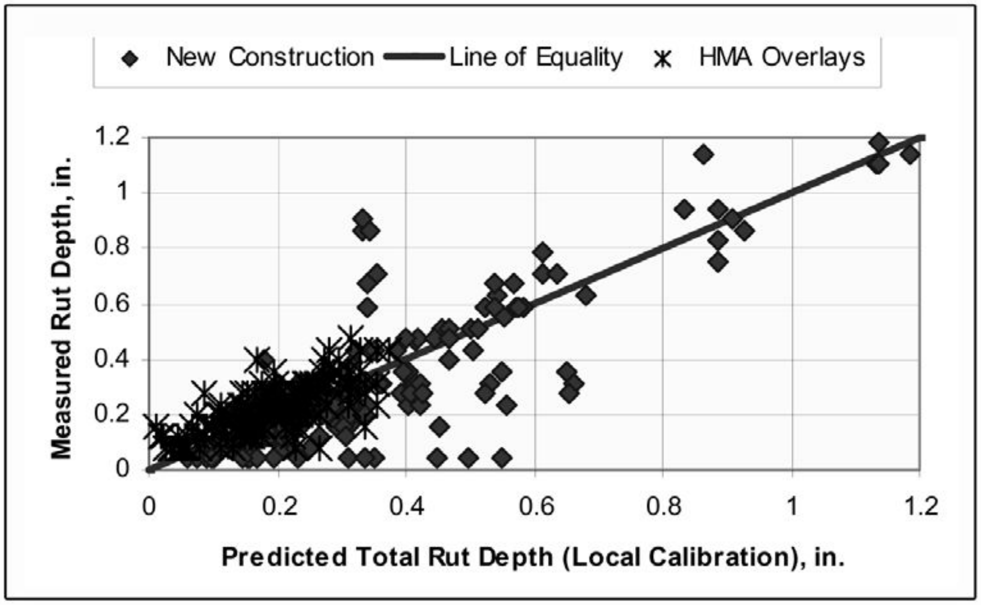

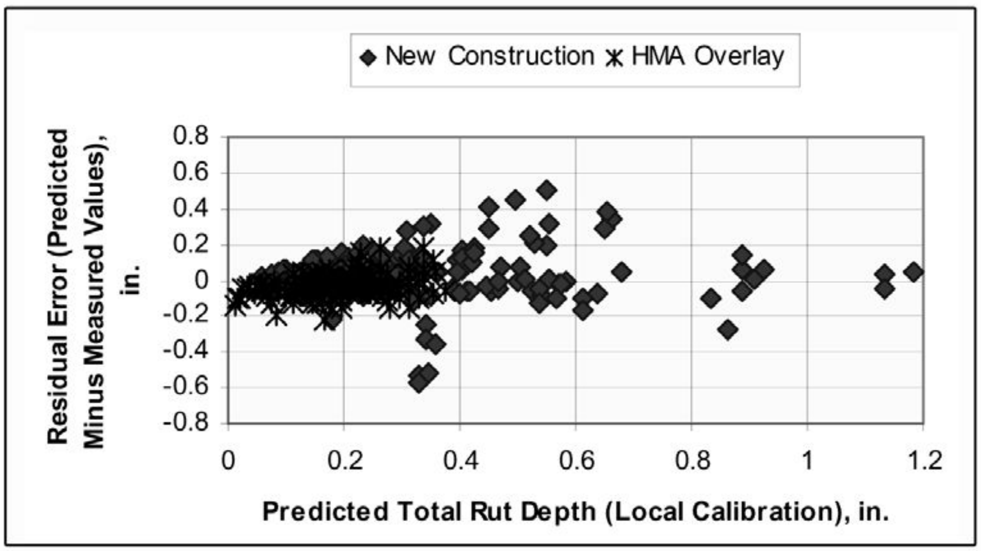

Figure A2-21. Comparison of Predicted and Measured Rut Depths Using the Local Calibration Values for the Subgrade, Unbound Aggregate, and HMA Layers

The bias of the fatigue cracking prediction model can be adjusted through four parameters; β_{f1}, β_{f2}, β_{f3}, and C_2. The β-terms are related to calculating the allowable number of load applications for a specific condition and layer, while the C_2-term is related to calculating the percent area of fatigue cracking from the damage index. The β_{f1}- and C_2-terms are the ones typically used to eliminate the model bias and/or reduce the standard error of the estimate. The other two local calibration parameters are assumed to be adequate.

The C_2 parameter in the bottom-up fatigue cracking prediction equation was also excluded from the analysis. It was assumed that the C_2 value of unity determined from the global calibration process was appropriate for the LTPP SPS projects considered within this demonstration. That assumption for C_2, however, is probably incorrect, just like for the Kansas PMS segments. The growth in fatigue cracking with time can be much steeper than predicted by the MEPDG using the global calibration value of unity. This condition is illustrated in Figure A2-22 for some of the LTPP SPS-1 and SPS-5 test sections with the higher amounts of fatigue cracking. This difference between the measured and predicted values with time decreases the precision of the fatigue cracking prediction model for the LTPP projects. However, there are too few LTPP SPS projects and individual test sections without anomalies and with appreciable amounts of fatigue cracking to determine a reliable estimate of C_2, similar to the finding for the Kansas PMS segments.

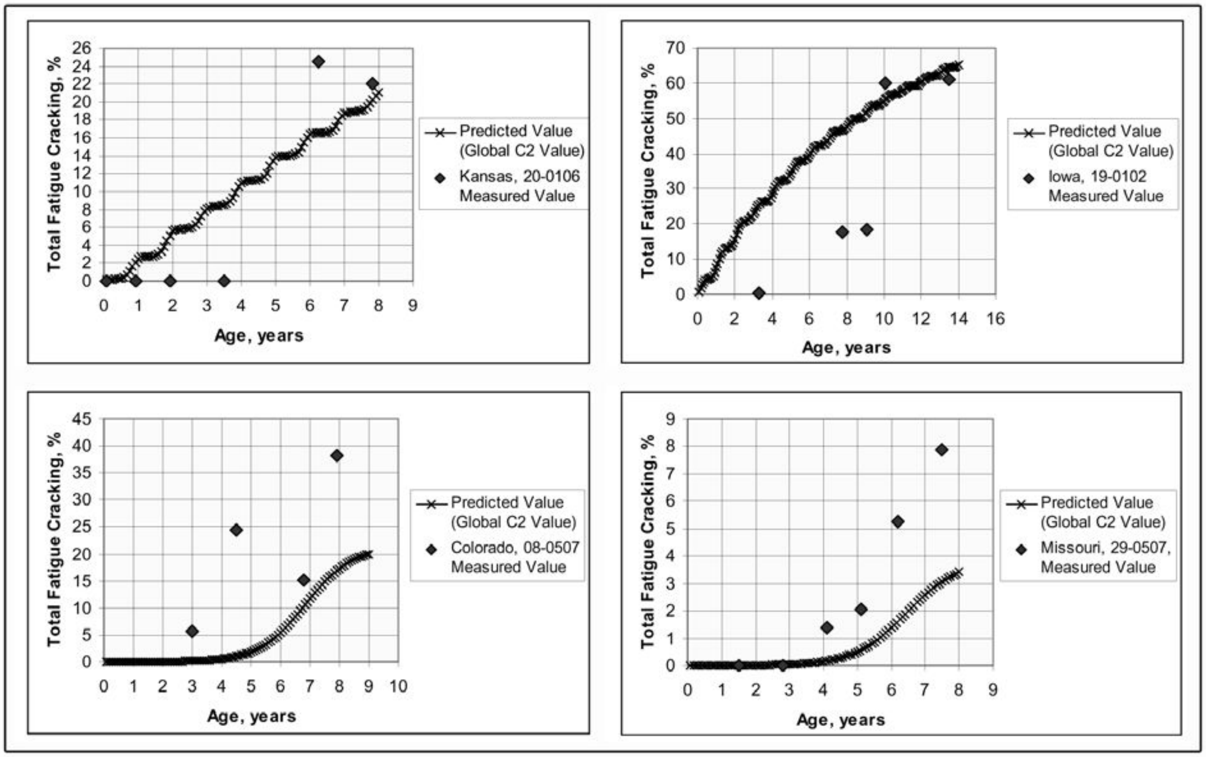

Figure A2-22. Comparison of Measured and Predicted Values of Fatigue Cracking for Specific Test Sections

An analysis of the residual errors for the test sections that exhibited the higher areas of fatigue cracking was completed to identify the material properties or site features related to the residual error. No clear correlation was identified, probably because of the confounding factors and higher number of anomalies between the LTPP SPS projects (refer to Attachment A2.4.C). Thus, a constant value was used to predict the fatigue cracking for the local calibration β_{f1}-term, which is 0.005.

In order for the residual error to be minimized for the SPS-5 Colorado project, the local calibration term would have to be much lower than the above value. This LTPP SPS-5 project was the only one with a thin leveling course. Assuming zero interface friction or bond between the existing surface and HMA overlay results in a local calibration value of 0.005 for this project. No significant difference in cracking was found between the HMA mixture with and without RAP.

Table A2-17 provides a summary of the statistical parameters resulting from use of the fatigue cracking local calibration value. Figure A2-23 provides a comparison of the predicted and measured fatigue cracking for new construction (SPS-1 projects) and HMA overlays (SPS-5 projects). As shown, there is an increase in the accuracy of the transfer function (Figure A2-18 compared to Figure A2-23), but the correlation between the predicted and measured values is still considered poor for the LTPP SPS-1 projects (i.e., the MEPDG is considered accurate but has poor precision based on the LTPP projects included for this demonstration).

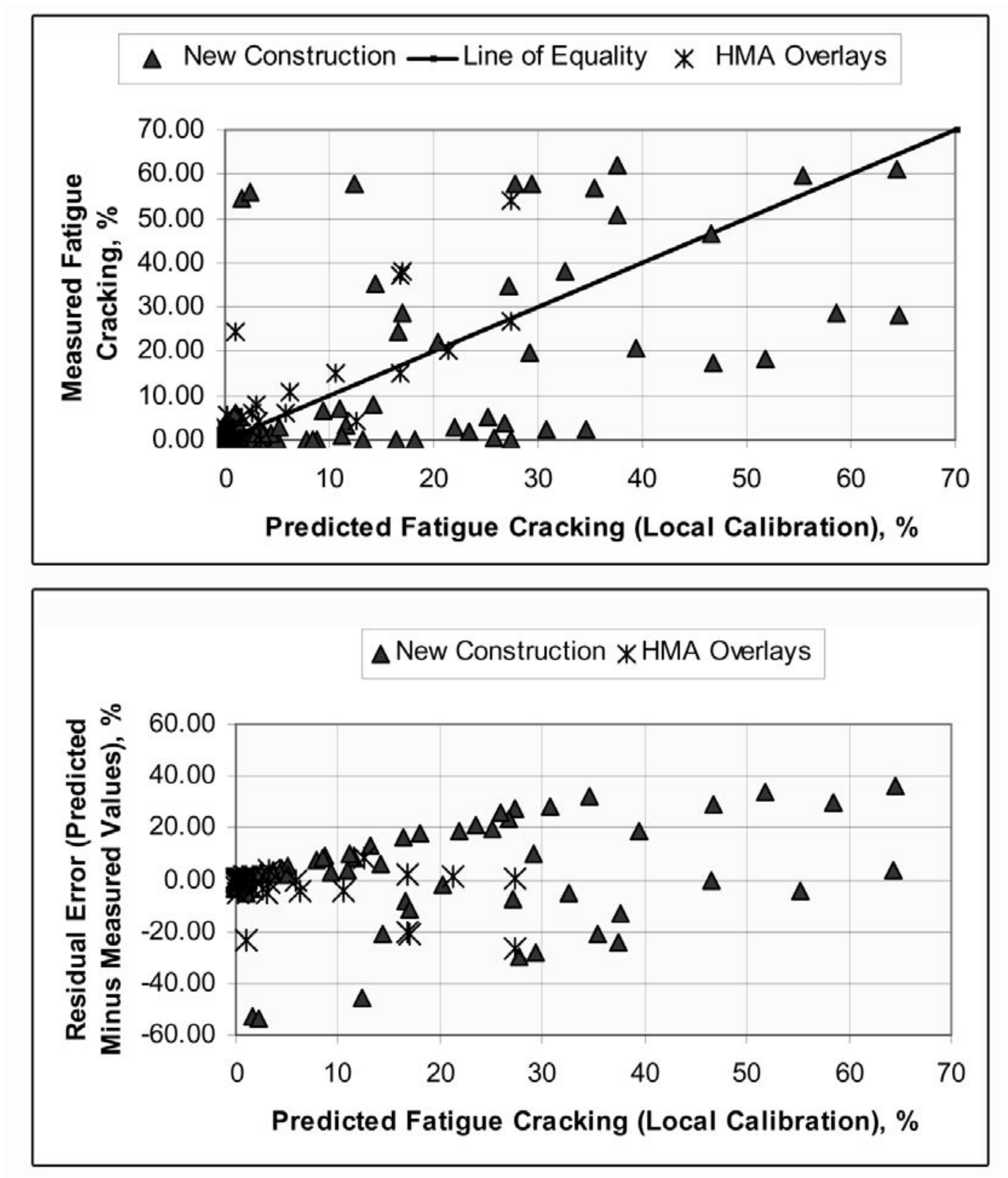

Figure A2-23. Comparison of Predicted and Measured Fatigue Cracking Using a Local Calibration Value for the HMA Mixture That Is Air Void Dependent

Reasons for this poor correlation are believed to be the result of different construction problems or anomalies that occurred on all of the LTPP SPS-1 projects selected for this demonstration. Variable support conditions of the unbound layers and problems that occurred during HMA production (resulting in hard to brittle HMA mixtures) would have a significant effect on the fatigue resistance of the pavement structure. On a positive note, however, the HMA-mixture production problems that severely hardened the HMA mixtures should result in low local calibration values in comparison to the global calibration values of unity, which they do.

Although the hypothesis for the condition of using the local calibration values was accepted, these values should not be used from a practical engineering standpoint because they are heavily influenced by severely hardened or aged HMA.

Transverse Cracking Transfer Function

The length of transverse or thermal cracks was significantly under predicted for nearly all of the test sections for new construction and HMA overlays using the global calibration values (refer to Figure A2-19). Only one of the SPS-1 sites had significant lengths of transverse cracking—the Iowa project. Most of the SPS-5 projects, however, did exhibit various levels of transverse cracking. Thus, the MEPDG prediction model resulted in a significant negative bias, and that bias should be eliminated.

The maximum length of thermal cracks predicted by the MEPDG is 2,200 ft/mi, which corresponds to about a 30-ft spacing of transverse cracks. Many of the LTPP sites with transverse cracks exceed that maximum limit. Thus, only those measured responses less than about 2,500 ft/mi should be used in the local calibration process.

Thermal cracking was under predicted for nearly all of the test sections, and the magnitude of the residual error did correspond to the magnitude of the air voids of the wearing surface. The HMA-mixture production and mixture design issues, however, resulted in significant confounding factors that reduced the significance of air voids and asphalt contents on the occurrence of transverse cracking. These construction problems are considered anomalies within this demonstration. The β_{t3} local calibration parameter was estimated based on the air voids and production problems of the wearing surface and used to reduce the model bias (refer to Table A2-13). The local calibration values (β_{t3}) determined for the different air void ranges related to thermal cracking are listed below.

Table A2-18. Local Calibration Values for Ranges of Air Voids in Relation to Thermal Cracking

Plant Hardening of Asphalt	Range of Asphalt Contents, %	Range of Air Voids, %	Local Calibration Value, β_{t3}
Typical, no excessive hardening during production	>10 (high)	5 to 7 (typical specification range)	1.0
	8 to 10 (typical to higher asphalt contents)	7 to 9	1.7
		>10	2.0
	<8 (low)	>10	5.0
Excessive	Not important	Not important	7.5
Severe	Not important	Not important	20.0

Table A2-17 lists the thermal cracking bias using the local calibration values listed above. As shown, the hypothesis is now accepted for the new construction projects (SPS-1) but is still rejected for the HMA overlays (SPS-5). Figure A2-24 compares the predicted and measured thermal cracking using the local calibration values and shows an increase in the accuracy of the transfer function, as compared to use of the global calibration values (refer to Figures A2-19 and A2-24).

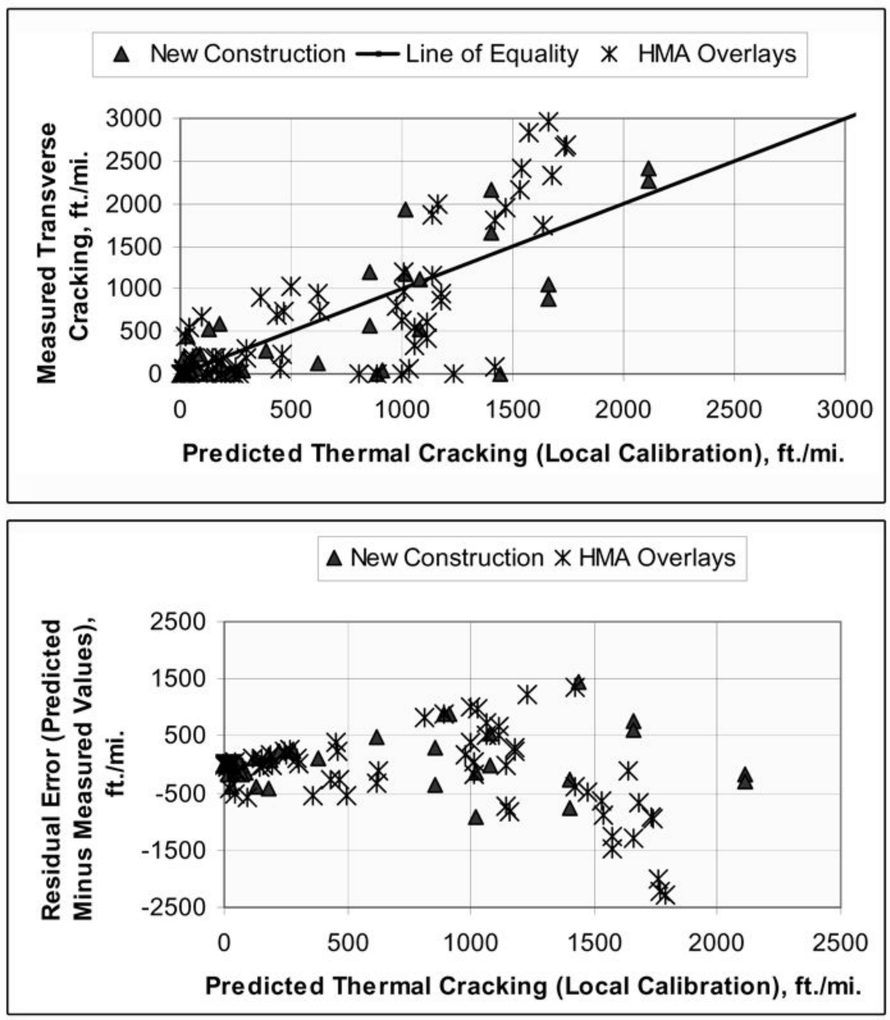

Figure A2-24. Comparison of Predicted Thermal Cracking and Measured Transverse Cracking Using the Local Calibration Values for the HMA Mixture

Roughness or IRI Regression Model

The IRI values predicted by the MEPDG using the global calibration values are within acceptable limits of the measured values. The hypothesis was accepted in that the bias is considered minimal (refer to Table A2-13 and Figure A2-20). Those IRI values, however, are heavily dependent on the other distresses predicted by the MEPDG. Any changes to the predicted distresses from the global calibration process will affect the IRI values. As an example, the test sections for which the IRI values were under predicted were for those sections where the transverse cracks were significantly under predicted. Greater predicted lengths of the thermal cracks using the local calibration values will result in higher IRI values being predicted by the MEPDG. Thus, the IRI model needs to be re-evaluated after the bias has been removed from the other prediction models.

IRI values were predicted with the MEPDG after all of the local calibration adjustments were made to the other distress prediction models. Table A2-17 summarizes the statistical values for the SPS-1 (new construction) and SPS-5 (HMA overlays) projects, while Figure A2-25 compares the predicted and measured IRI values. As shown, the hypothesis is accepted and the correlations are considered reasonable without bias. Some observations from this comparison and evaluation of the data are noted below.

- The MEPDG IRI prediction equation begins to over predict the measured IRI values for some of the test sections for longer times or older ages. These positive residual errors are probably caused by over predicting the other distresses discussed above.

- The MEPDG IRI prediction equation significantly under predicts the measured IRI for some of the new construction test sections. Other non-load related distresses that are not predicted by the MEPDG can affect the IRI values that are not considered in the MEPDG.

Step 9—Assess Standard Error of the Estimate

After the bias was reduced for each of the transfer functions, the SEE is evaluated over the range of predicted distress values. The SEE for the local calibration process and predictions is summarized in Table A2-17. Figure A2-26 compares the SEE for the globally calibrated transfer functions to the SEE for the locally calibrated transfer functions. Using the local calibration values, the SEE values were found to be similar to or greater than the SEE values included in the MEPDG software. The following summarizes the comparison of the values between the global and local calibration values.

- **Rut Depth Transfer Function (Total Rut Depth)**—Standard errors are lower from the local calibration in comparison to the global calibration, similar to the findings from Demonstration 1.

- **Alligator Cracking Transfer Function—**Standard error based on the local calibration is similar to the global values at the lower predicted values of fatigue cracking, but continues to increase to values significantly greater than the global values. A limit was placed on the SEE value from the global calibration, but that limit was found not to be applicable to the LTPP sites included within this demonstration.

- **Thermal Cracking Transfer Function—**Standard error based on the local calibration is consistently higher than the values determined from the global calibration process, similar to the findings from Demonstration 1.

- **IRI Regression Model—**Standard error for the IRI regression equations is not provided in the MEPDG software screens and cannot be changed.

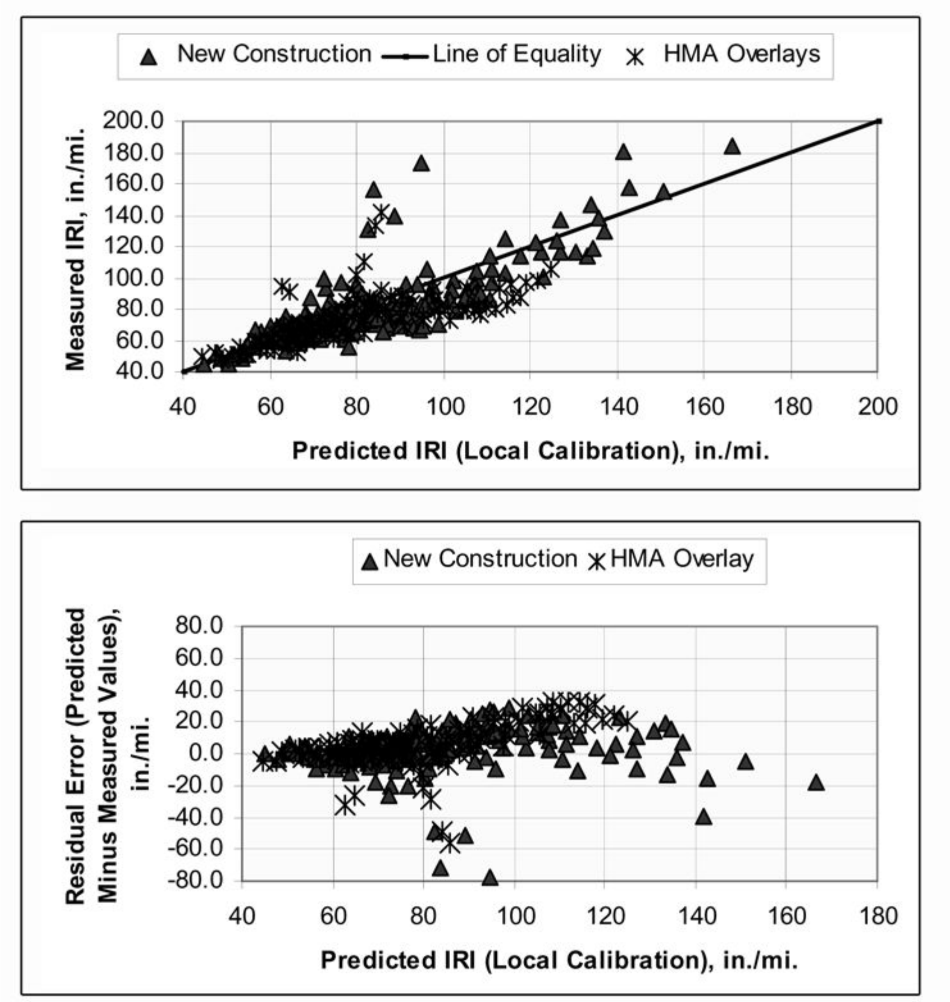

Figure A2-25. Comparison of Predicted and Measured IRI Values Using the Global Calibration Values

Step 10—Reduce Standard Error of the Estimate

As noted in Step 9 and shown in Figure A2-26, the SEE from the local calibration process was found to be different than the SEE relationships included in the MEPDG software for rutting, fatigue cracking, and thermal cracking. An ANOVA can be completed to determine if the residual error or bias is dependent on some other parameter or material/layer property for the LTPP test sections. No correlation was identified, so the SEE values shown in Figure A2-26 and the local calibration factors summarized in Step 8 are believed to be the final values for the LTPP test sections included in the sampling template. A possible reason that the values were not correlated is a result of the anomalies found at these LTPP sites. Thus, no further reduction in the SEE is possible based on the more simplistic evaluation.

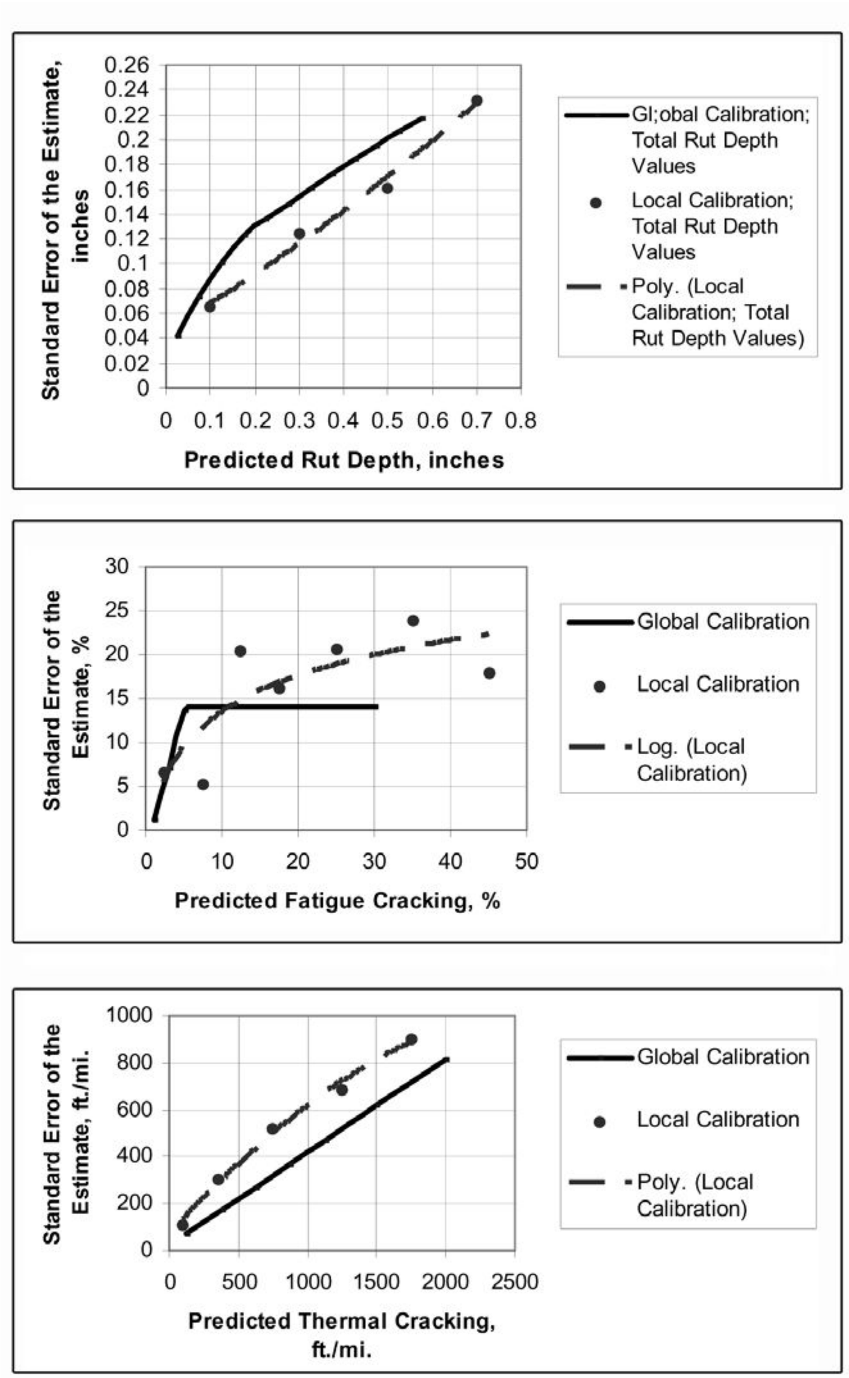

Figure A2-26. Comparison of the Standard Error of the Estimate from the Global and Local Calibration Process

Step 11—Interpretation of Results and Deciding on Adequacy of Calibration Factors

For this demonstration, the global calibration values did result in a bias for all distresses, with the exception of the IRI regression model. The MEPDG did not accurately explain the differences in performance between the different HMA mixtures and pavement structures. To reduce that bias required local calibration values that were significantly different from unity. The MEPDG IRI regression equation was the only model that was confirmed using data from selected LTPP SPS projects in Kansas and adjacent states. The purpose of this step is to decide whether to adopt the local calibration values or continue to use the global values that were based on data included in the LTPP program from around the United States.

As stated under Demonstration 1 using the Kansas PMS data, to make that decision an agency should identify major differences between the LTPP projects and the standard practice of the agency to specify, construct, and maintain its roadway network. The agency should also determine whether the local calibration values can explain those differences, and evaluate any change from unity for the local calibration parameters to ensure that the change provides engineering reasonableness.

The interpretation of results is discussed further in Section A2.3 (Summary for Local/Regional Calibration Values) using the two different data sets: PMS segments and selected LTPP SPS projects in and adjacent to Kansas. The following briefly interprets some of the results using the LTPP SPS data.

- The IRI regression equation was found to be a reasonable simulation of the IRI values measured on the LTPP test sections. This finding was expected because other LTPP test sections were used to develop the regression model. The IRI prediction equation is believed to be adequate for Kansas' climate, materials, and other site features.

- All HMA mixtures included in the LTPP SPS projects included in this demonstration are more susceptible to fracture than included in the global calibration process. These mixtures are brittle in comparison to those used to determine the global calibration values. Most of these sections that have exhibited higher amounts fatigue and transverse cracking are those where plant problems occurred that severely hardened the asphalt. The local calibration values determined from those projects would not be recommended for use for typical pavement design projects.

- The C_2 parameter is significantly different from unity (refer to Figure A2-21), but there were too few LTPP SPS projects with higher levels of fatigue cracking and without anomalies to determine a reliable estimate for this parameter. Thus, the global calibration value for C_2 (unity) should continue to be used until more projects are included in the local calibration process without construction anomalies and with higher amounts of fatigue cracking to confirm or dispute that observation.

- All mixtures are also more susceptible to thermal cracking than those included in the global calibration process. Substantial lengths of transverse cracking were exhibited on many of the LTPP SPS projects. Most of the projects with excessive transverse cracking were those that exhibited construction and mixture production problems. Other LTPP SPS projects were included without any known construction problems or anomalies. The local calibration value was significantly greater than unity. Thus, it would be recommended that the local calibration value for thermal cracking be used for design.

- The HMA mixtures with and without RAP in the LTPP SPS-5 projects did not exhibit any difference between the local calibration values for each distress. Thus, the local calibration values would be the same regardless of the percentages of RAP included in those mixtures. The percentage of RAP used in the HMA mixtures for the LTPP SPS-5 projects was generally less than 25 percent.

- The subgrade rutting local calibration value is believed to be reasonable because of the findings from previous forensic studies and would be recommended for use.
- The rut depth local calibration values for the HMA mixtures do deviate from unity. In summary, the HMA local calibration values for rutting would be recommended for use. The SEE values derived from the local calibration were also lower than the SEE values derived from the global calibration.

A2.3 Summary for Local/Regional Calibration Values

The summary of results is discussed in two parts, which is a further interpretation of the results from Step 11 of both demonstrations. The first part is to compare the results from the two demonstrations—the Kansas PMS segments and the LTPP test sections. The second part of the discussion relates to whether the results represent standard practice and should be used for designing flexible pavements and HMA overlays that are commonly used in Kansas.

A2.3.1 Comparison of Results: PMS Segments and LTPP SPS Test Sections

There are differences between the two demonstrations of the local validation-calibration process. Table A2-19 summarizes the more important differences, as well as similarities, that can have an effect on the outcome. Although substantial differences exists between the two data sets, the MEPDG transfer functions were found to be reasonably accurate after local calibration for all performance indicators using both the Kansas LTPP and adjacent state projects and the Kansas PMS segments. The PMS segments do exhibit higher within project variability, while the between project variability is greater for the LTPP test sections. As previously noted, this was expected because of the experimental design for the LTPP program.

The statistical parameters resulting from the two demonstrations were summarized in Tables A2-8 and A2-17. The precision of the transfer functions is less than desired based on the target values included in Table A2-5. The s_e/s_y term is relatively high and the R^2 term relatively low for most of the transfer functions. The reason for the lower precision is not necessarily the result of poor prediction models in the MEPDG or high lack-of-fit modeling errors. Making the transfer function more precise (reducing the s_e/s_y and increasing R^2) is not likely, as previously stated, because of the large measurement error within both data sets, especially for the PMS data set (refer to Attachment A2.4.B). Until the measurement precision of the performance indicators can be improved (reduction of the measurement error), it would be recommended that the SEE relationships included in the MEPDG for each transfer function continued to be used for Kansas, with the exception of the rut depth function. The SEE values for the rut depth transfer function were found to be consistently lower than the values derived from the global calibration process. The following summarizes and compares the local calibration values for the MEPDG distress transfer functions that were determined from the two demonstrations.