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# Local Calibration Studies on DARWin-ME/ Mechanistic-Empirical Pavement Design Guide Jointed Plain Concrete Pavement Performance Prediction Models

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# Local Calibration Studies on DARWin-ME/Mechanistic-Empirical Pavement Design Guide Jointed Plain Concrete Pavement Performance Prediction Models

## **Abstract**

The AASHTO Mechanistic-Empirical Pavement Design Guide (MEPDG) pavement performance models and the associated AASHTOWare® pavement design software of DARWin-ME are nationally calibrated using design inputs and distress data largely from the national Long-Term Pavement Performance (LTPP). Further calibration and validation studies are necessary for local highway agencies' implementation by taking into account local materials, traffic information, and environmental conditions. This study aims to improve the accuracy of MEPDG/ DARWin-ME pavement performance predictions for Iowa jointed plain concrete pavements (JPCPs) through local calibration of MEPDG prediction models. The accuracy of the nationally calibrated MEPDG prediction models for Iowa conditions was evaluated. The local calibration factors of MEPDG performance prediction models were identified using both linear and nonlinear optimization approaches. The local calibration improved the accuracy of JPCP performance predictions. A comparison of MEPDG predictions with those from DARWin-ME was performed to assess if the local calibration coefficients determined from MEPDG version 1.1 software are acceptable in DARWin-ME, which has not been addressed before. Few differences are observed between DARWin-ME and MEPDG with national and local calibrated models for faulting and transverse cracking predictions for JPCP but not for International Roughness Index (IRI). With the use of locally calibrated JPCP IRI prediction model for Iowa conditions, the prediction differences between DARWin-ME and MEPDG are reduced. Finally, recommendations are presented on the use of identified local calibration coefficients of DARWin-ME/MEPDG for Iowa JPCPs.

## **Keywords**

Accuracy, Calibration, Pavement performance

## **Disciplines**

Civil and Environmental Engineering | Construction Engineering and Management

## **Comments**

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Local Calibration Studies on DARWin-ME / Mechanistic-Empirical Pavement Design Guide Jointed Plain Concrete Pavement Performance Prediction Models

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## ABSTRACT

The AASHTO Mechanistic-Empirical Pavement Design Guide (MEPDG) pavement performance models and the associated AASHTOWare® pavement design software of DARWin-ME are nationally calibrated using design inputs and distress data largely from the national Long-Term Pavement Performance (LTPP). Further calibration and validation studies are necessary for local highway agencies' implementation by taking into account local materials, traffic information, and environmental conditions. This study aims to improve the accuracy of MEPDG/ DARWin-ME pavement performance predictions for Iowa jointed plain concrete pavements (JPCPs) through local calibration of MEPDG prediction models. The accuracy of the nationally calibrated MEPDG prediction models for Iowa conditions was evaluated. The local calibration factors of MEPDG performance prediction models were identified using both linear and nonlinear optimization approaches. The local calibration improved the accuracy of JPCP performance predictions. A comparison of MEPDG predictions with those from DARWin-ME was performed to assess if the local calibration coefficients determined from MEPDG version 1.1 software are acceptable in DARWin-ME, which has not been addressed before. Few differences are observed between DARWin-ME and MEPDG with national and local calibrated models for faulting and transverse cracking predictions for JPCP but not for International Roughness Index (IRI). With the use of locally calibrated JPCP IRI prediction model for Iowa conditions, the prediction differences between DARWin-ME and MEPDG are reduced. Finally, recommendations are presented on the use of identified local calibration coefficients of DARWin-ME/MEPDG for Iowa JPCPs.

## INTRODUCTION

The Mechanistic Empirical Pavement Design Guide (MEPDG) was developed under the National Cooperative Highway Research Program (NCHRP) Project 1-37A (1) to overcome the deficiencies and limitations of the empirical design procedures in the 1993 AASHTO Guide for Design of Pavement Structures. The MEPDG is now deployed as the AASHTO MEPDG Manual of Practice (2) and the associated AASHTOWare<sup>®</sup> pavement design software, DARWin-ME (3).

The mechanistic-empirical procedure in the MEPDG uses the principles of engineering mechanics to mechanistically calculate pavement responses (stresses, strains, and deflection) as well as the empirical distress transfer functions for predicting pavement performance. The empirical distress transfer functions used in the MEPDG are nationally calibrated using design inputs and distress data largely from the national Long-Term Pavement Performance (LTPP) database. Although this effort was comprehensive, further calibration and validation studies to suit local conditions are highly recommended by the NCHRP Project 1-37A as a prudent step in implementing a new design procedure that is so different from the previous procedures.

Several national-level research studies (4, 5, 6) supported by the NCHRP and Federal Highway Administration (FHWA) have been conducted to demonstrate the MEPDG local calibration procedure after the release of the original research version of the MEPDG software.

Parallel to national-level research projects, many state/local agencies have conducted or plan to undertake local calibration studies for their own pavement conditions. Flexible pavement calibration studies include the work by Galal and Chehab (7) in Indiana; Von Quintus and Moulthrop (8) in Montana; Kang et al.(9) mainly in Wisconsin; Schram and Abdelrahman (10) in Nebraska; Muthadi and Kim (11), Corley-Lay et al. (12), and Jadoun (13) in North Carolina; Li et al. (14) and Liu et al.(15) in Washington; Banerjee et al.(16), Banerjee et al.(17), and Banerjee et al.(18) in Texas; Glover and Mallela (19) in Ohio; Darter et al (20) in Utah; Souliman et al.(21), Mamlouk and Zapata (22), Darter et al. (37) in Arizona; Kim et al. (23) in Iowa; Khazanovich et al. (24), Velasquez et al (25) and Hoegh et al. (26) in Minnesota; and Hall et al (27) in Arkansas. Limited studies on rigid pavement performance prediction model calibration, primarily focusing on jointed plain concrete pavement (JPCP) include the work by Li et al. (28) in Washington; Schram and Abdelrahman (10) in Nebraska; Darter et al. (20) in Utah; Velasquez et al (25) in Minnesota; Kim et al. (23) in Iowa; Bustos et al. (29) in Argentina; and Delgadillo et al (30) in Chile. The procedures and findings of all these studies related to both flexible and rigid pavements are summarized by Ceylan et al. (31).

Some significant findings derived from previous studies which are also relevant to the present study include: (1) all JPCP performance predictions (faulting, transverse cracking and roughness) could be improved by local calibration, (2) rutting, alligator (bottom-up) cracking, and roughness predictions for flexible pavement could be improved through local calibration, (3) no consistent trend in the longitudinal (top-down) cracking predictions of flexible pavement could be identified to reduce the bias and standard error, and improve the accuracy of this prediction model, and (4) few or no thermal (transverse) cracking is predicted by MEPDG when using a properly selected PG binder for local conditions but transverse cracking is in fact observed in actual HMA pavement. However, not all previous studies utilized the latest version

of MEPDG software (version 1.1) which forms the main framework of DARWin-ME released in April 2011. More importantly, very few studies try to assess if the local calibration coefficients determined from the research grade MEPDG software are acceptable in DARWin-ME. In addition to these, a previously completed research study (23) in pursuit of the MEPDG implementation initiatives in Iowa indicated the need for local calibration of MEPDG performance prediction models for Iowa conditions. Thus, it is necessary to calibrate the MEPDG/ DARWin-ME performance models for implementation in Iowa DOT by taking into account local materials, traffic information, and environmental conditions.

The primary objective of this research study is to improve the accuracy of MEPDG/ DARWin-ME projected pavement performance predictions for Iowa JPCP systems through local calibration of MEPDG version 1.1 performance prediction models. The accuracy of the nationally calibrated MEPDG prediction models for Iowa conditions was evaluated. The procedure and results of local calibration are presented in this paper along with other significant findings and recommendations for using MEPDG/DARWin-ME for JPCP in Iowa.

## **LOCAL CALIBRATION METHODOLOGY**

Based on the AASHTO guide for the local calibration of the MEPDG (4), a procedure was formulated in consultation with the Iowa DOT engineers for the local calibration of the MEPDG performance predictions. The procedure is detailed into the following steps:

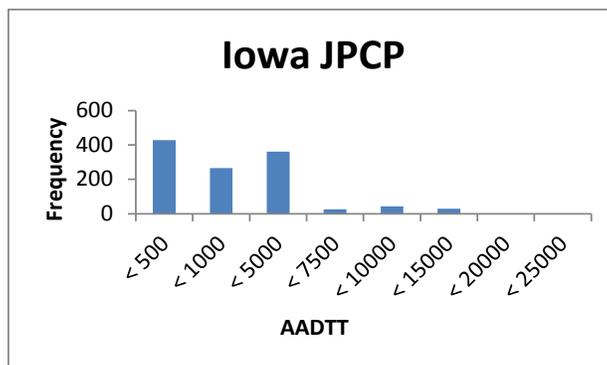
- Step 1: Select typical pavement sections around the State
- Step 2: Identify available sources to gather input data and determine the desired level for obtaining each input data
- Step 3: Prepare MEPDG input database from available sources including Iowa Department of Transportation (DOT) Pavement Management Information System (PMIS), material testing records, design database, and research project reports relevant to MEPDG implementation in Iowa
- Step 4: Prepare a database of performance data for the selected Iowa pavement sections from Iowa DOT PMIS
- Step 5: Assessment of local bias from national calibration factors
- Step 6: Identification of local calibration factors (sensitivity analysis and optimization of calibration factors)
- Step 7: Determination of adequacy of local calibration factors

### **Site Selection**

To develop the database for conducting MEPDG local calibration, representative pavement sites across Iowa were selected in consultation with Iowa DOT engineers considering geographical locations and traffic levels. A total of 35 JPCP sections (rigid pavements) were selected from a list of potential roadway segments. Among the selected sites, twenty-five sections were utilized for calibration and 10 sections were utilized for verification of identified calibration coefficients.

Figure 1 presents the average annual daily truck traffic (AADTT) distributions for Iowa JPCP. As seen in this figure, the use of JPCPs has a wider spread with respect to AADTT. To

comprise all traffic conditions found in Iowa, three categories of traffic levels were utilized in selecting sites for calibration. AADTT fewer than 500 is categorized as *low* traffic volume; anywhere between 500 and 1,000 is categorized as *medium* traffic volume, and AADTT higher than 1,000 is categorized as *high* traffic volume. A detailed description of the selected sites can be found in Ceylan et al. (31).



**Figure 1 Iowa JPCP by AADTT distribution (as of 2011)**

### MEPDG Calibration Database

The MEPDG inputs required for the selected sections were primarily obtained from the Iowa DOT PMIS and material testing records. Other major sources of the data include online project reports relevant to MEPDG implementation in Iowa

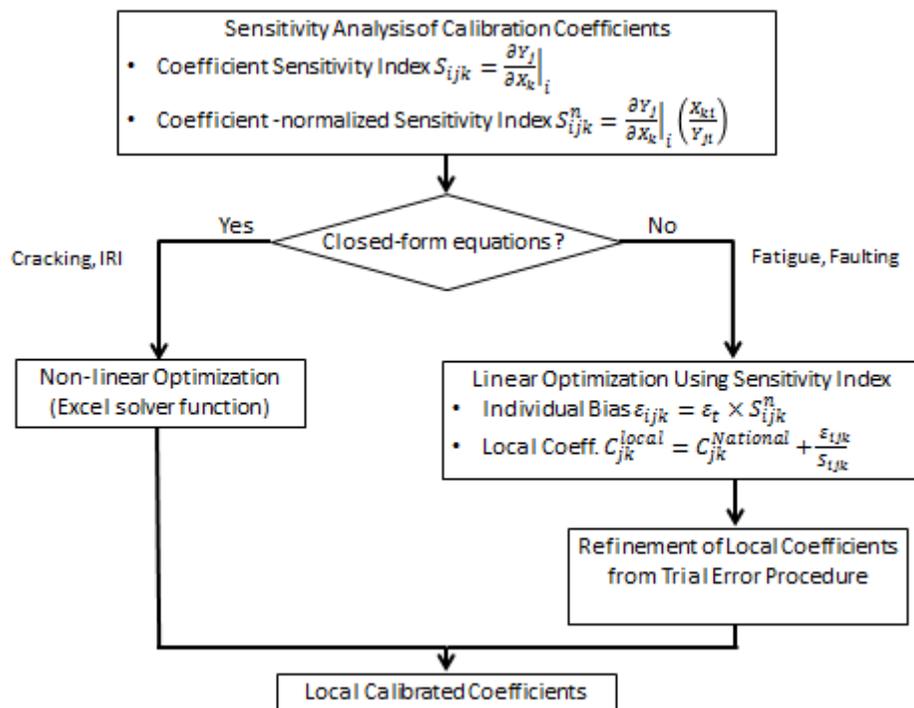
(<http://www.iowadot.gov/operationsresearch/reports.aspx>;  
<http://www.ctre.iastate.edu/research/reports.cfm>).

If a specific input data was not available, the default value or its best estimate was inputted considering its level of sensitivity with respect to MEPDG predicted performance. The NCHRP 1-47 project final report, “*Sensitivity Evaluation of MEPDG Performance Prediction*”, was referred to assess the level of MEPDG design input sensitivity. The NCHRP 1-47 project report documents most of the MEPDG sensitivity studies conducted up to date using the initial version to the latest version of the MEPDG software. It also presents results of comprehensive MEPDG (local and global) sensitivity analyses carried out through this project under five climatic conditions and three traffic levels in the U.S. (32).

A database of historical performance data for the selected sections was prepared from Iowa DOT PMIS. Most of the MEPDG performance predictions are recorded in Iowa DOT PMIS. However, the unit reported in PMIS for JPCP transverse cracking is different from those used in MEPDG. These distress measures in PMIS were converted into same units as those of MEPDG predictions in accordance with the AASHTO local calibration guide (4).

### Identification of Local Calibration Factors

Figure 2 depicts the procedure used in the study to identify local calibration factors (coefficients) of MEPDG performance prediction models. As a first step, sensitivity analyses of calibration coefficients on MEPDG predictions were performed. Two optimization approaches were utilized depending on the constitution (form) of MEPDG performance prediction models. More details are presented in the following subsections.



**Figure 2** Flow chart of the procedure used in determination of local calibration factors.

#### *Sensitivity Analysis of MEPDG JPCP Performance Prediction Model Calibration Coefficients*

Sensitivity analysis (SA) is the apportionment of output variability from a model to its various inputs. Sensitivity of MEPDG performance predictions to calibration coefficients was analyzed to: (1) to derive a better understanding of how the values of calibration coefficients affect performance predictions, and (2) to reduce the search space for subsequent calibration coefficient optimization by identifying the changes in performance predictions to changes in calibration coefficients. A coefficient sensitivity index ( $S_{ijk}$ ) and a coefficient-normalized sensitivity index ( $S_{ijk}^n$ ) were adapted to quantify the sensitivity of each calibration coefficient and to compare the sensitivity level among all calibration coefficients, respectively. The coefficient sensitivity index  $S_{ijk}$  is defined as:

$$S_{ijk} = \left. \frac{\partial Y_j}{\partial X_k} \right|_i \cong \left. \frac{\Delta Y_j}{\Delta X_k} \right|_i \quad (1)$$

$$\left. \frac{\Delta Y_j}{\Delta X_k} \right|_i = \frac{Y_{j,i+1} - Y_{j,i}}{X_{k,i+1} - X_{k,i}} \quad \text{when } X_{j,i+1} > X_{j,i} \quad (2)$$

$$\left. \frac{\Delta Y_j}{\Delta X_k} \right|_i = \frac{Y_{j,i} - Y_{j,i-1}}{X_{k,i} - X_{k,i-1}} \quad \text{when } X_{j,i-1} < X_{j,i} \quad (3)$$

in which  $Y_{ji}$ ,  $X_{ki}$  are the values of the performance prediction  $j$  and calibration coefficient  $k$  evaluated at national calibration coefficient condition  $i$  in a given performance prediction model. The partial derivative can be approximated using a standard central difference approximation.

The  $S_{ijk}$  can be interpreted as the percentage change in performance prediction  $Y_j$  caused by a given percentage change in the calibration coefficient  $X_k$  at national calibrated condition  $i$  in a performance prediction model. For example,  $S_{ijk} = 0.5$  implies that a 20% change in the calibration coefficient value of  $X_{ki}$  will cause a 10% change in performance prediction  $Y_{ji}$ . Two coefficient sensitivity indices ( $S_{ijk}$ ) for each calibration coefficient  $X_k$  were calculated when increasing and decreasing the calibration coefficient values from national calibration coefficient value ( $X_{j,i+1} > X_{j,i}$  and  $X_{j,i-1} < X_{j,i}$ ). Since calibration coefficients at the national calibration condition  $i$  ranged broadly, they should have some scale for comparisons. Thus,  $S_{ijk}$  was normalized using the associated national calibration coefficient. A “national coefficient” normalized sensitivity index ( $S_{ijk}^n$ ) was defined as:

$$S_{ijk}^n = \left. \frac{\partial Y_j}{\partial X_k} \right|_i \left( \frac{X_{ki}}{Y_{ji}} \right) \cong \left. \frac{\Delta Y_j}{\Delta X_k} \right|_i \left( \frac{X_{ki}}{Y_{ji}} \right) \quad (4)$$

In-service pavement of a JPCP section in I-29, Harrison County representing typical Iowa JPCP was modeled for SA. The modeled JPCP section consisted of 304.8-mm (12-in) thick PCC slab with 6.1-m (20-ft) transverse joint spacing over a 254-mm (10-in) A-1-b granular base, and an A-7-6 compacted embankment subgrade. AADTT values of 3,104 was inputted and the MEPDG climate file for this pavement location was generated and inputted. The other required design inputs were prepared as described in the previous section on MEPDG input database preparation.

The nationally calibrated MEPDG performance model predictions for the JPCP resulted in 92% transverse cracking, 0.84-mm (0.033-in) faulting and 4.83-m/km (306-in/mile) International Roughness Index (IRI) for a 30-year design life. The nationally calibrated coefficients were utilized as base cases. The coefficients were varied by 20% to 50% of the nationally calibrated coefficient values.

Table 1 summarizes calibration coefficient sensitivity indices for the modeled JPCP. The negative sign of the coefficient sensitivity indices means that performance predictions decrease with increase in calibration coefficients and vice versa. Most calibration coefficients of the JPCP faulting prediction model, except C7, affect the faulting predictions. For JPCP transverse cracking predictions, the fatigue model related calibration coefficients are the ones which are

most sensitive in the transfer function. Note that the transfer function in transverse cracking models convert predicted fatigue damage from fatigue model to equivalent transverse cracking measurements. In the JPCP IRI models, coefficients C1 related to faulting and C4 related to site factors are the ones which are most sensitive.

The sensitivity results related to calibration coefficients in this study were made from limited sensitivity analysis using the local SA method. The much more computationally intensive global sensitivity analysis should be carried out to confirm these results. However, the local SA can still provide some insights into the sensitivity of MEPDG performance predictions to calibration coefficients to fulfill the objectives of this study.

**Table 1 Summary of Calibration Coefficient Sensitivity Indices for JPCP**

Distress	Coefficient	Coefficient sensitivity index ( $S_{ijk}$ )		Coefficient-normalized sensitivity index ( $S^n_{ijk}$ )
		$X_{j,i+1} > X_{j,i}$	$X_{j,i-1} < X_{j,i}$	
Faulting	C1	0.04	0.03	1.09
	C2	0.03	0.03	0.76
	C3	9.15	10.98	0.67
	C4	6.79	9.05	0.21
	C5	0.00	0.00	0.06
	C6	0.25	0.10	2.09
	C7	0.00	0.00	0.00
	C8	0.00	0.00	0.09
Fatigue for Crack	C1	-196.50	-19.75	-2.35
	C2	-299.18	-31.97	-2.20
Crack	C4	-7.50	-7.50	-0.08
	C5	-7.58	-11.11	0.20
IRI	C1	91.92	91.92	0.43
	C2	6.79	7.24	0.02
	C3	8.57	8.44	0.07
	C4	3.30	3.29	0.48

### *Optimization Approaches*

Nonlinear programming optimization technique through the MS Excel<sup>®</sup> solver routine has been commonly used to minimize the bias ( $\epsilon$ ) and the root mean square error (RMSE) between the actual distress measurements and the MEPDG predicted values (5, 25, 13). To use this approach, all input values required by the performance models are needed to satisfy closed-form solution requirements. As seen in Figure 2, it was checked whether MEPDG could provide this information as well as the model input values required at output files.

MEPDG can provide fatigue damage predictions as the input values for the crack transfer function model and the distress predictions as the input values required by the IRI model. However, MEPDG does not output pavement response results which are key components for the rutting, faulting, fatigue, and thermal fracture models. Therefore, these prediction models could not be closed between inputs and outputs to be able to employ conventional optimization methodologies. These cases require numerous runs of MEPDG software to identify calibrated coefficients through a trial-and-error procedure.

A linear optimization approach using the sensitivity index was implemented as a screening procedure to reduce the computational burden of the trial-and-error procedure. In this linear optimization approach, the individual bias ( $\varepsilon_{ijk}$ ) of each calibration coefficient per distress could be calculated by weight partition of total bias ( $\varepsilon_t$ ) of all calibration coefficients per performance prediction determined from coefficient- normalized sensitivity index ( $S_{ijk}^n$ ) as:

$$\varepsilon_{ijk} = \varepsilon_t \times S_{ijk}^n \quad (5)$$

Under the optimization constraint of  $y_j^{measured} \cong y_j^{local-predicted}$ , the individual bias ( $\varepsilon_{ijk}$ ) and the coefficient sensitivity index ( $S_{ijk}$ ) could be expressed as:

$$\varepsilon_{ijk} = y_j^{measured} - y_j^{national-predicted} = \frac{y_j^{local-predicted} - y_j^{national-predicted}}{y_j^{local-predicted} - y_j^{national-predicted}} \quad (6)$$

$$S_{ijk} = \left. \frac{\Delta Y_j}{\Delta X_k} \right|_i = \frac{y_j^{local-predicted} - y_j^{national-predicted}}{x_k^{local} - x_k^{national}} = \frac{\varepsilon_{ijk}}{x_k^{local} - x_k^{National}} \quad (7)$$

$y_j^{measured}$  is the actual measured value for the performance prediction  $j$ ;  $y_j^{national-predicted}$  and  $y_j^{local-predicted}$  are the values of the performance prediction  $j$  of nationally calibrated model coefficient,  $x_k^{national}$  and locally calibrated model coefficient,  $x_k^{local}$ , respectively. From equation (7), the locally calibrated model coefficient satisfying the optimization constraint could be derived as:

$$x_k^{local} = x_k^{National} + \frac{\varepsilon_{ijk}}{S_{ijk}} \quad (8)$$

The calculated locally calibrated model coefficient,  $x_k^{local}$ , is an approximate solution assuming linear relationship between the calibration coefficient and prediction. The trial-and-error procedure by running MEPDG based on the locally calibrated model coefficient,  $x_k^{local}$ , was found to more closely match the solution. This approach was also applied to identify the local calibration coefficients of the crack transfer function and IRI model when nonlinear programming optimization did not much improve the accuracy of performance predictions or provided underestimation of performance prediction. Note that overestimation of performance prediction can be considered a more conservative design approach when there is not much difference of bias compared to underestimation of performance predictions.

The MEPDG IRI prediction model consists of the primary distresses (e.g., faulting and cracking) and a site factor along with calibration coefficients. The changes in distress predictions after local calibration of the associated distress models could result in the changes in IRI predictions even when using same nationally calibrated model coefficient of the IRI model. The predictions from: one for the nationally calibrated IRI model inputs with nationally calibrated model coefficients, and the other for the locally calibrated model inputs with nationally calibrated model coefficients, were compared to the field measures values. If significant bias was identified from this comparison, the nationally calibrated model coefficient values of the IRI model were modified to reduce the bias of IRI model.

## LOCAL CALIBRATION RESULTS FOR IOWA JPCP

The MEPDG was executed using the nationally calibrated model values to predict the performance indicators for each selected PMIS roadway section. The predicted performance measures were plotted relative to the measured values for the PMIS roadway sections. Based on the accuracy of performance predictions using the nationally calibrated model coefficient values, it was determined whether or not it was necessary to modify the national coefficient values for Iowa conditions. If needed, the locally calibrated model coefficients were identified to improve the accuracy of model predictions. The accuracy of performance predictions were evaluated by plotting the measurements against the predictions on a 45-degree line of equality, as well as by observing the average bias and standard error values. The average bias and standard error in this study are defined as:

$$Ave\ Bias = \varepsilon_{ave} = \frac{\sum_{j=1}^n (y_j^{measured} - y_j^{predicted})}{n} \quad (9)$$

$$Stand.\ Error = \sqrt{\frac{\sum_{j=1}^n (y_j^{measured} - y_j^{predicted})^2}{n}} \quad (10)$$

$n$  is the number of data points in each distress comparison. The lower absolute value of average bias and standard error indicate better accuracy. A positive sign for the average bias indicates underestimated predictions. This process was applied to identify the calibration coefficients for Iowa JPCP performance prediction models as described below.

The MEPDG JPCP performance predictions include faulting, transverse cracking and IRI. Two models, namely the fatigue damage model and the transverse cracking transfer model, are involved in transverse cracking predictions. Fatigue model estimates fatigue damage and then transverse cracking transfer model converts fatigue damage estimation into transverse cracking predictions to equivalent transverse cracking measurements. Table 2 summarizes the nationally and locally calibrated model coefficients for JPCP performance predictions. The accuracy of each performance model with nationally and locally calibrated model coefficients are evaluated and discussed in the following subsection.

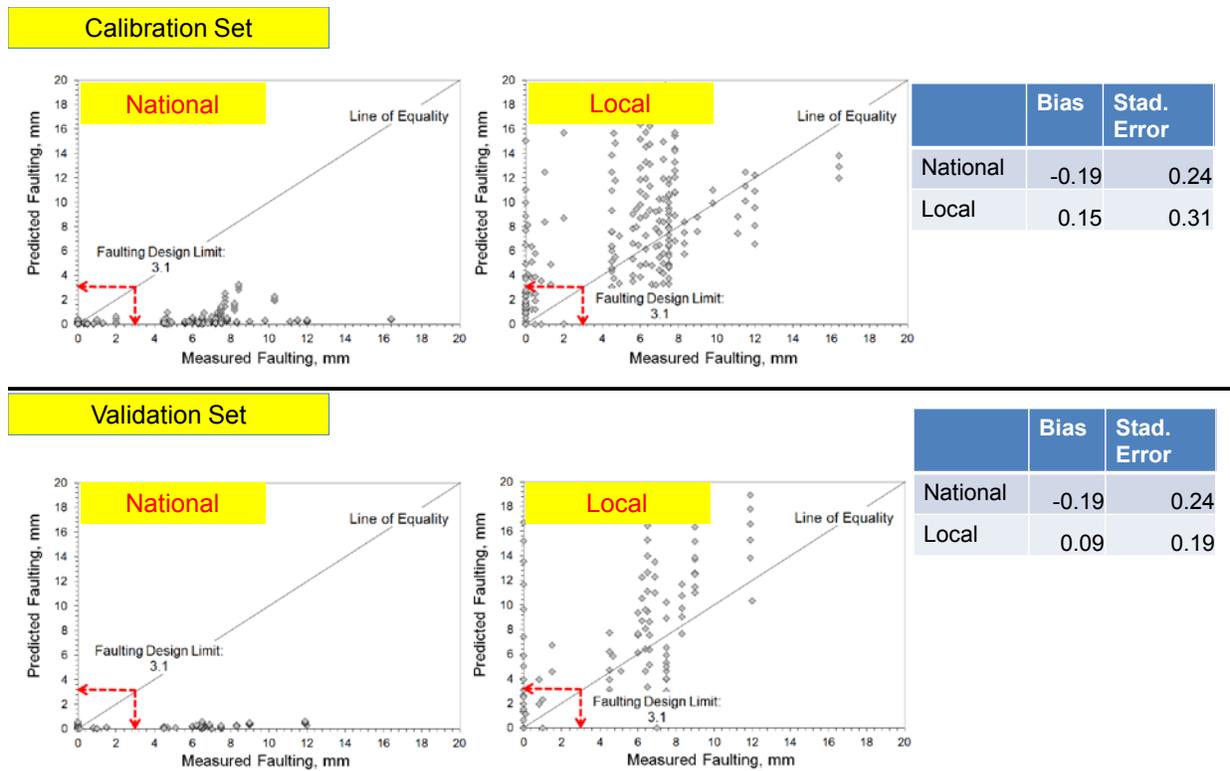
**Table 2 Summary of Calibration Coefficients for JPCP Performance Predictions**

<b>Distress</b>	<b>Factors</b>	<b>National</b>	<b>Local</b>
Faulting	C1	1.0184	2.0427
	C2	0.91656	1.83839
	C3	0.0021848	0.0043822
	C4	0.0008837	0.001772563
	C5	250	250
	C6	0.4	0.8
	C7	1.83312	1.83312
	C8	400	400
Fatigue for Crack	C1	2	2.17
	C2	1.22	1.32
Cracking	C4	1	1.08
	C5	-1.98	-1.81
IRI	C1	0.8203	0.04
	C2	0.4417	0.02
	C3	1.4929	0.07
	C4	25.24	1.17

*Faulting*

Figure 3 compares measured and predicted JPCP faulting predictions before and after local calibration for all sections utilized. As stated previously, about 70 % of the total selected sections were utilized to identify the local calibration factors while the remaining 30%, as an independent validation set, were utilized to verify the identified local calibration factors. The labels “Calibration Set” and “Validation Set” in Figure 3 denote comparisons between nationally calibrated and locally calibrated model predictions using the calibration and validation data sets, respectively.

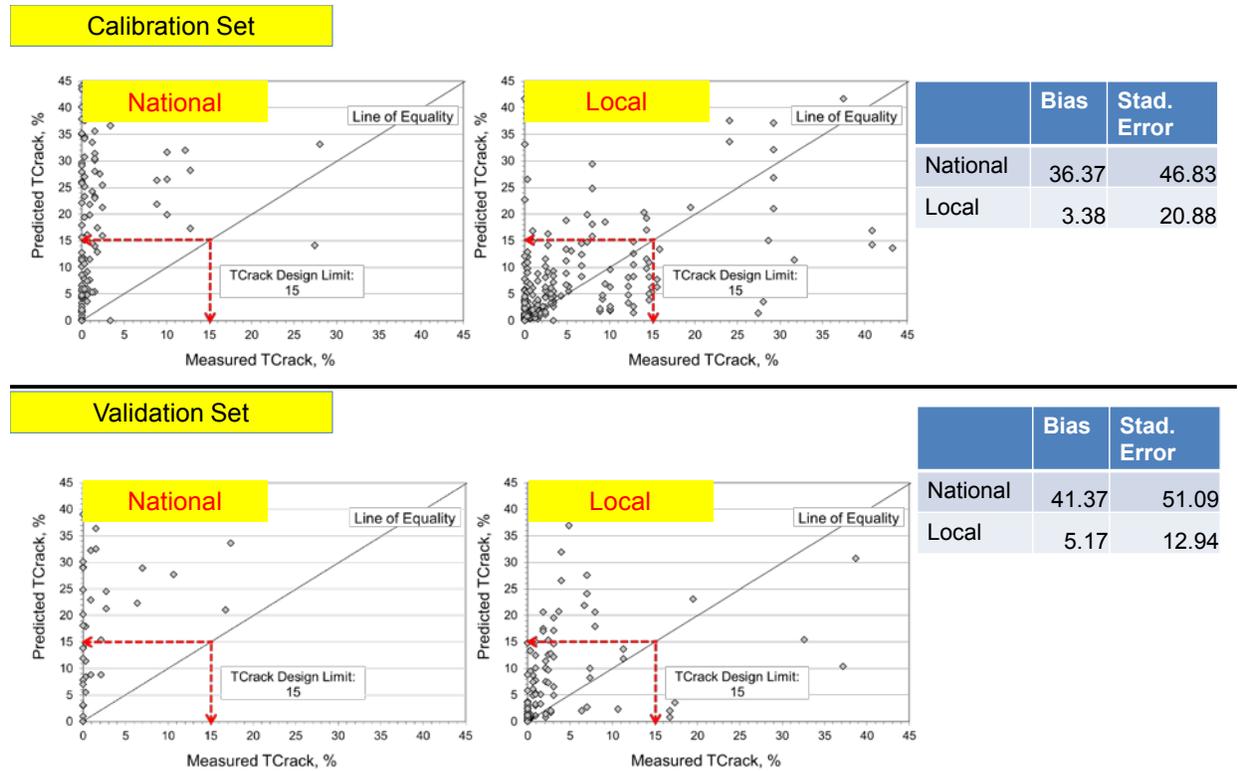
The comparison suggests that the JPCP faulting model, after local calibration, yields more accurate predictions with respect to field measurements than the nationally calibrated model which severely under-predicts the extent of faulting. The positive sign of reduced bias values from the locally calibrated model predictions indicates lesser extent of overestimation. This change could make the design more conservative. The lower values of bias and standard error of locally calibrated model predictions from the validation data set suggest that the locally calibrated faulting model could improve the prediction accuracy even in other Iowa JPCP sections not used in the calibration procedures.



**Figure 3 Overall summary of comparisons between measured and predicted JPCP faulting.**

*Transverse Cracking*

Figure 4 compares measured and predicted JPCP transverse cracking predictions before and after local calibration using the calibration and validation sets. The highly overestimated transverse cracking predictions using the nationally calibrated model coefficients moved more close to the line of equality when using the locally calibrated model coefficients. The lower values of bias and standard error also indicate that the transverse cracking prediction model was improved by modification of calibration coefficients for Iowa conditions.



**Figure 4 Overall summary of comparisons between measured and predicted JPCP transverse cracking.**

*IRI*

The local calibration of IRI model for JPCP involved the calibration of distress models (faulting and transverse cracking) as IRI model inputs and the calibration of associated coefficients to each distress input in the IRI model. Figure 5 compares the measured and predicted JPCP IRI predictions before and after local calibration using the calibration and validation sets. The nationally calibrated IRI model predictions overestimated the measured values while the locally calibrated IRI model predictions were placed on the line of equality. The lower values of bias and standard error also indicate that the locally calibrated IRI model provide better estimation of the measured values.

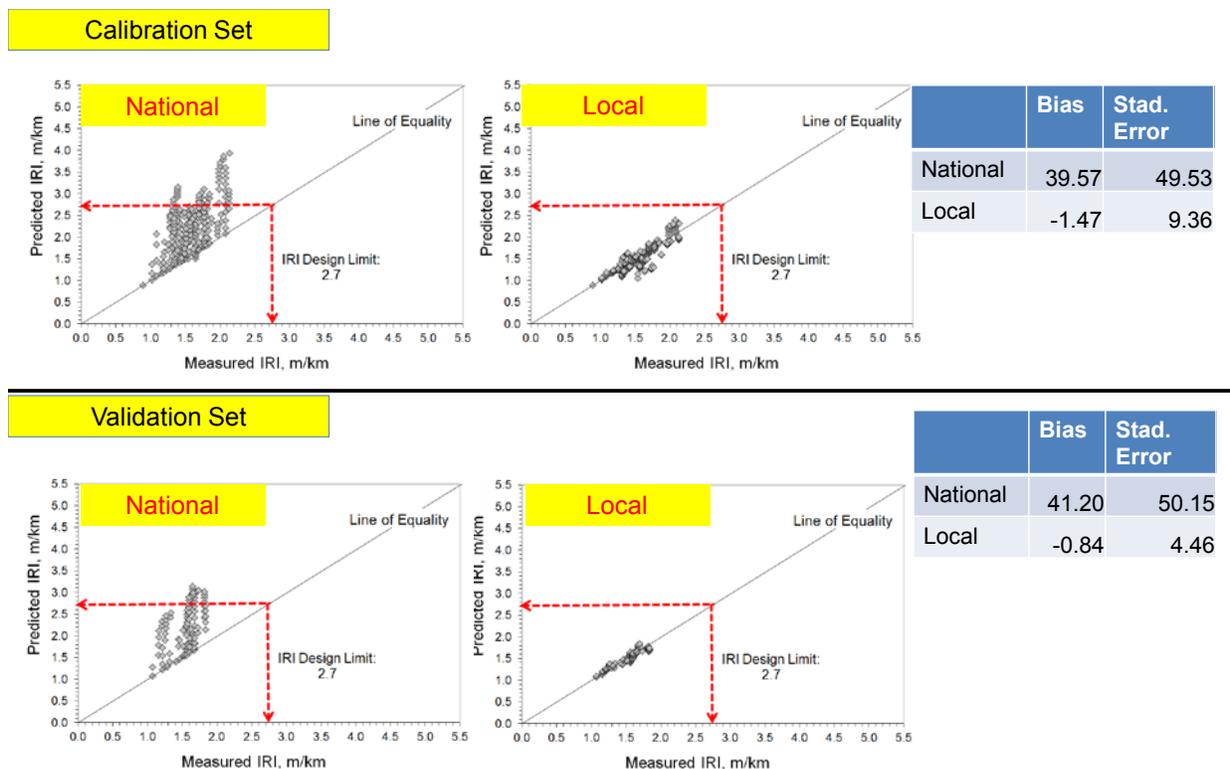


Figure 5 Overall summary of comparisons between measured and predicted JPCP IRI.

## DISCUSSION: COMPARISON BETWEEN MEPDG AND DARWIN-ME JPCP PREDICTIONS

The DARWin-ME released in April 2011 builds upon the latest version of research grade MEPDG software (version 1.1). Key features and enhancements in DARWin-ME over the MEPDG are found in DARWin-ME help manual (36). The comparison of MEPDG predictions with DARWin-ME for JPCP conducted to ensure that the local calibration coefficients determined from MEPDG version 1.1 are acceptable in DARWin-ME.

The modeled JPCP section consisted of 203.2-mm (8-in) thick PCC slab with 6.1-m (20-ft) transverse joint spacing over a 152.4-mm (6-in) cement treated base (CTB), a 152.4-mm (6-in) crush granular subbase, and an A-7-6 compacted embankment subgrade. 30-year design life for JPCP with 50% and 90% reliability were utilized. Two traffic levels of AADTT utilized are 1,000 and 5,000. The climate site location is Des Moines, Iowa.

DARWin-ME allows user to use climate data in XML format generated in DARWin-ME and ICM format climate data file generated in MEPDG. However, DARWin-ME requires more hourly climate data points rather than MEPDG. The error or a warning message was listed in the error list pane area of the program when ICM format climate data file generated from MEPDG for Des Moines in Iowa was imported into DARWin-ME. Thus, it was not able to use same format of climate file in both DARWin-ME and MEPDG. In this comparison, DARWin-ME utilized XML climate file format and MEPDG utilized ICM climate data format for same climate

site location (Des Moines, Iowa). Except climate file format, the all design input values required for both DARWin-ME and MEPDG were identical.

Table 3 summarizes design life performance prediction comparison results between MEPDG and DARWin-ME with nationally and locally calibrated JPCP performance prediction models. JPCP faulting and transverse cracking predictions from MEPDG and DARWin-ME do not show significant difference. However, the national IRI predictions from MEPDG and DARWin-ME have difference. The IRI model in both MEPDG and DARWin-ME is an empirical relation consisting of transverse cracking, the joint faulting and site specifics. Since transverse cracking and the joint faulting predictions in both MEPDG and DARWin-ME are similar, the national IRI prediction differences between MEPDG and DARWin-ME might come from site specifics having climate related variables (freezing index and number of freezing cycles). Note that the XML climate file in DARWin-ME has more hourly climate data points than ICM climate data format in MEPDG. However, the difference in IRI predictions is reduced using the locally calibrated IRI model since the coefficient associated with the site factor reduces from 25.24 (national coefficient) to 1.17 (local coefficient) (see Table 2).

**Table 3 Prediction comparison between MEPDG and DARWin-ME**

Type	AADTT	Reliability (%)	Distress	National		Local	
				MEPDG 1.1	DARWin-ME	MEPDG 1.1	DARWin-ME
JPCP	1,000	50	IRI (m/km)	1.48	1.06	1.03	1.01
			TCracking (% slabs)	0.0	0.0	0.0	0.0
			Faulting (mm)	0.03	0.02	0.61	0.64
	1,000	90	IRI (m/km)	2.09	1.49	1.40	1.36
			TCracking (% slabs)	4.5	4.5	3.8	3.8
			Faulting (mm)	0.53	0.51	1.50	1.53
	5,000	50	IRI (m/km)	1.53	1.12	1.10	1.08
			TCracking (% slabs)	0.7	0.7	0.1	0.1
			Faulting (mm)	0.15	0.14	5.11	5.16
	5,000	90	IRI (m/km)	2.18	1.59	1.51	1.47
			TCracking (% slabs)	6.6	6.6	4.6	4.6
			Faulting (mm)	0.81	0.76	6.86	6.91

## CONCLUSIONS AND RECOMMENDATIONS

This research aims to improve the accuracy of MEPDG/ DARWin-ME projected pavement performance predictions for Iowa JPCP systems through local calibration of MEPDG performance prediction models. The local calibration factors of MEPDG prediction models were identified using both linear and nonlinear optimization approaches to improve the accuracy of model predictions. The comparison of MEPDG predictions with DARWin-ME ones were

conducted to ensure that the local calibration coefficients determined from MEPDG version 1.1 are acceptable in DARWin-ME. Based on this study, the following conclusions were made for each of JPCP performance prediction models. Finally, recommendations for use of the calibration coefficients in DARWin-ME/MEPDG for Iowa pavement systems are also provided.

- The locally calibrated faulting model for Iowa JPCP gives better predictions with lower bias and standard errors than the nationally calibrated model with severely underestimated faulting measures.
- The locally calibrated IRI model for Iowa JPCP improves the accuracy of predictions by tightening the scatter around the line of equality. The nationally calibrated model overestimates IRI measures.
- The locally calibrated JPCP performance prediction models (faulting, transverse cracking and IRI) identified in this study are recommended for use in Iowa as alternatives to their nationally calibrated counterparts.
- Fewer differences are observed in faulting and transverse cracking predictions from DARWin-ME and MEPDG using nationally and locally calibrated models.
- The national IRI predictions from MEPDG and DARWin-ME have differences. These differences might be related to climate data used in MEPDG and DARWin-ME since locally calibrated JPCP IRI model with a reduced site factor coefficient reduces prediction difference between DARWin-ME and MEPDG for Iowa conditions. However, further research is warranted to investigate cause of these differences.

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