m \eta)]}$$

Equation 3.4

where:

η = 0.8[1+1/m];

k_t = Coefficient determined through global calibration;

E_{AC} = AC indirect tensile modulus, (psi);

σ_m = Mixture tensile strength, (psi);

m = The m-value derived from the indirect tensile creep compliance curve measured in the laboratory, and

β_t = Local or mixture calibration factor.

Equation 3.5 showed the determination of thermal cracking:

$$TC = \beta_{t1} N \left[\frac{1}{\sigma_d \log(\frac{C_d}{H_{AC}})} \right]$$

Equation 3.5

where:

TC = Observed amount of thermal cracking, (ft/mi);

β_{t1} = Regression coefficient determined through global calibration (400);

N[z] = Standard normal distribution evaluated at [z];

σ_d = Standard deviation of the log of the depth of cracks in the pavement (0.769), (in.);

C_d = Crack depth, (in.); and

H_{AC} = Thickness of AC layers, (in.).

In this research, creep-compliance inputs were applied to AC overlays in the PMED software to predict asphalt pavement performance, comparing Level 1 and Level 3 inputs.

Level 1 inputs of creep compliance can be obtained by following AASHTO T 322-07 Standard Method of Test for Determining the Creep Compliance and Strength of Hot-Mix Asphalt (HMA) Using the Indirect Tensile Test Device.

In this study, the test samples were sawn no thicker than two in. with a diameter of six in. at 7 ± 0.5% target air voids. The tests were conducted at -4 °F, 14 °F, and 32 °F. Four brass gauge points were glued on each face of the specimen, two along the vertical axis and two along the horizontal axis. The displacement transducers were attached to the gauge points to record vertical and horizontal deformation. Once the test temperature stabilized, a static load producing horizontal deformation of 0.00125 to 0.0190 mm was applied to the specimen for 1,000 seconds. If the limit was violated, the test was stopped and restarted with an adjusted load after a 5-minute recovery period. The data acquisition frequency was 10 Hz for the first 10 seconds, 1 Hz for the next 90 seconds, and 0.1 Hz for the remaining 900 seconds. All horizontal and vertical deformations on both sides were recorded automatically. The tensile strength was determined after each creep test at the corresponding temperature. The PMED software requires tensile strength values at a minimum of three temperatures. In this study, the tensile strength of each specimen was determined only at 32 °F. Therefore, Level 3 inputs were used for the indirect tensile strength.

3.2.2.1 Project Information

AC overlays can be divided into two types: AC over AC and AC over JCPC. This research selected twenty-five (25) AC over AC projects and fourteen (14) AC over JCPC projects from a previous study (Islam, 2019) at KSU to predict distress. The general description of rehabilitated pavement projects is shown in Tables 3.13 and 3.14.

Table 3.13: General Descriptions of Selected AC over AC Projects in Kansas

No.	Project Name	Route	County	Begin milepost	End milepost	Length (mile)	Overlay Thickness (in.)
1	KA-2628-01	I-70	Saline	0	8.000	8.00	3.6
2	KA-9466-01	I-70	Saline	8.000	15.000	7.00	1.5
3	KA-4013-01	US-24	Osborne	23.000	30.000	7.00	1.5
4	KA-1436-01	US-36	Cheyenne	14.029	19.000	4.97	1.5
5	KA-2188-01	US-36	Republic	7.000	8.101	1.10	4.0
6	KA-0813-01	US-36	Washington	17.269	26.445	9.18	1.5
7	K-0657-01	US-69	Bourbon	6.009	9.603	3.60	1.5
8	KA-0811-01	US-75	Montgomery	27.000	31.000	4.00	1.0
9	KA-0310-01	US-75	Osage	7.000	12.738	5.74	2.0
10	KA-4192-01	US-77	Butler	0	12.000	12.00	1.0
11	KA-2941-01	US-77	Butler	43.558	50.671	7.11	1.5
12	KA-2923-01	US-81	McPherson	0	2.562	2.56	1.5
13	K-8431-01	US-83	Seward	1.000	6.000	5.00	1.0
14	KA-1480-01	US-160	Clark	6.000	1.000	5.00	1.0
15	K-7756-01	US-166	Chautauqua	0.000	5.000	5.00	2.0
16	KA-1460-01	US-166	Cowley	13.145	19.145	6.00	1.5
17	KA-2200-01	US-169	Allen	14.897	22.941	8.04	3.0
18	KA-2204-01	US-169	Anderson	0	4.153	4.15	7.0
19	KA-2966-01	US-183	Ellis	0	3.000	3.00	1.5
20	KA-2505-01	US-183	Rooks	20.315	22.332	2.02	2.0
21	KA-1444-01(1)	US-183	Phillips	15.050	22.000	6.95	1.5
22	KA-1444-01(2)	US-183	Phillips	23.000	32.753	9.75	1.5
23	KA-3674-01	US-283	Norton	20.790	32.049	11.26	1.5
24	K-9364-01	K-92	Jefferson	8.000	12.738	4.74	1.0
25	KA-3496-01	K-254	Sedgwick	5.000	10.319	5.32	1.5

Table 3.14: General Descriptions of Selected AC over JPCP Projects in Kansas

No.	Project Name	Route	County	Begin milepost	End milepost	Length (mile)	Overlay Thickness (in.)
1	KA-4136-01	I-70	Shawnee	11.000	15.657	4.66	3.6
2	KA-3282-01	I-70	Wyandotte	8.000	12.000	4.00	3.6
3	KA-4236-01	I-135	Harvey	0	7.015	7.02	3.5
4	KA-1950-01	US-50	Marion	16.126	20.995	4.87	3.0
5	KA-1951-01	US-50	Chase	0	9.000	9.00	3.0
6	KA-0378-01(1)	US-50	Harvey	28.641	35.560	6.92	2.6
7	KA-0378-01(2)	US-50	Harvey	27.000	28.641	1.64	2.6
8	KA-2669-01	US-54	Shawnee	17.841	20.326	2.49	3.0
9	KA-1931-01	US-81	Cloud	0	16.000	16.00	3.0
10	KA-3848-01	US-400	Labette	0	8.807	8.81	3.1
11	KA-2681-01	K-57	Marion	0	8.008	8.01	3.0
12	KA-2682-01	K-150	Chase	0	8.637	8.64	3.0
13	KA-3006-01	K-156	Finney	1.936	3.000	1.06	2.0
14	KA-2001-01	K-254	Butler	11.882	14.309	2.43	2.6

3.2.2.2 Material Selection

Due to the limited sample size, only Mix 1 to Mix 4 from the previous dynamic modulus test were tested for creep compliance. In Kansas, 12.5 NMAS mixtures were used for overlay; therefore, only Mix 1 and 4 are applicable for Level 1 creep compliance inputs. Mix 1 and Mix 4 both have 25% RAP. Mix 1 has a higher PG binder grade, PG 70-28, than Mix 4 (PG 58-28). Mix 1 and Mix 4 information were input into the PMED software separately to predict distresses with Level 1 and Level 3 inputs, and the results were compared between Mix 1 and Mix 4 prediction.

3.2.2.3 Input Parameters

3.2.2.3.1 HMA Layer Properties

The aggregate gradation and mixture volumetric properties for each selected mixture were input into PMED software for Level 1 and 3 predictions. All required inputs are listed in Table 3.15.

Table 3.15: Aggregate Gradation and Volumetric Properties Inputs

Mix ID	Volumetric Properties				Aggregate Gradation			
	Binder Grade	Asphalt Content	Effective Binder Content (%)	Unit Weight	Passing 3/4	Passing 3/8	Passing #4	Passing #200
1	PG 70-28	5.8	10.43	143.03	100	89	74	4.7
4	PG 58-28	5.5	11.92	149.38	100	86	74	4.7

The air void for all courses was 7%. The Poisson's ratio for the HMA mix was assumed to be 0.35.

3.2.2.3.2 Creep Compliance Inputs

The PMED software requires laboratory creep-compliance data for the asphalt mix as level 1 input. Since creep is time-dependent, creep compliance values were calculated at 1, 2, 5, 10, 20, 50, and 100 seconds for -4 °F, 14 °F, and 32 °F. All creep compliance results are listed in Table 3.16.

Table 3.16: Level 1 Creep Compliance Inputs

		Mix 1			Mix 4		
		Temperature (°F)			Temperature (°F)		
		-4	14	32	-4	14	32
Time (s)	1	2.75E-07	2.39E-07	4.90E-07	1.2E-07	2.71E-07	1.29E-07
	2	2.88E-07	3.77E-07	6.03E-07	2.72E-07	4.12E-07	6.24E-07
	5	3.06E-07	4.42E-07	7.08E-07	3.08E-07	4.78E-07	8.86E-07
	10	3.31E-07	4.77E-07	8.27E-07	3.47E-07	5.36E-07	1.06E-06
	20	3.51E-07	5.24E-07	9.02E-07	3.95E-07	6.01E-07	1.29E-06
	50	3.75E-07	5.79E-07	1.16E-06	4.63E-07	7.12E-07	1.71E-06
	100	4E-07	6.33E-07	1.39E-06	5.14E-07	7.90E-07	2.16E-06

For level 3 inputs, the PMED software uses a regression model to estimate creep compliance.

3.2.2.3.3 Failure Criteria

Since KDOT does not have an established failure criterion for rehabilitated pavements, the criteria used in the previous study (Islam, 2019) were also used in this research. The detailed values are listed in Table 3.17.

Table 3.17: KDOT Performance Criteria for Each Road Category

AC over AC			AC over JPCP		
Performance Criteria	Target Value	Reliability	Performance Criteria	Target Value	Reliability
Terminal IRI (in./mile)	172	50	Terminal IRI (in./mile)	172	50
Permanent deformation – total pavement (in.)	0.75	50	Permanent deformation – AC only (in.)	0.25	50
AC total fatigue cracking: bottom-up + reflective (% lane area)	25	50	AC bottom-up fatigue cracking (% lane area)	25	50
AC total transverse cracking: thermal + reflective (ft/mile)	2500	50	AC total transverse cracking: thermal + reflective (ft/mile)	2500	50
Permanent deformation – AC only (in.)	0.25	50	AC thermal cracking (ft/mile)	1000	50
AC bottom-up fatigue cracking (% lane area)	25	50	*AC top-down fatigue cracking (% lane area)	25	50
AC thermal cracking (ft/mile)	1000	50	JPCP transverse cracking (percent slabs)	15	50
AC top-down fatigue cracking (% lane area) *	25	50	Chemically stabilized layer – fatigue fractures (% lane area)	25	-

*Top-down fatigue cracking changed the unit from ft/mile to % lane area in version 2.6.2.2. The value of the new criteria was unavailable; therefore, the default value was used.

3.2.2.4 Level 1 and Level 3 Creep Compliance Input Prediction Results

3.2.2.4.1 AC over AC Results

Figure 3.9 shows the distress results for an AC-over-AC project, KA-0310-01, with Mix 1 inputs. Figure 3.10 shows distress predictions of Mix 4 of the same project. As shown in Figure 3.9, Level 1 inputs overpredicted AC thermal cracking of Mix 1. The thermal cracking amount obtained was very high and reached the failure criteria at Level 1. The total transverse cracking values increased sharply with Level 1 inputs but did not exceed the target value. Mix 4 with a softer binder (PG 58-28) showed total transverse cracking that slightly increased with Level 1 inputs. The remaining distresses were relatively similar between Level 1 and Level 3 inputs. There were no apparent differences between the results for Mix 1 and Mix 4 for the Level 3 inputs. The stiffer mix, Mix 1, resulted in higher thermal and total transverse cracking at Level 1. Similar results were also observed for the other 21 projects. For projects KA-0811-01, K-7756-01, and K-8431-01, there was no discernible difference in predicted distresses due to input levels or mixtures except for the bottom-up fatigue cracking. The detailed results are shown in Appendix A. In conclusion, mixtures with softer binders produce less thermal cracking on asphalt overlays over existing asphalt pavements.

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	97.92	50.00	99.56	Pass
Permanent deformation - total pavement (in)	0.75	0.14	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	1531.20	50.00	92.65	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1531.20	50.00	0.00	Fail
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

(a) Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	85.68	50.00	99.98	Pass
Permanent deformation - total pavement (in)	0.75	0.14	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	1.16	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

(b) Level 3 Prediction Results

Figure 3.9: Project KA-0310-01 Distress Prediction Comparison with Mix 1 Inputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	88.38	50.00	99.95	Pass
Permanent deformation - total pavement (in)	0.75	0.15	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	296.10	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

(a) Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	86.14	50.00	99.97	Pass
Permanent deformation - total pavement (in)	0.75	0.15	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	16.17	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

(b) Level 3 Prediction Results

Figure 3.10: Project KA-0310-01 Distress Prediction Comparison with Mix 4 Inputs

3.2.2.4.2 AC over JPCP Results

Figures 3.11 and 3.12 show the prediction results of an AC overlay over the JPCP project, KA-3282-01, for Mix 1 and 4 at different input levels. As shown in Figure 3.11, the AC thermal cracking of Mix 1 met the failure criterion at Level 1 and exceeded the Level 3 value. Increased transverse cracking was observed at both levels, with a higher value for Level 1, but it did not exceed the target value. Mix 4's total transverse cracking values were higher at both levels, and the failure criteria were reached at Level l. The amount of thermal cracking was lower with the soft binder at both levels. When Mix 1 results were compared with Mix 4, total transverse cracking increased and thermal cracking decreased, regardless of input level.

Project KA-2669-01, KA-1951-01, and KA-1950-01 showed similar results. In total, eight projects showed similar predictions, except that the total transverse cracking of Mix 4 did not reach the failure criteria, and both thermal cracking and total transverse cracking were similar when Mix 1 was compared to Mix 4. This was true at both levels of input. However, the two projects performed slightly differently.

For Project KA-1931-01, Mix 1 failed due to thermal cracking at Level 1, and the total transverse cracking value at Level 1 was very close to the limit; it failed at Level 3. For Mix 4, both levels predicted higher total transverse cracking and reached the failure criteria.

In Project KA-0378-01(1), thermal cracking and total transverse cracking reached failure criteria for Mix 1 at Level 1, but the racking amount decreased for Mix 4 at Level 1. The detailed results are shown in Appendix A. In conclusion, a mixture with a lower PG-grade binder would eliminate thermal cracking on the overlays constructed on the JPCP layer. For most projects, a softer binder also helped decrease the total transverse cracking.

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	77.08	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.04	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	2114.74	50.00	68.99	Pass
AC thermal cracking (ft/mile)	1000.00	2112.00	50.00	0.00	Fail
AC top-down fatigue cracking (% lane area)	25.00	5.01	50.00	99.99	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

(a) Level 1 Prediction Results

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	75.79	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.04	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	1190.30	50.00	99.20	Pass
AC thermal cracking (ft/mile)	1000.00	81.10	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	5.01	50.00	99.99	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

(b) Level 3 Prediction Results

Figure 3.11: Project KA-3282-01 Distress Prediction Comparison with Mix 1 Inputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	79.59	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.07	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	3168.29	50.00	25.25	Fail
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	4.99	50.00	99.99	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

(a) Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	77.54	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.07	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	1700.69	50.00	88.06	Pass
AC thermal cracking (ft/mile)	1000.00	19.32	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	4.99	50.00	99.99	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

(b) Level 3 Prediction Results

Figure 3.12: Project KA-3282-01 Distress Prediction Comparison with Mix 4 Inputs

Chapter 4: Correlation between FWD Backcalculated Subgrade Modulus and DCP Value

4.1 Subgrade

Subgrade soils in Kansas are generally classified based on the percentages of clay, silt, and sand-sized particles. The challenge for the pavement designer is to identify the project's design soil and its properties.

The design soil is typically taken from the B or C horizon (Yoder & Witczak, 1975) and is the most common soil on the project. The most important soil properties that the pavement designer must know about the design soil are the resilient modulus, the modulus of subgrade reaction, the swell potential, Atterberg limits, and textural classification. Swelling soils are a significant cause of pavement distress and failure.

Two of the best indicators of soil swelling potential are the plasticity index (PI) and the liquid limit (LL). High PI's (over 25) and high liquid limits (over 50) strongly indicate that the soil will swell. Soil stabilization should be specified if non-swelling soils cannot be guaranteed on the proposed project alignment.

The top 18 in. of the subgrade must be compacted to 95% of standard Proctor density at the optimum ± 5% (for flexible pavements) or to a value not less than the optimum and not more than 5 percentage points above the optimum (KDOT, 2007). Soils with more than 2% swell potential will require the top 6 in. of the subgrade to be treated with 5% hydrated lime.

The lime reacts with the clay particles, chemically stabilizing them and reducing soil swelling. This treatment is designated as lime-treated subgrade (LTSG). The 5% lime requirement is a baseline value and may need adjustment based on lime pH tests, as described in ASTM D6276 (KDOT, 2007).

Soils with over 2% swell potential or an abundance of silt-sized particles tend to be unstable when moist. These soils must be stabilized with fly ash. This treatment is designated as fly ash-treated subgrade (FATSG).

Fly ash treatment consists of treating the top 6 in. of the subgrade with approximately 12–16% fly ash by weight, based on unconfined compression test results (assuming the soil density is 110 lb/ft^3).

Sandy soils should be stabilized to provide a stable working platform for construction. The top 6 in. of a sandy subgrade may be stabilized with 7% cement by weight. The amount of portland cement used should be based on laboratory unconfined compressive strength tests. Fly ash is not an acceptable substitute.

This stabilization method is designated as cement-treated subgrade (CTSG). Subgrade modification (SUBMOD) can be considered an alternative stabilization method to the methods mentioned above. A subgrade modification involves modifying the upper portion of the subgrade, typically with 6 to 8 in. of rock. The rock is placed on the subgrade and then mixed with a pre-determined thickness of the underlying soil, which acts as a binder for the rock. Asphalt milling or reclaimed asphalt pavement (RAP) has recently been used as a rock substitute. Some fly ash is added to the soil-RAP mixture to comprise the subgrade modification (KDOT, 2007).

The resilient modulus of the subgrade soils is one of the most critical factors in designing flexible pavements. KDOT policy limits the design MR to 2,600-5,000 psi. Limiting the resilient modulus prevents under and over-conservative designs and reduces the risk associated with non-uniformity of the subgrade. Non-uniformity can affect the required pavement thickness by 30% to 40%. The resilient modulus, MR, is calculated using an equation for lime-treated and Class C fly-ash-treated layers for the treated subgrade.

$$M_R \text{ (psi)} = 2.03 \times \text{untreated } M_R + 225$$

Equation 4.1

However, the MEPDG Manual (AASHTO, 2020) lists a different equation by Thompson (1970):

$$M_R \text{ (ksi)} = 0.124 \times q_u \text{ (psi)} + 9.98$$

Equation 4.2

where:

q_u is presented in psi and M_r in ksi.

4.2 Pavement/Subgrade Evaluation

At present, most common pavement evaluation techniques usually involve the measurement of pavement surface deflections by a non-destructive load testing (NDT) device (mostly falling weight deflectometer, FWD) and the back calculation of pavement layer moduli using a proper mechanistic model. The 1993 AASHTO Design Guide for Pavements (AASHTO, 1993) offers a model for back-calculating subgrade modulus from the FWD data. Another device that has become popular for evaluating pavement and subgrade materials since the 1990s is the dynamic cone penetrometer (DCP). This test can be done in test beds and boreholes.

The DCP is an effective tool for assessing subsurface pavement conditions and strength, thanks to its portability, simplicity, and ability to accurately measure the in-situ strength of pavement layers and subgrades. No excavation of the existing pavement would be required. The DCP could correlate with the falling weight deflectometer (FWD) deflection test results obtained by KDOT on the state highway system.

4.2.1 Historical Development and Test Procedure of DCP

DCP was initially developed in South Africa as an in-situ pavement evaluation technique for continuously measuring the depths of pavement layers and subgrade soil parameters (Kleyn, 1975). Since then, this device has been used extensively in South Africa, the United Kingdom, the US, Australia, and many other countries because it is simple, economical, and less time-consuming (Livneh & Ishai, 1987).

KDOT started using DCP in the late 1980s. The KDOT DCP consists of a slender steel rod with a conical tip, as shown in Figure 4.1. The rod is fabricated in two pieces for ease of packing and portability. The cone tip is made of hardened steel and is angled at 30^{o} with a diameter at its head of 20 mm. The driving hammer, which slides down the steel rod, measures 575 mm in height and weighs 8 kg. The unit also includes two aluminum blocks and a reference beam to help measure penetration depth during testing.

Usually, pavement testing at a given point involves extruding a 10-cm-diameter core from the asphalt layer and penetrating the DCP from the top of the base course down to the required pavement or subgrade layer. The properties of the asphalt layers can be evaluated directly in the laboratory using an appropriate mechanical test or, when needed, back-calculated. The resistance of other pavement and subgrade layers to penetration is continuously measured and recorded by the DCP at depth. At the end of the test, the shallow 10 cm hole could be quickly filled with either portland cement concrete (regular or fast curing) or a proper cold asphalt mixture. The DCP is driven into the top of the natural soil or compacted subgrade for subgrade evaluation and pavement design. During testing, the number of blows is recorded as a function of depth. The "DCP value" is defined as the slope of the blow vs. depth curve (in mm per blow) at a given linear depth segment.

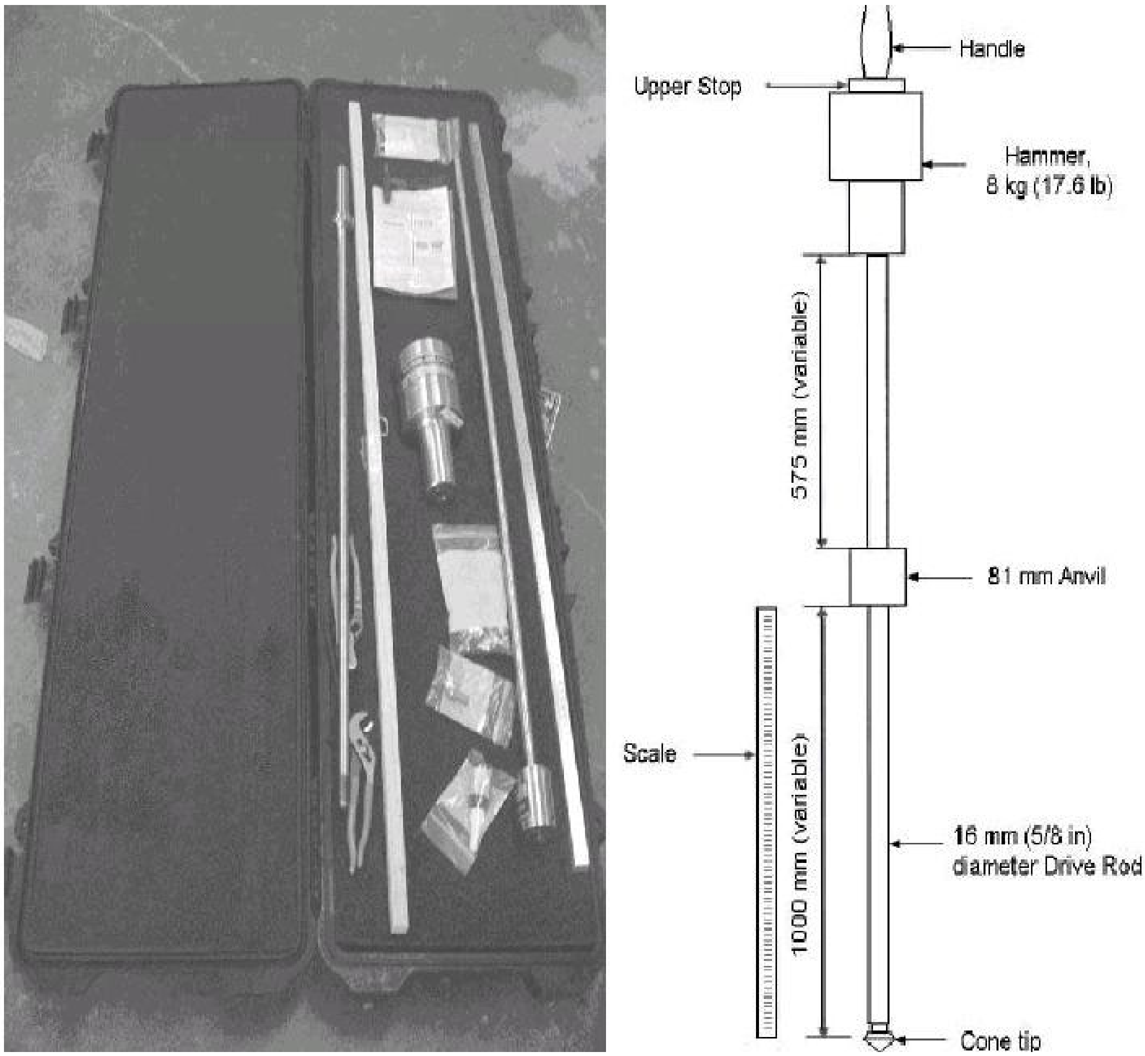


Figure 4.1: KDOT DCP Setup

4.2.2 Correlation between DCP and CBR

California Bearing Ratio (CBR) is an index of a soil's strength and deflection characteristics. In reality, it is a plate-bearing test that measures the static penetration resistance of soil as a function of a cylinder's penetration before reaching the soil's ultimate shearing value. The CBR is defined as the percentage obtained by dividing the resistance in psi at 2.5-mm penetration of the soil under test by the resistance of a standard, well-graded, crushed stone at the same penetration (2.5 mm), then multiplying by 100. This standard value is usually 6,890 kPa (Yoder & Witczak, 1975).

To assess the structural properties of the pavement subgrade, DCP values were correlated with its CBR. Once the CBR value of soil is known, the subgrade modulus could be determined by a relationship between the CBR and subgrade modulus. Perhaps the most well-known relationship is the one proposed by MEPDG (AASHTO, 2020):

$$CBR = \frac{292}{DCP^{1.12}}$$

Equation 4.3

$$M_R = 2555(CBR)^{0.64}$$

Equation 4.4

In Equation 4.4, M_R is the subgrade modulus (psi).

4.2.3 Correlation between MR and DCP in Kansas

Since its introduction to KDOT in the early 1990s, the DCP has been extensively used in pavement evaluation in Kansas. The primary use of DCP has been in subgrade evaluation (and subsequent structural evaluation) of a milled pavement to support vehicular traffic during construction and to accommodate heavy construction equipment.

Typically, KDOT conducts 20 to 40 DCP tests on a project, computes the subgrade CBR value using the relationship in Equation 4.3, and then computes subgrade M_R using the methodology described in Chapter 5 of the 1993 AASHTO Pavement Design Guide. This back-calculated M_R is used as input to the 1993 AASHTO flexible pavement design equation to estimate the allowable 18-kip equivalent single-axle loads (ESALs) on the milled pavement. However, it has been observed that the correlated subgrade resilient modulus varies widely due to sharp variations in the subgrade CBR values derived from DCP test results (Chen et al., 1999).

The objective of this study was to establish a correlation between the CBR (derived from DCP values) and the back-calculated subgrade modulus, based on deflection test results from the Falling Weight Deflectometer. The back-calculated subgrade modulus was calculated using the 1993 AASHTO Pavement Design Guide algorithm. This is expected to improve the subgrade evaluation procedure, as this relationship would uniquely estimate the subgrade resilient moduli from DCP test results for Kansas soils.

4.3 Site Selection and Data Collection

Table 4.1 shows the seven sections selected in this study. All sections are asphalt pavements, ranging in length from about 0.4 miles to 13.5 miles, along State and US routes in Kansas. The soil data on classification, plasticity index, and liquid limit have been collected from the United States Department of Agriculture (USDA) soil survey of Kansas (Soil Conservation Service, 1985). The project soils can be classified as SC-SM to MH according to the Unified Classification system and A-4 to A-7-6 according to the AASHTO classification. The Liquid Limit varies from 3 to 61, and the Plasticity Index (PI) from 1 to 35. These soils are relatively representative of the Kansas subgrade soils.

Table 4.1: Test Sections in this Study

No.	Route	County	Mile Post		Soil Type		LL	PI	Sand %	Silt %	Clay %
			From	To	Unified	AASHTO					
1	US-83	Scott	17	30.5	CL	A-6	30–40	11–17	10–38	35–69	21–31
2	US-56	Pawnee	7.5	12.6	CL	A-6	30–33	14–16	37–46	33–38	21–24
3	US-169	Neosho	0.1	3.9	CL, MH	A-6, A-7-5, A-7-6	49–61	27–34	4–17	45–52	38–47
4	K-177	Morris	15.8	24.6	CL, CH	A-7-6	53–60	30–35	2–6	50–55	41–48
5	K-177	Geary	0.4	12.6	CL, CH	A-7-6	53–58	29–33	4–7	50–55	41–46
6	K-14	Reno	28.6	32.6	SC-SM, SP-SM	A-2-4, A-3	3–14	1–5	78–88	9–14	3–8
7	K-383	Phillips	0.3	0.7	CL	A-4, A-6	22–33	5–14	10–51	39–69	10–21

KDOT collected FWD deflection and DCP data during rehabilitation design. Seven to 22 DCP tests were done on each section. Usually, the boring logs recorded the pavement layer types and conditions. Layer thicknesses were obtained from either core/bore data. FWD tests were conducted at about 100-meter intervals in each section. The target load level was 40 kN, and three load drops were generally used at each test station. Seven sensors were used at LTPP sensor spacing. Air and pavement surface temperatures were automatically recorded during the test period. FWD and DCP data were generally taken one after the other, but there was a much longer time gap between the DCP and FWD tests on a few projects.

This study used data from five projects listed in Table 2.1 to develop a regression equation relating subgrade moduli to DCP-derived CBR values.

4.4 Calculation of CBR from the DCP Test Results

In this study, the quantitative relationship between the material's CBR and its DCP value, as described in Equation 2.1, was used to compute the CBR values in Table 4.2. The mean CBR values across all counties except Neosho are similar, but the coefficient of variation for each project is very high.

Table 4.2: Summary of Derived CBR Values

County	CBR				
	Mean	Min.	Max.	Std. Dev.	C.O.V (%)
Geary	12	4	20	5	42
Morris	11	6	19	5	45
Neosho	42	9	84	30	71
Pawnee	14	6	30	7	50
Phillips	12	7	19	4	33
Scott	14	6	26	5	36

4.5 Back calculation of Subgrade Layer Moduli

The deflection basins from the FWD tests were used to back-calculate the subgrade layer moduli in accordance with the 1993 AASHTO Pavement Design Guide (AASHTO, 1993). The AASHTO algorithm suggests that, at a sufficiently large distance from the load center, pavement surface deflections are due solely to subgrade deformation and are independent of load plate size. This allows back-calculation of the subgrade resilient modulus from a single deflection measurement and the load magnitude, as shown in Equation 4.5.

$$M_R = \frac{0.24 \times P}{d_r \times r}$$

Equation 4.5

where:

M_R= back-calculated subgrade resilient modulus (psi);

P = applied load (psi); and

d_r= deflection at a distance r (in.) from the load's center (in.).

To use a particular sensor deflection to estimate the subgrade resilient modulus, the deflection must be measured far enough away from the load so that it provides a reasonable estimate of the subgrade modulus, independent of the effects of any layer above, but also close enough so that it is not too small to be measured accurately. The AASHTO Guide further suggests that the minimum distance be determined based on the radius of the stress bulb at the subgrade-pavement interface (AASHTO, 1993).

$$r = 0.7\sqrt{a^2 + \left\{D\sqrt[3]{\frac{E_P}{M_R}}\right\}^2}$$

Equation 4.6

where:

a = radius of load plate (in.);

D = total thickness of pavement layers above the subgrade (in.); and

E_p = effective modulus of all pavement layers above the subgrade (psi).

When the subgrade resilient modulus and the total thickness of all layers above the subgrade are known, the effective modulus E_p of the entire pavement structure (all pavement layers above the subgrade) may be determined from the deflection measured at the center of the load plate (AASHTO, 1993).

$$\frac{M_R d_0}{qa} = 1.5\left\{\frac{1}{\sqrt{1+\left(\frac{D}{a}\times\sqrt[3]{\frac{E_P}{M_R}}\right)^2}} + \frac{\left[1-\frac{1}{\sqrt{1+\left(\frac{D}{a}\right)^2}}\right]}{\left(\frac{E_P}{M_R}\right)}\right\}$$

Equation 4.7

where:

E_p= effective modulus of all pavement layers above the subgrade (psi);

d_0 = deflection measured at the center of the load plate (and adjusted to a standard temperature of 68 °F) (in.);

q = NDT load plate pressure (psi);

a = NDT load plate radius (in.);

D = total thickness of pavement layers above the subgrade (in.); and

M_R= subgrade resilient modulus (psi).

Table 4.3 shows the coefficients of variation for the FWD-back-calculated subgrade moduli for all sections. The coefficients of variation are similar for all sections except for the one in Neosho County. Table 4.4 and Table 4.5 present details of soil types in Neosho County from the USDA soil maps. Although the predominant soil types are A-6 and A-7-6, considerable variability is observed in CBR values from DCP tests. Earlier research showed that for materials with CBR values greater than 20, the CBR-modulus correlation for subgrade soils would overestimate the subgrade moduli. Therefore, the subgrade moduli derived from Neosho County were not used to develop the CBR-modulus correlation in this study.

Table 4.3: Summary of Back-calculated Subgrade Moduli

Country	**M_R (psi)**				
	Mean	**Min.**	**Max.**	**Std. Dev.**	**C.O.V (%)**
Geary	5,308	3,735	6,934	981	18
Morris	5,365	4,334	6,864	757	14
Neosho	5,933	3,837	8,174	1,589	27
Pawnee	5,007	4,178	6,420	671	13
Phillips	3,414	2,776	3,978	429	13
Scott	4,393	2,733	5,901	673	15

Table 4.4: Soil Details in Neosho County (AASHTO)

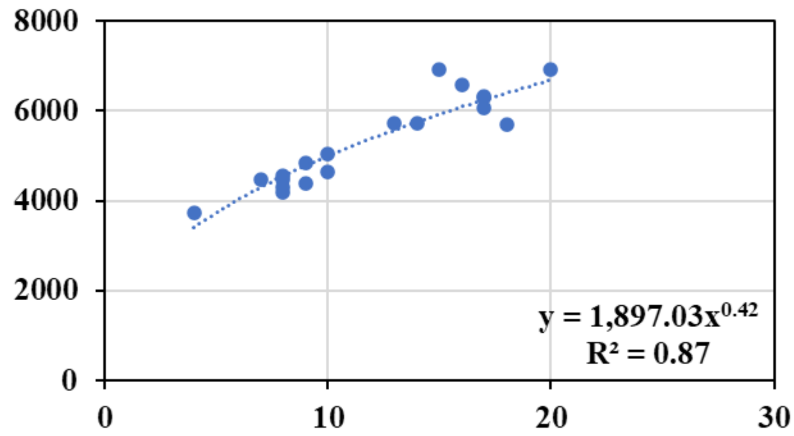
Map Unit Symbol	**Map Unit Name**	**Rating**	**Acres in AOI**	**Percent of AOI (%)**
6982	Stephenville-Darnell complex, 6 to 20% slopes	A-4	0.1	0
8300	Verdigris silt loam, channeled, 0 to 2% slopes	A-6	5	1.9
8302	Verdigris silt loam, 0 to 1% slopes	A-6	11.2	4.4
8627	Bates-Collinsville complex, 3 to15% slopes	A-6	4.9	1.9
8675	Deepwater silt loam, 1 to 3% slopes	A-7-6	8.4	3.3
8679	**Dennis silt loam, 1 to 3% slopes**	**A-6**	**74.7**	**29.1**
8733	Eram silty clay loam, 1 to 3% slopes	A-7-6	7.9	3.1
8735	**Eram silty clay loam, 3 to 7% slopes**	**A-7-6**	**11.2**	**4.4**
8775	Kenoma silt loam, 1 to 3% slopes	A-6	5.2	2.0
8951	Wagstaff silty clay loam, 1 to 3% slopes	A-7-5	9.7	3.8
8961	**Woodson silt loam, 0 to 1% slopes**	**A-6**	**97.6**	**38.0**
8991	Zaar silty clay, 1 to 3% slopes	A-7-5	20.6	8.0
Totals for Area of Lane Zones			256.9	100

Table 4.5: Soil Details in Neosho County (USCIS)

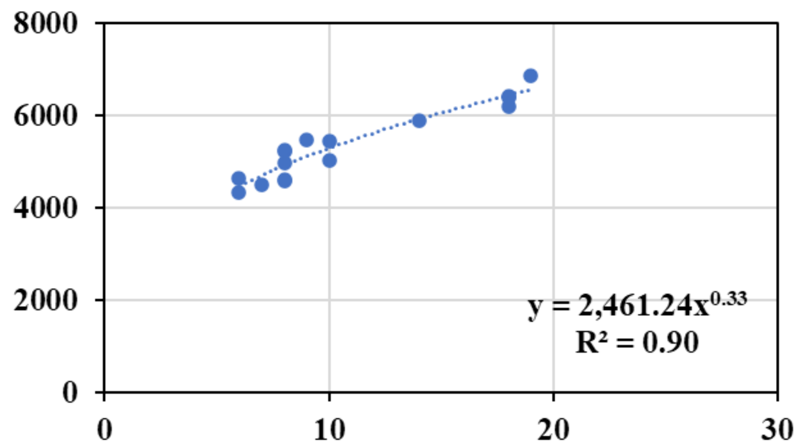
Map Unit Symbol	Map Unit Name	Rating	Acres in AOI	Percent of AOI (%)
6982	Stephenville-Darnell complex, 6 to 20% slopes	SC-SM	0.1	0
8300	Verdigris silt loam, channeled, 0 to 2% slopes	CL	5	1.9
8302	Verdigris silt loam, 0 to 1% slopes	CL	11.2	4.4
8627	Bates-Collinsville complex, 3 to 15% slopes	CL	4.9	1.9
8675	Deepwater silt loam, 1 to 3% slopes	CL	8.4	3.3
8679	**Dennis silt loam, 1 to 3% slopes**	**CL**	**74.7**	**29.1**
8733	Eram silty clay loam, 1 to 3% slopes	CL	7.9	3.1
8735	**Eram silty clay loam, 3 to 7% slopes**	**CL**	**11.2**	**4.4**
8775	Kenoma silt loam, 1 to 3% slopes	CL	5.2	2.0
8951	Wagstaff silty clay loam, 1 to 3% slopes	MH	9.7	3.8
8961	**Woodson silt loam, 0 to 1% slopes**	**CL**	**97.6**	**38.0**
8991	Zaar silty clay, 1 to 3% slopes	MH	20.6	8.0
Totals for Area of Lane Zones			256.9	100

4.6 Correlation between Subgrade CBR and Back-calculated Subgrade Moduli

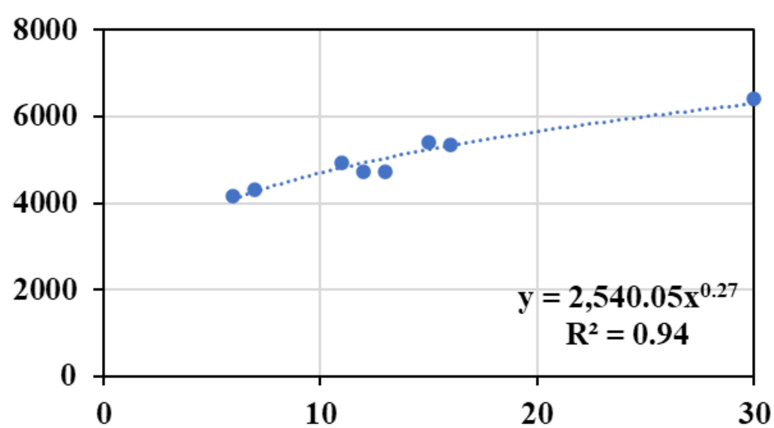
Microsoft Excel was used to perform linear regression analysis in this study. The CBR value was used as the independent variable, and the back-calculated subgrade moduli from the FWD data were used as the dependent variable. First, the regression analysis was performed on a project-by-project basis. The goodness of fit was examined by the coefficient of determination, R^2. If $R^2 = 0$, no correlation exists, whereas $R^2 = 1$ expresses a perfect fit with no stochastic component (Ott, 1993). Figure 4.3 shows the individual project models. The R^2 values vary from 0.74 to 0.94. Later, the data from various projects were combined, and models based on soil types and the range of liquid limits were developed. Those models are shown in Table 4.6. The CBR-M_R relationship for the soil, as recommended by MEPDG, is also shown in Table 4.5. The R^2 values vary from 0.74 to 0.94.



(a) Geary (District 2)

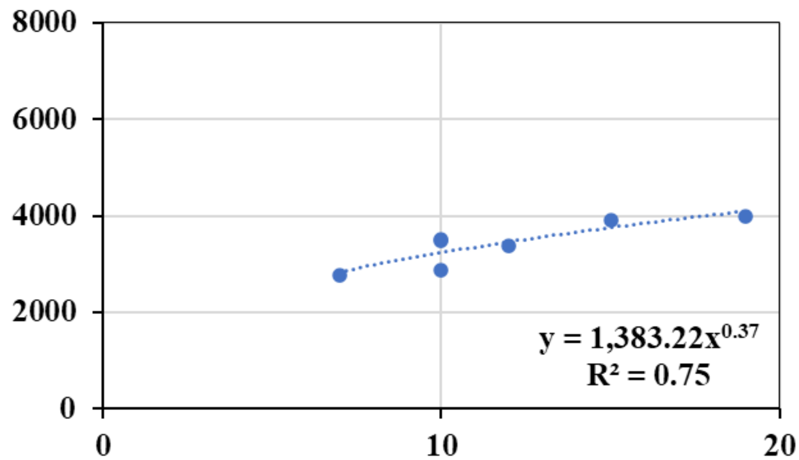


(b) Morris (District 2)

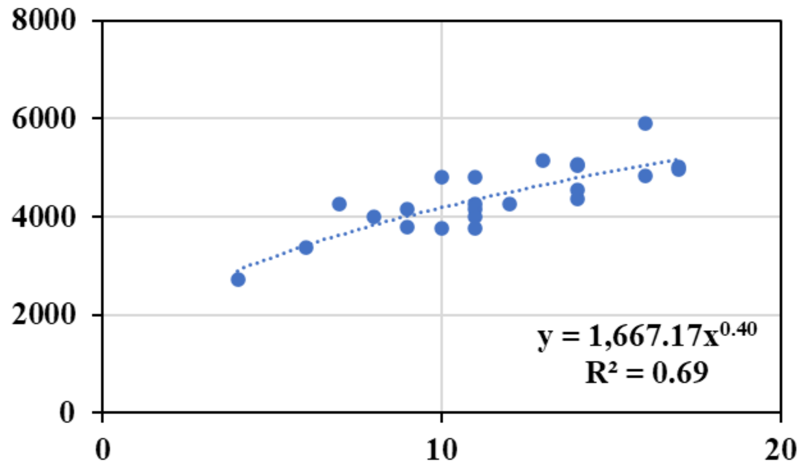


(c) Pawnee (District 5)

Figure 4.2: CBR-DCP Correlation



(a) Philips (District 3)



(b) Scott (District 6)

Figure 4.3: CBR-DCP Correlation (continued)

Table 4.6: Subgrade-CBR Correlations

Soil Type		LL	PI	CBR	M_R (FWD Backcalculated) (psi)	Equation	R^2
SC-SM, SP-SM	A-2-4, A-3	3–14	1–5		-	-	
SC-SM, CL	A-4, A-6	22–33	5–14	7–20	2,776–3,978	M_R= 1383×CBR$^{0.37}$	0.74
CL	A-6	30–40	11–17	6–30	2,733–6,420	M_R = 1868×CBR$^{0.36}$	0.71
CL, CH, MH	A-6, A-7-5, A-7-6	49–61	27–35	4–84	3,735–8,100	M_R = 2828×CBR$^{0.25}$	0.82
AASHTO MEPDG	-	-	-	-	-	M_R = 2555×CBR$^{0.64}$	-

4.7 Effect of Back-calculated Subgrade Resilient Modulus on PMED Design Analysis

The KDOT (2007) Geotechnical Manual contends that subgrade resilient modulus (M_R) is one of the most critical factors in designing flexible pavements. As mentioned earlier, KDOT policy limits the M_R value for design to 2,000 to 5,000 psi. KDOT contends that limiting the resilient modulus prevents under- and over-conservative designs and reduces the risk associated with subgrade non-uniformity. Non-uniformity can increase the required pavement thickness by 30% to 40%. This study assessed the impact of subgrade modulus variability on pavement design analysis using PMED.

4.7.1 HMA Pavements

This study used four new flexible pavement projects to investigate differences between predictions of subgrade resilient modulus obtained from the KSU equation and those from calibration studies. Four projects, selected from those shown in Table 3.5 in Section 3.2.1, were used to investigate the effect of dynamic modulus on PMED analysis results. Two minor arterial and two principal arterial projects were selected.

The inputs for subgrade moduli and other properties are summarized in Table 4.6. The design M_R values were used in the calibration/recalibration studies. The CBR was back-calculated from the subgrade resilient modulus based on the AASHTO/MEPDG equation in Table 4.5. Then, the applicable equation from Table 4.7 for the given soil type was used to calculate KSU M_R. In this study, all four projects selected had A-7-6 soil. Therefore, the equation $M_R = 2828 * CBR^{0.25}$ was used. The calculated KSU M_R values were much lower than the calibration values. The calculated KSU M_R was then used as input to the PMED software, and the prediction results were compared with those obtained using the calibration M_R.

The results show that for Projects 011U0006900-NB, 033U0028300-NB, and 052U0007300-NB, a slight increase in terminal IRI and AC bottom-up fatigue cracking was observed with KSU MR compared with the distresses obtained using the calibration subgrade resilient modulus. The permanent deformation of the total pavement, thermal cracking, top-down fatigue cracking, and permanent deformation of the AC layer remained unchanged. Figure 4.4 shows an example of a comparison of the predicted distresses between KSU and calibration M_R.

For Project 008U0005400-EB, a slight decrease was observed in terminal IRI and AC bottom-up fatigue with KSU MR, since KSU MR increased relative to the calibration M_R. The rest of the distresses remained unchanged. Figure 4.5 shows the detailed results.

Table 4.7: Subgrade Property Inputs for HMA Pavements

Road Type	Minor Arterial		Principal Arterial	
Project ID	011U0006900-NB	033U0028300-NB	008U0005400-EB	052U0007300-NB
Subgrade	A-7-6	A-7-6	A-7-6	A-7-6
Plasticity Index (PI)	30	30	30	30
Percent Passing #200 sieve	79.1	79.1	79.1	79.1
Percent Passing #4 sieve	94.9	94.9	94.9	94.9
Calibration M_R (psi)	3,900	3,600	2,600	3,100
CBR (AASHTO T193)	1.94	1.71	1.03	1.35
KSU M_R (psi)	3,336	3,233	2,847	3,050

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	66.53	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.09	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	52.07	75.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	65.73	65.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	22.16	75.00	83.53	Pass
Permanent deformation - AC only (in)	0.35	0.03	75.00	100.00	Pass

(a) Calibration M_R Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	68.08	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.10	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	54.97	75.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	65.73	65.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	22.16	75.00	83.53	Pass
Permanent deformation - AC only (in)	0.35	0.03	75.00	100.00	Pass

(b) KSU M_R Prediction Results

Figure 4.4: Project 011U0006900-NB Distress Prediction Comparison between Calibration MR and KSU MR

Distress Prediction Summary					
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	53.70	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.09	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	20.64	85.00	65.54	Fail
AC thermal cracking (ft/mile)	750.00	114.31	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.79	85.00	100.00	Pass
Permanent deformation - AC only (in)	0.45	0.02	85.00	100.00	Pass

(a) Calibration M_R Prediction Results

Distress Prediction Summary					
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	53.10	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.09	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	19.74	85.00	90.32	Pass
AC thermal cracking (ft/mile)	750.00	114.31	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.79	85.00	100.00	Pass
Permanent deformation - AC only (in)	0.45	0.02	85.00	100.00	Pass

(b) KSU M_R Prediction Results

Figure 4.5: Project 008U0005400-EB Distress Prediction Comparison between Calibration MR and KSU MR

4.7.2 JPCP Pavements

Three JPCP projects studied earlier in Chapter 3 were used to study the effect of subgrade M_R. Subgrade property inputs for the PMED software are summarized in Table 4.7. The design subgrade M_R was the default subgrade modulus used earlier (detailed input parameters are provided in Table 3.4). The KSU M_R was calculated using the applicable equations listed in Table 4.8. The CBR value was determined by using Equation 4.8 proposed by MEPDG/AASHTO:

$$M_R(psi) = 2555 \times CBR^{0.64}$$

Equation 4.8

where:

CBR = computed from the applicable KSU equation in Table 4.8.

Table 4.8: Subgrade Property Inputs

Project ID	**I-70 TH**	**K-10 DG**	**I-70 GO**
Subgrade Soil Type	A-6	A-7-6	A-6
Plasticity Index (PI)	16	30	16
Percent Passing #200 sieve	63.2	79.1	63.2
Percent Passing #4 sieve	93.5	94.9	93.5
Design M_R (psi)	5,000	2,600	5,400
CBR (AASHTO T193)	2.85	1.03	3.22
KSU M_R (psi)	2,723	2,849	2,846

Figure 4.6 summarizes the slab thicknesses obtained from the PMED design analysis. The results show that using KSU M_R parameters increases slab thickness by 0.5 in. for the I-70 TH and I-70 GO projects. The slab thickness for the K-10 DG project remained the same regardless of the input subgrade modulus. Both I-70 projects had much higher truck traffic.

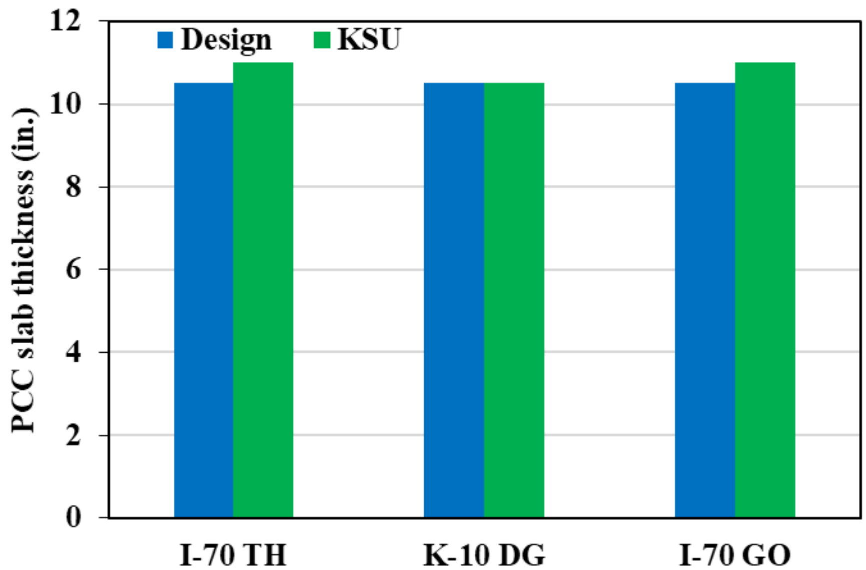


Figure 4.6: Comparison of Slab Thicknesses for Various Subgrade MR

Chapter 5: Conclusions & Recommendations

The Kansas Department of Transportation (KDOT) is transitioning from using the 1993 AASHTO Pavement Design Guide to implementing AASHTOWare Pavement ME Design, PMED software. The software uses the mechanistic-empirical pavement design approach. The prediction models for the AASHTOWare PMED need to be calibrated to local conditions to make accurate, dependable pavement performance predictions.

Previously, multiple efforts were made to calibrate performance models locally in Kansas. The first local calibration was completed using AASHTOWare version 2.2 for newly constructed/reconstructed pavements. Then the process was repeated, and a second effort was made to rehabilitate projects using AASHTOWare version 2.5. Since the latest version of AASHTOWare PMED is 2.6, the performance models must be evaluated to see if further calibration is needed.

The main objective of this study was to determine whether the local calibration factors developed using version 2.5 are still valid for version 2.6.2, released in September 2022. Another objective was to see any significant changes between the two versions that might affect the performance prediction. This was done by analyzing several selected projects and evaluating those against the failure criteria. Also, several issues related to input material characteristics were studied. Based on this study, the following conclusions can be made:

- The recalibration process is pretty straightforward.
- Local calibration process is dependent upon measured performance data. This study's JPCP slab-cracking data were unavailable because this distress is not present on Kansas pavements.
- Not all global coefficients must be changed in the calibration/recalibration process.
- Engineering judgment is critical in the calibration process.
- For projects with high truck traffic, the 1993 AASHTO design guide yielded higher slab thickness than the PMED software when no friction is assumed between the JPCP slab and PCTB. For sections with medium truck traffic,

PMED produced higher thicknesses than those specified in the 1993 AASHTO design guide.

- An assumption of full friction between the JPCP slab and PCTB has a discernible effect on the JPCP slab thickness obtained from PMED.
- Dynamic modulus is a key HMA input. Comparing distress predictions for Level 1 and Level 3 HMA modulus inputs, AC top-down fatigue cracking increased significantly but did not exceed the target value. Similar results were observed in four other projects. However, five projects showed no change in AC top-down fatigue-cracking values between Level 1 and Level 3 HMA moduli inputs. The other predicted distresses were similar for Level 1 and 3 inputs. Five of 11 principal arterial projects showed that the AC top-down fatigue cracking value increased significantly with Level 3 input and exceeded the failure criterion. The other six projects showed no change in AC top-down fatigue-cracking values between Level 1 and Level 3 inputs. The other distress predictions were similar for the Level 1 and Level 3 inputs.
- Level 1 creep test inputs impact predicted AC thermal cracking that may reach the failure criteria. The total transverse cracking values increased sharply with Level 1 inputs but did not exceed the target value. However, mixes with a softer binder (PG 58-28) showed total transverse cracking that slightly increased with Level 1 inputs. The remaining distresses did not vary much between Level 1 and Level 3 inputs. There were no apparent differences among the various mix results for the Level 3 inputs. A stiffer mix resulted in higher thermal and total transverse cracking for Level 1 inputs. Mixtures with softer binders produce less thermal cracking in asphalt overlays over existing asphalt pavements.
- Lower subgrade moduli result in higher IRI and percentage AC bottom-up fatigue cracking for the HMA pavements. The other distresses remain practically unchanged.
- Lower subgrade modulus results in a slight increase in slab thickness for projects with higher truck traffic.

References

AASHTO T 322-07. (2020). *Standard method of test for determining the creep compliance and strength of hot-mix asphalt (HMA) using the indirect tensile test device*. American Association of State Highway and Transportation Officials.

AASHTO T 342-22. (2022). *Standard method of test for determining dynamic modulus of hot mix asphalt (HMA)*. American Association of State Highway and Transportation Officials.

Abdo, A. A., Bayomy, F., Nielsen, R., Weaver, T., Jung, S. J., & Santi, M. J. (2009). Prediction of the dynamic modulus of Superpave mixes. In E. Tutumluer & I. L. Al-Qadi (Eds.), *Bearing Capacity of Roads, Railways and Airfields: Proceedings of the 8th International Conference (BCR2A'09), June 29–July 2, 2009, University of Illinois at Urbana-Champaign, Champaign, Illinois, USA* (pp. 305–314). CRC Press.

Ali, O. (2005). *Evaluation of the Mechanistic Empirical Pavement Design Guide (NCHRP 1-37 A)*. https://doi.org/10.4224/20377776

American Association of State Highway and Transportation Officials (AASHTO). (1993). *Guide for design of pavement structures*.

American Association of State Highway and Transportation Officials (AASHTO). (2008). *Mechanistic-empirical pavement design guide: A manual of practice* (Interim edition).

American Association of State Highway and Transportation Officials (AASHTO). (2010). *Guide for the local calibration of the Mechanistic-Empirical Pavement Design Guide*.

American Association of State Highway and Transportation Officials (AASHTO). (2017). *Pavement ME National Users Group Meetings: Technical report: Second annual meeting—Denver, CO, October 11-12, 2017*. https://me-design.com/medesign/data/user%20group/ME%20UG%202%20Denver_Summary%20Report_2-15-18_Final.pdf

American Association of State Highway and Transportation Officials (AASHTO). (2020). *Mechanistic-empirical pavement design guide: A manual of practice* (3rd ed.).

American Association of State Highway and Transportation Officials (AASHTO). (2021, Jan. 6). *Top-down cracking enhancement: Enhancements to the Mechanistic-empirical pavement design guide: A manual of practice, 2020 third edition* (Addendum No. FY2020.02). https://me-design.com/MEDesign/data/TopDownCracking_Addendum%20to%20MOP_Draft_V5_6January2021.pdf

American Association of State Highway and Transportation Officials (AASHTO). (2022). *Meeting minutes for* Mechanistic-Empirical Pavement Design Guide (MEPDG) *Implementation RoadMap Workshop: Pavement ME User Group Meetings, June 1-2, 2022.* https://pooledfund.org/Document/Download?id=11539

Applied Research Associates, Inc. (2004). *Guide for mechanistic-empirical design of new and rehabilitated pavement structures* (NCHRP Project 1-37A). Transportation Research Board.

ASTM D6276-19. (2019). *Standard test method for using pH to estimate the soil-lime proportion requirement for soil stabilization*. ASTM International. doi: 10.1520/D6276-19, www.astm.org

Awed, A. M., El-Badawy, S. M., Bayomy, F. M., & Santi, M. (2011). Influence of the MEPDG binder characterization input level on the predicted dynamic modulus for Idaho asphalt concrete mixtures (Paper No. 11-1268). In *TRB 90th Annual Meeting compendium of papers DVD*. Transportation Research Board.

Brown, S. F., Darter, M., Larson, G., Witczak, M., & El-Basyouny, M. M. (2006). Independent review of the "Mechanistic-Empirical Pavement Design Guide" and software. *NCHRP Research Results Digest, 307*.

Chen, J., Hossain, M., & LaTorella, T. M. (1999). Use of falling weight deflectometer and dynamic cone penetrometer in pavement evaluation. *Transportation Research Record, 1655*, 145–151. https://doi.org/10.3141/1655-19

Croney, D., & Croney, P. (1991). *The design and performance of road pavements* (2nd ed.). McGraw-Hill Book Company.

Darter, M. I., Mallela, J., Titus-Glover, L., Rao, C., Larson, G., Gotlif, A., Von Quintus, H., Khazanovich, L., Witczak, M., El-Basyouny, M., El-Badawy, S., Zborowski, A., & Zapata, C. (2006). Changes to the Mechanistic-Empirical Pavement Design Guide software through version 0.900, July 2006. *NCHRP Research Results Digest, 308*.

Esfandiarpour, S. (2017). *Calibrating MEPDG inputs prediction models for asphalt mixes containing reclaimed asphalt pavement* (Doctoral dissertation). University of Manitoba.

Esfandiarpour, S., & Shalaby, A. (2018). Effect of local calibration of dynamic modulus and creep compliance models on predicted performance of asphalt mixes containing RAP. *International Journal of Pavement Research and Technology, 11*(5), 517–529.

Federal Highway Administration (FHWA). (1999). *Pavement subsurface drainage design* (Publication No. FHWA-HI-99-028, NHI Course No. 131026).

Federal Highway Administration (FHWA). (2014). *Traffic monitoring guide: Appendix C. Vehicle types*. https://www.fhwa.dot.gov/policyinformation/tmguide/tmg_2013/vehicle-types.cfm

Gao, Y., Islam, S., & Hossain, M. (2018). *Durable recycled Superpave mixes in Kansas* (Report No. K-TRAN: KSU-14-6). Kansas Department of Transportation.

Gong, W., Tao, M., Mallick, R. B., & El-Korchi, T. (2012). Investigation of moisture susceptibility of warm-mix asphalt mixes through laboratory mechanical testing. *Transportation Research Record, 2295*, 27–34.

Islam, S. (2019). *Implementation of AASHTOWare Pavement ME Design Software for pavement rehabilitation* (Doctoral dissertation). Kansas State University.

Islam, S., Sufian, A., Hossain, M., Velasquez, N., & Barrett, R. (2019). Practical issues in implementation of mechanistic empirical design for concrete pavements. *Journal of Transportation Engineering, Part B, 145*(3).

Kansas Department of Transportation (KDOT). (2007). 12: Analysis and design of pavements. *Geotechnical manual, Vol. 1, 2007 edition*.

Kansas Department of Transportation (KDOT). (2015). Section 306: Cement treated base. *Standard specifications for state road & bridge construction*.

Khanum, T., Hossain, M., & Gisi, A. J. (2005). Performance of SPS-2 project in Kansas. In *Proceedings of the 2005 Mid-Continent Transportation Research Symposium*. Iowa State University, Center for Transportation Research and Education. https://www.intrans.iastate.edu/wp-content/uploads/2023/08/Proc_Midcon_2005.pdf

Khazanovich, L., & Tompkins, D. (2017). *Incorporating slab/underlying layer interaction into the concrete pavement analysis procedures* (NCHRP Web-Only Document 236). Transportation Research Board.

Kim, Y. R., Jadoun, F. M., Hou, T., & Muthadi, N. (2011). *Local calibration of the MEPDG for flexible pavement design* (Report No. FHWA\NC\2007-07). North Carolina Department of Transportation.

Kleyn, E. G. (1975). *The use of the dynamic cone penetrometer (DCP)* (Report No. 2/74). Transvaal Provincial Administration, Pretoria, South Africa.

KT-37 Kansas Test Method. (2018). Making, curing and testing cement treated and unbound bases. *Kansas Department of Transportation construction manual, Part V*. Kansas Department of Transportation.

Livneh, M., & Ishai. I. (1987). Pavement and material evaluation by a dynamic cone penetrometer. In *Proceedings, Sixth International Conference, Structural Design of Asphalt Pavements* (Vol. 1, pp. 665–676). University of Michigan.

Ott, R. L. (1993). *An introduction to statistical methods and data analysis* (4th ed). Duxbury Press.

Pavement Interactive. (n.d.). *PCC pavement*. Retrieved July 31, 2023, from https://pavementinteractive.org/reference-desk/pavement-types-and-history/pavement-types/pcc-pavement/

Romanoschi, S. A., Momin, S., Bethu, S., & Bendana, L. (2011). Development of traffic inputs for new Mechanistic–Empirical Pavement Design Guide: Case study. *Transportation Research Record, 2256*(1), 142–150. https://doi.org/10.3141/2256-17

Sharp, D. R. (1970). *Concrete in highway engineering*. Pergamon Press.

Soil Conservation Service (SCS). (1985). *Soil survey of Kansas*. U.S. Department of Agriculture.

Solanki, P., Zaman, M., Adje, D., & Hossain, Z. (2014). Effect of recycled asphalt pavement on thermal cracking resistance of hot-mix asphalt. *International Journal of Geomechanics, 15*(5). https://doi.org/10.1061/(ASCE)GM.1943-5622.0000398

Sufian, A. A. (2016). *Local calibration of the mechanistic empirical pavement design guide for Kansas* (Master's thesis). Kansas State University.

Sun, X., Han, J., Parsons, R. L., Misra, A., & Thakur, J. K. (2015). *Calibrating the mechanistic-empirical pavement design guide for Kansas* (Report No. KS-14-17). Kansas Department of Transportation.

Tam, W. O., & Von Quintus, H. (2003). Use of long-term pavement performance data to develop traffic defaults in support of mechanistic-empirical pavement design procedures. *Transportation Research Record, 1855*(1), 176-182. https://doi.org/10.3141/1855-22

Tashman, L., & Elangovan, M. A. (2007). *Dynamic modulus test – Laboratory investigation and future implementation in the state of Washington* (Report No. WA-RD 704.1). Washington State Department of Transportation.

Thompson, M. R. (1970). *Soil stabilization for pavement systems—State of the art*. Construction Engineering Research Laboratory, Champaign, IL.

Von Quintus, H. L. (2008). Local calibration of MEPDG—An overview of selected studies (with discussion). *Asphalt paving technology 2008: Journal of the Association of Asphalt Paving Technologists*, *77*, 935–974.

Von Quintus, H. L., Darter, M. I., & Mallela, J. (2005). *Phase I – Local calibration adjustments for the HMA distress prediction models in the M-E Pavement Design Guide software* (NCHRP Project 1-40B). Transportation Research Board.

Von Quintus, H. L., Darter, M. I., & Mallela, J. (2009). *Recommended practice for local calibration of the M-E Pavement Design Guide* (NCHRP Project 1-40B). Transportation Research Board.

Von Quintus, H., & Scofield, L. (2003, Jan.). *2002 Design guide – Implementation* [2002 AASHTO Design Guide Workshop presentation]. 82nd Annual Meeting of the Transportation Research Board, Washington, D.C.

Witczak, M. W., & Bari, J. (2004). *Development of a master curve (E*) database for lime modified asphaltic mixtures*. Arizona State University.

Worthey, H. (2020). *Use of creep compliance and dynamic modulus interconversion to evaluate flexible pavement performance in Mechanistic Empirical Pavement Design Guide* (Doctoral dissertation). University of Georgia.

Yoder, E. J., & Witczak, M. W. (1975). *Principles of pavement design* (2nd ed.). John Wiley & Sons.

Appendix A

A.1 Level 1 and Level 3 Dynamic Modulus Inputs Prediction Results

A.1.1 Minor Arterial Projects Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	56.33	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.09	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	30.27	75.00	65.54	Fail
AC thermal cracking (ft/mile)	750.00	65.73	65.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	2.47	75.00	100.00	Pass
Permanent deformation - AC only (in)	0.55	0.03	75.00	100.00	Pass

Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	54.12	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.08	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	26.47	75.00	100.00	Pass
AC thermal cracking (ft/mile)	750.00	65.73	65.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	2.47	75.00	100.00	Pass
Permanent deformation - AC only (in)	0.55	0.02	75.00	100.00	Pass

Level 3 Prediction Results

Figure A.1: Project 019K0000700-NB-1 Distress Prediction Comparison

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	64.40	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.11	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	46.57	75.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	65.73	65.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	2.47	75.00	100.00	Pass
Permanent deformation - AC only (in)	0.55	0.03	75.00	100.00	Pass

Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	61.83	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.09	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	42.07	75.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	65.73	65.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	2.47	75.00	100.00	Pass
Permanent deformation - AC only (in)	0.55	0.02	75.00	100.00	Pass

Level 3 Prediction Results

Figure A.2: Project 019K0000700-NB-2 Distress Prediction Comparison

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	48.65	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.09	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	13.27	75.00	100.00	Pass
AC thermal cracking (ft/mile)	750.00	65.73	65.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	2.47	75.00	100.00	Pass
Permanent deformation - AC only (in)	0.55	0.02	75.00	100.00	Pass

Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	47.61	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.08	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	11.87	75.00	100.00	Pass
AC thermal cracking (ft/mile)	750.00	65.74	65.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	2.47	75.00	100.00	Pass
Permanent deformation - AC only (in)	0.55	0.02	75.00	100.00	Pass

Level 3 Prediction Results

Figure A.3: Project 019U0016000-EB Distress Prediction Comparison

Distress Prediction Summary					
Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied?**
	Target	**Predicted**	**Target**	**Achieved**	
Terminal IRI (in/mile)	200.00	58.75	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.10	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	35.27	75.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	65.73	65.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	2.47	75.00	100.00	Pass
Permanent deformation - AC only (in)	0.55	0.03	75.00	100.00	Pass

Level 1 Prediction Results

Distress Prediction Summary					
Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied?**
	Target	**Predicted**	**Target**	**Achieved**	
Terminal IRI (in/mile)	200.00	56.46	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.09	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	31.27	75.00	27.43	Fail
AC thermal cracking (ft/mile)	750.00	65.73	65.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	2.47	75.00	100.00	Pass
Permanent deformation - AC only (in)	0.55	0.02	75.00	100.00	Pass

Level 3 Prediction Results

Figure A.4: Project 25K0009900-NB Distress Prediction Comparison

Distress Prediction Summary					
Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied?**
	Target	**Predicted**	**Target**	**Achieved**	
Terminal IRI (in/mile)	200.00	53.89	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.08	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	26.37	75.00	100.00	Pass
AC thermal cracking (ft/mile)	750.00	65.73	65.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	2.47	75.00	100.00	Pass
Permanent deformation - AC only (in)	0.55	0.03	75.00	100.00	Pass

Level 1 Prediction Results

Distress Prediction Summary					
Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied?**
	Target	**Predicted**	**Target**	**Achieved**	
Terminal IRI (in/mile)	200.00	51.85	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.07	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	22.87	75.00	100.00	Pass
AC thermal cracking (ft/mile)	750.00	65.73	65.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	21.54	75.00	85.28	Pass
Permanent deformation - AC only (in)	0.55	0.02	75.00	100.00	Pass

Level 3 Prediction Results

Figure A.5: Project 033U0028300-NB Distress Prediction Comparison

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	50.20	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.09	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	21.37	75.00	100.00	Pass
AC thermal cracking (ft/mile)	750.00	65.73	65.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	2.47	75.00	100.00	Pass
Permanent deformation - AC only (in)	0.55	0.04	75.00	100.00	Pass

Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	48.51	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.08	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	18.77	75.00	100.00	Pass
AC thermal cracking (ft/mile)	750.00	65.73	65.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	2.47	75.00	100.00	Pass
Permanent deformation - AC only (in)	0.55	0.03	75.00	100.00	Pass

Level 3 Prediction Results

Figure A.6: Project 065K0002700-NB Distress Prediction Comparison

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	46.17	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.08	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	13.77	75.00	100.00	Pass
AC thermal cracking (ft/mile)	750.00	65.73	65.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	2.47	75.00	100.00	Pass
Permanent deformation - AC only (in)	0.55	0.03	75.00	100.00	Pass

Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	46.89	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.07	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	11.87	75.00	100.00	Pass
AC thermal cracking (ft/mile)	750.00	65.73	65.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	21.54	75.00	85.28	Pass
Permanent deformation - AC only (in)	0.55	0.02	75.00	100.00	Pass

Level 3 Prediction Results

Figure A.7: Project 065U0005600-EB Distress Prediction Comparison

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	49.24	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.07	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	17.47	75.00	100.00	Pass
AC thermal cracking (ft/mile)	750.00	65.73	65.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	2.47	75.00	100.00	Pass
Permanent deformation - AC only (in)	0.55	0.02	75.00	100.00	Pass

Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	47.69	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.06	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	14.87	75.00	100.00	Pass
AC thermal cracking (ft/mile)	750.00	65.73	65.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	19.05	75.00	91.52	Pass
Permanent deformation - AC only (in)	0.55	0.02	75.00	100.00	Pass

Level 3 Prediction Results

Figure A.8: Project 069U0028300-NB Distress Prediction Comparison

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	52.37	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.08	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	24.17	75.00	100.00	Pass
AC thermal cracking (ft/mile)	750.00	133.16	65.00	98.55	Pass
AC top-down fatigue cracking (% lane area)	25.00	2.47	75.00	100.00	Pass
Permanent deformation - AC only (in)	0.55	0.03	75.00	100.00	Pass

Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	50.59	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.07	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	21.17	75.00	100.00	Pass
AC thermal cracking (ft/mile)	750.00	133.16	65.00	98.55	Pass
AC top-down fatigue cracking (% lane area)	25.00	23.04	75.00	80.98	Pass
Permanent deformation - AC only (in)	0.55	0.02	75.00	100.00	Pass

Level 3 Prediction Results

Figure A.9: Project 095U0005600-EB Distress Prediction Comparison

A.1.2 Principal Arterial Projects Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	55.81	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.10	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	23.84	85.00	0.26	Fail
AC thermal cracking (ft/mile)	750.00	114.31	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.79	85.00	100.00	Pass
Permanent deformation - AC only (in)	0.45	0.03	85.00	100.00	Pass

Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	53.70	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.09	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	20.64	85.00	65.54	Fail
AC thermal cracking (ft/mile)	750.00	114.31	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.79	85.00	100.00	Pass
Permanent deformation - AC only (in)	0.45	0.02	85.00	100.00	Pass

Level 3 Prediction Results

Figure A.10: Project 008U0005400-EB Distress Prediction Comparison

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	71.66	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.13	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	52.34	85.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	114.31	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.79	85.00	100.00	Pass
Permanent deformation - AC only (in)	0.45	0.04	85.00	100.00	Pass

Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	68.99	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.12	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	48.24	85.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	114.32	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.79	85.00	100.00	Pass
Permanent deformation - AC only (in)	0.45	0.03	85.00	100.00	Pass

Level 3 Prediction Results

Figure A.11: Project 008U0007700-NB Distress Prediction Comparison

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	59.68	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.11	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	30.74	85.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	114.31	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.79	85.00	100.00	Pass
Permanent deformation - AC only (in)	0.45	0.03	85.00	100.00	Pass

Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	57.27	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.09	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	26.94	85.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	114.31	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.79	85.00	100.00	Pass
Permanent deformation - AC only (in)	0.45	0.02	85.00	100.00	Pass

Level 3 Prediction Results

Figure A.12: Project 008U0007700-NB-2 Distress Prediction Comparison

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	53.66	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.09	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	20.24	85.00	78.81	Fail
AC thermal cracking (ft/mile)	750.00	114.31	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.79	85.00	100.00	Pass
Permanent deformation - AC only (in)	0.45	0.02	85.00	100.00	Pass

Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	51.76	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.08	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	17.34	85.00	99.99	Pass
AC thermal cracking (ft/mile)	750.00	114.32	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.79	85.00	100.00	Pass
Permanent deformation - AC only (in)	0.45	0.02	85.00	100.00	Pass

Level 3 Prediction Results

Figure A.13: Project 008U0007700-NB-3 Distress Prediction Comparison

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	58.11	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.10	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	27.54	85.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	114.31	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.79	85.00	100.00	Pass
Permanent deformation - AC only (in)	0.45	0.03	85.00	100.00	Pass

Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	55.74	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.09	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	23.84	85.00	0.26	Fail
AC thermal cracking (ft/mile)	750.00	114.32	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.79	85.00	100.00	Pass
Permanent deformation - AC only (in)	0.45	0.02	85.00	100.00	Pass

Level 3 Prediction Results

Figure A.14: Project 023U0004000-EB Distress Prediction Comparison

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	51.85	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.08	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	18.14	85.00	99.81	Pass
AC thermal cracking (ft/mile)	750.00	114.31	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.79	85.00	100.00	Pass
Permanent deformation - AC only (in)	0.45	0.03	85.00	100.00	Pass

Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	51.14	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.07	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	15.64	85.00	100.00	Pass
AC thermal cracking (ft/mile)	750.00	114.31	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	26.41	85.00	81.35	Fail
Permanent deformation - AC only (in)	0.45	0.02	85.00	100.00	Pass

Level 3 Prediction Results

Figure A.15: Project 027K0015600-EB Distress Prediction Comparison

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	61.53	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.10	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	35.24	85.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	114.31	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.79	85.00	100.00	Pass
Permanent deformation - AC only (in)	0.45	0.04	85.00	100.00	Pass

Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	58.42	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.09	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	30.24	85.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	114.31	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	27.23	85.00	79.11	Fail
Permanent deformation - AC only (in)	0.45	0.03	85.00	100.00	Pass

Level 3 Prediction Results

Figure A.16: Project 028U0005000-EB Distress Prediction Comparison

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	59.41	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.10	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	30.34	85.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	114.31	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.79	85.00	100.00	Pass
Permanent deformation - AC only (in)	0.45	0.03	85.00	100.00	Pass

Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	56.97	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.09	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	26.44	85.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	114.32	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	26.54	85.00	80.98	Fail
Permanent deformation - AC only (in)	0.45	0.02	85.00	100.00	Pass

Level 3 Prediction Results

Figure A.17: Project 031K0001800-WB Distress Prediction Comparison

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	60.10	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.11	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	31.04	85.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	114.31	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.79	85.00	100.00	Pass
Permanent deformation - AC only (in)	0.45	0.03	85.00	100.00	Pass

Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	57.58	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.09	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	27.14	85.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	114.33	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.79	85.00	100.00	Pass
Permanent deformation - AC only (in)	0.45	0.02	85.00	100.00	Pass

Level 3 Prediction Results

Figure A.18: Project 052U0007300-NB Distress Prediction Comparison

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	56.63	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.09	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	26.34	85.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	114.31	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.79	85.00	100.00	Pass
Permanent deformation - AC only (in)	0.45	0.03	85.00	100.00	Pass

Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	54.34	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.08	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	22.74	85.00	4.46	Fail
AC thermal cracking (ft/mile)	750.00	114.31	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	26.54	85.00	80.98	Fail
Permanent deformation - AC only (in)	0.45	0.02	85.00	100.00	Pass

Level 3 Prediction Results

Figure A.19: Project 082U0018300-NB Distress Prediction Comparison

A.1.3 HMA Base Course Thickness Reduction Results

A.1.3.1 Minor Arterial

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	66.07	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.11	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	49.67	75.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	65.73	65.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	2.47	75.00	100.00	Pass
Permanent deformation - AC only (in)	0.55	0.04	75.00	100.00	Pass

Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	63.29	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.09	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	45.07	75.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	65.74	65.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	2.47	75.00	100.00	Pass
Permanent deformation - AC only (in)	0.55	0.02	75.00	100.00	Pass

Level 3 Prediction Results

Figure A.20: Project 019K0000700-NB-1 Distress Prediction Comparison with 2” Reduced Thickness

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	76.34	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.12	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	71.37	75.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	65.73	65.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	2.47	75.00	100.00	Pass
Permanent deformation - AC only (in)	0.55	0.04	75.00	100.00	Pass

Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	73.95	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.11	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	67.17	75.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	65.74	65.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	2.47	75.00	100.00	Pass
Permanent deformation - AC only (in)	0.55	0.03	75.00	100.00	Pass

Level 3 Prediction Results

Figure A.21: Project 019K0000700-NB-2 Distress Prediction Comparison with 2” Reduced Thickness

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	54.84	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.10	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	25.27	75.00	100.00	Pass
AC thermal cracking (ft/mile)	750.00	65.73	65.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	2.47	75.00	100.00	Pass
Permanent deformation - AC only (in)	0.55	0.03	75.00	100.00	Pass

Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	53.25	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.09	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	22.77	75.00	100.00	Pass
AC thermal cracking (ft/mile)	750.00	65.74	65.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	2.47	75.00	100.00	Pass
Permanent deformation - AC only (in)	0.55	0.02	75.00	100.00	Pass

Level 3 Prediction Results

Figure A.22: Project 019U0016000-EB Distress Prediction Comparison with 2” Reduced Thickness

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	69.29	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.12	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	56.77	75.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	65.73	65.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	2.47	75.00	100.00	Pass
Permanent deformation - AC only (in)	0.55	0.03	75.00	100.00	Pass

Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	66.77	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.10	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	52.27	75.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	65.73	65.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	2.47	75.00	100.00	Pass
Permanent deformation - AC only (in)	0.55	0.02	75.00	100.00	Pass

Level 3 Prediction Results

Figure A.23: Project 25K0009900-NB Distress Prediction Comparison with 2” Reduced Thickness

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	62.84	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.10	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	44.37	75.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	65.73	65.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	2.47	75.00	100.00	Pass
Permanent deformation - AC only (in)	0.55	0.04	75.00	100.00	Pass

Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	60.23	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.08	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	39.77	75.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	65.73	65.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	21.91	75.00	84.23	Pass
Permanent deformation - AC only (in)	0.55	0.03	75.00	100.00	Pass

Level 3 Prediction Results

Figure A.24: Project 033U0028300-NB Distress Prediction Comparison with 2” Reduced Thickness

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	59.03	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.11	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	38.97	75.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	65.73	65.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	2.47	75.00	100.00	Pass
Permanent deformation - AC only (in)	0.55	0.04	75.00	100.00	Pass

Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	56.65	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.09	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	34.97	75.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	65.73	65.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	2.47	75.00	100.00	Pass
Permanent deformation - AC only (in)	0.55	0.03	75.00	100.00	Pass

Level 3 Prediction Results

Figure A.25: Project 065K0002700-NB Distress Prediction Comparison with 2” Reduced Thickness

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	51.73	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.10	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	24.17	75.00	100.00	Pass
AC thermal cracking (ft/mile)	750.00	65.73	65.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	2.47	75.00	100.00	Pass
Permanent deformation - AC only (in)	0.55	0.04	75.00	100.00	Pass

Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	49.87	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.08	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	21.27	75.00	100.00	Pass
AC thermal cracking (ft/mile)	750.00	65.73	65.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	21.79	75.00	84.59	Pass
Permanent deformation - AC only (in)	0.55	0.03	75.00	100.00	Pass

Level 3 Prediction Results

Figure A.26: Project 065U0005600-EB Distress Prediction Comparison with 2” Reduced Thickness

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	55.78	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.09	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	30.17	75.00	69.15	Fail
AC thermal cracking (ft/mile)	750.00	65.73	65.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	2.47	75.00	100.00	Pass
Permanent deformation - AC only (in)	0.55	0.03	75.00	100.00	Pass

Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	53.56	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.08	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	26.37	75.00	100.00	Pass
AC thermal cracking (ft/mile)	750.00	65.73	65.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	20.79	75.00	87.29	Pass
Permanent deformation - AC only (in)	0.55	0.02	75.00	100.00	Pass

Level 3 Prediction Results

Figure A.27: Project 069U0028300-NB Distress Prediction Comparison with 2" Reduced Thickness

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	60.24	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.10	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	39.67	75.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	133.16	65.00	98.55	Pass
AC top-down fatigue cracking (% lane area)	25.00	2.47	75.00	100.00	Pass
Permanent deformation - AC only (in)	0.55	0.04	75.00	100.00	Pass

Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	57.82	65.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.08	75.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	30.00	35.57	75.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	133.16	65.00	98.55	Pass
AC top-down fatigue cracking (% lane area)	25.00	23.16	75.00	80.61	Pass
Permanent deformation - AC only (in)	0.55	0.03	75.00	100.00	Pass

Level 3 Prediction Results

Figure A.28: Project 095U0005600-EB Distress Prediction Comparison with 2" Reduced Thickness

A.1.3.2 Principal Arterial

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	64.99	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.12	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	40.24	85.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	114.31	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.79	85.00	100.00	Pass
Permanent deformation - AC only (in)	0.45	0.03	85.00	100.00	Pass

Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	62.22	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.10	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	35.84	85.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	114.31	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.79	85.00	100.00	Pass
Permanent deformation - AC only (in)	0.45	0.02	85.00	100.00	Pass

Level 3 Prediction Results

Figure A.29: Project 008U0005400-EB Distress Prediction Comparison with 2” Reduced Thickness

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	83.81	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.15	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	75.34	85.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	114.31	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.79	85.00	100.00	Pass
Permanent deformation - AC only (in)	0.45	0.05	85.00	100.00	Pass

Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	83.81	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.15	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	75.34	85.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	114.31	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.79	85.00	100.00	Pass
Permanent deformation - AC only (in)	0.45	0.05	85.00	100.00	Pass

Level 3 Prediction Results

Figure A.30: Project 008U0007700-NB Distress Prediction Comparison with 2" Reduced Thickness

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	69.77	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.12	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	49.04	85.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	114.31	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.79	85.00	100.00	Pass
Permanent deformation - AC only (in)	0.45	0.04	85.00	100.00	Pass

Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	66.93	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.11	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	44.44	85.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	114.31	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.79	85.00	100.00	Pass
Permanent deformation - AC only (in)	0.45	0.03	85.00	100.00	Pass

Level 3 Prediction Results

Figure A.31: Project 008U0007700-NB-2 Distress Prediction Comparison with 2" Reduced Thickness

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	61.31	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.11	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	33.54	85.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	114.31	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.79	85.00	100.00	Pass
Permanent deformation - AC only (in)	0.45	0.03	85.00	100.00	Pass

Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	58.70	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.10	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	29.44	85.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	114.32	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.79	85.00	100.00	Pass
Permanent deformation - AC only (in)	0.45	0.02	85.00	100.00	Pass

Level 3 Prediction Results

Figure A.32: Project 008U0007700-NB-3 Distress Prediction Comparison with 2” Reduced Thickness

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	67.86	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.12	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	45.14	85.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	114.31	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.79	85.00	100.00	Pass
Permanent deformation - AC only (in)	0.45	0.04	85.00	100.00	Pass

Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	64.90	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.10	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	40.34	85.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	114.32	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.79	85.00	100.00	Pass
Permanent deformation - AC only (in)	0.45	0.03	85.00	100.00	Pass

Level 3 Prediction Results

Figure A.33: Project 023U0004000-EB Distress Prediction Comparison with 2” Reduced Thickness

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	58.44	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.09	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	29.74	85.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	114.31	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.79	85.00	100.00	Pass
Permanent deformation - AC only (in)	0.45	0.04	85.00	100.00	Pass

Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	56.12	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.08	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	26.14	85.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	114.31	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	26.54	85.00	80.98	Fail
Permanent deformation - AC only (in)	0.45	0.03	85.00	100.00	Pass

Level 3 Prediction Results

Figure A.34: Project 027K0015600-EB Distress Prediction Comparison with 2” Reduced Thickness

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	70.46	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.12	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	51.44	85.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	114.31	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.79	85.00	100.00	Pass
Permanent deformation - AC only (in)	0.45	0.05	85.00	100.00	Pass

Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	67.00	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.10	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	45.84	85.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	114.31	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	27.23	85.00	79.11	Fail
Permanent deformation - AC only (in)	0.45	0.03	85.00	100.00	Pass

Level 3 Prediction Results

Figure A.35: Project 028U0005000-EB Distress Prediction Comparison with 2” Reduced Thickness

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	68.57	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.12	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	46.64	85.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	114.31	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.79	85.00	100.00	Pass
Permanent deformation - AC only (in)	0.45	0.04	85.00	100.00	Pass

Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	65.58	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.11	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	41.84	85.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	114.32	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	26.68	85.00	80.61	Fail
Permanent deformation - AC only (in)	0.45	0.03	85.00	100.00	Pass

Level 3 Prediction Results

Figure A.36: Project 031K0001800-WB Distress Prediction Comparison with 2" Reduced Thickness

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	73.05	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.12	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	55.14	85.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	114.31	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.79	85.00	100.00	Pass
Permanent deformation - AC only (in)	0.45	0.03	85.00	100.00	Pass

Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	70.00	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.11	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	50.04	85.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	114.34	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.79	85.00	100.00	Pass
Permanent deformation - AC only (in)	0.45	0.02	85.00	100.00	Pass

Level 3 Prediction Results

Figure A.37: Project 052U0007300-NB Distress Prediction Comparison with 2" Reduced Thickness

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	65.83	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.11	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	42.74	85.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	114.31	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.79	85.00	100.00	Pass
Permanent deformation - AC only (in)	0.45	0.04	85.00	100.00	Pass

Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	180.00	62.89	75.00	100.00	Pass
Permanent deformation - total pavement (in)	0.55	0.09	85.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	38.04	85.00	0.00	Fail
AC thermal cracking (ft/mile)	750.00	114.31	75.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	26.54	85.00	80.98	Fail
Permanent deformation - AC only (in)	0.45	0.03	85.00	100.00	Pass

Level 3 Prediction Results

Figure A.38: Project 082U0018300-NB Distress Prediction Comparison with 2” Reduced Thickness

A.2 Level 1 and Level 3 Creep Compliance Inputs Prediction Results

A.2.1 AC over AC

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	106.56	50.00	98.27	Pass
Permanent deformation - total pavement (in)	0.75	0.19	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	45.03	50.00	10.58	Fail
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	2399.51	90.00	92.39	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1541.76	50.00	0.00	Fail
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix1 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	76.22	50.00	100.00	Pass
Permanent deformation - total pavement (in)	0.75	0.19	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	61.52	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix1 Level 3 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	76.42	50.00	100.00	Pass
Permanent deformation - total pavement (in)	0.75	0.20	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	0.10	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	39.12	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix4 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	76.41	50.00	100.00	Pass
Permanent deformation - total pavement (in)	0.75	0.20	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	0.07	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	61.52	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix4 Level 3 Prediction Results

Figure A.39: Project K-9364-01 Distress Prediction Comparison of Mix 1 and Mix 4 Inputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	85.28	50.00	99.97	Pass
Permanent deformation - total pavement (in)	0.75	0.07	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	2177.79	90.00	96.26	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1351.68	50.00	0.00	Fail
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix1 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	74.47	50.00	100.00	Pass
Permanent deformation - total pavement (in)	0.75	0.07	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	75.75	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix1 Level 3 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	74.76	50.00	100.00	Pass
Permanent deformation - total pavement (in)	0.75	0.07	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	38.60	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix4 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	74.76	50.00	100.00	Pass
Permanent deformation - total pavement (in)	0.75	0.07	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	61.52	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix4 Level 3 Prediction Results

Figure A.40: Project KA-2188-01 Distress Prediction Comparison of Mix 1 and Mix 4 Inputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	74.76	50.00	100.00	Pass
Permanent deformation - total pavement (in)	0.75	0.07	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	61.52	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix1 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	84.53	50.00	99.98	Pass
Permanent deformation - total pavement (in)	0.75	0.15	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	23.45	50.00	55.75	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	247.21	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.02	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.97	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix1 Level 3 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	83.75	50.00	99.99	Pass
Permanent deformation - total pavement (in)	0.75	0.16	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	20.85	50.00	66.11	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	225.77	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.02	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix4 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	80.97	50.00	99.99	Pass
Permanent deformation - total pavement (in)	0.75	0.16	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	13.87	50.00	92.12	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	225.77	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.02	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix4 Level 3 Prediction Results

Figure A.41: Project KA-0813-01 Distress Prediction Comparison of Mix 1 and Mix 4 Inputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	90.09	50.00	99.91	Pass
Permanent deformation - total pavement (in)	0.75	0.08	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	2.85	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	2128.10	90.00	96.88	Pass
Permanent deformation - AC only (in)	0.25	0.02	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1309.44	50.00	0.00	Fail
AC top-down fatigue cracking (% lane area)	25.00	4.90	50.00	99.99	Pass

Mix1 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	79.77	50.00	100.00	Pass
Permanent deformation - total pavement (in)	0.75	0.08	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	0.05	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	149.13	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.02	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	4.90	50.00	99.99	Pass

Mix1 Level 3 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	80.09	50.00	100.00	Pass
Permanent deformation - total pavement (in)	0.75	0.08	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	2.45	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	168.05	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.02	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	4.80	50.00	99.99	Pass

Mix4 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	80.09	50.00	100.00	Pass
Permanent deformation - total pavement (in)	0.75	0.08	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	0.22	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	168.05	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.02	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	4.80	50.00	99.99	Pass

Mix4 Level 3 Prediction Results

Figure A.42: Project K-9466-01 Distress Prediction Comparison of Mix 1 and Mix 4 Inputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	87.60	50.00	99.95	Pass
Permanent deformation - total pavement (in)	0.75	0.07	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	2.95	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	2387.27	90.00	92.65	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1531.20	50.00	0.00	Fail
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix1 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	74.17	50.00	100.00	Pass
Permanent deformation - total pavement (in)	0.75	0.07	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	75.75	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix1 Level 3 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	74.47	50.00	100.00	Pass
Permanent deformation - total pavement (in)	0.75	0.08	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	38.60	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix4 Level 1 Prediction Results

Distress Prediction Summary					
Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied?**
	Target	**Predicted**	**Target**	**Achieved**	
Terminal IRI (in/mile)	172.00	74.47	50.00	100.00	Pass
Permanent deformation - total pavement (in)	0.75	0.08	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	61.52	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix4 Level 3 Prediction Results

Figure A.43: Project KA-2628-01 Distress Prediction Comparison of Mix 1 and Mix 4 Inputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	127.42	50.00	89.92	Pass
Permanent deformation - total pavement (in)	0.75	0.20	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	16.75	50.00	82.63	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	3050.69	90.00	70.18	Fail
Permanent deformation - AC only (in)	0.25	0.03	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	2112.00	50.00	0.00	Fail
AC top-down fatigue cracking (% lane area)	25.00	6.06	50.00	99.94	Pass

Mix1 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	119.98	50.00	94.09	Pass
Permanent deformation - total pavement (in)	0.75	0.20	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	16.73	50.00	82.69	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	1670.84	90.00	99.97	Pass
Permanent deformation - AC only (in)	0.25	0.03	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	208.03	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	6.06	50.00	99.94	Pass

Mix1 Level 3 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	118.76	50.00	94.67	Pass
Permanent deformation - total pavement (in)	0.75	0.21	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	16.76	50.00	82.60	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	1105.08	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.04	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	5.71	50.00	99.96	Pass

Mix4 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	119.07	50.00	94.53	Pass
Permanent deformation - total pavement (in)	0.75	0.21	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	16.77	50.00	82.54	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	1320.13	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.04	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	37.59	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	5.71	50.00	99.96	Pass

Mix4 Level 3 Prediction Results

Figure A.44: Project KA-2923-01 Distress Prediction Comparison of Mix 1 and Mix 4 Inputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	112.49	50.00	96.59	Pass
Permanent deformation - total pavement (in)	0.75	0.19	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	66.34	50.00	2.18	Fail
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	1562.88	50.00	91.84	Pass
Permanent deformation - AC only (in)	0.25	0.03	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1562.88	50.00	0.00	Fail
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix1 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	73.53	50.00	100.00	Pass
Permanent deformation - total pavement (in)	0.75	0.19	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	0.22	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	0.05	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.03	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix1 Level 3 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	75.13	50.00	100.00	Pass
Permanent deformation - total pavement (in)	0.75	0.19	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	2.82	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	32.90	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.03	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix4 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	74.08	50.00	100.00	Pass
Permanent deformation - total pavement (in)	0.75	0.19	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	0.86	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	0.07	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.03	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix4 Level 3 Prediction Results

Figure A.45: Project KA-4013-01 Distress Prediction Comparison of Mix 1 and Mix 4 Inputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	110.22	50.00	97.38	Pass
Permanent deformation - total pavement (in)	0.75	0.14	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	51.94	50.00	6.23	Fail
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	1203.84	50.00	98.12	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1203.84	50.00	0.00	Fail
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix1 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	83.17	50.00	99.99	Pass
Permanent deformation - total pavement (in)	0.75	0.14	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	1.77	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	331.14	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix1 Level 3 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	99.57	50.00	99.37	Pass
Permanent deformation - total pavement (in)	0.75	0.14	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	42.14	50.00	13.25	Fail
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	332.84	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix4 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	89.57	50.00	99.92	Pass
Permanent deformation - total pavement (in)	0.75	0.14	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	17.13	50.00	81.19	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	332.83	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix4 Level 3 Prediction Results

Figure A.46: Project KA-1436-01 Distress Prediction Comparison of Mix 1 and Mix 4 Inputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	157.91	50.00	63.01	Pass
Permanent deformation - total pavement (in)	0.75	0.20	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	100.00	50.00	0.01	Fail
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	1826.88	50.00	83.10	Pass
Permanent deformation - AC only (in)	0.25	0.02	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	100.00	50.00	0.00	Fail
AC thermal cracking (ft/mile)	1000.00	1826.88	50.00	0.00	Fail
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix1 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	121.67	50.00	92.56	Pass
Permanent deformation - total pavement (in)	0.75	0.20	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	100.00	50.00	0.21	Fail
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	37.53	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.02	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	100.00	50.00	0.00	Fail
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix1 Level 3 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	99.46	50.00	99.39	Pass
Permanent deformation - total pavement (in)	0.75	0.20	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	46.57	50.00	9.38	Fail
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	37.53	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.02	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix4 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	89.56	50.00	99.93	Pass
Permanent deformation - total pavement (in)	0.75	0.20	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	21.83	50.00	62.11	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	37.57	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.02	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix4 Level 3 Prediction Results

Figure A.47: Project KA-1444-01(1) Distress Prediction Comparison of Mix 1 and Mix 4 Inputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	122.52	50.00	92.35	Pass
Permanent deformation - total pavement (in)	0.75	0.24	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	63.63	50.00	2.64	Fail
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	1890.24	50.00	80.49	Pass
Permanent deformation - AC only (in)	0.25	0.05	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1890.24	50.00	0.00	Fail
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix1 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	83.98	50.00	99.99	Pass
Permanent deformation - total pavement (in)	0.75	0.24	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	3.47	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	80.24	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.05	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix1 Level 3 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	103.57	50.00	98.87	Pass
Permanent deformation - total pavement (in)	0.75	0.24	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	51.95	50.00	6.22	Fail
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	80.23	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.05	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix4 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	92.92	50.00	99.84	Pass
Permanent deformation - total pavement (in)	0.75	0.24	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	25.32	50.00	48.85	Fail
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	80.30	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.05	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix4 Level 3 Prediction Results

Figure A.48: Project KA-1444-01(2) Distress Prediction Comparison of Mix 1 and Mix 4 Inputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	95.23	50.00	99.72	Pass
Permanent deformation - total pavement (in)	0.75	0.16	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	4.76	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	1615.68	50.00	90.38	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1615.68	50.00	0.00	Fail
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix1 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	80.41	50.00	100.00	Pass
Permanent deformation - total pavement (in)	0.75	0.16	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	0.04	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	0.54	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix1 Level 3 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	92.67	50.00	99.84	Pass
Permanent deformation - total pavement (in)	0.75	0.17	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	2.87	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	1329.89	50.00	96.59	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix4 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	91.76	50.00	99.87	Pass
Permanent deformation - total pavement (in)	0.75	0.17	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	0.59	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	1329.86	50.00	96.59	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix4 Level 3 Prediction Results

Figure A.49: Project KA-2505-01 Distress Prediction Comparison of Mix 1 and Mix 4 Inputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	117.89	50.00	94.99	Pass
Permanent deformation - total pavement (in)	0.75	0.13	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	1.57	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	2261.34	50.00	62.53	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1774.08	50.00	0.00	Fail
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix1 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	103.57	50.00	99.00	Pass
Permanent deformation - total pavement (in)	0.75	0.13	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	1.21	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	489.66	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	2.40	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix1 Level 3 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	104.00	50.00	98.94	Pass
Permanent deformation - total pavement (in)	0.75	0.14	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	1.64	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	487.59	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix4 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	103.99	50.00	98.94	Pass
Permanent deformation - total pavement (in)	0.75	0.14	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	1.59	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	490.02	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	2.76	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix4 Level 3 Prediction Results

Figure A.50: Project KA-2966-01 Distress Prediction Comparison of Mix 1 and Mix 4 Inputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	106.92	50.00	98.09	Pass
Permanent deformation - total pavement (in)	0.75	0.12	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	65.32	50.00	2.35	Fail
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	1129.92	50.00	98.74	Pass
Permanent deformation - AC only (in)	0.25	0.02	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1129.92	50.00	0.00	Fail
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix1 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	71.82	50.00	100.00	Pass
Permanent deformation - total pavement (in)	0.75	0.12	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	0.17	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	0.00	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.02	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix1 Level 3 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	74.43	50.00	100.00	Pass
Permanent deformation - total pavement (in)	0.75	0.12	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	6.12	50.00	99.99	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	6.00	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.02	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix4 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	72.38	50.00	100.00	Pass
Permanent deformation - total pavement (in)	0.75	0.12	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	1.11	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	0.01	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.02	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix4 Level 3 Prediction Results

Figure A.51: Project KA-3674-01 Distress Prediction Comparison of Mix 1 and Mix 4 Inputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	119.75	50.00	94.15	Pass
Permanent deformation - total pavement (in)	0.75	0.13	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	11.26	50.00	97.53	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	1774.08	50.00	85.13	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1774.08	50.00	0.00	Fail
AC top-down fatigue cracking (% lane area)	25.00	5.60	50.00	99.97	Pass

Mix1 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	105.96	50.00	98.64	Pass
Permanent deformation - total pavement (in)	0.75	0.13	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	11.24	50.00	97.55	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	50.58	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	35.59	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	5.60	50.00	99.97	Pass

Mix1 Level 3 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	106.50	50.00	98.54	Pass
Permanent deformation - total pavement (in)	0.75	0.14	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	12.53	50.00	95.34	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	15.72	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.02	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	4.78	50.00	99.99	Pass

Mix4 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	106.75	50.00	98.49	Pass
Permanent deformation - total pavement (in)	0.75	0.14	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	12.54	50.00	95.31	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	46.78	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.02	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	31.79	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	4.78	50.00	99.99	Pass

Mix4 Level 3 Prediction Results

Figure A.52: Project KA-0657-01 Distress Prediction Comparison of Mix 1 and Mix 4 Inputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	116.54	50.00	95.61	Pass
Permanent deformation - total pavement (in)	0.75	0.18	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	35.44	50.00	22.48	Fail
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	0.60	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.04	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	2.03	50.00	100.00	Pass

Mix1 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	115.71	50.00	95.94	Pass
Permanent deformation - total pavement (in)	0.75	0.18	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	33.39	50.00	26.41	Fail
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	0.00	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.04	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	2.03	50.00	100.00	Pass

Mix1 Level 3 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	116.62	50.00	95.58	Pass
Permanent deformation - total pavement (in)	0.75	0.18	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	35.34	50.00	22.65	Fail
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	0.00	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.04	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix4 Level 1 Prediction Results

Distress Prediction Summary					
Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied?**
	Target	**Predicted**	**Target**	**Achieved**	
Terminal IRI (in/mile)	172.00	116.62	50.00	95.58	Pass
Permanent deformation - total pavement (in)	0.75	0.18	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	35.34	50.00	22.65	Fail
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	0.00	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.04	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix4 Level 3 Prediction Results

Figure A.53: Project KA-0811-01 Distress Prediction Comparison of Mix 1 and Mix 4 Inputs

Distress Prediction Summary					
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	71.71	50.00	100.00	Pass
Permanent deformation - total pavement (in)	0.75	0.08	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	0.65	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	11.19	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	11.19	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix1 Level 1 Prediction Results

Distress Prediction Summary					
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	71.35	50.00	100.00	Pass
Permanent deformation - total pavement (in)	0.75	0.08	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	0.00	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix1 Level 3 Prediction Results

Distress Prediction Summary					
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	71.74	50.00	100.00	Pass
Permanent deformation - total pavement (in)	0.75	0.09	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	0.06	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	0.00	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.02	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix4 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	71.72	50.00	100.00	Pass
Permanent deformation - total pavement (in)	0.75	0.09	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	0.01	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	0.00	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.02	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix4 Level 3 Prediction Results

Figure A.54: Project K-7756-01 Distress Prediction Comparison of Mix 1 and Mix 4 Inputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	115.69	50.00	95.92	Pass
Permanent deformation - total pavement (in)	0.75	0.14	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	1562.88	50.00	91.84	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1562.88	50.00	0.00	Fail
AC top-down fatigue cracking (% lane area)	25.00	5.47	50.00	99.97	Pass

Mix1 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	103.20	50.00	99.10	Pass
Permanent deformation - total pavement (in)	0.75	0.14	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	1.18	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.18	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	5.47	50.00	99.97	Pass

Mix1 Level 3 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	103.20	50.00	99.10	Pass
Permanent deformation - total pavement (in)	0.75	0.15	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	0.16	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	0.25	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.02	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	4.47	50.00	99.99	Pass

Mix4 Level 1 Prediction Results

Distress Prediction Summary					
Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied?**
	Target	**Predicted**	**Target**	**Achieved**	
Terminal IRI (in/mile)	172.00	103.21	50.00	99.10	Pass
Permanent deformation - total pavement (in)	0.75	0.15	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	1.28	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.02	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.28	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	4.47	50.00	99.99	Pass

Mix4 Level 3 Prediction Results

Figure A.55: Project KA-2200-01 Distress Prediction Comparison of Mix 1 and Mix 4 Inputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	119.38	50.00	94.41	Pass
Permanent deformation - total pavement (in)	0.75	0.19	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	0.01	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	1721.28	50.00	87.02	Pass
Permanent deformation - AC only (in)	0.25	0.02	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1721.28	50.00	0.00	Fail
AC top-down fatigue cracking (% lane area)	25.00	5.92	50.00	99.95	Pass

Mix1 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	105.62	50.00	98.75	Pass
Permanent deformation - total pavement (in)	0.75	0.19	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	0.28	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	1.72	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.02	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.72	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	5.92	50.00	99.95	Pass

Mix1 Level 3 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	114.29	50.00	96.47	Pass
Permanent deformation - total pavement (in)	0.75	0.22	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	22.65	50.00	58.84	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	127.84	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.03	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	5.46	50.00	99.97	Pass

Mix4 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	106.41	50.00	98.61	Pass
Permanent deformation - total pavement (in)	0.75	0.22	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	2.48	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	1.86	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.03	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.78	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	5.46	50.00	99.97	Pass

Mix4 Level 3 Prediction Results

Figure A.56: Project KA-2204-01 Distress Prediction Comparison of Mix 1 and Mix 4 Inputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	123.46	50.00	92.18	Pass
Permanent deformation - total pavement (in)	0.75	0.11	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	23.36	50.00	56.11	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	2727.32	90.00	83.10	Fail
Permanent deformation - AC only (in)	0.25	0.00	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1826.88	50.00	0.00	Fail
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix1 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	108.73	50.00	98.02	Pass
Permanent deformation - total pavement (in)	0.75	0.11	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	20.94	50.00	65.74	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	320.19	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.00	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	9.04	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix1 Level 3 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	109.48	50.00	97.84	Pass
Permanent deformation - total pavement (in)	0.75	0.11	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	22.50	50.00	59.45	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	227.27	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix4 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	108.27	50.00	98.13	Pass
Permanent deformation - total pavement (in)	0.75	0.11	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	19.46	50.00	71.84	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	239.94	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.52	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix4 Level 3 Prediction Results

Figure A.57: Project KA-2941-01 Distress Prediction Comparison of Mix 1 and Mix 4 Inputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	109.92	50.00	97.40	Pass
Permanent deformation - total pavement (in)	0.75	0.18	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	58.61	50.00	3.80	Fail
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	2448.41	90.00	91.28	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1584.00	50.00	0.00	Fail
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix1 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	74.18	50.00	100.00	Pass
Permanent deformation - total pavement (in)	0.75	0.18	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	0.92	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	131.58	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix1 Level 3 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	78.95	50.00	100.00	Pass
Permanent deformation - total pavement (in)	0.75	0.18	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	8.68	50.00	99.65	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	302.98	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix4 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	75.99	50.00	100.00	Pass
Permanent deformation - total pavement (in)	0.75	0.18	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	1.49	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	291.83	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix4 Level 3 Prediction Results

Figure A.58: Project KA-4192-01 Distress Prediction Comparison of Mix 1 and Mix 4 Inputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	119.48	50.00	93.85	Pass
Permanent deformation - total pavement (in)	0.75	0.15	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	63.63	50.00	2.64	Fail
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	2618.61	90.00	86.65	Fail
Permanent deformation - AC only (in)	0.25	0.02	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1731.84	50.00	0.00	Fail
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix1 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	83.38	50.00	99.99	Pass
Permanent deformation - total pavement (in)	0.75	0.15	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	7.68	50.00	99.89	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	147.06	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.02	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix1 Level 3 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	98.43	50.00	99.49	Pass
Permanent deformation - total pavement (in)	0.75	0.16	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	44.57	50.00	10.96	Fail
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	147.06	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.03	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix4 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	85.96	50.00	99.97	Pass
Permanent deformation - total pavement (in)	0.75	0.16	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	13.40	50.00	93.36	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	147.06	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.03	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix4 Level 3 Prediction Results

Figure A.59: Project KA-1460-01 Distress Prediction Comparison of Mix 1 and Mix 4 Inputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	160.15	50.00	61.31	Pass
Permanent deformation - total pavement (in)	0.75	0.42	50.00	99.99	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	76.02	50.00	1.13	Fail
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	3200.61	90.00	62.74	Fail
Permanent deformation - AC only (in)	0.25	0.23	50.00	62.31	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	1.03	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	2112.00	50.00	0.00	Fail
AC top-down fatigue cracking (% lane area)	25.00	5.75	50.00	99.96	Pass

Mix1 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	142.24	50.00	78.32	Pass
Permanent deformation - total pavement (in)	0.75	0.42	50.00	99.99	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	73.46	50.00	1.34	Fail
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	300.29	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.23	50.00	62.31	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	1.03	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.88	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	5.75	50.00	99.96	Pass

Mix1 Level 3 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	143.69	50.00	77.03	Pass
Permanent deformation - total pavement (in)	0.75	0.44	50.00	99.95	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	74.85	50.00	1.22	Fail
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	280.49	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.25	50.00	51.66	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.02	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	5.10	50.00	99.98	Pass

Mix4 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	143.25	50.00	77.44	Pass
Permanent deformation - total pavement (in)	0.75	0.44	50.00	99.95	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	73.73	50.00	1.31	Fail
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	280.49	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.25	50.00	51.66	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.02	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	5.10	50.00	99.98	Pass

Mix4 Level 3 Prediction Results

Figure A.60: Project KA-3496-01 Distress Prediction Comparison of Mix 1 and Mix 4 Inputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	75.70	50.00	100.00	Pass
Permanent deformation - total pavement (in)	0.75	0.08	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	1.05	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	210.30	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	7.23	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.68	50.00	100.00	Pass

Mix1 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	75.64	50.00	100.00	Pass
Permanent deformation - total pavement (in)	0.75	0.08	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	0.85	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	38.60	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.68	50.00	100.00	Pass

Mix1 Level 3 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	75.36	50.00	100.00	Pass
Permanent deformation - total pavement (in)	0.75	0.08	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	1.05	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	61.52	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	2.78	50.00	100.00	Pass

Mix4 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	75.36	50.00	100.00	Pass
Permanent deformation - total pavement (in)	0.75	0.08	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	0.98	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	38.60	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	2.78	50.00	100.00	Pass

Mix4 Level 3 Prediction Results

Figure A.61: Project K-8431-01 Distress Prediction Comparison of Mix 1 and Mix 4 Inputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	129.36	50.00	88.23	Pass
Permanent deformation - total pavement (in)	0.75	0.31	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	66.13	50.00	2.22	Fail
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	2859.54	90.00	78.20	Fail
Permanent deformation - AC only (in)	0.25	0.07	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1943.04	50.00	0.00	Fail
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix1 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	99.78	50.00	99.42	Pass
Permanent deformation - total pavement (in)	0.75	0.31	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	30.93	50.00	32.03	Fail
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	201.40	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.07	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	6.14	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix1 Level 3 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	92.93	50.00	99.85	Pass
Permanent deformation - total pavement (in)	0.75	0.32	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	11.97	50.00	96.40	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	187.54	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.07	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix4 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	92.28	50.00	99.87	Pass
Permanent deformation - total pavement (in)	0.75	0.32	50.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	10.90	50.00	98.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	164.53	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.07	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.21	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass

Mix4 Level 3 Prediction Results

Figure A.62: Project KA-1480-01 Distress Prediction Comparison of Mix 1 and Mix 4 Inputs

A.2.2 AC over JCPC

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	76.46	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.03	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	2135.38	50.00	67.94	Pass
AC thermal cracking (ft/mile)	1000.00	2112.00	50.00	0.00	Fail
AC top-down fatigue cracking (% lane area)	25.00	4.92	50.00	99.99	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix1 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	76.53	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.03	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	2181.75	50.00	65.59	Pass
AC thermal cracking (ft/mile)	1000.00	24.60	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	4.92	50.00	99.99	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix1 Level 3 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	80.04	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.05	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	4224.56	50.00	7.59	Fail
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	4.82	50.00	99.99	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix4 Level 1 Prediction Results

Distress Prediction Summary					
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	78.14	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.05	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	2871.18	50.00	34.68	Fail
AC thermal cracking (ft/mile)	1000.00	7.16	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	4.82	50.00	99.99	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix4 Level 3 Prediction Results

Figure A.63: Project KA-2669-01 Distress Prediction Comparison of Mix 1 and Mix 4 Inputs

Distress Prediction Summary					
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	76.85	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.04	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	2135.18	50.00	67.95	Pass
AC thermal cracking (ft/mile)	1000.00	2112.00	50.00	0.00	Fail
AC top-down fatigue cracking (% lane area)	25.00	4.98	50.00	99.99	Pass
JPCP transverse cracking (percent slabs)	15.00	0.16	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix1 Level 1 Prediction Results

Distress Prediction Summary					
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	74.46	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.04	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	427.01	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	15.21	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	4.98	50.00	99.99	Pass
JPCP transverse cracking (percent slabs)	15.00	0.16	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix1 Level 3 Prediction Results

Distress Prediction Summary					
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	77.14	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.06	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	1681.62	50.00	88.77	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	4.93	50.00	99.99	Pass
JPCP transverse cracking (percent slabs)	15.00	0.10	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix4 Level 1 Prediction Results

Distress Prediction Summary					
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	75.73	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.06	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	677.37	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	4.07	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	4.93	50.00	99.99	Pass
JPCP transverse cracking (percent slabs)	15.00	0.10	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix4 Level 3 Prediction Results

Figure A.64: Project KA-4136-01 Distress Prediction Comparison of Mix 1 and Mix 4 Inputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	75.92	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.03	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	2143.69	50.00	67.52	Pass
AC thermal cracking (ft/mile)	1000.00	2112.00	50.00	0.00	Fail
AC top-down fatigue cracking (% lane area)	25.00	4.57	50.00	99.99	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix1 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	74.66	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.03	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	1240.93	50.00	98.79	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	4.57	50.00	99.99	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix1 Level 3 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	78.15	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.04	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	3454.86	50.00	18.36	Fail
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	4.21	50.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix4 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	75.80	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.04	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	1773.45	50.00	85.16	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	4.21	50.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix4 Level 3 Prediction Results

Figure A.65: Project KA-1951-01 Distress Prediction Comparison of Mix 1 and Mix 4 Inputs

Distress Prediction Summary					
Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied?**
	Target	**Predicted**	**Target**	**Achieved**	
Terminal IRI (in/mile)	172.00	76.08	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.03	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	2158.18	50.00	66.79	Pass
AC thermal cracking (ft/mile)	1000.00	2112.00	50.00	0.00	Fail
AC top-down fatigue cracking (% lane area)	25.00	4.76	50.00	99.99	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix1 Level 1 Prediction Results

Distress Prediction Summary					
Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied?**
	Target	**Predicted**	**Target**	**Achieved**	
Terminal IRI (in/mile)	172.00	75.40	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.03	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	1667.35	50.00	89.29	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	4.76	50.00	99.99	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix1 Level 3 Prediction Results

Distress Prediction Summary					
Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied?**
	Target	**Predicted**	**Target**	**Achieved**	
Terminal IRI (in/mile)	172.00	79.17	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.04	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	3976.99	50.00	10.10	Fail
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	4.56	50.00	99.99	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix4 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	76.82	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.04	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	2292.58	50.00	60.01	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	4.56	50.00	99.99	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix4 Level 3 Prediction Results

Figure A.66: Project KA-1950-01 Distress Prediction Comparison of Mix 1 and Mix 4 Inputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	76.68	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.03	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	2440.59	50.00	52.78	Pass
AC thermal cracking (ft/mile)	1000.00	2112.00	50.00	0.00	Fail
AC top-down fatigue cracking (% lane area)	25.00	4.85	50.00	99.99	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix1 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	78.16	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.03	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	3501.57	50.00	17.42	Fail
AC thermal cracking (ft/mile)	1000.00	3.24	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	4.85	50.00	99.99	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix1 Level 3 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	79.79	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.05	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	4224.28	50.00	7.59	Fail
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	4.71	50.00	99.99	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix4 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	79.37	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.05	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	3920.33	50.00	10.79	Fail
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	4.71	50.00	99.99	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix4 Level 3 Prediction Results

Figure A.67: Project KA-1931-01 Distress Prediction Comparison of Mix 1 and Mix 4 Inputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	74.29	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.02	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	2113.83	50.00	69.03	Pass
AC thermal cracking (ft/mile)	1000.00	2112.00	50.00	0.00	Fail
AC top-down fatigue cracking (% lane area)	25.00	2.26	50.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix1 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	71.65	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.02	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	229.52	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.61	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	2.26	50.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix1 Level 3 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	71.91	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.03	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	1045.25	50.00	99.81	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix4 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	70.95	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.03	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	359.39	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix4 Level 3 Prediction Results

Figure A.68: Project KA-2682-01 Distress Prediction Comparison of Mix 1 and Mix 4 Inputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	74.44	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.02	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	2113.90	50.00	69.03	Pass
AC thermal cracking (ft/mile)	1000.00	2112.00	50.00	0.00	Fail
AC top-down fatigue cracking (% lane area)	25.00	2.53	50.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix1 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	71.82	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.02	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	238.99	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.53	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	2.53	50.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix1 Level 3 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	71.97	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.03	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	1082.49	50.00	99.71	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix4 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	70.97	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.03	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	374.06	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix4 Level 3 Prediction Results

Figure A.69: Project KA-2681-01 Distress Prediction Comparison of Mix 1 and Mix 4 Inputs

Distress Prediction Summary					
Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied?**
	Target	**Predicted**	**Target**	**Achieved**	
Terminal IRI (in/mile)	172.00	75.84	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.03	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	2115.14	50.00	68.97	Pass
AC thermal cracking (ft/mile)	1000.00	2112.00	50.00	0.00	Fail
AC top-down fatigue cracking (% lane area)	25.00	4.14	50.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix1 Level 1 Prediction Results

Distress Prediction Summary					
Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied?**
	Target	**Predicted**	**Target**	**Achieved**	
Terminal IRI (in/mile)	172.00	72.98	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.03	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	71.33	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	4.14	50.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix1 Level 3 Prediction Results

Distress Prediction Summary					
Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied?**
	Target	**Predicted**	**Target**	**Achieved**	
Terminal IRI (in/mile)	172.00	74.48	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.04	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	1022.09	50.00	99.86	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.29	50.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix4 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	73.41	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.04	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	257.43	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.29	50.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix4 Level 3 Prediction Results

Figure A.70: Project KA-3259-01 Distress Prediction Comparison of Mix 1 and Mix 4 Inputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	75.45	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.02	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	2139.20	50.00	67.75	Pass
AC thermal cracking (ft/mile)	1000.00	2112.00	50.00	0.00	Fail
AC top-down fatigue cracking (% lane area)	25.00	3.78	50.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix1 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	72.51	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.02	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	36.62	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	2.41	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.78	50.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix1 Level 3 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	73.05	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.04	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	605.66	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.03	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	2.30	50.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix4 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	72.39	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.04	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	134.37	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	2.49	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	2.30	50.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix4 Level 3 Prediction Results

Figure A.71: Project KA-3848-01 Distress Prediction Comparison of Mix 1 and Mix 4 Inputs

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	77.72	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.03	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	2623.74	50.00	44.47	Fail
AC thermal cracking (ft/mile)	1000.00	2112.00	50.00	0.00	Fail
AC top-down fatigue cracking (% lane area)	25.00	4.58	50.00	99.99	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix1 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	74.25	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.03	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	144.77	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	4.58	50.00	99.99	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix1 Level 3 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	76.76	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.05	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	1640.32	50.00	90.25	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	4.05	50.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix4 Level 1 Prediction Results

Distress Prediction Summary					
Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied?**
	Target	**Predicted**	**Target**	**Achieved**	
Terminal IRI (in/mile)	172.00	75.15	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.05	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	493.17	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	4.05	50.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix4 Level 3 Prediction Results

Figure A.72: Project KA 0378-01(1) Distress Prediction Comparison of Mix 1 and Mix 4 Inputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	77.06	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.03	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	2169.08	50.00	66.24	Pass
AC thermal cracking (ft/mile)	1000.00	2112.00	50.00	0.00	Fail
AC top-down fatigue cracking (% lane area)	25.00	4.52	50.00	99.99	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix1 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	74.21	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.03	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	128.39	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	4.52	50.00	99.99	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix1 Level 3 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	76.20	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.05	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	1292.73	50.00	98.25	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.92	50.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix4 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	74.90	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.05	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	365.46	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	3.92	50.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix4 Level 3 Prediction Results

Figure A.73: Project KA 0378-01(2) Distress Prediction Comparison of Mix 1 and Mix 4 Inputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	76.70	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.04	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	2128.71	50.00	68.28	Pass
AC thermal cracking (ft/mile)	1000.00	2112.00	50.00	0.00	Fail
AC top-down fatigue cracking (% lane area)	25.00	4.95	50.00	99.99	Pass
JPCP transverse cracking (percent slabs)	15.00	0.02	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix1 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	73.87	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.04	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	101.08	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	2.19	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	4.95	50.00	99.99	Pass
JPCP transverse cracking (percent slabs)	15.00	0.02	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix1 Level 3 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	76.97	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.06	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	1683.21	50.00	88.71	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	4.88	50.00	99.99	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix4 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	75.16	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.06	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	392.31	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	2.26	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	4.88	50.00	99.99	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix4 Level 3 Prediction Results

Figure A.74: Project KA-4236-01 Distress Prediction Comparison of Mix 1 and Mix 4 Inputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	75.85	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.03	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	2113.44	50.00	69.05	Pass
AC thermal cracking (ft/mile)	1000.00	2112.00	50.00	0.00	Fail
AC top-down fatigue cracking (% lane area)	25.00	4.36	50.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix1 Level 1 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	73.08	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.03	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	130.97	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	4.36	50.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix1 Level 3 Prediction Results

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	76.38	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.04	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	2172.61	50.00	66.06	Pass
AC thermal cracking (ft/mile)	1000.00	2.65	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	4.14	50.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix4 Level 1 Prediction Results

Distress Prediction Summary					
Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied?**
	Target	**Predicted**	**Target**	**Achieved**	
Terminal IRI (in/mile)	172.00	74.12	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.04	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	562.88	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	42.03	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	4.14	50.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix4 Level 3 Prediction Results

Figure A.75: Project KA-2001-01 Distress Prediction Comparison of Mix 1 and Mix 4 Inputs

Distress Prediction Summary					
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	72.99	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	2112.76	50.00	69.09	Pass
AC thermal cracking (ft/mile)	1000.00	2112.00	50.00	0.00	Fail
AC top-down fatigue cracking (% lane area)	25.00	1.14	50.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix1 Level 1 Prediction Results

Distress Prediction Summary					
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	71.08	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.01	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	743.40	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	1.14	50.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix1 Level 3 Prediction Results

Distress Prediction Summary					
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	72.83	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.02	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	2300.19	50.00	59.63	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix4 Level 1 Prediction Results

Distress Prediction Summary					
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	71.19	50.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.02	50.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	1129.85	50.00	99.53	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	0.00	50.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	61.90	-	-	-

Mix4 Level 3 Prediction Results

Figure A.76: Project KA-3006-01 Distress Prediction Comparison of Mix 1 and Mix 4 Inputs

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