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16. Abstract

The new Mechanistic-Empirical Pavement Design Guide (MEPDG) developed under the National Cooperative Highway Research Program (NCHRP) Project 1-37A represents a major change as compared to the 1993 AASHTO Pavement Design Guide. The MEPDG provides a rational pavement design framework based on mechanistic-empirical principles to characterize the impacts of traffic, climate, and material properties on the pavement performance. Before replacing the 1993 Pavement Design Guide (and its accompanying DARWin 3.1 design software) currently used by Louisiana Department of Transportation and Development (LADOTD), the nationally calibrated MEPDG distress prediction models need to be further validated and calibrated against the local conditions in Louisiana. The objectives of this study were to use the MEPDG design software (version 1.1) to evaluate the performance of typical Louisiana flexible pavement types, materials, and structures as compared with the pavement performance data from the pavement management system (PMS) and identify the areas for further local calibration of the MEPDG in Louisiana. In this study, a total of 40 asphalt concrete (AC) pavement projects were strategically selected throughout Louisiana with different design traffic and subgrade properties. The selected projects included five typical Louisiana flexible pavement structure types: AC over AC base, AC over rubblized Portland cement concrete (RPCC) base, AC over crushed stone, AC over soil cement base, and AC over stone interlayer pavements. The original pavement structural design information as well as network-level PMS data for the selected projects were retrieved from multiple LADOTD data sources, including the Louisiana pavement management system (LA-PMS) and other project tracking databases. Based on the sensitivity analyses and available pavement design information, a set of Louisiana-condition-based design inputs (i.e., materials, climate, and traffic inputs) for the MEPDG flexible pavement design was developed, and the results were stored in a database named LA-MEPDG along with the pavement performance data retrieved from the LA-PMS for all the projects evaluated in this study. The comparison results between the MEPDG-predicted and the LA-PMS-measured distresses indicated that the MEPDG rutting model tended to over-predict the total rutting for AC over RPCC base, AC over crushed stone, and AC over soil cement base pavements in Louisiana. However, it seemed to be adequate for those AC over AC base pavements selected. Meanwhile, the MEPDG load-related fatigue cracking models were found to be adequate for Louisiana's AC over AC base, AC over RPCC base, and AC over crushed stone pavements. However, for AC over soil cement base pavements in Louisiana, the MEPDG-predicted fatigue cracking was considerably less than the wheel-path cracking reported in the LA-PMS. Further statistical analyses generally indicated that the MEPDG prediction errors for both the rutting and the load-related fatigue cracking models could be significantly influenced by different design factors, such as pavement type, traffic volume, subgrade modulus, and project location. Finally, based on the available data, a preliminary local calibration of the MEPDG rutting model was conducted for the selected AC over RPCC base and AC over soil cement base pavements, respectively. A set of local calibration factors was proposed for different pavement materials. On the other hand, further local calibration of the MEPDG fatigue cracking models was recommended before using the MEPDG for the AC over soil cement based pavement design in Louisiana.

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Finally, based on the available data, a preliminary local calibration of the MEPDG rutting model was conducted for the selected AC over RPCC base and AC over soil cement base pavements, respectively. A set of local calibration factors was proposed for different pavement materials. On the other hand, further local calibration of the MEPDG fatigue cracking models was recommended before using the MEPDG for the AC over soil cement based pavement design in Louisiana.

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IMPLEMENTATION STATEMENT

This study provides a pilot evaluation of the current version MEPDG software (Version 1.1) based on performance of typical flexible pavement structures in Louisiana. The outcomes from this study provide valuable information for pavement design engineers when using the newly released DARWin-ME software. Some of the MEPDG input data developed in this study, such as the E* master curves for typical Louisiana hot mix asphalt (HMA) mixtures and the local rutting calibration factors, can be used directly by the Department as initial input trials when implementing the DARWin-ME.

It is realized that this research work is based on the data currently available within the Department and some of the data may have deficiencies for model calibration purposes. Also, some of the models in the current version MEPDG software need to be recalibrated nationwide as indicated by other research work and also confirmed by this research study. Therefore, the current version MEPDG software should be used only as a design comparison tool to LADOTD's currently used pavement design method (DARWin 3.1) until further improvement is made on the software models and input data, as the result of the completion of on-going research both nationally and by LTRC. Careful engineering judgment is needed when large discrepancies exist in the design thickness results from the current version MEPDG and the DARWin 3.1 design method.

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Problem Statement

LADOTD is currently using the 1993 AASHTO Pavement Design Guide. This design guide was developed based on the AASHO Road Test completed in 1960. Due to its empirical characteristics as well as other limitations, the 1993 design guide cannot account for the rapidly developing pavement structure and traffic conditions today. The new MEPDG developed under the NCHRP Project 1-37A represents a major change as compared to the 1993 design guide. The MEPDG provides a rational framework to consider the impact of traffic, climate, and material properties on pavement performance. It is expected to replace the 1993 pavement design in the near future. LADOTD is currently following the national trend in the implementation of the MEPDG.

The successful use of the MEPDG in Louisiana requires evaluation and, if necessary, calibration of the design model against local conditions. Ideally, the Long-Term Pavement Performance (LTPP) database should be used in the local evaluation and calibration because it has project-level information on pavement performance, traffic, and material properties. Unfortunately, Louisiana has very few LTPP sites and none of them was included in the national calibration. An alternative data source for the local evaluation and calibration of the MEPDG is the network-level pavement performance data stored in the Louisiana Pavement Management System (LA-PMS). Some of the MEPDG input information about traffic, pavement structure, and material are available in other LADOTD databases (e.g., Content Manager, Mainframe, etc.). LTRC has recently sponsored several completed and on-going research projects to investigate the typical traffic and materials characteristics in Louisiana. Some of the results from these studies can fill the gap between the available information and the required input information by the MEPDG.

In this study, the network-level information available from the LA-PMS and other sources (LTRC studies, LADOTD databases, etc.) were used to evaluate the new MEPDG for local implementation in Louisiana.

Introduction of the MEPDG

Development of the MEPDG

The 1972, 1986, and 1993 versions of *AASHTO Guide for Design of Pavement Structures* are based on empirical performance equations developed using 1960s' AASHO Road Test data. The 1986 and 1993 AASHTO design guides contain some refinements in material input, design reliability, and empirical procedures for rehabilitation design. The NCHRP Project 1-

37A was sponsored by the AASHTO Joint Task Force on Pavements, NCHRP, and the Federal Highway Administration (FHWA) to develop a mechanistic-empirical pavement design procedure. The MEPDG was released to the public for review and evaluation in 2004. A formal review of the MEPDG was conducted under NCHRP Project 1-40A. The Project 1-40D resulted in version 1.0 of the MEPDG software and an updated design guide document. The version 1.0 of the software was submitted to the NCHRP, FHWA, and AASHTO in April 2007 for further consideration as an AASHTO provisional standard. To the date of this report, the current version of the MEPDG design software is version 1.1.

Approach of the MEPDG

Pavement design using the MEPDG is an iterative process – the outputs of the design are pavement distresses and smoothness, not layer thicknesses. The design approach consists of three major stages, as shown in Figure 1.

Stage 1 consists of the development of input values for the analysis. During this stage, potential strategies are identified for consideration in the analysis stage. A key step of this process is the foundation analysis. The pavement material characterization and traffic input data are developed as well. The Enhanced Integrated Climate Model (EICM) is used to model temperatures and moistures within each pavement layer and the subgrade. Stage 2 of the design process is the structural/performance analysis. The analysis approach is an iterative one that begins with the selection of an initial trial design. If the trial design does not meet the performance criteria, modifications have to be made and the analyses are re-run until a satisfactory result is obtained. Stage 3 of the process includes activities required to evaluate the structurally viable alternatives. These activities include the engineering analysis and the life cycle cost analysis of the design alternatives.

One of the fundamental differences between the 1993 AASHTO guide and the MEPDG is that the 1993 AASHTO guide only evaluates one performance indicator (Pavement Service Index, PSI) while the MEPDG predicts multiple performance indicators and provides a direct tie among materials, structural design, construction, climate, traffic, and pavement management systems.

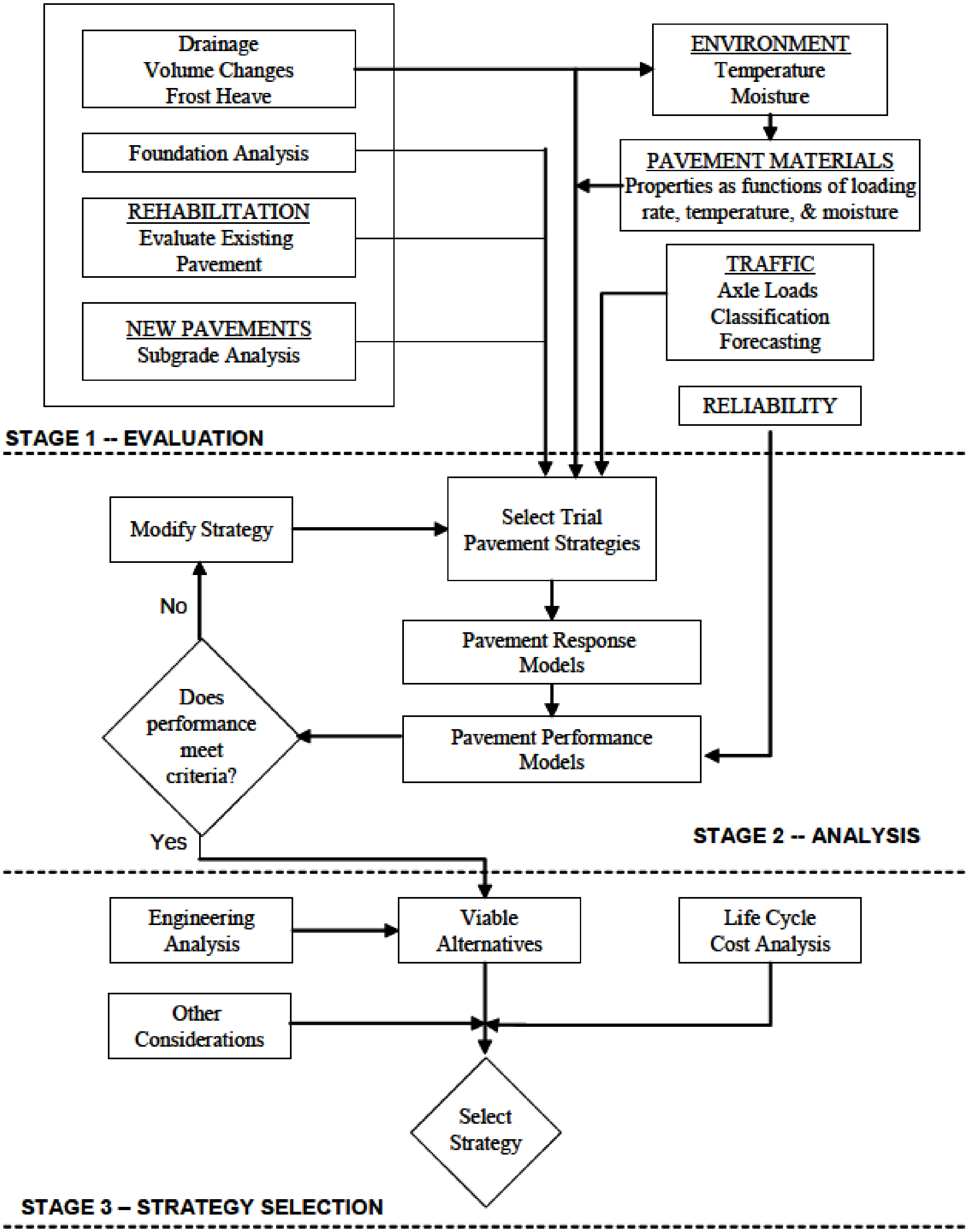


Figure 1
Conceptual schematic of the three-stage design process in the MEPDG ***[1]***

Hierarchical Design Inputs

The hierarchical approach to design inputs is a unique feature of the MEPDG. This approach is employed with regard to traffic, materials, and environmental inputs. Level-1 inputs provide the highest level of accuracy. It would typically be used for designing heavily trafficked pavements or wherever there is dire safety or economic consequences of early failure. Level-1 inputs require laboratory/field testing, site-specific axle load spectra data collection, and nondestructive deflection testing. Level-2 inputs provide an intermediate level of accuracy and would be closest to the typical procedure used with earlier editions of the AASHTO design guide. This level could be used when resources or testing equipments are not available for tests required for Level-1. Level-3 inputs provide the lowest level of accuracy. This level might be used for design where there are minimal consequences of early failure (e.g., lower volume roads). Inputs may be user-selected values or typical average for the region.

HMA-surfaced Pavements in the MEPDG *[1]*

In the MEPDG, the HMA-surfaced pavement types include: conventional flexible pavements, deep strength flexible pavements, full-depth HMA pavements, semi-rigid pavements, full depth reclamation (in-place pulverization of conventional flexible pavements), and HMA overlays.

Performance indicators and the corresponding transfer functions for HMA-surfaced pavements are introduced as follows:

Load-related Fatigue Cracking. Load-related fatigue cracking is the cracking in the AC layer that is caused by the repeated traffic load. In the MEPDG, two types of load-related fatigue cracking are predicted for flexible pavements: bottom-up cracking (sometimes also referred as alligator cracking) and top-down cracking. The allowable number of axle-load applications needed for the incremental damage index approach to predict both types of load-related fatigue cracking is:

$$N_{f-HMA} = k_{f1}(C)(C_H)\beta_{f1}(\varepsilon_t)^{k_{f2}\beta_{f2}}(E_{HMA})^{k_{f3}\beta_{f3}} \quad (1)$$

where,

N_{f-HMA} = Allowable number of axle-load applications for a flexible pavement and HMA overlays;

ε_t = Tensile strain at critical locations and calculated by the structural response model, in./in.;

E_{HMA} = Dynamic modulus of the HMA measured in compression, psi;

$k_{f1,f2,f3}$ = Global field calibration parameters (k_{f1} = 0.007566, k_{f2} = -3.9492, k_{f3} = -1.281);

$\beta_{f1,f2,f3}$ = Local or mixture specific field calibration constants; for the global calibration effort, these constants were set to 1.0;

C = 10^{M}

$$M = 4.84\left(\frac{V_{be}}{V_a + V_{be}} - 0.69\right)$$

V_{be} = Effective asphalt content by volume, percent;

V_a = Percent of air voids in the HMA mixture; and

C_H = Thickness correction term, dependent on type of cracking.

For bottom-up cracking:

$$C_H = \frac{1}{0.000398 + \frac{0.003602}{1 + e^{(11.02 - 3.49 H_{HMA})}}}$$

For top-down cracking:

$$C_H = \frac{1}{0.01 + \frac{12}{1 + e^{(15.676 - 2.8186 H_{HMA})}}}$$

H_{HMA} = Thickness of HMA layer

The MEPDG calculates the amount of fatigue cracking of each type by the cumulative damage index DI. The cumulative damage index is determined by summing up the incremental damage indices over time, as shown in Equation (2).

$$DI = \sum (\Delta DI)_{j,m,l,p,T} = \sum \left(\frac{n}{N_f}\right)_{j,m,l,p,T} \quad (2)$$

where,

n = Actual number of axle load applications within a specific time period;

j = Axle load interval;

m = Axle load type (single, tandem, tridem, quad, or special axle configuration);

l = Truck type using the truck classification groups included in the MEPDG;

p = Month; and

T = Median temperature for the five temperature intervals or quintiles used to subdivide each month.

Bottom-up cracking is the fatigue cracking that initiates from the bottom of the of the HMA layer. It starts as a few short longitudinal or transverse cracks in the early stage and will develop into interconnected cracks with a chicken wire/alligator pattern. The unit for alligator cracking in the MEPDG is the percentage of total lane area.

The transfer function for bottom-up alligator cracking in the MEPDG is:

$$FC_{Bottom} = \left(\frac{1}{60}\right)\left(\frac{C_4}{1 + e^{\left(C_1 C_1^* + C_2 C_2^* Log\left(DI_{bottom} * 100\right)\right)}}\right) \tag{3}$$

where,

FC_{Bottom} = area of alligator cracking, percentage of total lane area;
DI_{bottom} = cumulative damage index of alligator cracking;
$C_{1,2,4}$ = transfer function regression constants, C_1 = 1.00, C_2 = 1.00, C_4 = 6,000,
C_1^* = $-2C_2^*$; and
C_2^* = $-2.40874 - 39.748(1 + H_{HMA})^{-2.856}$.

Top-down cracking is another form of fatigue cracking that initiates at the surface of the HMA layer. It is often parallel to the pavement longitudinal centerline and does not develop into an alligator pattern. The unit for top-down cracking in the MEPDG is feet per mile.

The transfer function for top-down cracking in the MEPDG is:

$$FC_{Top} = 10.56\left(\frac{C_4}{1 + e^{\left(C_1 - C_2 Log\left(DI_{Top}\right)\right)}}\right) \tag{4}$$

where,

FC_{Top} = length of longitudinal cracking, ft./mi.;
DI_{top} = cumulative damage index of longitudinal cracking; and
$C_{1,2,4}$ = transfer function regression constants, C_1 = 7.0, C_2 = 3.5, C_4 = 1,000.

Transverse Cracking (Thermal Cracking). Transverse cracking is a non-load-related cracking, which is usually caused by low temperature or thermal cycling. The unit for transverse cracking in the MEPDG is feet per mile.

The transfer function for transverse cracking in the MEPDG is:

$$TC = \beta_{t1} N\left[\frac{1}{\sigma_d}\left(\frac{C_d}{H_{HMA}}\right)\right] \tag{5}$$

where,

TC = amount of thermal cracking, ft./mi.;
β_{t1} = regression coefficient determined through global calibration (= 400);
N = 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_{HMA} = thickness of HMA layers.

Rutting (Rut Depth). Rutting is caused by permanent deformation developed in different pavement layers. Rut depth is defined as the maximum difference in elevation between the transverse profile of the HMA surface and a wire-line across the lane width. The unit for rut depth in the MEDPG is inches.

The transfer function for the AC layer is:

$$\Delta_{p(HMA)} = \varepsilon_{p(HMA)} h_{(HMA)} = \beta_{1r} k_z \varepsilon_{r(HMA)} 10^{k_{1r}} N^{k_{2r} * \beta_{2r}} T^{k_{3r} * \beta_{3r}} h_{(HMA)} \qquad (6)$$

where,

$\Delta_{p(HMA)}$ = accumulated permanent or plastic vertical deformation in the HMA layer/sublayer, in.;
$\varepsilon_{p(HMA)}$ = accumulated permanent or plastic axial strain in the HMA layer/sublayer, in./in.;
$\varepsilon_{r(HMA)}$ = Resilient or elastic strain calculated by the structural response model at the mid-depth of each HMA sublayer, in./in.;
$h_{(HMA)}$ = Thickness of the HMA layer/sublayer, in.;
N = Number of axle-load repetitions;
T = Mix or pavement temperature, °F;
k_z = Depth confinement factor;
$k_z = (C_1 + C_2 D) 0.328196^D$;
$C_1 = -0.1039(H_{HMA})^2 + 2.4868 H_{HMA} - 17.342$;
$C_2 = -0.0172(H_{HMA})^2 - 1.7331 H_{HMA} + 27.428$;
D = depth below the surface, in.;
H_{HMA} = Total HMA thickness, in.;
$k_{1r,2r,3r}$ = Global field calibration constants (k_{1r} = -3.35412, k_{2r} = 0.4791, k_{3r} = 1.5606); and

$\beta_{1r,2r,3r}$ = Local or mixture field calibration constants; for the global calibration, these constants were all set to 1.0.

The transfer function for rutting of the unbound layers is:

$$\Delta_{p(soil)} = \beta_{s1} k_{s1} \varepsilon_v h_{soil} \left(\frac{\varepsilon_0}{\varepsilon_r}\right) e^{-\left(\frac{\rho}{N}\right)^{\beta}} \tag{7}$$

where,

$\Delta_{p(soil)}$ = Permanent or plastic deformation for the layer/sublayer, in.;
N = Number of axle-load repetitions;
ε_0 = Intercept determined from laboratory repeated load permanent deformation tests, in./in.;
ε_r = Resilient strain imposed in laboratory test to obtain material properties ε_0, β and ρ, in./in.;
ε_v = Average vertical resilient or elastic strain in the layer/sublayer and calculated by the structural response model, in./in.;
h_{soil} = Thickness of the unbound layer/sublayer, in.;
k_{s1} = Global calibration coefficients; k_{s1} = 1.673 for granular materials and 1.35 for fine-grained materials;
β_{s1} = Local calibration constant for the rutting in the unbound layers; the local calibration constant was set to 1.0 for the global calibration effort;
$\log \beta$ = $-0.61119 - 0.017638W_c$;
$W_c =$ water content, percentage; and
ρ = $10^9 \left[\frac{4.89285}{1-(10^9)^{\beta}}\right]^{\frac{1}{\beta}}$.

Smoothness. International Roughness Index (IRI) is used to define the pavement smoothness in the MEPDG. The unit for IRI is in./mi. In the MEPDG, IRI is calculated based on an empirical function of other pavement distresses. The equation for calculating IRI in new flexible pavements is:

$$IRI = IRI_0 + 0.015(SF) + 0.400(FC_{Total}) + 0.0080(TC) + 40.0(RD) \tag{8}$$

where,

IRI_0 = initial IRI after construction, in./mi.;
SF = site factor;

$$SF = Age\big(0.02003(PI + 1) + 0.007947(Precip + 1) + 0.000636(FI + 1)\big)$$

Age = pavement age, years,
PI = plastic index of the soil,
FI = average annual freezing index, degree F-days, and
$Precip$ = average annual precipitation or rainfall, in.

FC_{Total} = area of fatigue cracking (combined alligator, longitudinal, and reflection cracking in the wheel path), percent of total lane area, (longitudinal cracking is multiplied by 1-ft. to convert to an area basis);
TC = length of transverse cracking, ft./mi.; and
RD = average rut depth, in.

Literature Review

After first released in 2004, a large number of studies were conducted by state agencies on the local implementation of the MEPDG. Common investigation issues include: development of the local input strategy (traffic, materials, etc.), sensitivity of inputs, local evaluation and calibration, and comparison of the MEPDG with the previous design methods (e.g., 1993 design guide). Due to the limited scope of this study, a literature review was conducted with an emphasis on the local validation and calibration of the MEPDG.

AASHTO recently published a guideline on performing a local calibration of the MEPDG *[2]*. According to the guideline, three types of roadway segments can be used in the local validation and calibration: (1) long-term full-scale roadway segments (LTPP and PMS), (2) APT sections with simulated truck loadings, and (3) APT sections with full-scale truck loadings. Preferably, Long-term full-scale roadway segments should be used to fully validate and calibrate the distress prediction models in the MEPDG. APT sections can be used in local validation and calibration as a supplement to the LTPP or PMS data, but cannot be used alone to evaluate the error of the estimate. When using PMS segments, the AASHTO guideline recommends either performing pavement condition surveys according to *LTPP Distress Identification Manual* or, as many agencies may prefer, adjusting the PMS distress data to be consistent with the MEPDG distress definitions *[2]*.

Many states have sponsored studies on local validation and calibration of the MEPDG. In lieu of the LTPP sites, some states have used PMS data as a supplement. The methodologies and the key findings/experiences of these studies are summarized next.

Arizona *[3]*

Data collected from 39 LTPP segments were used in the local calibration of the MEPDG. Daily traffic and vehicle classification distribution were obtained from Arizona DOT PMS. Arizona default axle load spectra developed from previous studies were adopted. Level-3 materials inputs were used. Subgrade moduli obtained from a local empirical correlation were compared with the MEPDG default values. In analyzing the rutting model, the predicted percentages of total rutting contributed by each layer were used to distribute the total measured rutting to each layer. With the national calibration, the MEPDG under-predicted the AC and subgrade rutting but over-predicted the granular base rutting. Meanwhile, it was found that the MEPDG under-predicted the bottom-up cracking but over-predicted the top-down cracking.

Arkansas *[4], [5]*

Wang et al. developed a database to store and process climate, traffic, material, and performance data for supporting the MEPDG in the state of Arkansas *[4]*. The database contained five categories of data similar to the data types in the MEPDG software: general information, climate, traffic, materials, and performance. The climate hourly data for the climate module were from 16 weather stations in Arkansas and 22 weather stations in six bordering states from the National Climatic Data Center (NCDC). For water table depth data, 34,015 test points at 552 water table depth testing locations in all 75 counties in Arkansas were collected from the National Water Information System online database. For traffic data, there were 79 automated continuous traffic data collection sites in Arkansas, among which 55 data collection sites were based on Weigh-in-Motion (WIM). For the materials module, several research projects were conducted to determine the dynamic modulus (E^*) for asphalt concrete (AC), coefficient of thermal expansion (CTE) for Portland cement concrete (PCC), and resilient modulus (M_r) for unbound base, sub-base and subgrade. The LTPP database was one of data sources used as well.

Hall et al. reported a local validation and calibration study using 26 LTPP and PMS segments with flexible pavements *[5]*. Daily traffic volume information was available in the PMS. Site-specific vehicle classification distribution was available for some projects in the PMS; otherwise, the MPEDG default values were selected based on the truck traffic classification (TTC) of the roadway. Axle load spectra were adopted from a previous study. Level-3 materials inputs were used. The predicted and measured fatigue cracking showed a poor correlation. The MEPDG slightly over-predicted the subgrade rutting and under-predicted the AC rutting.

Iowa *[6]*

In this study, PMS data were used in the local validation of the MEPDG in Iowa. New flexible, new rigid, and overlaid pavement types were studied. Five PMS segments were selected for the new flexible pavement type. Only daily truck traffic information was available from the PMS. Other traffic inputs were either default values or the best estimated values. Typical materials properties in Iowa were adopted from previous studies. Pavement distress data were checked for irregularities. Only IRI and rutting models were validated for flexible pavement type. The results showed that the MEPDG slightly over-predicted the total rutting. The measured and predicted IRI were in good agreement.

Kansas *[2]*

This work was presented in the AASHTO local calibration guideline as a demonstration of using PMS data to validate and calibrate the MEPDG *[2]*. Sixteen PMS segments were used in the analysis. Default traffic inputs were used with the exception of operation speed, number of lanes, traffic growth, vehicle classification distribution, and average annual daily truck traffic (AADTT). Level-2 and Level-3, mostly Level-3, materials inputs were used since Level-1 materials inputs were unavailable in the PMS. The Kansas PMS does not distinguish between bottom-up and top-down cracking. The MEPDG predicted load-related fatigue cracking (bottom-up and top-down cracking) was combined to compare with the measured fatigue cracking in the PMS. Comparisons between the predicted and measured performance showed that the bias of the rutting model in the MEPDG seems acceptable for new flexible pavement, although the MEPDG over-predicted the rutting for HMA overlay pavements. Comparison also showed that the MEPDG consistently under-predicted the load-related fatigue cracking.

Michigan *[7]*

This study evaluated the feasibility of the MPEDG for local use in Michigan. Both flexible and rigid pavements were evaluated. For flexible pavements, a sensitivity analysis of inputs was first conducted. Eleven design and materials inputs were identified as having significant effects on the predicted pavement performance. Field performance of eight LTPP segments and five PMS segments were compared with the MEPDG-predicted performance. Traffic inputs associated with PMS segments were collected from the closest WIM station. Level-3 materials inputs were used and many materials properties were assumed or estimated. Comparisons from LTPP segments indicated that the MEPDG reasonably well predicted bottom-up and top-down cracking, and IRI. However, the MEPDG over-predicted transverse cracking and rutting. Comparisons from PMS segments showed some discrepancies. An irregular trend (distress reduced without any maintenance records) was found in the PMS data in some segments. The IRI model was not used since the initial IRI for the segments were not recorded.

Minnesota ***[8]***

A number of issues regarding the local implementation of the MEPDG in Minnesota were investigated, including sensitivity of inputs, run-time issues with the software, and local recalibration of the prediction models. A total of 13 MnROAD segments were used in the local validation of the MEPDG for flexible pavements. Traffic, pavement structure, and materials inputs were all from the MnROAD database. Previous trench tests revealed that rutting in MnROAD segments happened mostly in the AC layer. However, the MEPDG predicted considerable rutting in the unbound layers especially for the first month of pavement life. Researchers proposed to modify the MEPDG rutting model by subtracting the predicted rutting in the unbound layers in the first month. The modified rutting model showed an improved prediction power. Since no alligator cracking was observed from the selected segments, the alligator cracking model was calibrated against the MnPave software. The transverse cracking model in the MEPDG under-predicted the field transverse cracking for all segments.

Montana ***[9]***

This study was sponsored by Montana DOT to develop the local calibration factors for flexible pavements. A total of 89 LTPP and PMS segments from Montana and adjacent states were selected. A calibration database was created. Initial daily traffic volume was back-calculated from the measured traffic during the service life. Other traffic inputs were taken as either MEPDG default or Montana default values. The validation results showed that the MEPDG over-predicted the alligator cracking for new and in-place pulverized flexible pavements while it under-predicted the alligator cracking for HMA-overlay pavements. Poor correlation was found between the measured and predicted longitudinal top-down cracking although the bias was low. The MEPDG generally over-predicted the transverse cracking of flexible pavements in Montana.

New Jersey ***[10]***

Mehta et al. presented the implementation of the MEPDG using Level-3 inputs for the state of New Jersey *[10]*. The data were collected from LTPP, PaveView, and HPMA databases. A case-by-case comparison was conducted between predicted and measured performance data for every section and each distress, such as rutting, load-related fatigue cracking, transverse cracking, and roughness.

North Carolina *[11]*

In this study, pavement performance data from 30 LTPP segments and 23 PMS segments in North Carolina were used to validate and calibrate the MEPDG. These LTPP segments were not included in the national calibration. Only the alligator cracking model and the rutting model were studied. Traffic inputs for each segment were collected from nearby WIM stations. Structure and materials inputs were collected from the construction unit of NCDOT. In analyzing the rutting model, the predicted percentages of rutting from each layer were used to distribute the total measured rut depth to each layer. With the national calibration, the MEPDG over-predicted the total rutting and under-predicted the alligator cracking.

Ohio *[12]*

This study consists of an input sensitivity analysis and a validation of the MEPDG prediction models for both flexible and rigid pavements in Ohio. A total of 24 roadway segments at 3 LTPP sites with flexible pavements were used. Some traffic inputs (daily traffic volume, direction and lane distribution, and axle load spectrum, etc.) were available from the LTPP traffic module and the Ohio DOT traffic database. The MEPDG default values were used for other traffic inputs. Level-1 and Level-2 inputs were used for AC properties. Ohio typical resilient moduli for unbound base/subbase were adopted. Subgrade resilient moduli were from the LTPP database. The comparison result showed that the MEPDG over-predicted the total rutting. The transverse cracking model in the MEPDG seemed adequate for Ohio implementation. A poor correlation was found between the measured and predicted IRI.

Texas *[13], [14]*

Banerjee et al. reported an extensive local calibration effort that was undertaken to calibrate the permanent deformation performance model in the MEPDG for five different regions in Texas and for Texas in general (state defaults) *[13]*. This study focused on determining Level-2 and Level-3 calibration factors. To determine Level-2 calibration factors, a joint optimization approach was adopted by minimizing the sum of squared errors (SSE) between the predicted and observed distresses; while trying to calculate the Level-3 calibration parameter, an average of the Level-2 calibration coefficients was computed. The data used in the calibration process were obtained from the LTPP database.

Aguiar-Moya et al. developed the Texas Flexible Pavement Database to aid in pavement design through the development of new and the calibration of the MEPDG *[14]*. This database was primarily based on FHWA’s LTPP database and had been upgraded with local traffic data. It was divided into four main modules: structure and materials, traffic, environment, and performance. The structure and materials module included information on pavement structure, specific layer properties, and characterization of the materials that constituted each layer. The traffic module contained indicators of traffic volume and traffic loads. The environment module contained information pertaining to temperature, precipitation, and other climatic factors considered important for flexible pavement design and performance. The performance module incorporated typical asphalt pavement performance measurements that included rutting, roughness, and cracking.

Virginia *[15]*

Flintsch et al. presented the results of dynamic modulus, creep compliance, and tensile strength of 11 HMA mixtures (4 base, 4 intermediate, and 3 surface mixtures) collected from different plants across Virginia *[15]*. They found that the MEPDG Level-2 dynamic modulus prediction equation reasonably estimated the measured dynamic modulus.

Washington *[16]*

In this study, two PMS segments were used to validate the MEPDG prediction models in Washington. Washington default axle load spectra were developed based on 38 WIM stations. Vehicle classification distribution and growth factors were available from the Washington DOT database. Materials inputs were collected from the PMS, construction standards, the local standard practice, as well as the MEPDG default values. Comparisons showed that the alligator cracking and transverse cracking models worked well. When all rutting was assumed to be developed in the AC layer, the MEPDG under-predicted the measured rutting in the PMS. The IRI model in the MEPDG showed a slight under-prediction.

Wisconsin *[17]*

Kang and Adams calibrated the MEPDG fatigue damage model for predicting the top-down cracking in flexible pavements in Wisconsin based on the data from WisDOT’s Pavement Information Files (PIF) database *[17]*. Representative sections were selected considering three criteria: sections with severe distresses, sections with no rehabilitation and overlay, and sections more than five years old.

Summary

With a lack of LTPP sites, many states used PMS data in the local validation and calibration of the MEPDG. However, traffic and materials inputs required by the MEPDG are not always available in the PMS, even at Level-3. Local default or best estimated input values were often used to represent the characteristics of the local traffic and materials conditions.

Most DOTs’ databases are maintained for the purpose of network level optimization of resources or monitoring the existing network. These databases are usually integral components of the PMS. However, most PMS databases are not well suited for the local validation and calibration of the MEPDG. Some states created new databases designed especially for the local validation and calibration of the MEPDG.

The climate condition, traffic level, and pavement structure differ significantly among each state. Therefore the conclusions drawn from the studies are also different from each other. The MEPDG may show different prediction trends on different pavement structure types even within one state.

It is commonly found that the MEPDG over-predicts the total rutting. It is difficult to tell in which layer(s) the permanent deformation is over-estimated because the permanent deformation in an individual layer is rarely measured. Many states attributed this phenomenon to an over-estimation of deformation in unbound layers. A study in Minnesota further pointed out that the predicted deformation in the unbound layers developed in the first month was unreasonably high.

Many studies found a poor prediction power and a high standard error inherent to the top-down cracking model. It is indicated that the top-down cracking model will be revised in the later version of the MEPDG design software.

Run-time issues with the design software were also identified. Li, et al. found that the IRI model cannot be calibrated due to a software bug in version 1.0 *[16]*. A number of issues of the software in analyzing semi-rigid pavements were pointed out by a study in Minnesota. For example, the fatigue cracking model for cement treated layer and the reflective cracking model in new flexible pavements were found to be implemented by the software improperly.

Louisiana Pavement Management System

LADOTD began collecting pavement distress data by windshield surveys in the early 1970s. Since 1995, LADOTD has used the Automatic Road Analyzer (ARAN) to conduct network-level pavement condition surveys. Pavement distress data collected for flexible pavements include rutting, IRI, alligator cracking, longitudinal cracking, transverse cracking, and block cracking. The sum of longitudinal cracking and transverse cracking are also called random cracking.

Louisiana network-level pavement condition survey is conducted once every two years, and the data are stored in the LA-PMS. The mean and the standard deviation of the IRI and rutting measurements are calculated and reported in every 0.1-mi. subsection. The length (or area) of cracking is summed up and reported in every 0.1 mi.

It should be noted that the definitions of cracking in the LA-PMS and the MEPDG are different (Figure 2). The LA-PMS does not differentiate top-down and bottom-up load-related fatigue cracking. All the cracks in the wheel paths are combined and reported as "alligator cracking," in square feet. The longitudinal cracking in the LA-PMS is actually the non-load-related cracking in longitudinal direction outside the wheel path. The term "block cracking" is not used in the MEPDG. In the LA-PMS, block cracking is used to report the interconnected longitudinal and transverse cracking that form a distressed area and are hard to quantify the amount of each type of cracking.

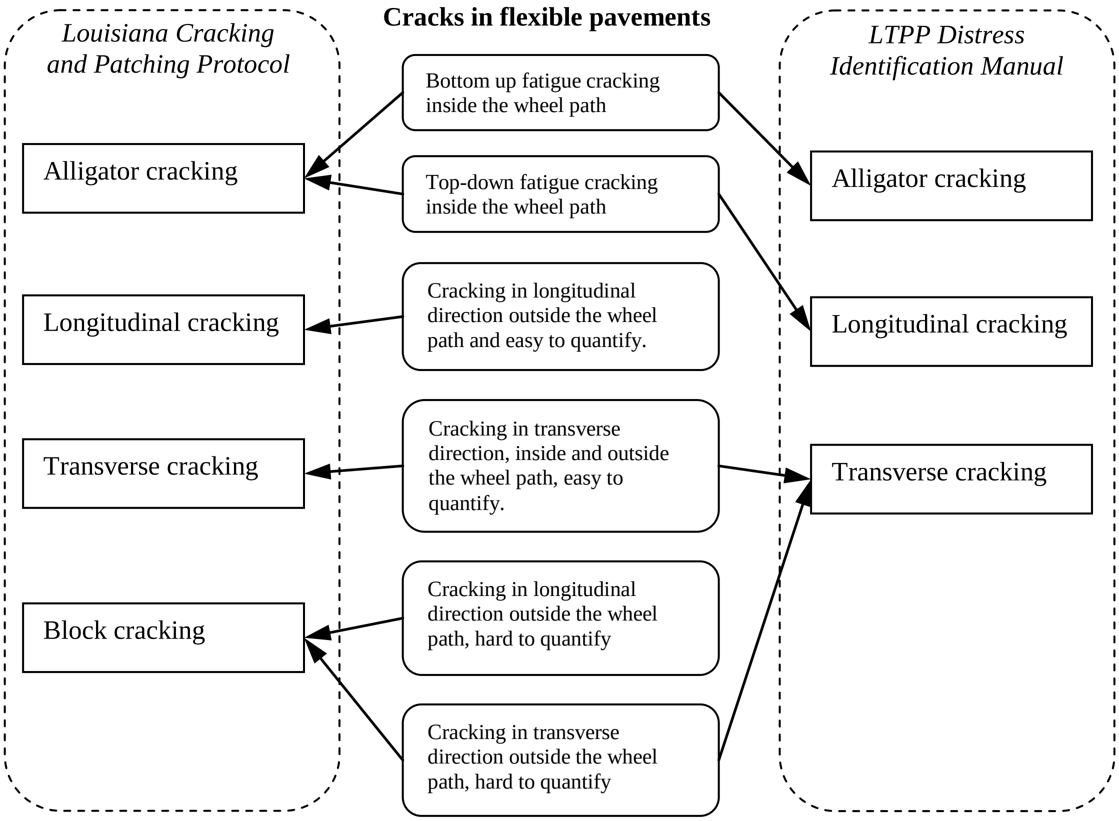
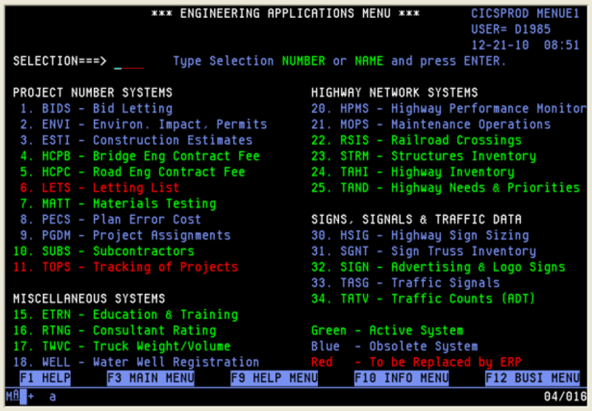


Figure 2
Different definitions in cracking between the LA-PMS and the LTPP

Other LADOTD Databases

LADOTD stores project, traffic, and materials information in isolated databases. These databases are maintained and used by different sections. Sometimes different databases may contain duplicated or even conflicted data. All the databases related to this study can be accessed using the LADOTD Mainframe system (as shown in Figure 3). The Mainframe system is a menu driven system that allows users to access and, for authorized users, to update a number of databases through the LADOTD network.



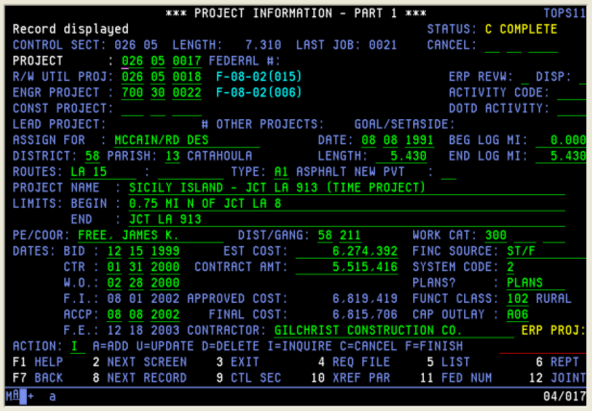
```
                    *** ENGINEERING APPLICATIONS MENU ***        CICSPROD MENUE1
                                                                 USER= D1985
                                                                 12-21-10  08:51
SELECTION===> ___     Type Selection NUMBER or NAME and press ENTER.

PROJECT NUMBER SYSTEMS                    HIGHWAY NETWORK SYSTEMS
 1. BIDS - Bid Letting                    20. HPMS - Highway Performance Monitor
 2. ENVI - Environ. Impact. Permits       21. MOPS - Maintenance Operations
 3. ESTI - Construction Estimates         22. RSIS - Railroad Crossings
 4. HCPB - Bridge Eng Contract Fee        23. STRM - Structures Inventory
 5. HCPC - Road Eng Contract Fee          24. TAHI - Highway Inventory
 6. LETS - Letting List                   25. TAND - Highway Needs & Priorities
 7. MATT - Materials Testing
 8. PECS - Plan Error Cost                SIGNS, SIGNALS & TRAFFIC DATA
 9. PGDM - Project Assignments            30. HSIG - Highway Sign Sizing
10. SUBS - Subcontractors                 31. SGNT - Sign Truss Inventory
11. TOPS - Tracking of Projects           32. SIGN - Advertising & Logo Signs
                                          33. TASG - Traffic Signals
MISCELLANEOUS SYSTEMS                     34. TATV - Traffic Counts (ADT)
15. ETRN - Education & Training
16. RTNG - Consultant Rating              Green - Active System
17. TWVC - Truck Weight/Volume            Blue  - Obsolete System
18. WELL - Water Well Registration        Red   - To be Replaced by ERP
  F1 HELP     F3 MAIN MENU     F9 HELP MENU     F10 INFO MENU     F12 BUSI MENU
MA + a                                                                   04/016
```

Figure 3
Engineering applications menu in the Mainframe

Tracking of Projects (TOPS)

The TOPS database (Figure 4) in the Mainframe system contains general information for all LADOTD projects from the time they are assigned through completion. Information provided includes project name, location, important dates, status, work type, cost, etc.



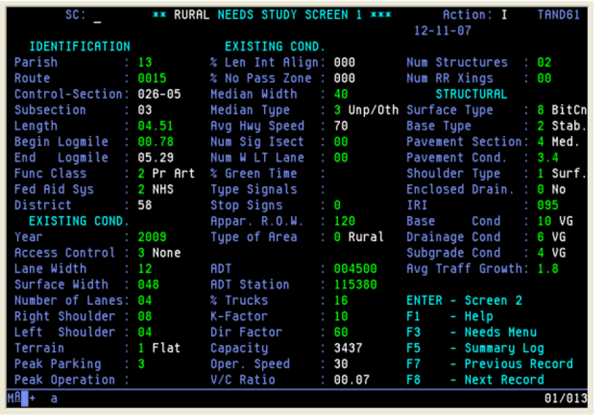
```
                    *** PROJECT INFORMATION - PART 1 ***                  TOPS11
Record displayed                                        STATUS: C COMPLETE
CONTROL SECT: 026 05  LENGTH:   7.310  LAST JOB: 0021   CANCEL: __ __ ____
PROJECT      : 026 05 0017 FEDERAL #:
R/W UTIL PROJ: 026 05 0018  F-08-02(015)                   ERP REVW: _ DISP: _
ENGR PROJECT : 700 30 0022  F-08-02(006)                   ACTIVITY CODE: ____
CONST PROJECT: ___ __ ____                                 DOTD ACTIVITY: ____
LEAD PROJECT:            # OTHER PROJECTS:    GOAL/SETASIDE:
ASSIGN FOR  : MCCAIN/RD DES              DATE: 08 08 1991  BEG LOG MI:   0.000
DISTRICT: 58 PARISH: 13 CATAHOULA        LENGTH:   5.430   END LOG MI:   5.430
ROUTES: LA 15     :          TYPE: A1 ASPHALT NEW PVT   : __
PROJECT NAME  : SICILY ISLAND - JCT LA 913 (TIME PROJECT)
LIMITS: BEGIN : 0.75 MI N OF JCT LA 8
        END   : JCT LA 913
PE/COOR: FREE, JAMES K.        DIST/GANG: 58 211        WORK CAT: 300
DATES: BID : 12 15 1999       EST COST:      6,274,392  FINC SOURCE: ST/F
       CTR : 01 31 2000  CONTRACT AMT:       5,515,416  SYSTEM CODE: 2
       W.O.: 02 28 2000                                 PLANS?     : PLANS
       F.I.: 08 01 2002 APPROVED COST:       6,819,419  FUNCT CLASS: 102 RURAL
       ACCP: 08 08 2002    FINAL COST:       6,815,706  CAP OUTLAY : A06
       F.E.: 12 18 2003 CONTRACTOR: GILCHRIST CONSTRUCTION CO.        ERP PROJ:
ACTION: I  A=ADD U=UPDATE D=DELETE I=INQUIRE C=CANCEL F=FINISH
F1 HELP     2 NEXT SCREEN     3 EXIT      4 REQ FILE     5 LIST         6 REPT
F7 BACK     8 NEXT RECORD     9 CTL SEC  10 XREF PAR    11 FED NUM     12 JOINT
MA + a                                                                   04/017
```

Figure 4
TOPS database in the Mainframe

In the TOPS database, Each LADOTD project is identified by its unique nine-digit project number (e.g., 000-00-0000). The first five digits identify the control section. The last four-digit job number identifies the project in this control section.

Highway Need System (TAND)

The TAND database (Figure 5) in the Mainframe system is used by LADOTD Highway Needs Section for planning purposes. It contains the current conditions (e.g., traffic, geometry, structural, etc.) of each control section or subsection.



```
       SC: _       ** RURAL NEEDS STUDY SCREEN 1 ***       Action: I    TAND61
                                                       12-11-07
  IDENTIFICATION             EXISTING COND.
Parish         : 13        % Len Int Align: 000       Num Structures  : 02
Route          : 0015      % No Pass Zone : 000       Num RR Xings    : 00
Control-Section: 026-05    Median Width   : 40            STRUCTURAL
Subsection     : 03        Median Type    : 3 Unp/Oth Surface Type    : 8 BitCn
Length         : 04.51     Avg Hwy Speed  : 70        Base Type       : 2 Stab.
Begin Logmile  : 00.78     Num Sig Isect  : 00        Pavement Section: 4 Med.
End   Logmile  : 05.29     Num W LT Lane  : 00        Pavement Cond.  : 3.4
Func Class     : 2 Pr Art  % Green Time   :           Shoulder Type   : 1 Surf.
Fed Aid Sys    : 2 NHS     Type Signals   :           Enclosed Drain. : 0 No
District       : 58        Stop Signs     : 0         IRI             : 095
  EXISTING COND.           Appar. R.O.W.  : 120       Base     Cond   : 10 VG
Year           : 2009      Type of Area   : 0 Rural   Drainage Cond   : 6 VG
Access Control : 3 None                               Subgrade Cond   : 4 VG
Lane Width     : 12        ADT            : 004500    Avg Traff Growth: 1.8
Surface Width  : 048       ADT Station    : 115380
Number of Lanes: 04        % Trucks       : 16        ENTER - Screen 2
Right Shoulder : 08        K-Factor       : 10        F1    - Help
Left  Shoulder : 04        Dir Factor     : 60        F3    - Needs Menu
Terrain        : 1 Flat    Capacity       : 3437      F5    - Summary Log
Peak Parking   : 3         Oper. Speed    : 30        F7    - Previous Record
Peak Operation :           V/C Ratio      : 00.07     F8    - Next Record
MA + a                                                                   01/013
```

Figure 5
TAND database in the Mainframe

Materials Testing System (MATT)

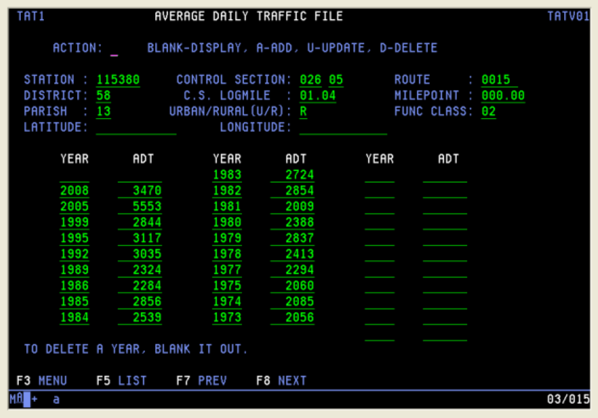
The MATT database (Figure 6) in the Mainframe system stores materials information for each LADOTD project. AC information is provided in great detail, including mix design, plant test results, and construction verification test results for each lot of AC material. Subgrade soil properties are also provided, including the soil classification, Atterberg limits, sieve analysis, moisture-density property, etc., of each soil sample. However, MATT does not provide materials information regarding base/subbase materials.

```
                   *** MATERIAL TESTING SYSTEM MENU ***   User= D1985    MATT81
USER UNKNOWN TO MATT--INQUIRY ONLY ALLOWED
 Selection No ==> __       Metric/English: _      Project No: ________________
                                               Material Code: ___
                                Lab, Lot, or Section/Test No: ________
    Test Files                                            Reports
 01 Accept Measure TR 602     17 Structural Concrete   60 Display Log
 02 Aggregate                 18 Superpave Roadway     61 Display Exception
 03 Asph Conc Pavement           Jobmix                62 Print Log/Except
 04 Asph Conc Plant           30 PCC                   63 Report Request
 05 Asph Conc Verif           31 Hotmix
 06 Asphalt Cement                                        Submitter: ____
 07 Density Moisture             Name Files               District : __
 08 Liquid Asphalt            40 Source                   Printer  : ____
 09 Miscellaneous             41 Contractor
 10 Paving Conc(Cores)        42 Submitter                Other
 11 PCC Pvmt Surf Tol                                  70 Section 22 Functions
 12 Portland Cement              Project               71 Mat Code Descriptions
 14 Soils/Soil-Aggregate      50 Project Info
 15 Steel Bar                 51 Roadway Xsect
 16 Steel Wire                52 Check Metric/English
                              53 Estimates Item List
Latest News 03-23-07  Matt Reports now available in PDF format
 F1 Help  2 News  3 Engr Menu  Type Number of Selection, Enter Pertinent Fields
MA + a                                                                   03/020
```

Figure 6
MATT database in the Mainframe

Traffic Counts ADT (TATV)

The TATV database (Figure 7) in the Mainframe system contains the ADT data from each traffic count station. ADT data are collected every approximately three years at each station.



```
TAT1                  AVERAGE DAILY TRAFFIC FILE                          TATV01

     ACTION: _     BLANK-DISPLAY, A-ADD, U-UPDATE, D-DELETE

  STATION : 115380     CONTROL SECTION: 026 05       ROUTE     : 0015
  DISTRICT: 58          C.S. LOGMILE  : 01.04        MILEPOINT : 000.00
  PARISH  : 13         URBAN/RURAL(U/R): R           FUNC CLASS: 02
  LATITUDE: ___________       LONGITUDE: ____________

       YEAR      ADT        YEAR      ADT          YEAR      ADT
                            1983      2724
       2008      3470       1982      2854
       2005      5553       1981      2009
       1999      2844       1980      2388
       1995      3117       1979      2837
       1992      3035       1978      2413
       1989      2324       1977      2294
       1986      2284       1975      2060
       1985      2856       1974      2085
       1984      2539       1973      2056

  TO DELETE A YEAR, BLANK IT OUT.

 F3 MENU    F5 LIST    F7 PREV    F8 NEXT
MA + a                                                                    03/015
```

Figure 7
TATV database in the Mainframe

Content Manager

The Content Manager is an electronic document management system that is used by LADOTD to store archive documents related to each project. The original plan file, pavement design (by DARWin 3.1) sheet of typical pavement section, and traffic assignment document can be found in this database.

OBJECTIVE

The objectives of this study were to use the MEPDG software (version 1.1) to evaluate the performance of typical Louisiana flexible pavement types, materials, and structures as compared with LA-PMS pavement performance data and identify the areas for further local calibration of the MEPDG in Louisiana.

SCOPE

In this study, the MEPDG pavement performance models were validated against the LA-PMS pavement condition data. Only new and full-depth rehabilitated (with a reconstruction of the base) flexible pavements were investigated. The sensitivity of the MEPDG design model to the inputs were studied based on typical flexible pavement structures and materials used in Louisiana. In the validation process, the MEPDG input information was collected from the network-level project information stored in LADOTD databases. When network-level information was unavailable, Louisiana typical values were used for input parameters that have sensitive effects to the design model. For parameters that do not vary significantly or have less impact on the MEPDG design model, national default values were accepted.

METHODOLOGY

Step 1 – Identify Typical Flexible Pavement Structures in Louisiana

Pavement design plan files of Louisiana highway projects are stored in the LADOTD Content Manager database and the Intranet Plan Room. A preliminary exploration of the plan files was conducted on flexible pavements constructed between 1997 and 2005. For new and rehabilitated pavement projects that involved a reconstruction of base, five typical flexible pavement structures (as shown in Figure 8) were identified:

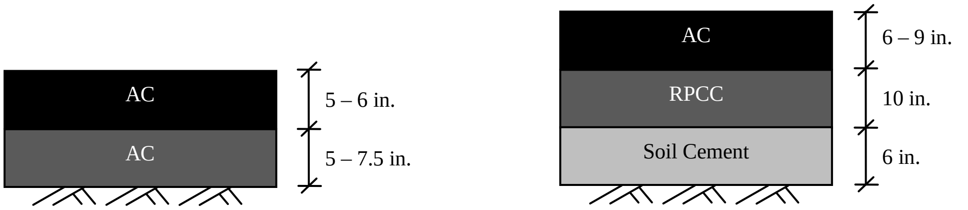
- AC over AC base pavement structure is often used in medium- and high-volume highways in Louisiana. This type of pavement structure typically consists of a 5~6 in. thick AC surface course (i.e., wearing course and binder course) over a 5~7.5 in. thick AC base course.

- AC over rubblized Portland cement concrete base pavement structure (referred as AC over RPCC base hereafter) is often used in rigid pavement rehabilitation projects on interstate highways. In these projects, the existing PCC (usually 10 in. thick) was rubblized and overlaid by a 6~9 in. thick AC.

- AC over crushed stone pavement structure (referred as AC over crushed stone hereafter) is sometimes used in medium- and low-volume highways in Louisiana. This type of pavement structure consists of a 3.5~6 in. thick AC on top of an 8.5~12 in. thick crushed stone or recycled PCC base course.

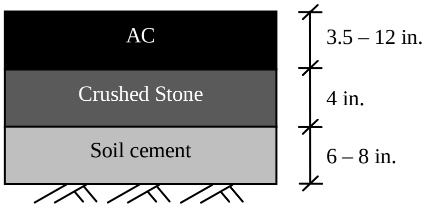
- AC over soil cement base pavement structure is commonly used in medium- to low-volume highways in Louisiana. This type of pavement structure consists of a 3.5~4.5 in. thick AC over an 8.5~12 in. thick base of cement stabilized/treated soil.

- AC over stone interlayer pavement structure was modified from AC over soil cement base pavement structure by introducing a 4 in. thick crushed stone base between the AC and the soil cement layers. The crushed stone interlayer helps to mitigate the reflective cracking from the soil cement layer.



(a) AC over AC base (b) AC over RPCC base

(c) AC over crushed stone (d) AC over soil cement base



(e) Interlayer

Figure 8
Typical flexible pavement structures in Louisiana

Projects were selected based on the information stored in the TOPS and the Content Manager databases. The criteria for the project selection are as follows:

- Flexible pavements
- New or full-depth rehabilitation projects that involved a reconstruction of base course
- At least five years of service life. If structural maintenance records (e.g., micro-surfacing, chip-seal, overlay, etc.) were found within the project segment, pavement condition data after the maintenance were excluded from the analysis.
- More than 0.5 mi. long

In addition, projects were also selected to represent the diversified conditions in Louisiana: (1) geographic location (i.e., north and south Louisiana); (2) traffic volume (i.e., high-, medium-, and low-volume roads); and (3) subgrade resilient modulus (i.e., stiff and soft subgrades). With these criteria, a total of 40 projects were selected. Basic information about the selected projects can be found in Table 1. The locations of the projects are mapped in Figure 9.

Table 1
Selected projects

Type	**Project ID**	**Dist**	**Parish**	**Route**	**Length (mi.)**	**Accept Date**	**ADT_0**
AC over AC Base	015-05-0038	58	30	US 165	3.958	6/6/2002	5485
	019-05-0025	61	63	US 61	4.805	9/18/2003	5996
	026-05-0017	58	13	LA 15	5.43	8/8/2002	4199
	055-06-0049	03	57	LA 14	3.07	5/8/2001	12022
	267-02-0022	61	3	LA 431	0.87	10/20/2004	7017
AC over RPCC Base	450-03-0037	07	27	I-10	10.68	6/6/2002	33325
	450-03-0064	07	27	I-10	11.68	6/7/2004	35744
	450-04-0065	03	1	I-10	13.9	10/9/2001	40998
	450-04-0084	03	1	I-10	6.882	7/19/2004	33055
	450-05-0046	03	28	I-10	10.217	9/1/2000	41310
	450-91-0076	07	10	I-10	7.894	6/17/2003	34847
	451-01-0083	04	9	I-20	10.54	11/29/1999	33505
	451-05-0075	05	31	I-20	4.356	10/29/1998	21490
	451-06-0092	05	37	I-20	2.65	9/23/1999	25702
	454-02-0026	62	32	I-12	12.139	6/18/2001	33062
	454-02-0043	62	32	I-12	7.68	4/12/2000	42857
	454-03-0028	62	53	I-12	6.22	12/21/1999	39985
AC over Crushed Stone	058-02-0009	62	52	LA 41	0.75	5/23/2005	5039
	077-02-0013	61	3	LA 73	1.219	3/12/2005	16157
	193-02-0039	07	12	LA 27	4.962	8/20/2002	3969
	230-03-0022	61	24	LA 75	2.2	10/17/2003	2065
	262-04-0005	62	46	LA 16	10.361	11/19/1999	6434
	847-02-0019	61	47	LA 641	1.419	10/12/2000	6626
AC over Soil Cement Base	018-30-0018	62	52	LA 433	6.45	1/3/2000	1927
	029-07-0055	08	40	LA 496	7.19	9/25/2000	2047
	036-03-0016	58	21	LA 4	4.65	3/20/1997	3331
	067-03-0009	04	7	LA 4	5.198	1/17/1997	1568
	139-06-0011	08	58	LA 463	5	5/5/1999	1027
	211-04-0009	03	1	LA 755	1.012	8/19/1999	4833
	260-03-0010	62	32	LA 22	10.74	3/23/2000	3014
	261-02-0020	62	32	LA 42	1.18	4/1/1999	4358
	268-01-0014	62	32	LA 447	8.63	7/27/2000	3947
	397-04-0004	03	57	LA 89	3.09	7/19/1999	3023
	432-01-0018	08	43	LA 191	6.524	7/24/2000	3363
	803-32-0001	61	3	LA 938	4.145	3/4/1999	2500
	810-07-0014	07	10	LA 3020	3.19	11/23/1998	3890
	828-15-0012	03	28	LA 93	3.306	1/5/1999	6515
	839-02-0016	61	39	LA 419	7.32	7/19/1999	806
	852-03-0009	62	52	LA 1077	6.24	1/31/2003	7025
Interlayer	219-30-0012	61	39	LA 10	3.606	1/27/1999	680

Figure 9
Locations of the selected projects (maps.google.com)

Step 2 – Determine the Input Strategy

This study utilized the network level information stored in LADOTD databases. Thus only Level-3 design input was available for most design parameters. Three categories of input information were collected: traffic inputs, climate inputs, as well as pavement structure and materials inputs.

Initial IRI

The initial IRI of the pavement immediately after the construction is unavailable in Louisiana. This value was back-calculated based on a linear fit of the measured IRI values in LA-PMS.

Traffic Level

Table 2 lists the source or the default value used for each MEPDG traffic input. Most of the traffic inputs in this study were obtained from the Mainframe database. A previous study in Louisiana analyzed the axle load distribution from the WIM station data *[18]*. The findings of that study were used to develop the default axle load spectra and the number of axle per truck inputs to represent Louisiana local traffic conditions. The detailed analyses are presented in Appendix A. For other traffic inputs on which no local information are available, MEPDG default values were used.

Table 2
Traffic inputs used in this study

	Traffic Input	**Source or Value**
Traffic Volume	AADT	Mainframe/TATV[1]
	% of heavy vehicles	Mainframe/TAND
	Number of lanes in the design direction	Mainframe/TAND
	% of truck in the design direction	100% for one-way traffic 50% for two-way traffic
	% of truck in the design lane	Single-lane: 1.0 Two-lane: 0.9 Three-lane: 0.6 Four-lane: 0.45
	Operational speed	Mainframe/TAND
Traffic Volume Adjustment Factors	Monthly adjustment factors	MEPDG default
	Vehicle class distribution	Content Manager/Traffic assign document
	Hourly Distribution factors	MEPDG default
	Growth Function	“Compound”
	Growth Rate	Mainframe/TAND
Axle Load	Axle load distribution factors	Louisiana default[2]
General Traffic Inputs	Lateral traffic wander	MEPDG default
	Number of axle per truck	Louisiana default[2]
	Axle configuration	MEPDG default
	Wheelbase	MEPDG default

[1] LADOTD routinely reports the traffic counts data (ADT) in about every three years. These data are stored in Mainframe/TATV database. ADT in between two reported years was estimated by interpolation.
[2] See APPENDIX A.

Climate

The location (longitude, latitude, and elevation) of each selected project was obtained from LA-PMS at the mid-point of the project. The ground water level was obtained from the National Water Information System provided by the US Geology Survey (USGS) (http://wdr.water.usgsgov/nwisgmap/). A virtual weather station was generated for each project by interpolating the climate data from the closest two or three weather stations.

Pavement Structure

Pavement structure design information can be found from several different sources: (1) plan documents from the Content Manager or the LADOTD Intranet Plan Room (\\h00001ms017\26Plan Room\Plans), (2) typical section DARWin design sheets from the Content Manager, and (3) the Mainframe database (Mainframe/MATT/X-SECT). Information from different sources may conflict with each other.

After some preliminary comparisons, it was found that the X-SECT database in the Mainframe has lots of incorrect and missing information. Thus it was not considered as a reliable source of information. Project plan and DARWin design files are more reliable but sometimes plan changes may not be recorded in the database. The investigators made their best effort to identify the final pavement structure for each project selected. The pavement structures of the selected projects are presented in Table 3.

Table 3
Pavement structures of the selected projects

Project ID	**AC thickness**	**Base Type**	**Base Thickness**	**Subbase Type**	**Subbase Thickness**	**Subgrade M_r (psi.)**
015-05-0038	6.0	AC	6.5			9176
019-05-0025	5.5	AC	7.5			10634
026-05-0017	5.5	AC	5.5			8797
055-06-0049	5.5	AC	6.5			7627
267-02-0022	5.0	AC	5.0			8413
450-03-0037	7.5	RPCC	10	Soil Cement	6	8413
450-03-0064	8.0	RPCC	10	Soil Cement	6	8413
450-04-0065	7.5	RPCC	10	Soil Cement	6	8797
450-04-0084	8.0	RPCC	10	Soil Cement	6	8797
450-05-0046	6.0	RPCC	10	Soil Cement	6	9916
450-91-0076	7.5	RPCC	10	Soil Cement	6	9176
451-01-0083	8.0	RPCC	10	Soil Cement	6	10278
451-05-0075	6.0	RPCC	10	Soil Cement	6	10278
451-06-0092	8.0	RPCC	10	Soil Cement	6	9916
454-02-0026	8.0	RPCC	10	Soil Cement	6	9549
454-02-0043	6.0	RPCC	10	Soil Cement	6	9549
454-03-0028	9.0	RPCC	10	Soil Cement	6	10634
058-02-0009	5.0	AC	5	Stone	10	9176
077-02-0013	3.5	AC	4.5	Stone	8.5	8413
193-02-0039	4.5	Stone	12			9176
230-03-0022	5.0	Stone	8.5			8413
262-04-0005	6.0	AC	4.5	Stone	8.5	9549
847-02-0019	6.0	Stone	8.5			8023
018-30-0018	3.5	Soil Cement	8.5			9176
029-07-0055	3.5	Soil Cement	8.5			9916

036-03-0016	3.5	Soil Cement	8.5			9916
067-03-0009	3.5	Soil Cement	10			9916
139-06-0011	3.5	Soil Cement	12			8797
211-04-0009	3.5	Soil Cement	8.5			8797
260-03-0010	3.5	Soil Cement	8.5			9549
261-02-0020	3.5	Soil Cement	8.5			9549
268-01-0014	4.5	Soil Cement	8.5			9549
397-04-0004	3.5	Soil Cement	8.5			7627
432-01-0018	4.5	Soil Cement	8.5			9549
803-32-0001	3.5	Soil Cement	12			8413
810-07-0014	3.5	Soil Cement	8.5			9176
828-15-0012	3.5	Soil Cement	8.5			9916
839-02-0016	3.5	Soil Cement	12			9176
852-03-0009	4.0	Soil Cement	12			9176
219-30-0012	3.5	Stone	4	Soil Cement	6	9176

Materials

Materials inputs were collected at Level-3. Input parameters for different materials are described as follows.

AC. AC properties available in the Mainframe/MATT database include binder type, aggregate gradation, unit weight, VMA, VA, etc. At Level-3 input, the MEPDG design software utilizes these data to predict the dynamic modulus master curve of the AC based on an empirical model.

Louisiana records AC properties for each lot of AC mixture in a project. A lot is a segment of continuous production of AC mixture using the same job mix formula from an individual plant. One project may have dozens of lots of AC materials. Obviously using all the lot records in a project is impractical. In fact, the same type (e.g., Superpave Level 3) of AC mixture may not vary significantly among different projects. In order to simplify the input strategy, representative master curves were constructed for typical AC mixtures used in Louisiana. The material properties corresponding to each representative master curve were used as the Louisiana default AC material inputs in this study. More details about this part of study are presented in Appendix B. The MEPDG default values were adopted for reference temperature (= 70 °F), Poisson’s ratio (= 0.35), thermal conductivity (= 0.67 BTU/hr-ft-°F), and heat capacity (= 0.23 BTU/lb-°F).

RPCC. The MEPDG default resilient modulus value for the RPCC is 150 ksi. However, a series of FWD tests conducted at I-10 in Louisiana suggested that the resilient modulus of rubblized PCC ranged from 124 ksi to 1,656 ksi with an average of 847 ksi. In this study, the resilient modulus of the RPCC was taken as 500 ksi to represent local conditions in Louisiana. MEPDG default values were adopted for other material properties:

unit weight (= 150 psi), Poisson's ratio (= 0.3), thermal conductivity (= 1.25 BTU/hr-ft-°F), and heat capacity (= 0.28 BTU/lb-°F).

Crushed Stone. No local information is available about the crushed stone properties in Louisiana. MEPDG default input values for crushed stone were adopted in this study.

Soil Cement. The MEPDG default resilient modulus for the cement stabilized soil (= 2,000 ksi) is much higher than the values in Louisiana's local experience. In this study, the resilient modulus of the existing soil cement layer in the interstate projects was taken as 30 ksi, because the soil cement layers in these projects were constructed at least 40 years ago. For newly constructed soil cement layers, the resilient modulus value was taken as 100 ksi.

Subgrade. The coring/sampling log records for LADOTD projects have been recorded in the Mainframe/MATT database since 1990. Soil property data that can be input into the MEPDG includes sieve analysis data, soil classification, liquid limit, plasticity index, optimum moisture content, and maximum dry density. Louisiana does not have subgrade soil resilient modulus test data. Instead, each parish in Louisiana uses a default subgrade resilient modulus value. These parish default resilient moduli were used as the input for the subgrade in this study.

Type D lime treatment is commonly used in Louisiana to prepare the subgrade for pavement construction. The presence of lime treated layer was accounted for by assigning a higher resilient modulus, which is twice of that of the untreated subgrade soil, within the thickness of the treatment *[2]*.

Step 3 – Construct the LA-MEPDG Database

This study utilized a number of LADOTD databases: Mainframe, Content Manager, LA-PMS, etc. These databases are maintained separately by different offices in LADOTD. There is a need to link these databases together so that researchers can easily collect, manage, and analyze the data. To fulfill this requirement, a database named LA-MEPDG was created in this study using the Access 2007 format. This database linked a number of LADOTD databases (TOPS, TAND_NEEDS, TATV, and MATT/SOILS) together. A detailed introduction and a step-by-step procedure of using the database are presented in Appendix C.

Step 4 – Interpret the LA-PMS Data

Identify Irregularities in LA-PMS Data

Ideally, pavement distresses (or IRI), if without any maintenance, should show a smoothly increasing trend with year of service. However, decreasing trend and abrupt changes are often observed when the pavement condition data of a particular project are retrieved from the LA-PMS. These irregularities may be introduced from several sources.

- LA-PMS stores network-level pavement condition data. These data are measured continuously by an automatic surveyor. Measurement errors are unavoidable. For example, the surveyor may run off the lane for a short period.
- Minor maintenance (e.g., micro surfacing, chip seal, etc.) may not always be recorded in the TOPS.
- Cracking is categorized and quantified manually from the road images. Joints on bridges may be ignored in one year but counted as cracking in another year. Although similar survey protocols were used every year, personal judgment still has to be made, which will introduce inconsistencies in the results.
- Rutting and IRI measurement are more automatic. However, pavement survey technology improves year by year. Pavement profile was measured with a three-point laser in 2000-2003 surveys and with a 1280-point laser in the 2004-2005 survey and after. Different technology often produces different outputs.

For the above reasons, pavement condition data for each selected project were inspected carefully before comparing with the MEPDG. The following procedure was taken to minimize the irregular trend in the LA-PMS data.

- When a project has more than one subsection with considerably different traffic levels, traffic and pavement condition data from one of the subsections should be used.
- If any maintenance record was found for a project, only the PMS data before the maintenance should be used.
- Structures were excluded from the PMS data.
- Data acquisition errors (often recorded as -1) were excluded from the analysis.

- If the pavement condition data at a particular part of the project were believed to be abnormal, only the range of project with reasonable pavement condition data was used.

After employing the previous procedures, pavement distress (or IRI) data were fitted using linear or power trend line to eliminate the data inconsistency among different years of surveys. The fitted distress development curve was used instead of the real measurement to compare with the MEPDG predictions. If pavement condition data still showed an irregular trend after the previous procedure, the project was excluded unless the data point of particular year(s) was obviously unreasonable while other data points showed a good trend. The abnormal data point was ignored and the pavement distress trend line was fitted based on the remaining data points.

Calculate the Mean and Variation of Distress (or IRI)

Pavement condition data stored in the LA-PMS were summarized in every 0.1 mi. For cracking, the lengths (or areas) of measured cracking were summed up and reported in each 0.1 mi. For IRI and rutting, both mean and standard deviation of the distress were reported in each 0.1 mi. The mean and standard deviation (also called pooled mean and pooled standard deviation) were then calculated from the measurement in both wheel paths.

Each project was considered as a single case, thus only the overall mean and standard deviation of the distress were of interest. For cracking, the total length (or area) of cracking was simply calculated by summing up the total length (or area) of cracking in each 0.1-mi. subsection. Standard deviation among different subsections was calculated directly. For IRI and rutting, the total mean value was calculated by averaging the pooled mean values. The total standard deviation was more complicated to obtain, which is explained below.

From the theory of statistics, the total sum of squares (TSS) equals the sum of the within sample sum of squares (SSW) and the sum of squares between samples (SSB).

$$TSS = SSW + SSB \tag{9}$$

or

$$\sum_{i,j}\left(y_{ij} - \overline{y}\right)^2 = \sum_{i,j}\left(y_{ij} - \overline{y_i}\right)^2 + \sum_{i,j}(\overline{y_i} - \overline{y})^2 \tag{10}$$

where, y_{ij} is the j^{th} individual distress (IRI or rutting) measurement in the i^{th} subsection, $\overline{y_i}$ is the pooled mean distress in the i^{th} subsection, and $\overline{y}$ is the total mean distress of the entire project. Let n_i be the number of 0.1-mi. subsections in a project and n_j be the number of distress measurements in each subsection. Equation (10) can be re-written in terms of total standard deviation s and pooled standard deviation s_i of the i^{th} 0.1-mi. subsection.

$$(n_i n_j - 1)s^2 = (n_j - 1)s_i^2 + \sum_i n_j (\overline{y_i} - \overline{y})^2 \tag{11}$$

Equation (11) can be used to calculate the total standard deviation s of rutting or IRI of a particular project. The number of distress measurements in each subsection n_j depends on the configuration of the surveyor. Based on a communication with the PMS section in Louisiana DOTD, n_j = 20 and n_j = 100 were used for rutting and IRI measurements, respectively.

Step 5 – Validate the MPEDG using LA-PMS data

With the input information collected and the PMS data processed, the MEPDG design software were run for each of the selected projects. The MEPDG-predicted distresses (or IRI) were compared with the PMS data.

As mentioned previously, the different definitions of cracking between the LA-PMS and the MEPDG must be carefully considered in the comparison. The LA-PMS reports the total wheel-path cracking, termed as alligator cracking in sq. ft., rather than differentiating top-down and bottom-up cracking as used in the MEPDG. Based on the distress survey manual, the wheel-path cracking in LA-PMS should be considered as load-related fatigue cracking. Therefore, the total MEPDG predicted load-related fatigue cracking (i.e., the combined bottom-up and top-down predicted cracking) was used to compare with the LA-PMS measured wheel-path alligator cracking. Equation (12) is used to combine the MEPDG-predicted bottom-up and top-down cracking for the cracking comparison analysis in this study.

$$\begin{aligned} &Predicted\_load\_related\_fatigue\_cracking\ (\%\ of\ total\ lane\ area) \\ &\quad = predicted\_bottom\_up\_craking \\ &\quad + \ (predicted\_\ top\_down\_cracking\ \times\ 1\ ft./12\ ft.) \\ &\quad \times 100\% \end{aligned} \tag{12}$$

Thermal (transverse) cracking is not considered in this study because it is not a major distress type in most parts of Louisiana.

The MEPDG predicts the pavement distress (or IRI) in two levels: average level and reliability level. On the other hand, field mean distress (or IRI) and the variation (standard deviation) were calculated from the PMS data. In this study, the following comparisons were made to validate the MEPDG design models.

In order to determine whether the MEPDG prediction models are biased from the pavement performance in Louisiana, the MEPDG predicted average distresses were compared with the field mean distresses.

In addition, the predicted distresses at the reliability level were also compared with the field distresses at the mean-plus-one-standard-deviation level. This comparison indicates to what extent the MEPDG-predicted pavement distress reflects the field variation of distress in Louisiana. Different reliability levels were used, depending on the highway functional class and pavement structure type. For example, the AC over RPCC pavement structure was often used on interstate highways. Therefore the design reliability for AC over RPCC pavements was set as 95 percent. Similarly, the design reliability for AC over AC base pavements, AC over crushed stone pavements, AC over soil cement base pavements, and interlayer pavements were set as 85 percent, 85 percent, 75 percent, and 75 percent, respectively.

When determining the bias between the MEPDG-predicted and LA-PMS measured distresses, a statistical analysis was performed according to the AASHTO Local Calibration Guide [2]. Bias can be evaluated by performing the following three null hypothesis tests:

Test 1. Determine if the mean of residual error e_r (the predicted value minors the measured value) is zero:

H_0: Mean (e_r) = 0

H_1: Mean (e_r) $\neq$ 0

Test 2. Determine if the linear regression relationship between measured and predicted distresses has an intercept of zero:

H_0: Intercept = 0

H_1: Intercept $\neq$ 0

Test 3. Determine if the linear regression relationship between measured and predicted distresses has a slope of 1.0:

H0: Slope = 1.0

H1: Slope $\neq$ 1.0

A rejection of any of the three null hypotheses indicates that bias exists between the predicted and measured distresses.

The accuracy of the MEPDG model can be determined by the standard error of estimate (S_e). The standard error of estimate is the standard deviation of the residual error (i.e., the predicted value – measured value) of the model. Prediction power of the MEPDG model can be determined by the coefficient of determination R^2. The calculated S_e and R^2 in this study were also compared with the values obtained from the national calibration of the MEPDG.

Finally, analysis of variance (ANOVA) was conducted to determine whether the errors in the MEPDG prediction models were affected by factors such as pavement type, traffic volume (ADT), subgrade modulus, and geographic location.

Step 6 – Calibrate the Rutting Models

In the current MEPDG, the permanent deformation of the RPCC and the stabilized base layers is not considered. Thus the total rutting of the pavement is the sum of the permanent deformation in AC, granular base/subbase, and subgrade layers. Each component of the total rutting corresponds to a rutting model for a specific material type.

Ideally, the permanent deformation in individual layers should be measured (by trench tests) and used to calibrate the sublayer rutting models. However, this information was not available in this study. Therefore, the sublayer rutting models may be calibrated either separately by making some assumptions about the contribution of rutting by each layer or at the same time by minimizing the Sum of Squared Errors (SSE) of the total rutting. Previous studies often used the former method by assuming the percentage of rutting in each layer predicted by the MEPDG is the “true” percentage of rutting distribution in the field.

In this study, the second method was used. An obvious advantage of this method is that the “same rutting distribution” assumption is avoided. This method works best when the biases of the three sublayer rutting models are significantly different. For example, one is over-predicting and the others are under-predicting the rutting. This method also relies on a sufficient amount of good-quality data; otherwise calibration factors obtained may be unreasonably large or small.

Calibration of the MEPDG rutting models was conducted for AC over RPCC and AC over soil cement pavements. These two pavement types were selected because we were able to locate a suitable number of projects. The following local calibration factors were obtained:

β_{1r} [in equation (6)] for AC and β_{s1} [in equation (7)] for subgrade. The optimization was performed using the Solver add-in in Microsoft Excel® 2007.

The prediction power of the AC rutting model can be further improved by calibrating the local calibration factors β_{r2} and β_{r3} in equation (6) through iterative method. However, it is beyond the scope of this study.

DISCUSSION OF RESULTS

Validate the MEPDG with LA-PMS Data

This section presents the comparisons between the MEPDG-predicted pavement performance and the LA-PMS data for the 40 selected projects.

AC over AC Base Pavement

A total of five projects with this type of pavement structure were selected. Table 4 presents the corresponding pavement structures of the AC over AC base pavements selected. Other project information can be found in Table 1. As mentioned in the preceding "Methodology" section, each of the selected projects was analyzed using the MEPDG software (version 1.1) with a set of Louisiana default inputs obtained from multiple sources. The example below provides the analysis procedure for one of these projects.

Table 4
Pavement structures of the selected AC over AC base pavements

Project ID	AC Surface	Thickness of AC (in.)	Base	Thickness of Base (in.)	Subgrade and Stabilization
015-05-0038	2" SMA WC + 4" SUPERPAVE LEVEL-2 BC	6.0	AC Type 5A	6.5	A-4
019-05-0025	1.5" TYPE 8F WC + 4" TYPE 8 BC	5.5	AC Type 5A	7.5	A-4, 12" TYPE D LIME TREATED
026-05-0017	1.5" TYPE 8F WC + 4" TYPE 8 BC	5.5	AC Type 5A	5.5	A-4, 12" TYPE D LIME TREATED
055-06-0049	1.5" TYPE 8F WC + 4" TYPE 8 BC	5.5	AC Type 5A	6.5	A-6
267-02-0022	2" TYPE 8F WC + 3" TYPE 8 BC	5.0	AC Type 5	5.0	A-4, 12" TYPE D LIME TREATED

WC = Wearing Course, BC = Binder Course

Project 019-05-0025 was a new flexible pavement project located on US-61 in south Louisiana. Two new lanes were added to the existing two-lane highway. The flexible pavement consisted of 1.5-in. Type 8F wearing course, 4-in. Type 8 binder course, and 7.5-in. Type 5A asphalt concrete base course. The project was accepted on September 18, 2003. Two-way ADT on this route was 5,996 in the year 2003. Pavement condition surveys were conducted in 2005, 2007, and 2008, respectively. The MEPDG design program was run with the collected input information. The predicted and measured distresses (and IRI) were compared in Figure 10.

For this particular project, both the measured and predicted fatigue cracking were found close to zero (Figure 10a). However, as shown in Figure 10b, the MEPDG under-predicted the field mean rutting by approximately 40 percent. The predicted rutting at a selected 85-percent reliability was also lower than the mean-plus-one-standard-deviation rutting obtained from the LA-PMS. On the other hand, the measured and the predicted mean IRI seemed to match very well. The predicted IRI at the 85-percent reliability was close to the mean-plus-one-standard-deviation IRI measured in the field.

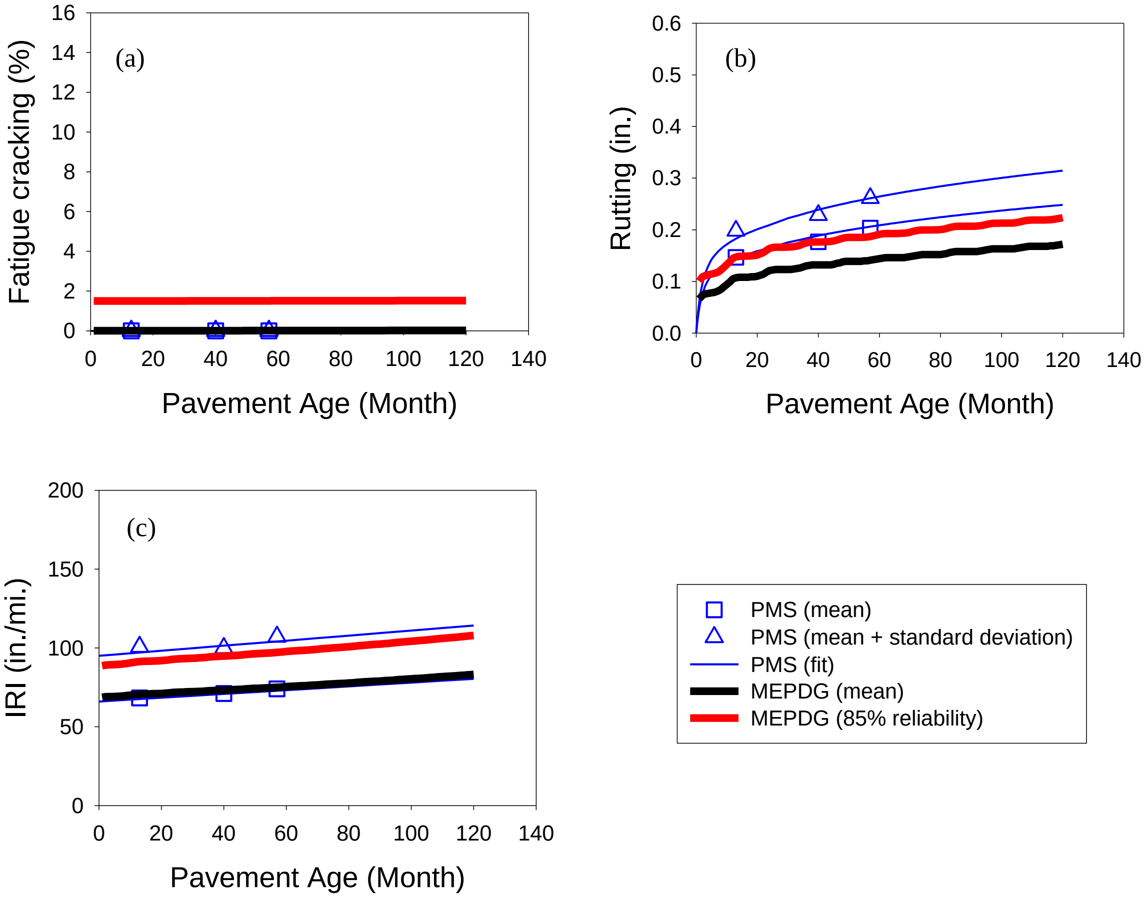


Figure 10
Predicted distress by MEPDG vs. measured distress in PMS for project 019-05-0025: (a) fatigue cracking, (b) rutting, and (c) IRI

The above analysis was then repeated for each of the selected AC over AC base pavement projects in this study. The results are summarized as follows.

Load-related Fatigue Cracking. In this part of analysis, the MEPDG-predicted fatigue cracking (i.e., combined with both bottom-up and top-down cracking) were compared with the measured wheel-path alligator cracking obtained from the LA-PMS. For all selected AC over AC base projects, almost no wheel-path alligator cracking was reported in the LA-PMS. The MEPDG also predicted less than 0.1 percent of fatigue cracking in each of those projects. Under such a low cracking distress level, the predicted and the measured fatigue cracking seemed to match each other. Therefore, the MEPDG load-related fatigue cracking models seemed to be adequate in predicting the mean load-related fatigue cracking for the AC over AC base pavements in Louisiana. More details of the MEPDG prediction results can be found in Appendix D.

Rutting. Figure 11 shows the comparison between the predicted and measured mean rutting for the AC over AC base pavements considered. Overall, it was observed that the MEPDG could predict roughly (with up-and-down variations) the mean of field rutting for the projects selected, although the hypothesis tests (see Table 5) showed that the MEPDG rutting prediction model was “biased.” Furthermore, the MEPDG-predicted rutting at a selected 85-percent design reliability level was compared with the field variations of rutting obtained from the LA-PMS. Figure 12 indicates that the MEPDG-predicted rut depths at the 85-percent reliability level were found either close or higher than the field measured rut depths at the mean-plus-one-standard-deviation level for three of selected projects, but lower than the field rut depths for the other two projects. Such results indicate that the MEPDG rutting model without local calibration seems to have a certain degree of prediction power for the AC over AC base pavements in Louisiana.

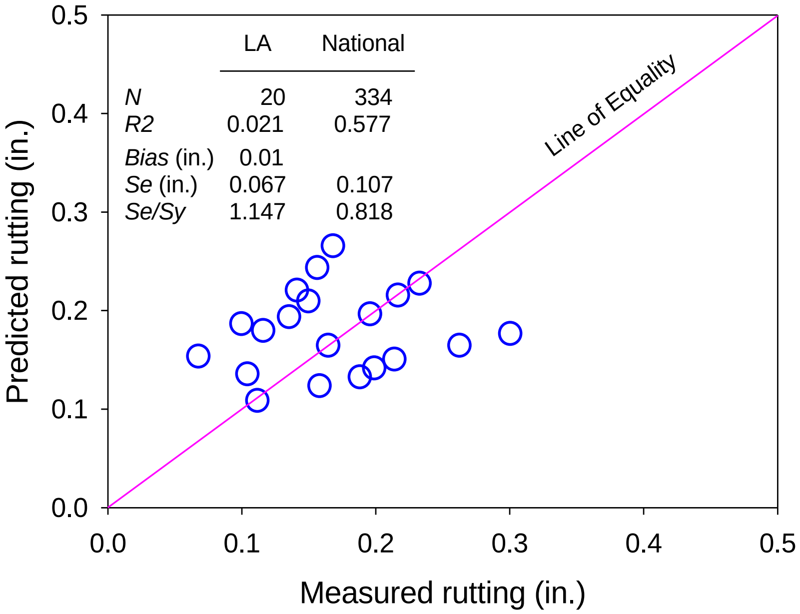


Figure 11
Predicted mean rutting by MEPDG vs. measured mean rutting in LA-PMS (AC over AC base pavement)

Table 5
Hypothesis analysis (rutting, AC over AC base pavement)

	Null hypothesis (H_0)	P-Value	Result
1	The mean of residual error (predicted rutting - predicted rutting) is zero.	0.547	H_0 accepted
2	The slope of the predicted rutting versus the measured rutting is one.	< 0.001	H_0 rejected
3	The intercept of the predicted rutting versus the measured rutting is zero.	< 0.001	H_0 rejected
Conclusion: Two of the H_0 hypotheses are rejected. The MEPDG-predicted rutting is “biased” from the measured rutting for AC over AC Base pavements.			

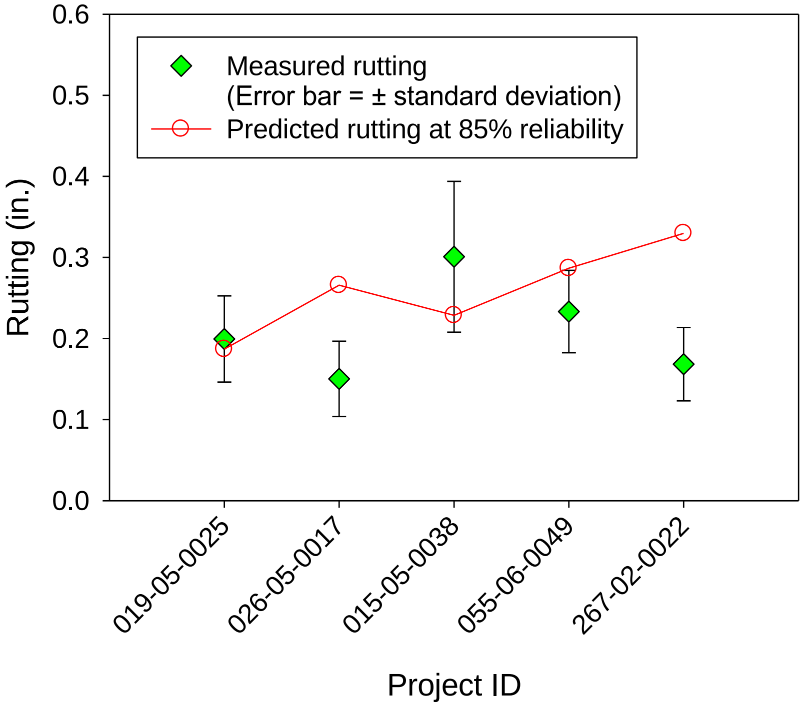


Figure 12
Field variation of rutting vs. MEPDG design reliability
(AC over AC base pavement)

IRI. Figure 13 shows the comparison between the predicted and measured mean IRI. Overall, the predicted mean IRI seemed to agree well with the measured mean IRI with a slight over-prediction, although the hypothesis tests (see Table 6) showed that the MEPDG IRI prediction model was “biased.” Figure 13 also indicates that the MEPDG IRI model seemed to be able to provide a better set of the goodness-of-fit parameters (such as R^2 and S_e) for the selected Louisiana pavements than those obtained in the national calibration. Furthermore, the MEPDG-predicted IRI at a selected 85-percent design reliability level was larger than the measured mean IRI for all five projects considered (see Figure 14). In four of the five projects (except project 026-05-0017), the predicted IRI at the 85-percent reliability level was close to the measured IRI at the mean-plus-one-standard-deviation level. Therefore, the MEPDG IRI prediction model seems to be adequate to the AC over AC base pavements in Louisiana. It should be noted that, however, the MEPDG IRI prediction model is a function of other predicted distresses (e.g., cracking and rutting). If any of the MEPDG distress prediction models will be locally calibrated, the IRI model should be, thus, also re-calibrated.

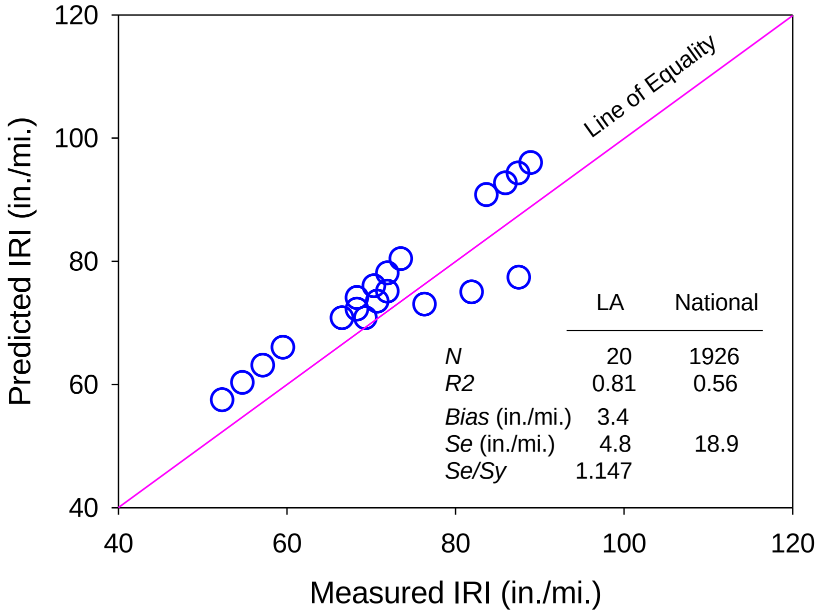


Figure 13
Predicted mean IRI by MEPDG vs. measured mean IRI in LA-PMS
(AC over AC base pavement)

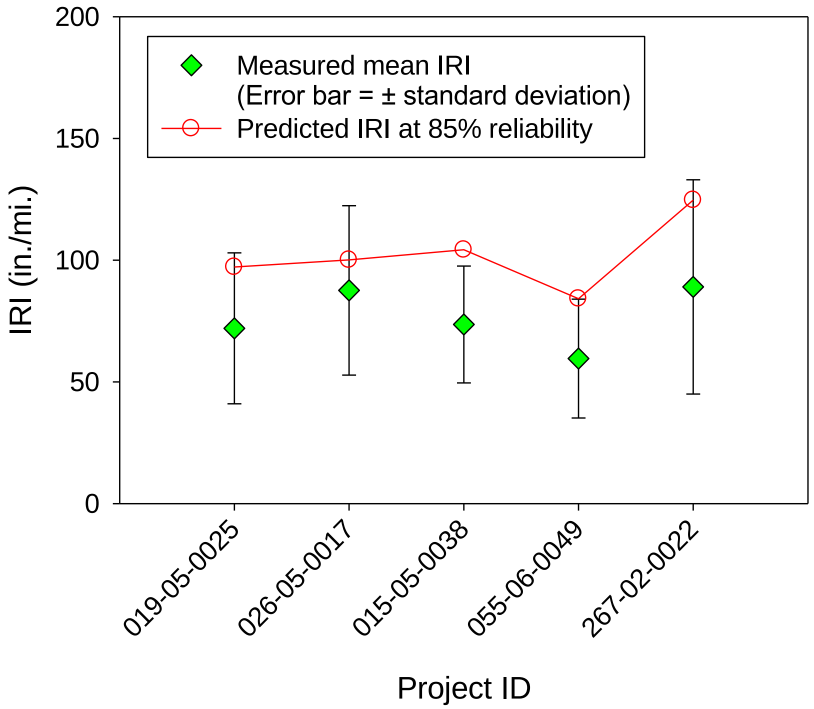


Figure 14
Field variation of IRI vs. MEPDG design reliability
(AC over AC base pavement)

Table 6
Hypothesis analysis (IRI, AC over AC base pavement)

	Null hypothesis (H_0)	P-Value	Result
1	The mean of residual error (predicted IRI - predicted IRI) is zero.	0.007	H_0 rejected
2	The slope of the predicted IRI versus the measured IRI is one.	0.220	H_0 accepted
3	The intercept of the predicted IRI versus the measured IRI is zero.	0.102	H_0 accepted
Conclusion: One of the H_0 hypothesis is rejected. The MEPDG-predicted IRI is "biased" from the measured IRI for AC over AC Base pavements.			

Summary. The above analysis results generally indicate that the MEPDG load-related fatigue cracking, rutting, and IRI models, without performing any local calibration, all seemed to be adequate for the performance prediction of the AC over AC base pavements in Louisiana.

AC over RPCC Base Pavement

A total of 12 AC over RPCC base pavement projects were selected. Table 7 presents the corresponding pavement structures of the selected projects. Other project information can be found in Table 1. Each of the selected projects was then analyzed using the MEPDG with a set of Louisiana default inputs obtained from multiple sources as outlined in the preceding sections of the *Methodology*. The example below provides the analysis procedure for one of these projects.

Project 450-04-0065 was a rigid pavement rehabilitation project located on Interstate I-10 in south Louisiana. The existing pavement was a 10- in. PCC on top of a 6-in. soil cement. In this project, the existing PCC was rubblized and overlaid by a 7.5-in. AC. The project was accepted on October 9, 2001. Two-way ADT on the route was 40,998 in the year 2001. Pavement condition surveys were conducted in 2003, 2005, 2007, and 2008, respectively. The MEPDG design program was run with the collected input information. The predicted and measured distresses (and IRI) were compared in Figure 15.

As shown in Figure 15a, the MEPDG and the LA-PMS both indicated no fatigue cracking for this particular project. However, the MEPDG significantly over-predicted the field mean rut depths (Figure 15b). In addition, the predicted rut depths at a selected 95-percent design reliability were also significantly higher than the mean-plus-one-standard-deviation rut depths in LA-PMS. Furthermore, Figure 15c indicates that the MEPDG significantly over-predicted the field measured mean IRI. The predicted IRI at the 95-percent design reliability was also found higher than the mean-plus-one-standard-deviation IRI measured in the field.

Table 7
Pavement structures of the selected AC over RPCC base pavements

Project ID	**AC Surface**	**Thickness of AC (in.)**	**Base**	**Thickness of Base (in.)**	**Subbase**	**Thickness of Subbase (in.)**	**Subgrade and Stabilization**
450-03-0037	2" SUPERPAVE WC + 5.5" SUPERPAVE BC	7.5	RUBBLIZED PCC	10	EXISTING SOIL CEMENT	6.0	A-6
450-03-0064	2" SUPERPAVE LEVEL 3 WC + 6" SUPERPAVE LEVEL 3 BC	8.0	RUBBLIZED PCC	10	EXISTING SOIL CEMENT	6.0	A-7-6
450-04-0065	2" SMA WC + 5.5 " TYPE 8 BC	7.5	RUBBLIZED PCC	10	EXISTING SOIL CEMENT	6.0	A-4
450-04-0084	2" SUPERPAVE LEVEL 3 WC + 6" SUPERPAVE LEVEL 3 BC	8.0	RUBBLIZED PCC	10	EXISTING SOIL CEMENT	6.0	A-4
450-05-0046	2" SMA WC + 4" TYPE 8 BC	6.0	RUBBLIZED PCC	10	EXISTING SOIL CEMENT	6.0	A-7-6
450-91-0076	2" SMA WC + 5.5" SUPERPAVE LEVEL 3 BC	7.5	RUBBLIZED PCC	10	EXISTING SOIL CEMENT	6.0	A-4
451-01-0083	2" SMA WC + 6" TYPE 8 BC	8.0	RUBBLIZED PCC	10	EXISTING SOIL CEMENT	6.0	A-4
451-05-0075	2" SMA WC + 4" SUPERPAVE LEVEL 3 BC	6.0	RUBBLIZED PCC	10	EXISTING SOIL CEMENT	6.0	A-2-4
451-06-0092	2" SMA WC + 6" TYPE 8 BC	8.0	RUBBLIZED PCC	10	EXISTING SOIL CEMENT	6.0	A-4
454-02-0026	4" SUPERPAVE LEVEL 3 WC + 4" SUPERPAVE LEVEL 3 BC	8.0	RUBBLIZED PCC	10	EXISTING SOIL CEMENT	6.0	A-7-6
454-02-0043	2" SUPERPAVE LEVEL 3 WC + 4" SUPERPAVE LEVEL 3 BC	6.0	RUBBLIZED PCC	10	EXISTING SOIL CEMENT	6.0	A-7-6
454-03-0028	2" SMA WC + 4" TYPE 8 BC + 3" TYPE 5A BS	9.0	RUBBLIZED PCC	10	EXISTING SOIL CEMENT	6.0	A-4

WC = Wearing Course, BC = Binder Course, BS = Base Course

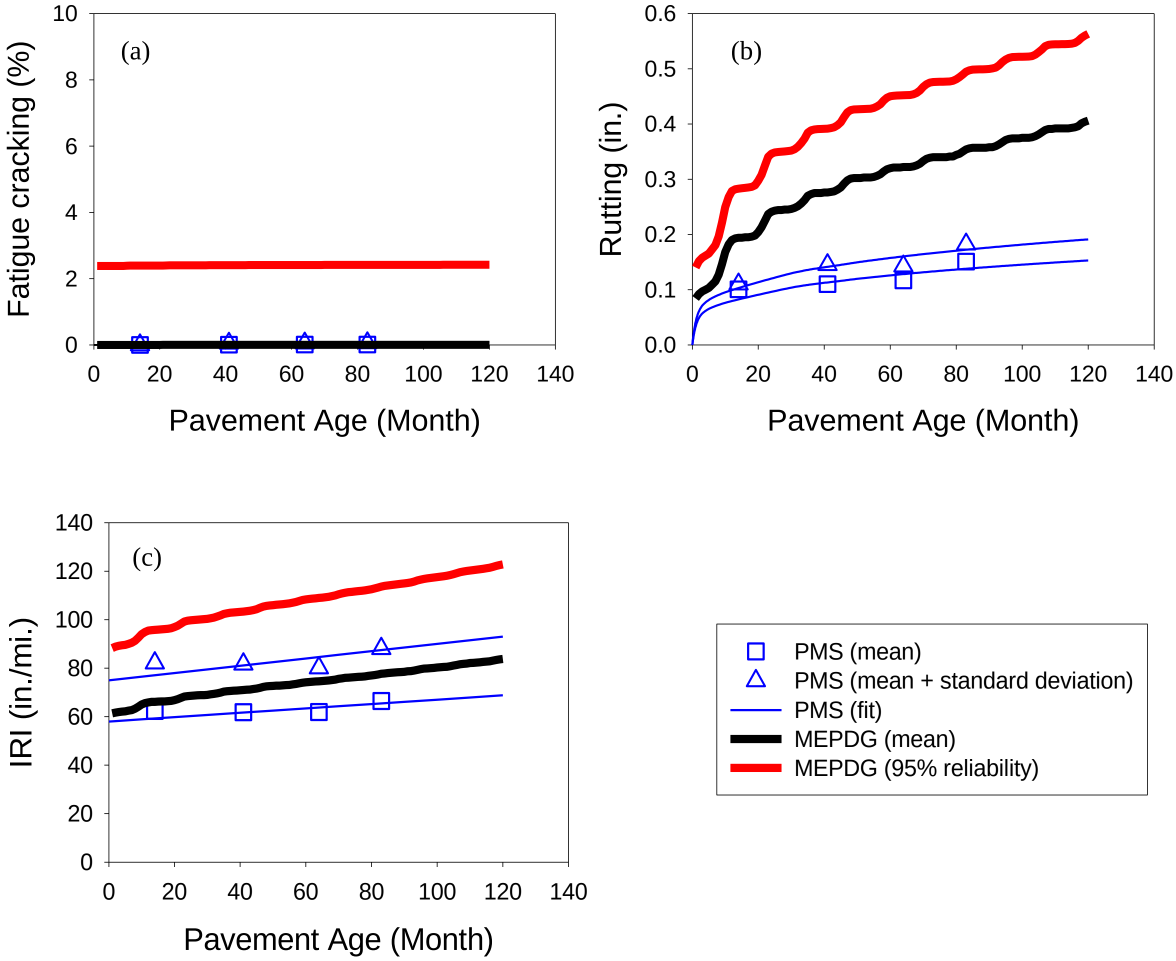


Figure 15
Predicted distress by MEPDG vs. measured distress in PMS for project 450-04-0065: (a) fatigue cracking, (b) rutting, and (c) IRI

Similarly, the above analyses were repeated for the rest of the AC over RPCC base pavements selected. The results are summarized as follows.

Load-related Fatigue Cracking. In this part of analysis, the MEPDG-predicted fatigue cracking were compared with the measured wheel-path alligator cracking reported in the LA-PMS. In this study, almost no wheel path alligator cracking (< 0.001 percent) was reported for all twelve AC over RPCC base pavements. The MEPDG also predicted less than 0.1 percent of load-related fatigue cracking for all the projects. Similar to the analysis results for the AC over AC base pavements, under such low-cracking distress levels, it may be deemed that the MEPDG fatigue cracking models seemed to be adequate for the AC over

RPCC base pavements in Louisiana. More details of the MEPDG prediction results can be found in Appendix D.

Rutting. Figure 16 presents the comparison between the predicted and the measured mean rutting for the AC over RPCC base pavements selected. Overall, the MEPDG over-predicted the rutting for this type of pavement in Louisiana. Hypothesis tests (Table 8) also showed that the predicted rutting by the MEPDG was significantly different from the measured rutting in the LA-PMS. Furthermore, as indicated in Figure 17, the MEPDG-predicted rutting at a selected 95-percent reliability level was also significantly higher than the field rutting at the mean-plus-one-standard-deviation level. These observations indicate that, without further local calibration of the MEPDG rutting model, the MEPDG would potentially over-design the AC over RPCC base pavements in Louisiana.

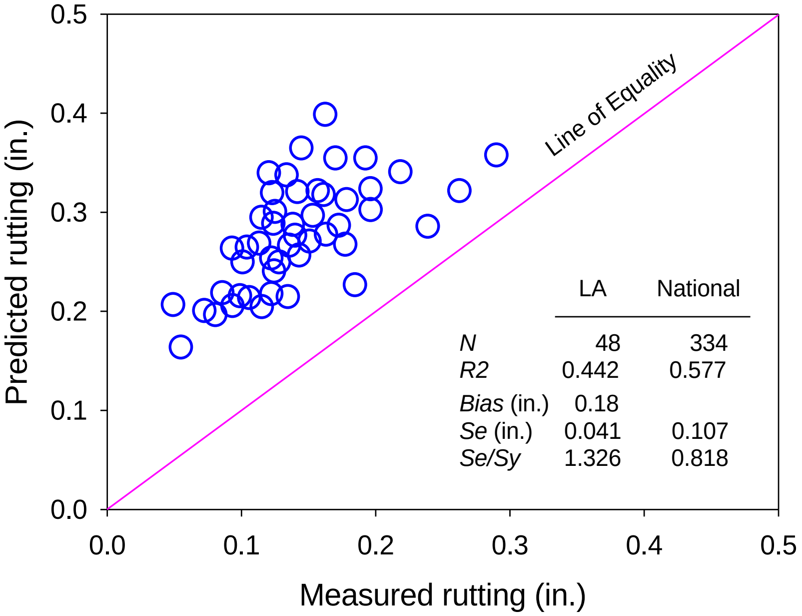


Figure 16
Predicted mean rutting by MEPDG vs. measured mean rutting in LA-PMS
(AC over RPCC base pavement)

Table 8
Hypothesis analysis (rutting, AC over RPCC base pavement)

	Null hypothesis (H_0)	P-Value	Result
1	The mean of residual error (predicted rutting - predicted rutting) is zero.	< 0.001	H_0 rejected
2	The slope of the predicted rutting versus the measured rutting is one.	0.516	H_0 accepted
3	The intercept of the predicted rutting versus the measured rutting is zero.	< 0.001	H_0 rejected

Conclusion: Two of the H_0 hypotheses are rejected. The MEPDG-predicted rutting is "biased" from the measured rutting for AC over RPCC pavements.

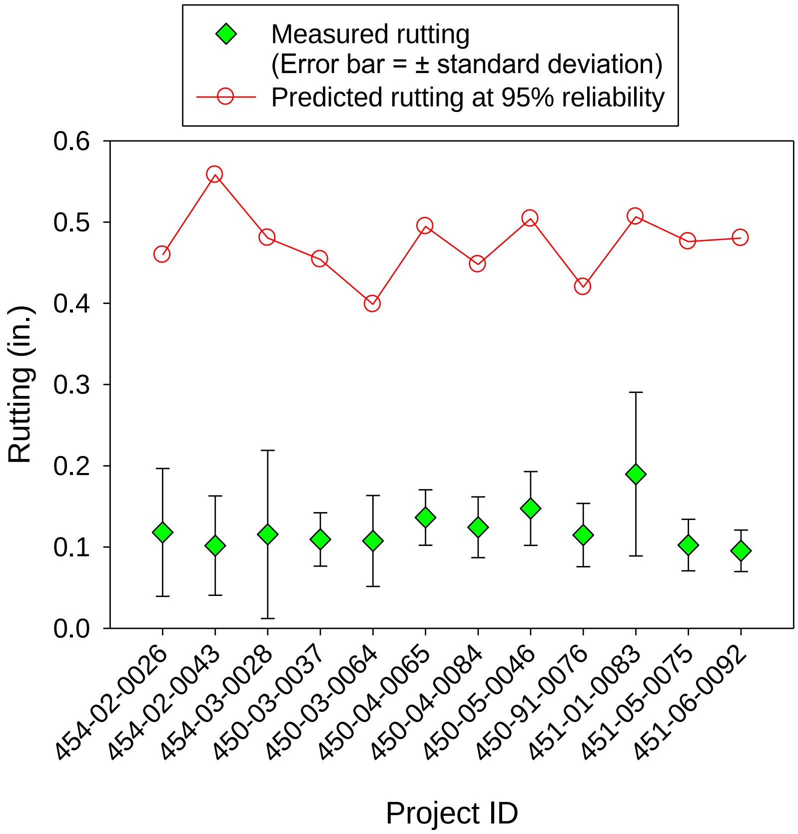


Figure 17
Field variation of rutting vs. MEPDG design reliability
(AC over RPCC base pavement)

IRI. Figure 18 shows the comparison between the predicted and the measured mean IRI. Overall, the predicted mean IRI agreed well with the measured mean IRI except for a slight offset. However, the hypothesis tests (Table 9) showed that the MEPDG IRI prediction model was "biased." The goodness-of-fit parameters obtained in this study shown in Figure 18 seemed to be better than those obtained in the national calibration of the MEPDG IRI model. In addition, as shown in Figure 19, the MEPDG-predicted IRI at a selected 95-

percent design reliability level was higher than both the measured mean IRI and the IRI at the mean-plus-one-standard-deviation level for all 12 projects. This indicates that the MEPDG IRI model seemed to be adequate for the AC over RPCC base pavements in Louisiana. However, as mentioned before, the MEPDG IRI model should be re-evaluated if any other MEPDG distress prediction models (e.g., cracking and rutting) are to be locally calibrated.

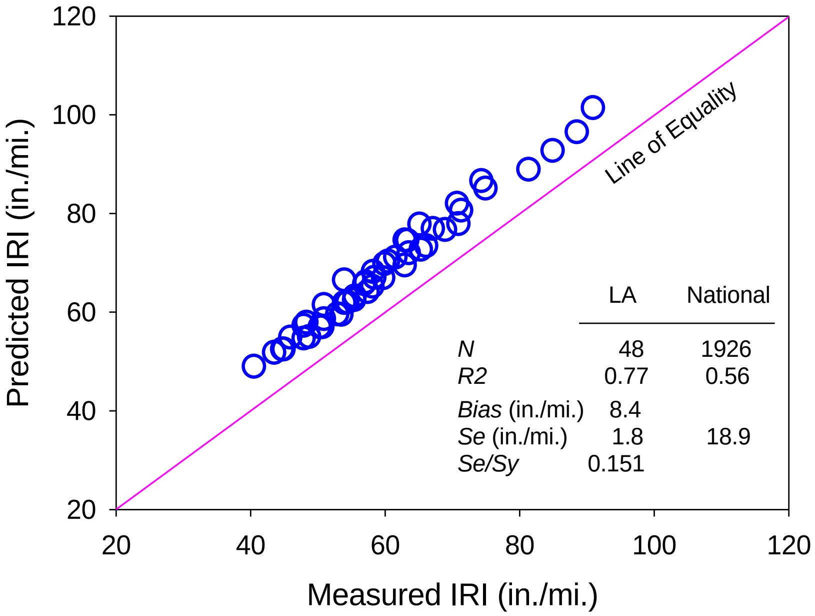


Figure 18
Predicted mean IRI by MEPDG vs. measured mean IRI in LA-PMS (AC over RPCC base pavement)

Table 9
Hypothesis analysis (IRI, AC over RPCC base pavement)

	Null hypothesis (H_0)	P-Value	Result
1	The mean of residual error (predicted IRI - predicted IRI) is zero.	< 0.001	H_0 rejected
2	The slope of the predicted IRI versus the measured IRI is one.	0.115	H_0 accepted
3	The intercept of the predicted IRI versus the measured IRI is zero.	< 0.001	H_0 rejected
Conclusion: Two of the H_0 hypotheses are rejected. The MEPDG-predicted IRI is “biased” from the measured IRI for AC over RPCC pavements.			

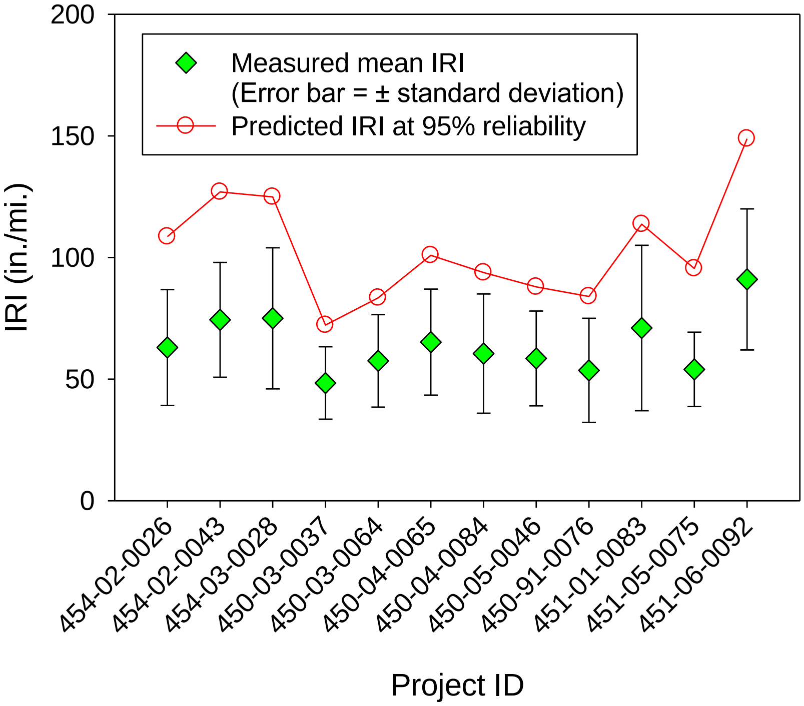


Figure 19
Field variation of IRI vs. MEPDG design reliability
(AC over RPCC base pavement)

Summary. Similar to AC over AC base pavements, the MEPDG load-related fatigue cracking model and the IRI model both seemed to be adequate for the AC over RPCC base pavements in Louisiana without the need of local calibration. However, since the MEPDG rutting model significantly over-predicted the field rutting for all 12 AC over RPCC base pavements selected in this study, a local calibration of the rutting models is recommended before implementing the MEPDG in Louisiana to design AC over RPCC base pavements.

AC over Crushed Stone Pavement

A total of six projects with this type of pavement structure were selected. Table 10 provides the corresponding pavement structures of the selected projects. Other project information can be found in Table 1. Each of the selected projects was then analyzed using the MEPDG with a set of Louisiana default inputs obtained from multiple sources as outlined in the preceding sections of the Methodology. The next example provides the analysis procedure for one of these projects.

Table 10
Pavement structures of the selected AC over crushed stone pavements

Project ID	AC Surface	Thickness of AC (in.)	Base	Thickness of Base (in.)	Subbase	Thickness of Subbase (in.)	Subgrade and Stabilization
058-02-0009	2" TYPE 8F WC + 3" TYPE 8 BC	5.0	AC TYPE 5	5.0	STONE	10.0	A-6, 12" TYPE D LIME TREATED
077-02-0013	1.5" TYPE 8F WC + 2" TYPE 8 BC	3.5	AC TYPE 5	4.5	STONE	8.5	A-4, 12" TYPE D LIME TREATED
193-02-0039	1.5" TYPE 8F WC + 3" TYPE 8 BC	4.5	STONE	12.0			A-4
230-03-0022	1.5" TYPE 3 WC + 3.5 TYPE 3 BC	5.0	STONE	8.5			A-6, 15" TYPE D LIME TREATED
262-04-0005	1.5" TYPE 8 WC + 4.5" TYPE 8 BC	6.0	AC TYPE 5B	4.5	STONE	8.5	A-4
847-02-0019	1.5" TYPE 8F WC + 4.5" TYPE 8 BC	6.0	STONE	8.5			A-7-6, 12" TYPE D LIME TREATED

WC = Wearing Course, BC = Binder Course

Project 230-03-0022 was a flexible pavement rehabilitation project located on LA 75 in south Louisiana. The existing AC and base course were removed and reconstructed. The finished flexible pavement consisted of a 1.5-in. Type 8F wearing course, a 3.5-in. Type 8 binder course, and an 8.5-in. crushed stone base course. The project was accepted on October 17, 2003. Two-way ADT on this route was 2,065 in the year 2003. Pavement condition surveys were conducted in 2005, 2007, and 2008, respectively. The MEPDG-predicted pavement distresses (and IRI) and the LA-PMS pavement performance data were compared in Figure 20.

For this particular project, the MEPDG significantly under-predicted the field wheel-path cracking. The predicted fatigue cracking at a selected 85-percent reliability level was lower than the mean wheel-path cracking in the field. Meanwhile, the MEPDG over-predicted the mean rutting. However, the predicted mean IRI seemed to match well with the measured mean IRI. The predicted IRI at 85-percent reliability level was close to the mean-plus-one-standard-deviation IRI measured in the field.

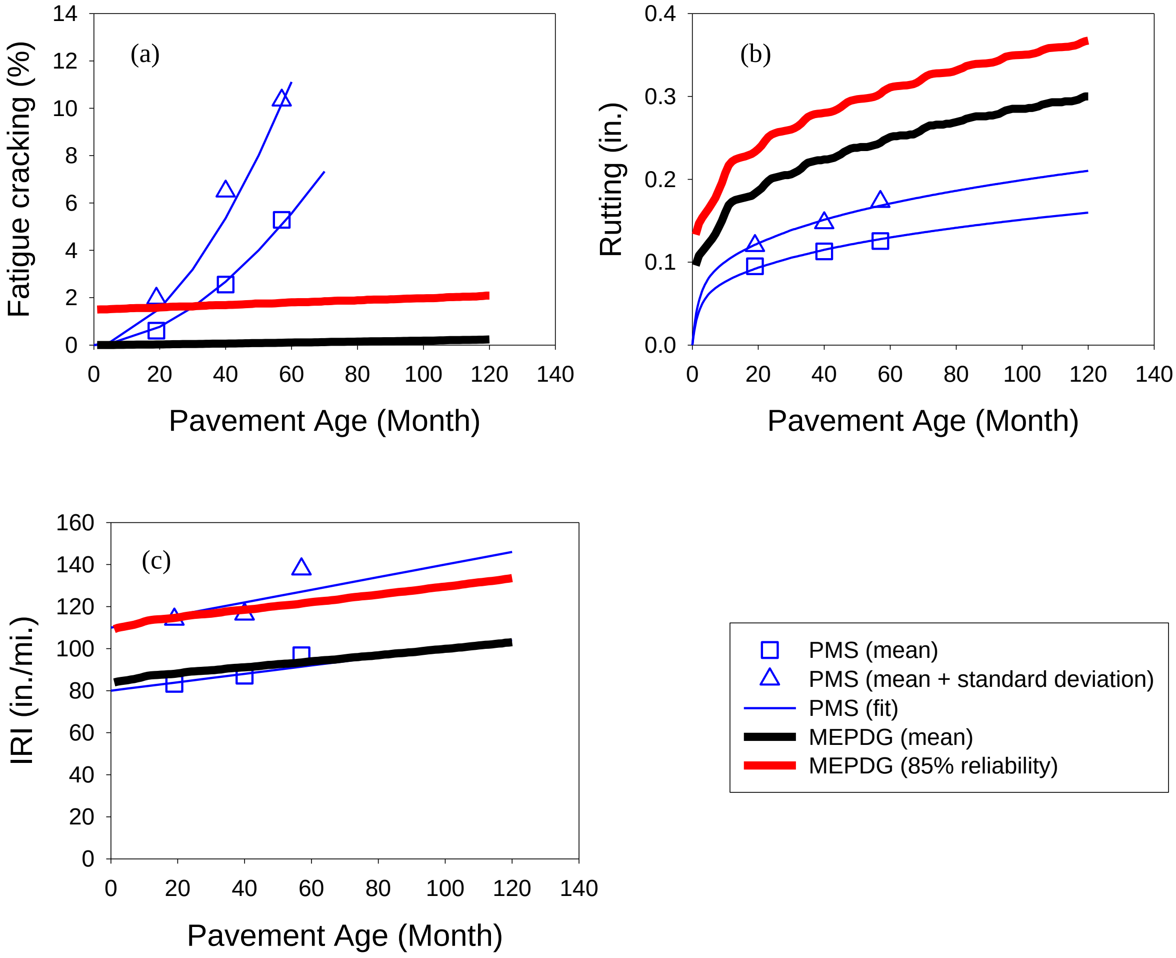


Figure 20
Predicted distress by MEPDG vs. measured distress in PMS for project 230-03-0022: (a) fatigue cracking, (b) rutting, and (c) IRI

The similar analyses were repeated for the other five selected projects and the summary results are presented below.

Load-related Fatigue Cracking. In this part of analysis, the MEPDG predicted fatigue cracking was used to compare to the measured wheel-path alligator cracking reported in the LA-PMS. As shown in Figure 21, the MEPDG predicted fatigue cracking was generally very low, less than 0.5 percent for all six selected projects. On the other hand, most of the measured alligator cracking values were less than 1 percent except six individual points, all of which were from two selected projects. In fact, the majority of the selected AC over crushed stone projects (four out of six) had less than 1 percent of the measured alligator cracking after approximate 10 years of service. Since the fatigue cracking may be not the critical distress for this type of pavement in Louisiana, under such a low level of fatigue cracking, the MEPDG fatigue cracking models seemed to be adequate in this study for AC over crushed stone pavements in Louisiana. However, the results of hypothesis tests in Table 11 indicated that the MEPDG fatigue cracking prediction model was "biased," partially due to the distinct observations from two of the six selected projects. Figure 22 further indicates that the MEPDG-predicted fatigue cracking at a selected 85-percent reliability level was able to cover the field mean alligator cracking for four out of six selected projects.

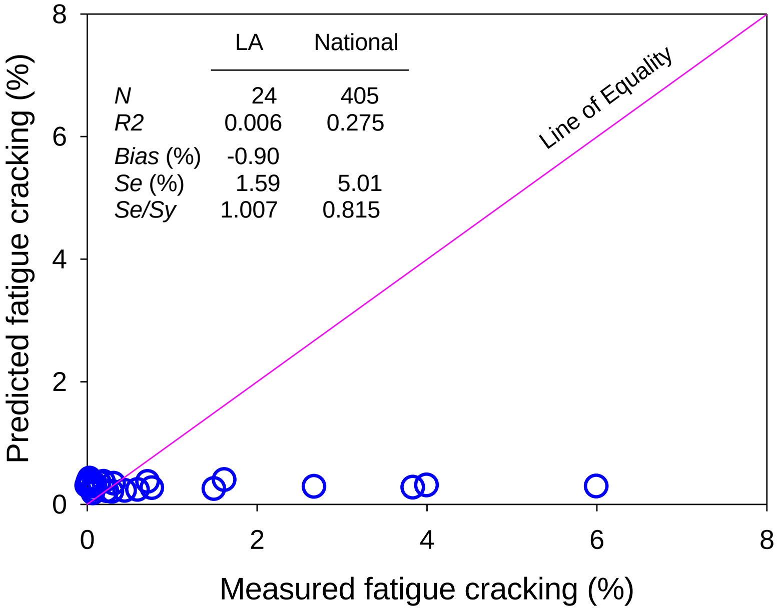


Figure 21
Predicted mean fatigue cracking by MEPDG vs. measured mean fatigue cracking in LA-PMS (AC over crushed stone pavement)

Table 11
Hypothesis analysis (fatigue cracking, AC over crushed stone pavement)

	Null hypothesis (H_0)	P-Value	Result
1	The mean of residual error (predicted cracking - predicted cracking) is zero.	0.012	H_0 rejected
2	The slope of the predicted cracking versus the measured cracking is one.	< 0.001	H_0 rejected
3	The intercept of the predicted cracking versus the measured cracking is zero.	0.001	H_0 rejected
Conclusion: All of the H_0 hypotheses are rejected. The MEPDG-predicted fatigue cracking is "biased" from the measured fatigue cracking for AC over crushed stone pavements.			

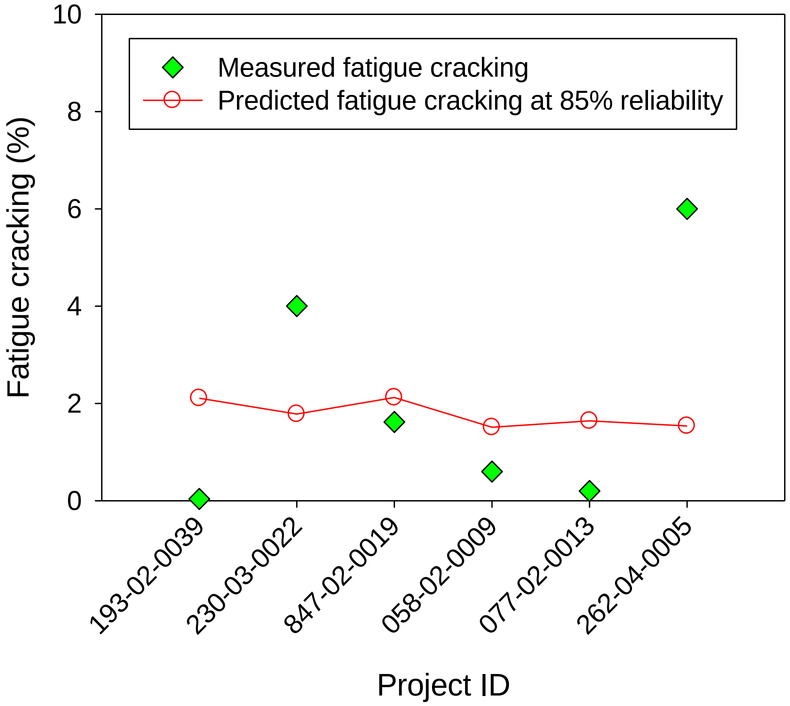


Figure 22
Field variation of fatigue cracking vs. MEPDG design reliability
(AC over Stone pavement)

Rutting. Figure 23 shows the comparison between the predicted and the measured mean rutting for the AC over crushed stone pavements considered. Overall, the MEPDG over-predicted the field rutting for this type of pavement structure in Louisiana. Hypothesis tests (Table 12) also showed that the MEPDG rutting prediction model was “biased.” In addition, the MEPDG-predicted rut depths at a selected 85-percent reliability level were compared with the field variation of rutting as shown in Figure 24. The results indicate that the MEPDG-predicted rutting at the 85-percent reliability level was significantly higher than both the measured mean rutting and the measured rutting at the mean-plus-one-standard-deviation level. Obviously, without local calibration the MEPDG rutting model is not applicable for the AC over crushed stone pavements in Louisiana.

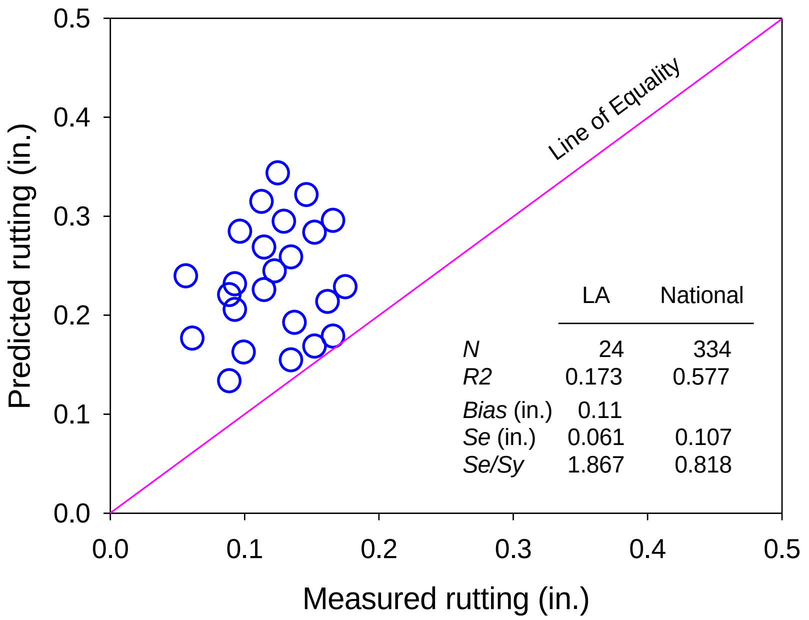


Figure 23
Predicted mean rutting by MEPDG vs. measured mean rutting in LA-PMS (AC over crushed stone pavement)

Table 12
Hypothesis analysis (rutting, AC over crushed stone pavement)

	Null hypothesis (H_0)	P-Value	Result
1	The mean of residual error (predicted rutting - predicted rutting) is zero.	< 0.001	H_0 rejected
2	The slope of the predicted rutting versus the measured rutting is one.	0.073	H_0 accepted
3	The intercept of the predicted rutting versus the measured rutting is zero.	< 0.001	H_0 rejected
Conclusion: Two of the H_0 hypotheses are rejected. The MEPDG-predicted rutting is “biased” from the measured rutting for AC over crushed tone pavements.			

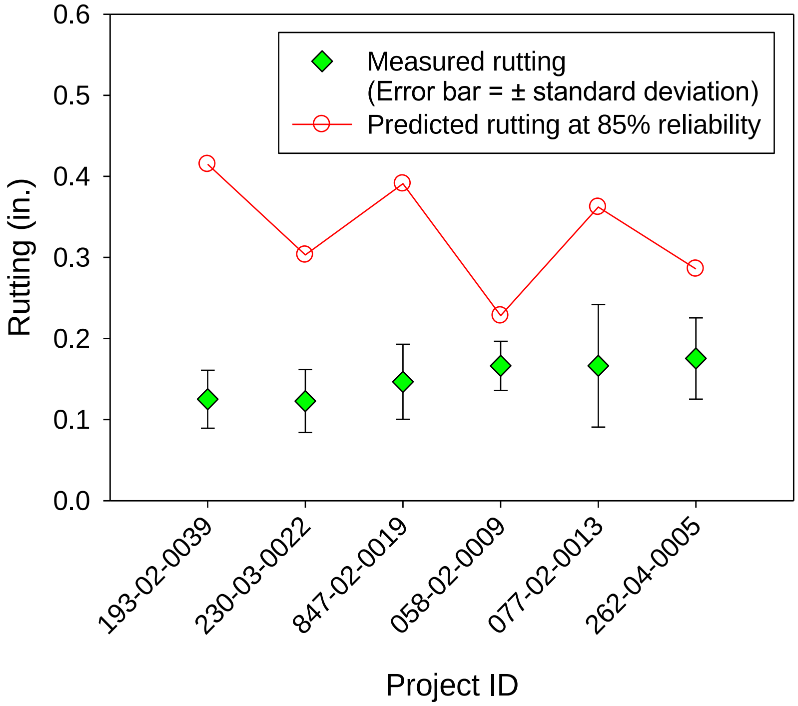


Figure 24
Field variation of rutting vs. MEPDG design reliability
(AC over crushed stone pavement)

IRI. Figure 25 shows the comparison between the predicted and the measured mean IRI for the selected AC over crushed stone pavements. Overall, the MEPDG-predicted mean IRI matched very well with the field mean IRI, although hypothesis tests shown in Table 13 indicated that the MEPDG IRI prediction model was “biased.” Figure 25 also indicates that the goodness-of-fit parameters obtained in this study were better than those obtained in the national calibration of the MEPDG. In addition, Figure 26 shows that the MEPDG-predicted IRI at an 85-percent reliability level was higher than the field mean IRI but very close to the field IRI at the mean-plus-one-standard-deviation level for all six AC over crushed stone projects considered. Based on the above results, the MEPDG IRI model seemed to be adequate for the AC over crushed stone pavements in Louisiana.

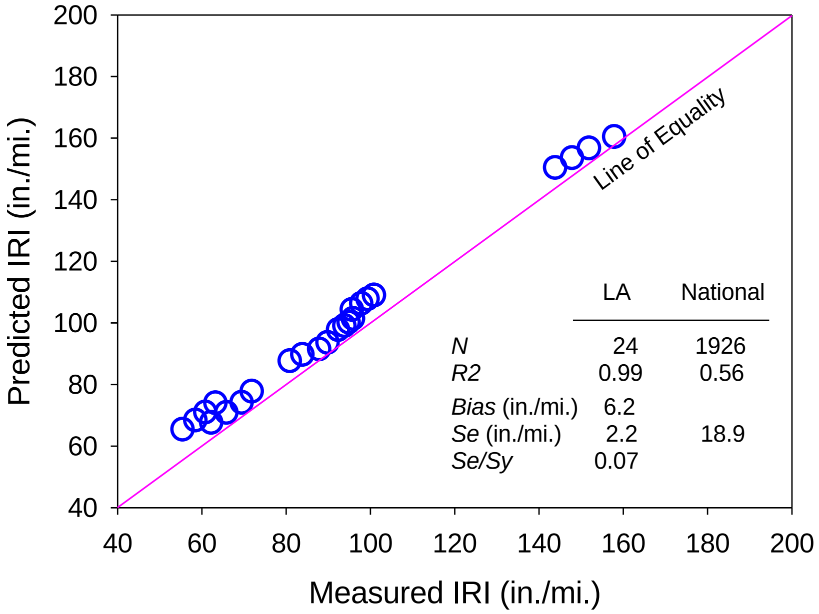


Figure 25
Predicted mean IRI by MEPDG vs. measured mean IRI in LA-PMS
(AC over crushed stone pavement)

Table 13
Hypothesis analysis (IRI, AC over crushed stone pavement)

	Null hypothesis (H_0)	P-Value	Result
1	The mean of residual error (predicted IRI - predicted IRI) is zero.	< 0.001	H_0 rejected
2	The slope of the predicted IRI versus the measured IRI is one.	0.031	H_0 rejected
3	The intercept of the predicted IRI versus the measured IRI is zero.	< 0.001	H_0 rejected
Conclusion: All the H_0 hypotheses are rejected. The MEPDG-predicted IRI is “biased” from the measured IRI for AC over crushed stone pavements.			

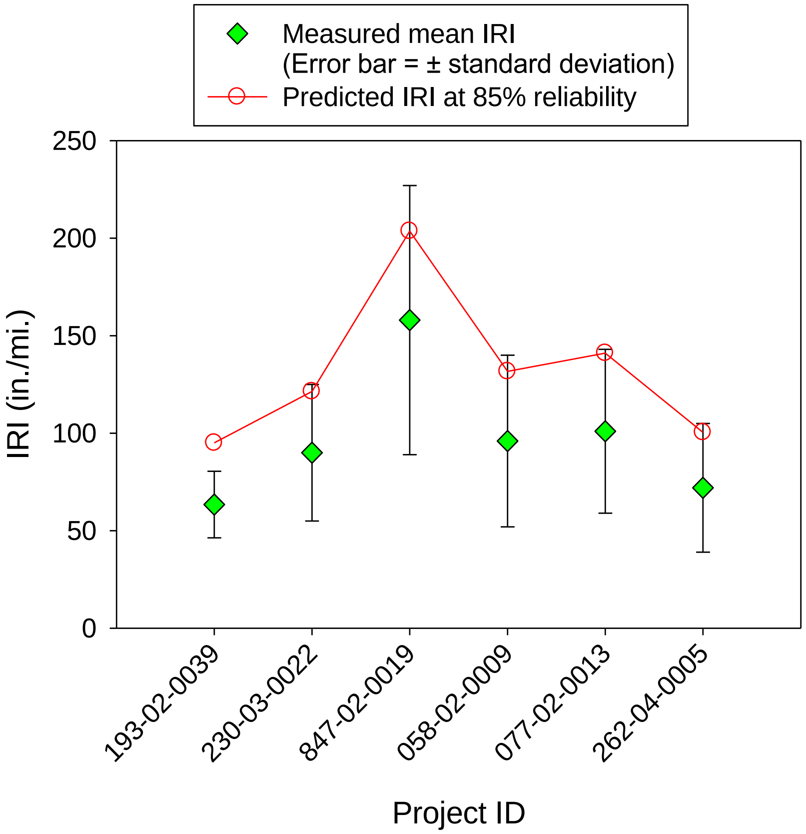


Figure 26
Field variation of IRI vs. MEPDG design reliability
(AC over crushed stone pavement)

Summary. Both the load-related fatigue cracking and IRI prediction models in the MEPDG were found to be adequate for the AC over crushed stone pavements in Louisiana. However, the MEPDG rutting model needs to be locally calibrated before its use for this pavement type.

AC over Soil Cement Base Pavement

A total of 16 AC over soil cement base pavement projects were selected in this study. Table 14 presents the corresponding pavement structures of the selected projects. Other project information can be found in Table 1. Each of the selected projects was then analyzed using the MEPDG design software with a set of Louisiana default inputs obtained from multiple sources as outlined in the preceding sections of the Methodology. The next example provides the analysis procedure for one of these projects.

Table 14
Pavement structures of the selected AC over soil cement base pavements

Project ID	AC Surface	Thickness of AC (in.)	Base	Thickness of Base (in.)	Subgrade and Stabilization
018-30-0018	1.5" TYPE 8 WC + 2" TYPE 8 BC	3.5	CEMENT STABILIZED	8.5	A-6
029-07-0055	1.5" TYPE 3 WC + 2" TYPE 3 BC	3.5	CEMENT STABILIZED	8.5	A-4
036-03-0016	1.5" TYPE 8 WC +2" TYPE 8 BC	3.5	CEMENT STABILIZED	8.5	A-6, 12" TYPE D LIME TREATED
067-03-0009	1.5" TYPE 3 WC + 2" TYPE 3 BC	3.5	LIME FLYASH STABILIZED	10.0	A-6
139-06-0011	1.5" TYPE 8 WC + 2" TYPE 8 BC	3.5	CEMENT TREATED	12.0	A-4, 12" TYPE D LIME TREATED
211-04-0009	1.5" TYPE 8 WC + 2" TYPE 8 BC	3.5	CEMENT STABILIZED	8.5	A-4, TYPE D LIME TREATED
260-03-0010	1.5" TYPE 8 WC + 2" TYPE 8 BC	3.5	CEMENT STABILIZED	8.5	A-6, 15" TYPE D LIME TREATED
261-02-0020	1.5" TYPE 8F WC + 2" TYPE 8 BC	3.5	CEMENT STABILIZED	8.5	A-6
268-01-0014	2" TYPE 8F WC + 2.5" TYPE 8 BC	4.5	CEMENT STABILIZED	8.5	A-6
397-04-0004	1.5" TYPE 8 WC + 2" TYPE 8 BC	3.5	CEMENT STABILIZED	8.5	A-4, 12" TYPE D LIME TREATED
432-01-0018	2" TYPE 8F WC + 2.5" TYPE 8 BC	4.5	CEMENT STABILIZED	8.5	A-4, 12" TYPE D LIME TREATED
803-32-0001	1.5" TYPE 3 WC + 2" TYPE 3 BC	3.5	CEMENT TREATED	12.0	A-4
810-07-0014	1.5" TYPE 8 WC + 2" TYPE 8 BC	3.5	CEMENT STABILIZED	8.5	A-6, 15" TYPE D LIME TREATED
828-15-0012	1.5" TYPE 8 WC + 2" TYPE 8 BINDER COURSE	3.5	CEMENT STABILIZED	8.5	A-4, 12" TYPE D LIME TREATED
839-02-0016	1.5" TYPE 3 WC + 2" TYPE 3 BC	3.5	CEMENT TREATED	12.0	A-4
852-03-0009	2" TYPE 8F WC + 2" TYPE 8 BC	4.0	CEMENT TREATED	12.0	A-7, 15" TYPE D LIME TREATED, 9% BY VOLUME

WC = Wearing Course, BC = Binder Course

Project 803-32-0001 was a flexible pavement rehabilitation project located on LA 938 in east Louisiana. The existing AC and base course were removed and reconstructed. The finished flexible pavement consisted of a 1.5-in. Type 3 wearing course, a 2-in. Type 3 binder course, and a 12-in. cement treated base course. The project was accepted on March 4, 1999. Two-way ADT on this route was 2,500 in the year 1999. Pavement condition surveys were conducted in 2000, 2002, 2004, 2007, and 2008. The MEPDG design program was run with the collected input information. The predicted and measured distresses (and IRI) were compared in Figure 27.

For this particular project, the LA-PMS recorded considerable wheel-path cracking during the 10-year service period. However, the MEPDG predicted almost zero mean fatigue cracking (Figure 27a). Meanwhile, the MEPDG significantly over-predicted the field mean rutting (Figure 27b). The predicted rutting at a selected 75 percent reliability was also higher than the mean-plus-one-standard-deviation rutting in the LA-PMS. On the other hand, the measured and predicted mean IRI matched each other very well (Figure 27c). The predicted IRI at 75-percent reliability level was lower than the mean-plus-one-standard-deviation IRI measured in the field.

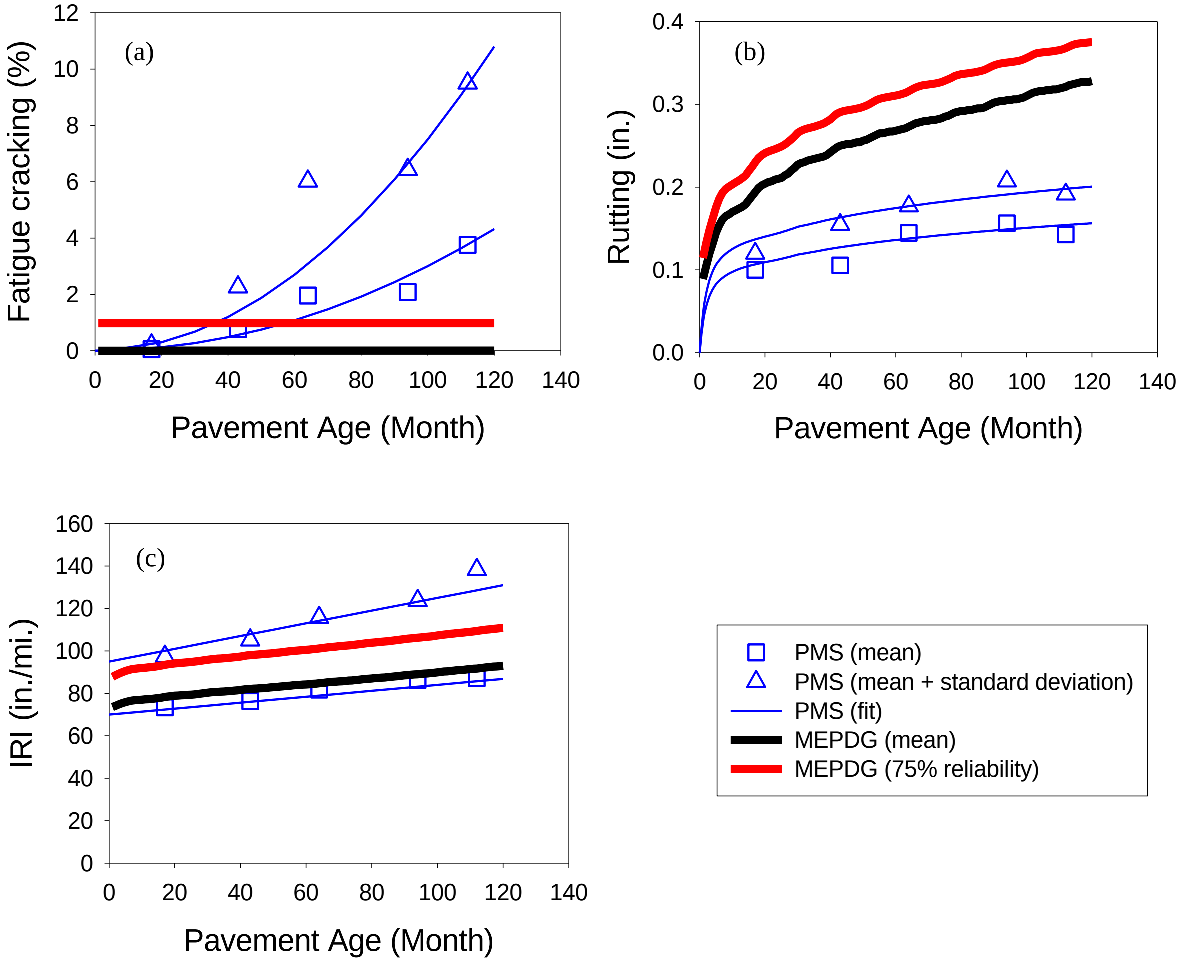


Figure 27
Predicted distress by MEPDG vs. measured distress in PMS for project 803-32-0001: (a) fatigue cracking, (b) rutting, and (c) IRI

The above analysis was repeated for the rest of AC over soil cement base pavements selected. The results are summarized as follows.

Load-related Fatigue Cracking. In this part of the analysis, the MEPDG-predicted load-related fatigue cracking was compared with the field wheel-path cracking reported in the LA-PMS. In contrast to other pavement structures analyzed previously, AC over soil cement base pavements in Louisiana often develop higher amounts of wheel-path cracking as reported in the LA-PMS (Figure 28). However, the MEPDG predicted almost zero load-related fatigue cracking for all the projects. Hypothesis tests (Table 15) also showed a significant difference between the predicted fatigue cracking and the measured wheel-path cracking. In addition, as shown in Figure 29, the MEPDG-predicted fatigue cracking at the 75-percent reliability level was also lower than the field mean wheel-path cracking for all but one select project (810-07-0014).

According to the user manual of the MEPDG, the design software should be able to predict the soil cement fatigue cracking and the resultant reduction of soil cement resilient modulus over time. The predicted load-related fatigue cracking on the pavement surface by the MEPDG should include both the load-related fatigue cracking in the AC and the reflective cracking from the soil cement base *[1]*. However, it was found in this study that the predicted reflective cracking from the soil cement base was always zero, and the resilient modulus of the soil cement base remained constant over time. It is suspected that the soil cement fatigue cracking model in the MEPDG may not be properly incorporated into the design software. Furthermore, based on the local experience in Louisiana, a considerable amount of surface cracks observed on AC over soil cement base pavements were reflective cracking due to soil cement shrinkage. This reflective cracking, if extended into the wheel-path, would be recorded as wheel-path alligator cracking by the LA-PMS. However, the current MEPDG does not consider the shrinkage cracking of the soil cement base. Both of the above two factors may contribute to the discrepancy between the measured wheel-path cracking and the MEPDG-predicted load-related fatigue cracking for AC over soil cement base pavements. Therefore, it is difficult to validate the accuracy of the MEPDG load-related fatigue cracking models for AC over soil cement base pavements in this study.

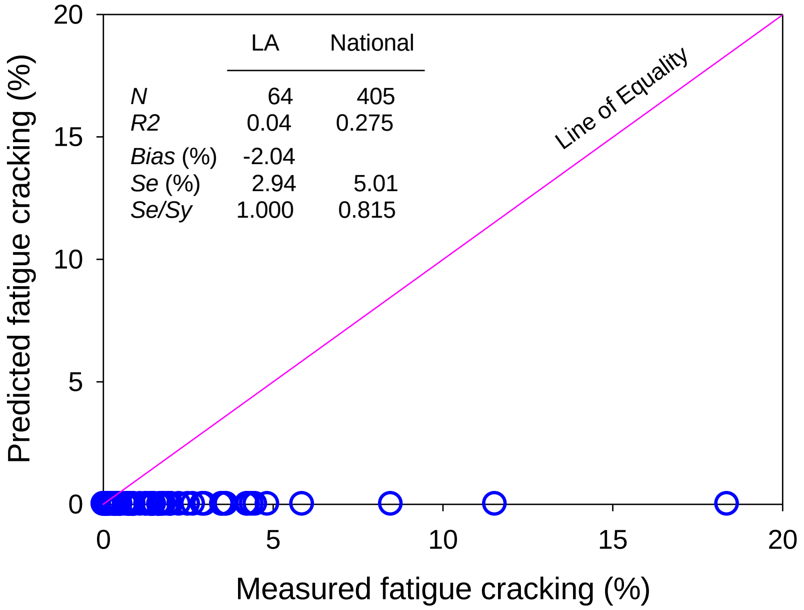


Figure 28
Predicted mean fatigue cracking by MEPDG vs. measured mean fatigue cracking in LA-PMS (AC over soil cement base pavement)

Table 15
Hypothesis analysis (fatigue cracking, AC over soil cement base pavement)

	Null hypothesis (H_0)	P-Value	Result
1	The mean of residual error (predicted cracking - predicted cracking) is zero.	< 0.001	H_0 rejected
2	The slope of the predicted cracking versus the measured cracking is one.	< 0.001	H_0 rejected
3	The intercept of the predicted cracking versus the measured cracking is zero.	< 0.001	H_0 rejected
Conclusion: All of the H_0 hypotheses are rejected. The MEPDG-predicted fatigue cracking is "biased" from the measured fatigue cracking for AC over soil cement pavements.			

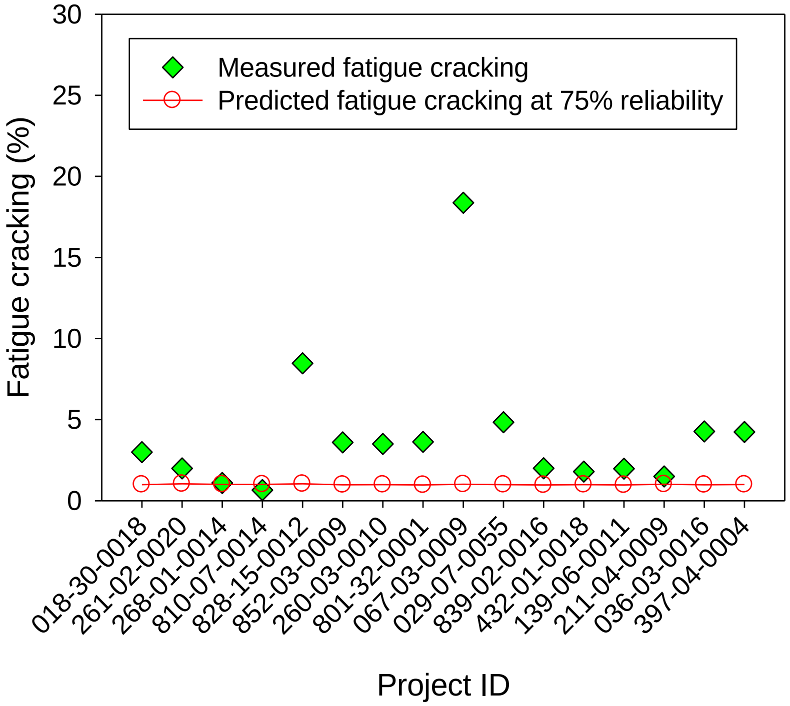


Figure 29
Field variation of fatigue cracking vs. MEPDG design reliability
(AC over soil cement base pavement)

Rutting. Figure 30 shows the comparison between the predicted and the measured mean rutting for the AC over soil cement base pavements selected. Overall, the MEPDG over-predicted the rutting for this type of pavement in Louisiana. Hypothesis tests (Table 16) also indicated a significant difference between the MEPDG-predicted and the measured rutting in the LA-PMS. In addition, as shown in Figure 31, the MEPDG-predicted rutting at a selected 75-percent reliability level was consistently higher than the field measured rutting at the mean-plus-one-standard-deviation level. These results suggest that a local calibration of the MEPDG rutting model is needed for designing the AC over soil cement base pavements in Louisiana.

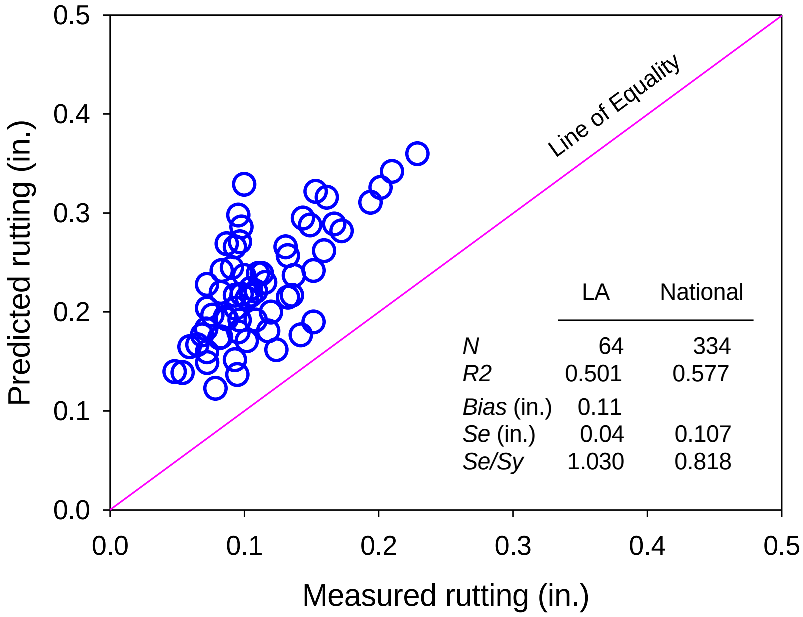


Figure 30
Predicted mean rutting by MEPDG vs. measured mean rutting in LA-PMS
(AC over soil cement base pavement)

Table 16
Hypothesis analysis (rutting, AC over soil cement base pavement)

	Null hypothesis (H_0)	P-Value	Result
1	The mean of residual error (predicted rutting - predicted rutting) is zero.	< 0.001	H_0 rejected
2	The slope of the predicted rutting versus the measured rutting is one.	0.806	H_0 accepted
3	The intercept of the predicted rutting versus the measured rutting is zero.	< 0.001	H_0 rejected
Conclusion: Two of the H_0 hypotheses are rejected. The MEPDG-predicted rutting is “biased” from the measured rutting for AC over soil cement pavements.			

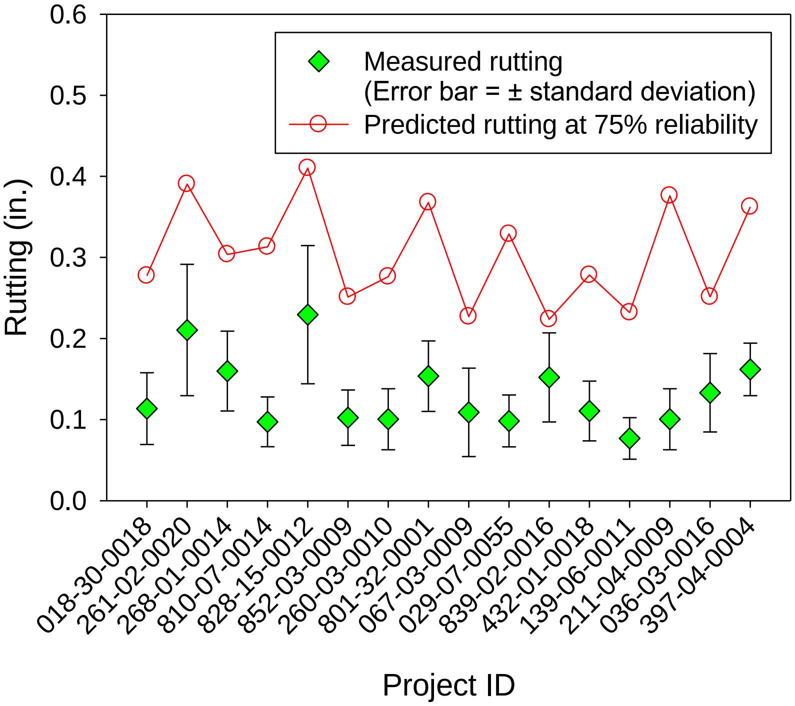


Figure 31
Field variation of rutting vs. MEPDG design reliability
(AC over soil cement base pavement)

IRI. Figure 32 shows the comparison between the predicted and the measured mean IRI. Overall, the predicted IRI agreed well with the measured IRI except for a couple projects where a higher IRI was reported in the LA-PMS. Although hypothesis tests (Table 17) showed that the MEPDG-predicted IRI was "biased" from the measured IRI in the LA-PMS, the goodness-of-fit parameters (Figure 32) obtained in this study seemed to be better than those obtained from the national calibration of the MEPDG IRI model. On the other hand, the MEPDG-predicted IRI at a selected 75-percent reliability was higher than the mean measured IRI but lower than the measure mean-plus-one-standard-deviation IRI. This result is reasonable because a lower design reliability level (75 percent) was selected.

From the above analyses, the MEPDG IRI model was considered adequate in this study for the AC over soil cement base pavements in Louisiana. Again, if any other MEPDG model will be locally calibrated, the IRI model should be re-evaluated.

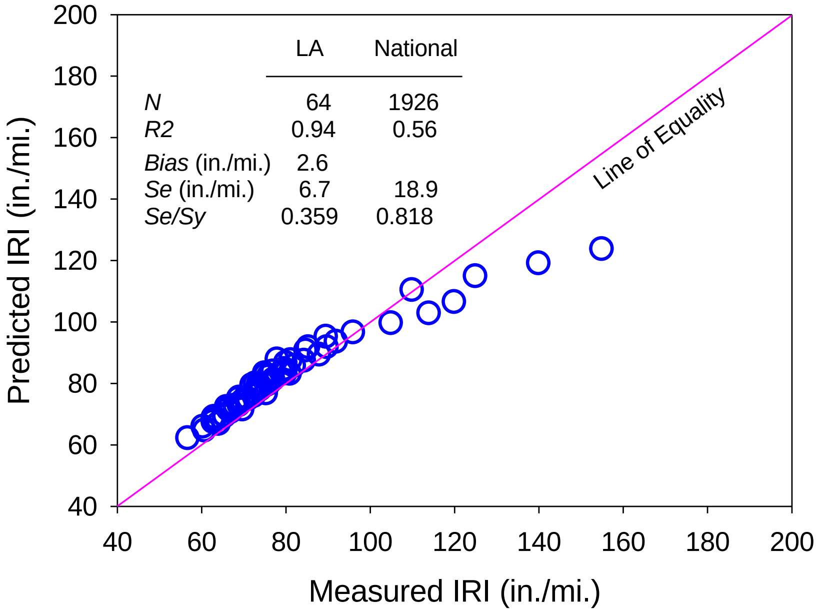


Figure 32
Predicted mean IRI by MEPDG vs. measured mean IRI in LA-PMS (AC over soil cement base pavement)

Table 17
Hypothesis analysis (IRI, AC over soil cement base pavement)

	Null hypothesis (H_0)	P-Value	Result
1	The mean of residual error (predicted IRI - predicted IRI) is zero.	0.002	H_0 rejected
2	The slope of the predicted IRI versus the measured IRI is one.	< 0.001	H_0 rejected
3	The intercept of the predicted IRI versus the measured IRI is zero.	< 0.001	H_0 rejected
Conclusion: All the H_0 hypotheses are rejected. The MEPDG-predicted IRI is “biased” from the measured IRI for AC over soil cement pavements.			

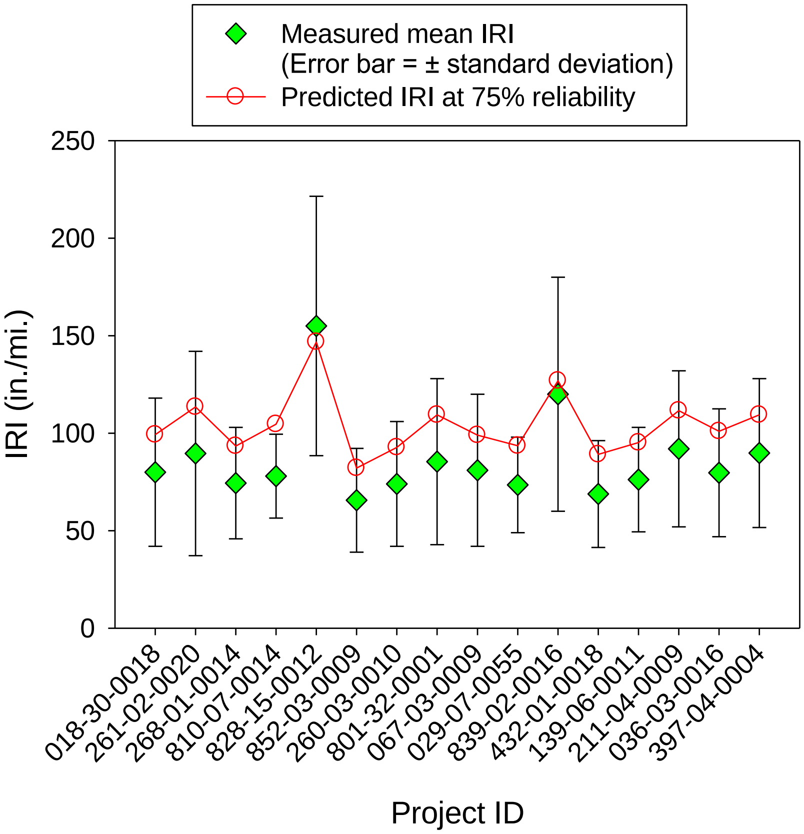


Figure 33
Field variation of IRI vs. MEPDG design reliability
(AC over soil cement base pavement)

Summary. AC over soil cement base pavements developed considerable wheel-path cracking as reported in the LA-PMS. The MEPDG-predicted load-related fatigue cracking was significantly less compared with the field wheel-path cracking for most of the selected projects. The discrepancy was likely caused by (1) the software issue in the MEPDG and (2) soil cement shrinkage cracking issue in the LA-PMS. Meanwhile, the MEPDG over-predicted the rutting for all the 16 selected projects. A local calibration of the MEPDG fatigue cracking and rutting models is thus recommended. The IRI model in the MEPDG seemed to be adequate for AC over soil cement base pavements in Louisiana.

AC over Stone Interlayer Pavement

AC over stone interlayer pavement is a special pavement structure used in Louisiana, which is modified from the conventional AC over soil cement base pavement structure. In this type of pavement, a crushed stone interlayer is placed between the AC and the soil cement layer in order to mitigate the reflective cracking in the AC due to soil cement shrinkage. Most of the projects with the AC over stone interlayer pavement structure in Louisiana were constructed within the last five years. These projects only have one or two pavement condition survey data points in the LA-PMS, mostly with very low distresses, which are not adequate to validate the prediction models in the MEPDG.

In this study, only one project (219-30-0012) with the AC over stone interlayer pavement structure was found with an adequate service life. The project was a new flexible pavement project located on LA 10 in east Louisiana. The pavement structure consisted of a 1.5-in. Type 3 wearing course, a 2-in. Type 3 binder course, a 4-in. crushed stone base course, and a 6-in. cement treated subbase. The project was accepted on January 27, 1999. Two-way ADT on this route was 680 in the year 1999. Pavement condition surveys were conducted in years 2000, 2002, 2004, 2007, and 2008. The MEPDG design program was run with the collected input information. The predicted and measured distresses (and IRI) were compared in Figure 34.

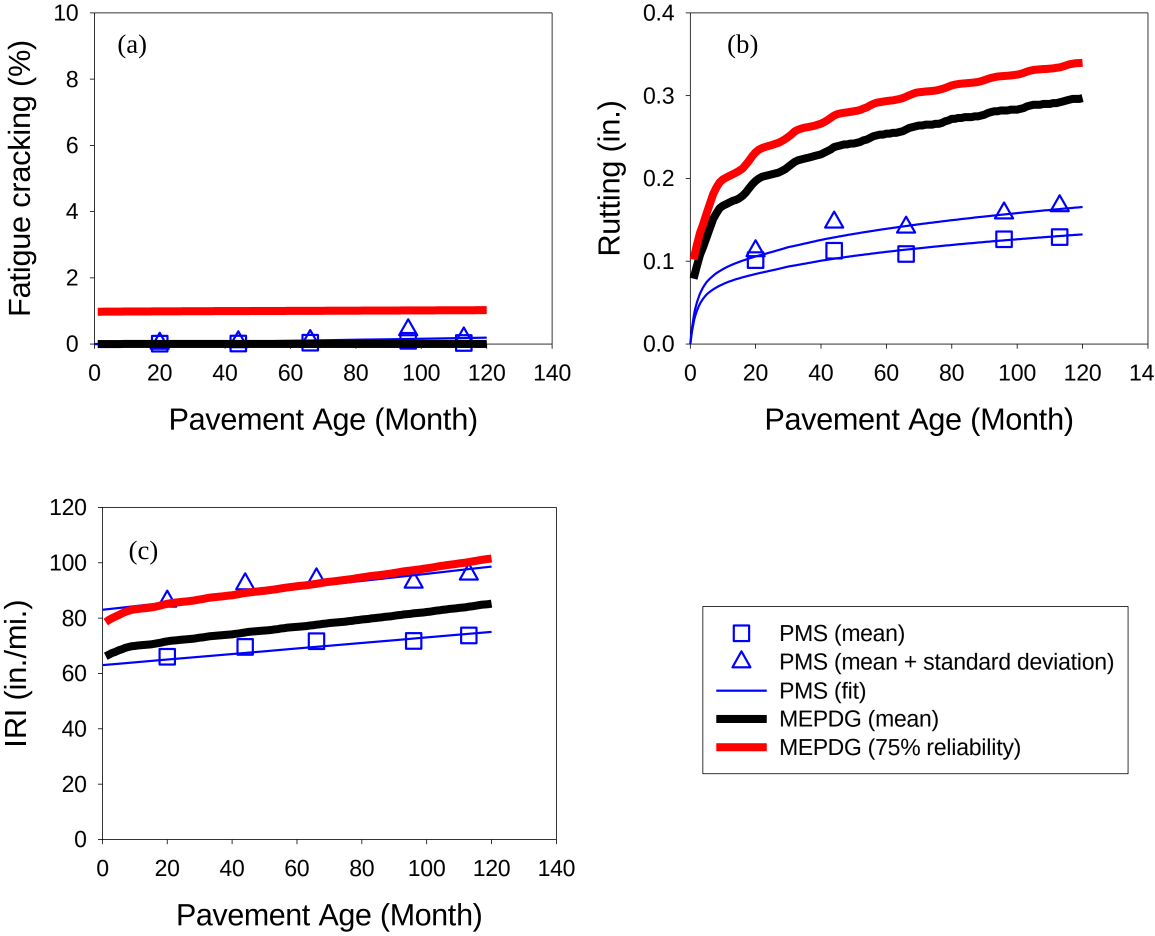


Figure 34
Predicted distress by MEPDG vs. measured distress in PMS for project 219-30-0012: (a) fatigue cracking, (b) rutting, and (c) IRI

As expected, in a 10-year service life, very little wheel-path cracking was reported in the LA-PMS for this project as compared to conventional AC over soil cement base pavements. The MEPDG-predicted load-related fatigue cracking was also almost zero (Figure 34a). However, the MEPDG significantly over-predicted the field measured rutting (as shown in Figure 34b). Similar trends were observed for AC over RPCC base, AC over crushed stone, and AC over soil cement base pavements. In addition, the measured and predicted mean IRI matched well with each other. The predicted IRI at a selected 75-percent reliability also matched well with the mean-plus-one-standard-deviation IRI measured in the field (Figure 34c).

The above analyses seemed to indicate that both the MEPDG fatigue cracking and the IRI models were adequate; whereas, the MEPDG rutting model over-predicted the field rutting for AC over stone interlayer pavements in Louisiana. However, these results have to be further verified as more projects with this type of pavement structure and longer service periods become available.

ANOVA and Multiple Comparisons

The ANOVA and multiple comparisons analyses were performed to determine whether the residual errors (the predicted value minus the measured value) of the MEPDG prediction models were affected by factors such as pavement type, traffic volume, subgrade modulus, and geographic locations.

Since the MEPDG IRI model was found generally adequate for most of the selected projects, only the residual errors of the MEPDG load-related fatigue cracking and rutting models were evaluated in the ANOVA and multiple comparisons analyses.

The Effect of Pavement Type

A total of 39 projects were included in this part of analysis except the AC over stone interlayer pavement project, because a single case cannot represent the statistical characteristics for this type of pavement.

The ANOVA result (Table 18) indicated that the mean residual error of the MEPDG fatigue cracking prediction models for at least one of the four pavement types was different from that of the other pavement types.

Table 18
ANOVA result on the error of the fatigue cracking prediction for different types of pavement

	SS	Df	MS	F	P-value	$F_{critical}$	Conclusion
Between samples	134.6621	3	44.8874	5.1979	0.004	2.874	H_0 Rejected
Within samples	302.2465	35	8.6356				
Totals	436.9086	38					

Figure 35 shows the mean residual error of the load-related fatigue cracking models for different pavement types. On average, the MEPDG fatigue cracking models provided the smallest residual error for AC over AC and AC over RPCC pavements. Multiple comparisons (presented in Table 19) suggested that the residual error of the load-related fatigue cracking models for AC over soil cement pavement was significantly different from that for the AC over RPCC base and AC over AC base pavements. Although AC over crushed stone pavements also showed a trend of under-prediction of fatigue cracking; no significant statistical difference was found.

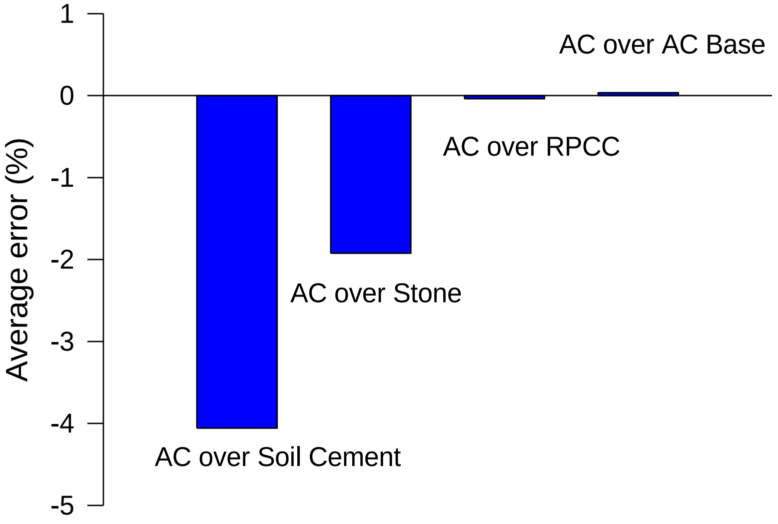


Figure 35
Mean residual error of fatigue cracking prediction for different types of pavement

As discussed previously, the current MEPDG design software cannot correctly predict fatigue cracking in the soil cement base. In addition, a considerable amount of wheel-path cracking observed from AC over soil cement base pavements in Louisiana was reflected from the shrinkage cracking of the soil cement layer. However, the current MEPDG design software does not consider the shrinkage cracking in the soil cement base. Both of the above two factors may contribute to the discrepancy between the measured wheel-path cracking and the MEPDG-predicted load-related fatigue cracking for AC over soil cement base pavements.

Table 19
Result of multiple comparisons (Fisher's LSD, α=0.05)

	AC over soil cement base	AC over crushed stone	AC over RPCC base	AC over AC base
Number of sample	16	6	12	5
Average error (%)	-4.06	-1.92	-0.04	0.04
AC over soil cement	—	C	SD	SD
AC over stone	—	—	C	C
AC over RPCC	—	—	—	C
AC over AC base	—	—	—	—

C = Comparable SD = Significantly Different

The ANOVA result for the residual error of rutting prediction is shown in Table 20. The ANOVA result indicated that the mean residual error of the MEPDG rutting prediction for at least one of the pavement types was different from that of the other types of pavements.

Table 20
ANOVA result on the error of the total rutting prediction for different types of pavement

	SS	Df	MS	F	P-value	$F_{critical}$	Conclusion
Between samples	0.1747	3	0.0582	19.2836	0.000	2.874	H_0 Rejected
Within samples	0.1057	35	0.0030				
Totals	0.2803	38					

Figure 36 shows the residual error in the rutting prediction model for different pavement types. On average, the MEPDG slightly under-predicted the total rutting for AC over AC base pavements while over-predicted the total rutting for the other three pavement types. To investigate the individual differences between different pavement types, multiple comparisons were performed using Fisher's LSD method at a significance level of $\alpha = 0.05$. The result (presented in Table 21) suggested that the mean residual error in rutting prediction for AC over AC base pavements was significantly lower than that of the other three types of pavement. The error in rutting prediction for AC over RPCC base pavement was significantly higher than the other three types of pavement. Meanwhile, the errors in total rutting prediction for AC over crushed stone and AC over soil cement base pavements were similar to each other.

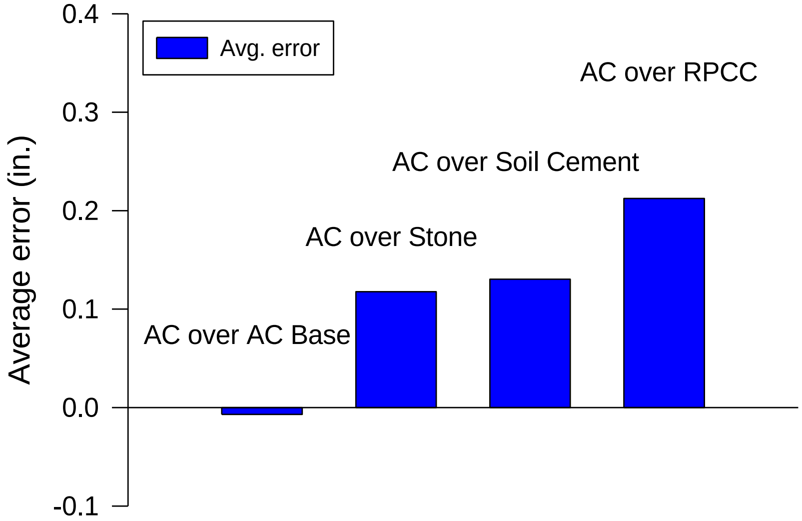


Figure 36
Mean residual error of total rutting prediction

Table 21
Result of multiple comparisons (Fisher's LSD, α=0.05)

	AC over AC base	AC over crushed stone	AC over soil cement base	AC over RPCC base
Number of sample	16	6	12	5
Average error (in.)	-0.01	0.12	0.13	0.21
AC over AC base	—	SD	SD	SD
AC over stone	—	—	C	SD
AC over soil cement	—	—	—	SD
AC over RPCC	—	—	—	—

C = Comparable SD = Significantly Different

Effect of Traffic Volume

In this part of analysis, the 40 selected projects were grouped in to two categories: low to medium volume (ADT < 8000) roads and high volume (ADT > 8000) roads. T-tests were used to evaluate the difference in the mean residual error of the MEPDG model in the two categories of pavements.

The T-test results were presented in Table 22 and Table 23. Note that H_0 hypotheses in both of the T-tests were rejected, meaning a significant difference between the two groups of data. The first T-test (shown in Table 22) suggested that the MEPDG tended to over-predict rutting in high volume roads more significantly. The second T-test (shown in Table 23) suggested that the MEPDG tended to under-predict the load-related fatigue cracking in low- to medium-volume roads more significantly.

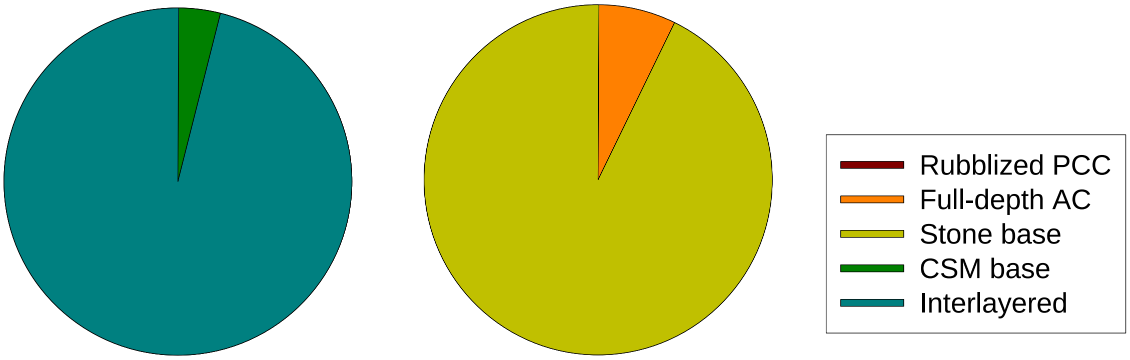
Table 22
T-test result on the error of the MEPDG rutting model

	Low to medium volume road	*High volume road*
Mean	0.108	0.191
Variance	0.006	0.005
Observations	26	14
Pooled Variance	0.006	
Hypothesized Mean Difference	0	
df	38	
t Stat	-3.315	
P(T<=t)	0.002	<0.05
t Critical	2.024	

Table 23
T-test result on the error of the MEPDG load-related fatigue cracking model

	Low to medium volume road	*High volume road*
Mean	-2.936	-0.036
Variance	14.553	0.002
Observations	26	14
Pooled Variance	9.575	
Hypothesized Mean Difference	0	
df	38	
t Stat	-2.827	
P(T<=t)	0.007	<0.05
t Critical	2.0244	

A further examination on the population of the two categories (shown in Figure 37) revealed that the AC over RPCC base pavement is the predominant pavement type and is exclusively used in high volume roads. Similarly, AC over soil cement base pavement is the predominant pavement type and is exclusively used in the low to medium volume roads. Thus the difference in the error of the MEPDG models for the two levels of traffic volume can be explained by the different pavement type as discussed previously.



(a) (b)

Figure 37
Pavement types in each category: (a) low to medium volume, (b) high volume

Effect of Subgrade Modulus

The subgade M_r values of the 40 selected projects ranged from 7,627 to 10,634 psi with an average of 9,212 psi. In this part of analysis, the selected projects were grouped into two categories: stiffer subgrade ($M_r > 9000$ psi) and weaker subgrade ($M_r < 9000$ psi).

In order to balance the effect of the pavement type, 26 projects were selected in this part of analysis, 13 of which are on stiffer subgrade and the other 13 projects are on softer subgrade. Each category includes the same amount of project of each pavement type. The result of the T-test result (shown in Table 24) on the error of total rutting indicated that the MEPDG tended to over-predict rutting for pavements on weaker subgrade more significantly. However, no significant difference was found in the error of fatigue cracking model between softer and stiffer subgrades, as shown in Table 25.

Table 24
T-test result on the error of the MEPDG rutting model

	Weaker subgrade	*Stiffer subgrade*
Mean	0.157	0.089
Variance	0.003	0.011
Observations	13	13
Pooled Variance	0.007	
Hypothesized Mean Difference	0	
df	24	
t Stat	2.066	
P(T<=t)	0.049	<0.05
t Critical	2.064	

Table 25
T-test result on the error of the MEPDG load-related fatigue cracking model

	Weaker subgrade	*Stiffer subgrade*
Mean	-1.273	-2.482
Variance	2.746	26.408
Observations	13	13
Pooled Variance	14.577	
Hypothesized Mean Difference	0	
df	24	
t Stat	0.807	
P(T<=t)	0.427	>0.05
t Critical	2.064	

Effect of Location

In this part of analysis, the state of Louisiana was divided into two geographic regions by a line with a latitude of 30.6 degree (shown in Figure 38). North of this line represents the hilly area with a higher average elevation, a lower year-round average temperature, and a wider range of temperature variation. South of this line represents the coastal plain areas with a lower average elevation, a higher year-round average temperature, and a narrower range of temperature variation.

To balance the effect of the pavement type, 10 projects were selected from each geographic region with same numbers of projects of each pavement type. The result of the T-test (shown in Table 26) on the error of total rutting indicated that the MEPDG tended to over-predict rutting more significantly for pavements in south Louisiana. Since subgrade soils in south

Louisiana are generally softer than those in the north Louisiana, the influence of the geographic location can be explained by the different subgrade M_r as described in the previous section of this report.

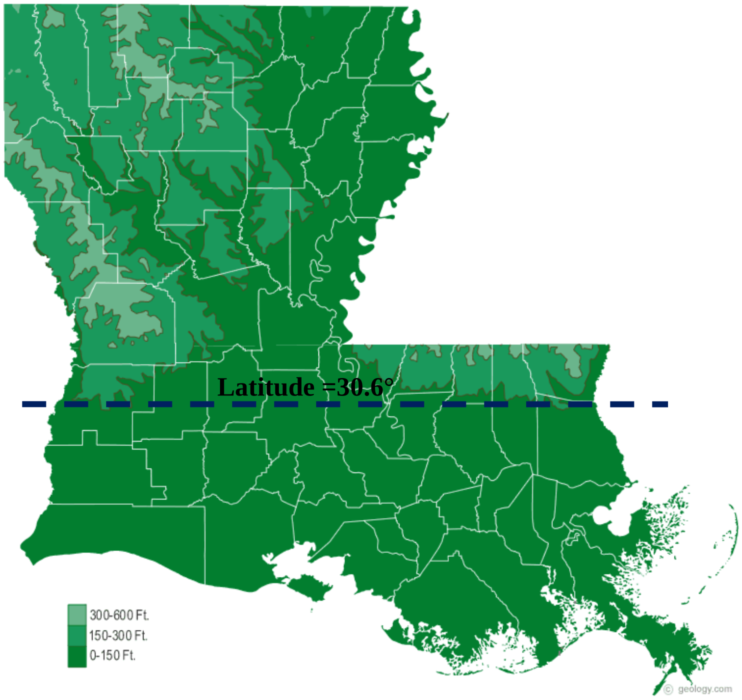


Figure 38
Division of the two geographic regions in Louisiana (courtesy of www.geology.com)

When analyzing load-related fatigue cracking, the AC over RPCC and AC over AC base projects were excluded because this two types of pavements show very small amounts of field cracking. For the remaining seven AC over soil cement base and AC over crushed stone projects in each group, T-test results (shown in Table 27) indicated that the MEPDG tended to under-predict load-related fatigue cracking in north Louisiana more significantly. Since the MEPDG predicted almost no fatigue cracking for all the selected projects as shown previously, the PMS records more fatigue cracking in pavements in north than in south Louisiana.

Table 26
T-test result on the error of the MEPDG rutting model

	South		*North*
Mean	0.154		0.060
Variance	0.007		0.010
Observations	10		10
Pooled Variance	0.008		
Hypothesized Mean Difference	0		
Degree of freedom	18		
t Stat	2.298		
P(T<=t)	0.034	<0.05	
t Critical	2.100		

Table 27
T-test result on the error of the MEPDG load-related fatigue cracking model

	South		*North*
Mean	-0.904		-3.064
Variance	0.619		3.847
Observations	7		7
Pooled Variance	2.233		
Hypothesized Mean Difference	0		
df	12		
t Stat	2.705		
P(T<=t)	0.019	<0.05	
t Critical	2.179		

Local Calibration Factors for the Rutting Models

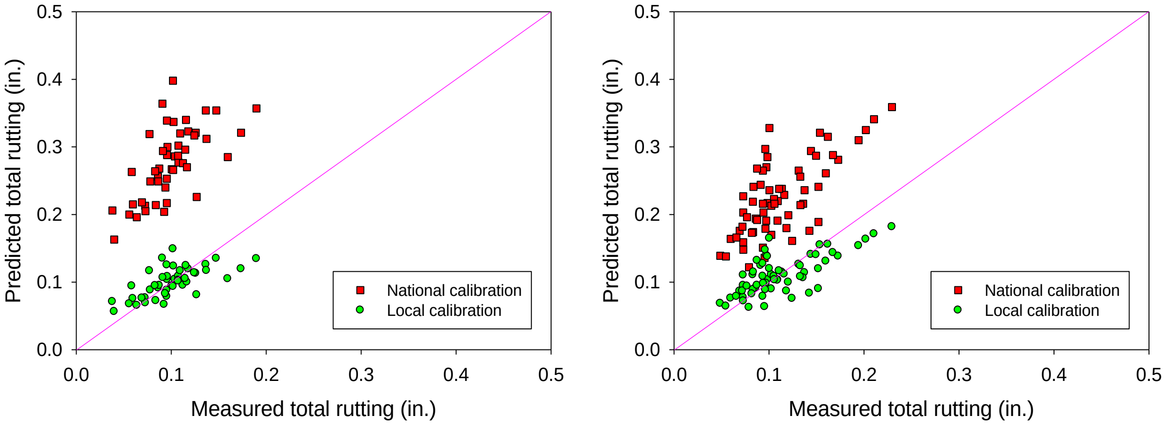
A preliminary calibration of the MEPDG rutting models was conducted for AC over RPCC base and AC over soil cement base pavements. These two pavement types were selected because the investigators were able to locate a sufficient number of projects to run a valid local calibration. Since the MEPDG does not consider the permanent deformation within either the RPCC or the soil cement layer, only the local calibration factors for AC (β_{1r}) and subgrade (β_{s1}) were obtained.

Table 28 presents the local calibration factors obtained in this study using the special calibration approach described in the preceding section of the Methodology. It is shown that all the local calibration factors are less than one, which means that the MEPDG over-predicted the amount of rutting for both AC and subgrade materials in Louisiana. In addition, the local calibration factors for subgrade rutting model were lower than those for the AC rutting model for both pavement structures. This result suggested that, without local calibration, the MEPDG tended to over-predict the subgrade rutting more significantly, which confirmed the findings from some other states *[5] [8]*.

The measured and predicted total rutting before and after the local calibration are compared in Figure 39. It is shown that, after the local calibration, the prediction accuracy of the MEPDG rutting model was significantly improved.

Table 28
Local calibration factors for the AC and subgrade rutting models

	β_{1r} for AC	β_{s1} for subgrade
AC over RPCC base	0.44	0.22
AC over soil cement base	0.68	0.42



(a) AC over RPCC base

(b) AC over soil cement

Figure 39
Local calibration of the rutting model

Design Example of Using MEPDG

An AC over AC base pavement project (ID: 267-02-0022) was selected to demonstrate the use of the MEPDG. AC over AC base pavement type was selected because the nationally calibrated MEPDG, based on the current available data, showed adequate prediction power for both rutting and fatigue cracking of this type of pavement. Table 29 summarizes the original design of the project according to the AASHTO 1993 design guide. The designed pavement structure consists of a 2.0-in. Type 8F AC wearing course, a 3.0-in. Type 8 AC binder course, and a 5.0-in. Type 5 AC base course. The calculated structure number of the designed pavement structure is 3.69, which meets the design requirement.

Table 29
Summary of the AASHTO 1993 design

Flexible Pavement Design					
Design Life				20 years	
18-kip ESALs over Initial Performance Period				2,257,822	
Initial Serviceability				4	
Terminal Serviceability				2	
Reliability Level				85%	
Roadbed Soil Resilient Modulus				8400 psi	
Calculated Design Structural Number				**3.56**	
Specified Layer Design					
Layer	Material	Struct. Coef.	Drain. Coef.	Thickness (in.)	SN
1	Type 8FAC WC	0.44	1	2.0	0.88
2	Type 8 AC BC	0.44	1	3.0	1.32
3	Type 5 AC BS	0.33	0.9	5.0	1.49
Total				**10.0**	**3.69**

If the same project is to be designed using the MEPDG, more input information is needed. Table 30 summarizes the input information for the project. Most of the inputs were collected as described in the Methodology section of this report except that the design traffic volume (AADTT and growth factor) was used rather than the monitored traffic volume. The pavement structure shown in Table 30 was determined from a trial-and-error process. The designed pavement structure, with a total of 8.5-in. thick AC, was able to meet all the performance criteria. The predicted pavement performance by the MEPDG is presented in Figures 40 to 43.

Table 30
Input information for the MEPDG

General Information	
Design Life	20 years
Base/Subgrade Construction Month	July, 2004
Pavement Construction Month	September, 2004
Traffic Open Month	October, 2004
Type of Design	Flexible Pavement

Analysis Parameters	
Initial IRI	83
Performance Criteria	MEPDG Default
Reliability	85%

Traffic	
Two-way AADTT	770
Number of Lane in Design Direction	1
% of Truck in the Design Direction	50%
% of Truck in the Design Lane	100%
Operation Speed	52
Growth Factor	No growth
Vehicle Class Distribution	Class: 4 5 6 7 8 9 10 11 12 13 %: 5 36.8 14 1.4 13.3 25.1 2.7 0 0 1.7
Monthly Adjustment	MEPDG Default
Hourly Truck Distribution	MEPDG Default
Axle Load Distribution Factors	Louisiana Default (TTC 12)
Number of Axle/Truck	Louisiana Default (See Table 31)
Axle Configuration	MEPDG Default
Wheel Base	MEPDG Default

Climate	
Weather Station	Baton Rouge, LA
Groundwater Table Annual Average	10 ft.

Structure	
Type 8F AC Wearing Course	1.5 in. PG 76-22
Type 8 AC Binder Course	2.0 in. PG 76-22
Type 5 AC Base course	5.0 in. PG 64-22
Subgrade (Treated)	12 in., A-6, M_r = 16800 psi
Subgrade (Natural)	A-6, M_r = 8400 psi

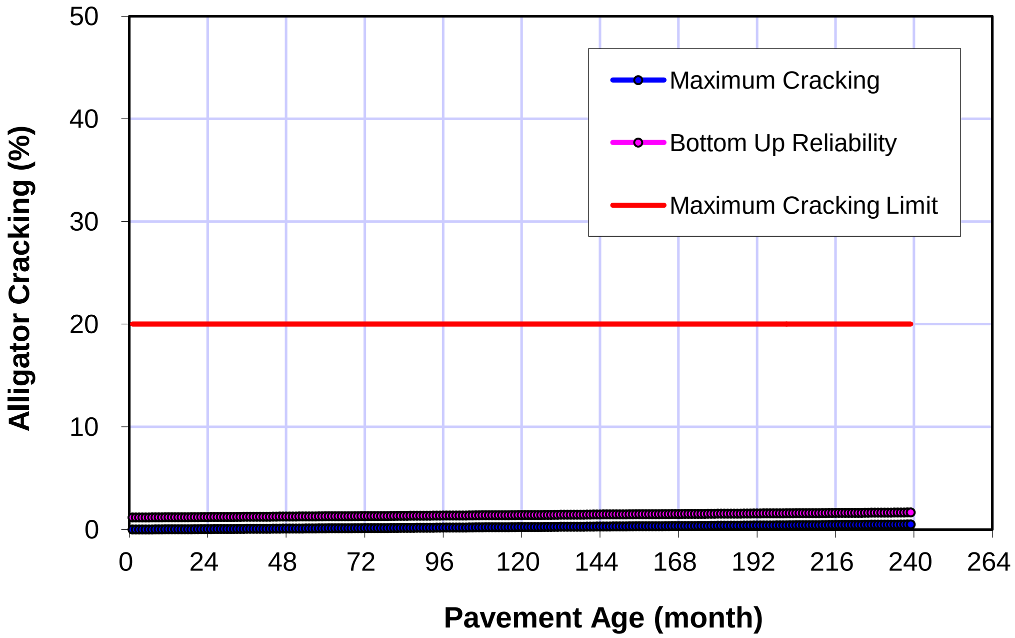


Figure 40
Predicted alligator cracking by the MEPDG

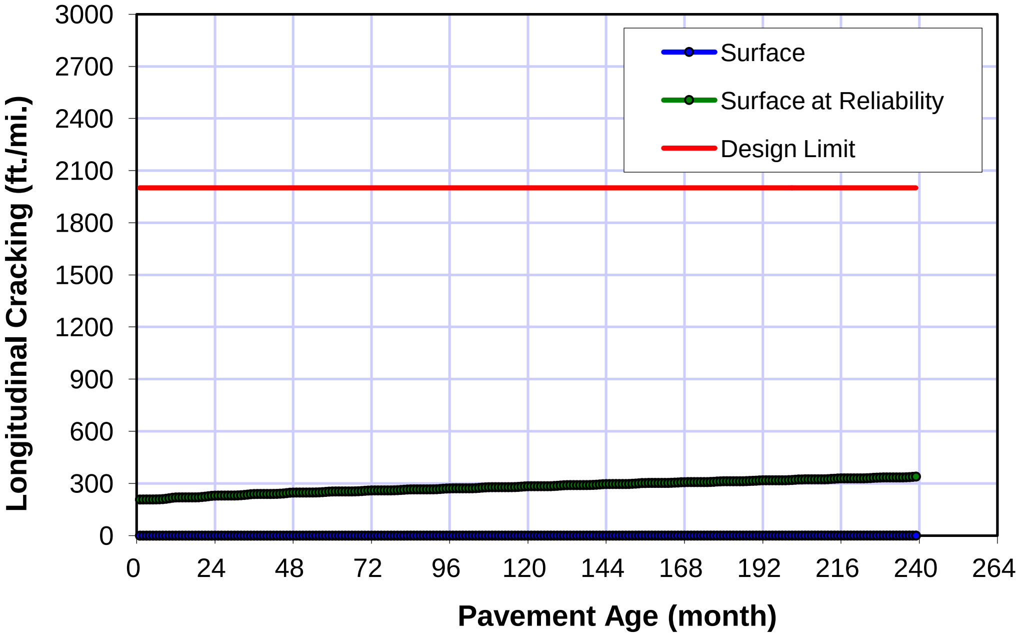


Figure 41
Predicted longitudinal cracking by the MEPDG

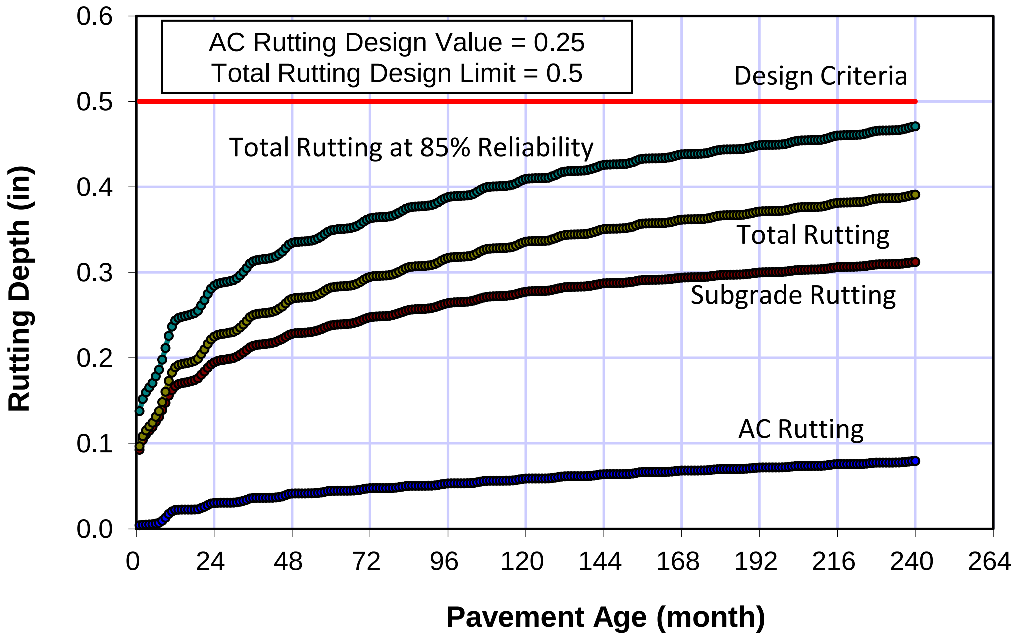


Figure 42
Predicted rutting by the MEPDG

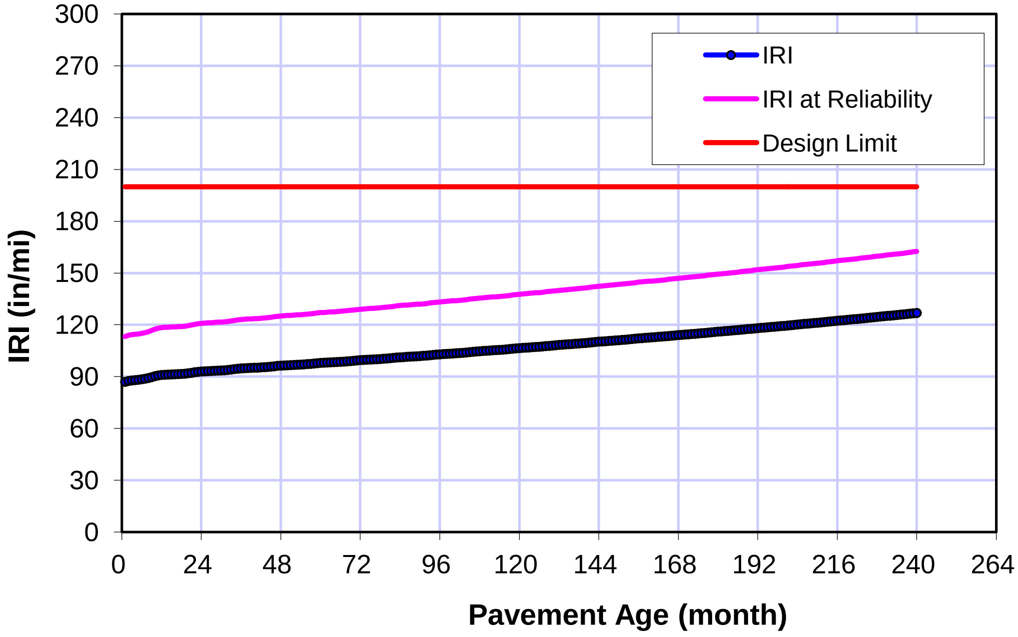
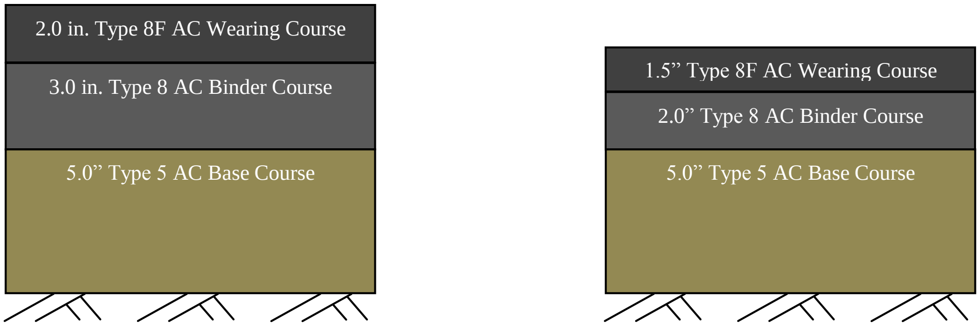


Figure 43
Predicted IRI by the MEPDG

The designed pavement structures by both the 1993 design guide and the MEPDG are compared in Figure 44. At the same design reliability level (85 percent), the MEPDG design saved the AC thickness by 1.5 in. Project 267-02-0022 is 0.87 mi. long and has two 12 ft. wide lanes. Assuming that the unit cost of Type 8 AC is 75 dollars/ton, the material cost saved by using the MEPDG design totals 1.5 in. × 0.87 mi. × 5280 ft./mi. × 0.33 yd./ft. × 2 lanes × 12 ft./lane × 0.33 yd./ft. × 110 lb/sq. yd./in. × 0.0005 ton/lb. × $75/ton = $74,286.

Note that the cost-benefit analysis was based on the nationally calibrated MEPDG models and typical traffic and materials inputs in Louisiana. The material saving only applies to the design scenario outlined above and should not be taken as the cost-benefit of using the MEPDG. The MEPDG design may require thicker AC in another design scenario.



(a) AASHTO 1993

(b) MEPDG

Figure 44
Comparison of designed pavement structures by the AASHTO 1993 guide and the MEPDG

CONCLUSIONS

In this study, pavement performance of five typical Louisiana flexible pavement structures (i.e., AC over AC base, AC over RPCC base, AC over crushed stone, AC over soil cement base, and AC over stone interlayer pavement) were evaluated using the MEPDG design software (version 1.1) and the LA-PMS data. The MEPDG design inputs for the selected projects were obtained from different database sources as outlined in the report. A set of Louisiana default material design inputs in the MEPDG were developed for typical AC mixes (default master curves), soil cement layer, RPCC layer, and crushed stone layer. Pavement performance evaluated in this study included fatigue cracking (i.e., combined top-down and bottom-up cracking), rutting, and IRI. In addition to comparing the mean values of pavement performance, MEPDG-predicted distresses at certain design reliability levels were also compared with the field variation of pavement distresses. The following observations and conclusions can be drawn from this study:

- For the AC over AC base pavements in Louisiana, the MEPDG load-related fatigue cracking, rutting, and IRI models, without performing any local calibration, all seemed to be adequate.

- For the AC over RPCC base and the AC over crushed stone pavements in Louisiana, the MEPDG load-related fatigue cracking and the IRI models both seemed to be adequate without the need of local calibration. However, the MEPDG rutting model significantly over-predicted the field rutting for these types of pavement structures. A local calibration of the rutting model is needed before using the MEPDG to design the AC over RPCC base and the AC over crushed stone pavements in Louisiana.

- For the AC over soil cement base pavements in Louisiana, the MEPDG-predicted load-related fatigue cracking was significantly less when compared with the field wheel-path cracking found on most of the selected projects. Meanwhile, the MEPDG also over-predicted the rutting for this type of pavement in Louisiana. However, the IRI model in the MEPDG seemed to be adequate. Therefore, local calibration of the fatigue cracking and the rutting models is recommended before using the MEPDG to design the AC over soil cement base pavements in Louisiana.

- Sensitivity analyses results indicated that, of all the Level-3 inputs for AC materials in the MEPDG, the binder type is the most influential parameter. Other input parameters (e.g., gradation and volumetric properties) were found to have minor effects on the shape of the predicted master curve within a practical range of temperature variations.

- Statistical analyses indicated that the mean difference between the predicted and the measured fatigue cracking was significantly influenced by pavement structure type, traffic volume, and geographic location. Among all the flexible pavement structures evaluated, AC over soil cement base pavements showed the largest mean difference between the predicted and the measured cracking. Meanwhile, a larger mean difference was found from pavements of high-volume roads. Furthermore, the selected pavements in north Louisiana seemed to have a significantly higher mean difference in cracking than those in south Louisiana.

- Statistical analyses also indicated that the mean difference between the measured and the predicted rutting was significantly affected by pavement structure type, traffic volume, subgrade stiffness, and geographic location. The largest mean difference between the predicted and the measured rutting was found from the AC over RPCC base pavements. In addition, larger mean differences between the predicted and the measured rutting were observed from pavements of high-volume roads, located in south Louisiana, or built upon softer subgrade.

- A unique calibration procedure was developed for local calibration of the MEPDG rutting model of the Louisiana AC over RPCC base and AC over soil cement base pavements. It was demonstrated that this calibration method was able to differentiate the MEPDG prediction errors of rutting from each sublayer. The obtained local calibration factors for different sublayer materials further indicated that the MEPDG over-predicted the rutting for both AC and subgrade layers, where the over-prediction for subgrade layer was more significant than that for AC layer.

RECOMMENDATIONS

1. LADOTD pavement design engineers may start to use the current version MEPDG software (version 1.1) as a design comparison tool to LADOTD's currently used DARWin 3.1 design method until further improvement can be made to the MEPDG prediction models and input data based on the results of several national on-going research studies as well as research projects currently being conducted by LTRC.

2. Some of the input data developed by this study, such as the E* master curves for typical Louisiana AC mixtures, the various calibration factors of rutting models for different pavement types and materials, etc., can be used as initial MEPDG input trials (or Level-3 inputs) by the Department. Careful engineering judgment is required when large discrepancies in the design thicknesses are encountered.

3. It is understood that the axle load spectra, developed under LTRC Project 07-2P (LTRC Report 445), were not recommended for a direct use in the implementation of the MEPDG in Louisiana. However, it was found in this study that the MEPDG default axle load spectra tend to significantly overload the Louisiana typical flexible pavements which results in a set of unreasonably high predicted distresses. Because the developed spectra of 07-2P project are deemed more representative of Louisiana's traffic conditions than the MEPDG default, it is suggested that the three axle load spectra (TTC1, TTC3, and TTC12) selected in this study be used in the comparative pavement design using the MEPDG until more accurate axle load spectra data become available in Louisiana.

4. LADOTD needs to begin developing a calibration database by monitoring newly constructed pavements. The database developed in this study creates links to a number of LADOTD databases (TOPS, TAND_NEEDS, TATV, and MATT/SOILS), which can be used as a starting point of the calibration database for the future work of the MEPDG local calibration.

5. The MEPDG load-related fatigue models need to be further calibrated based on different flexible pavement types.

6. The rutting calibration factors developed should be further validated and continuously updated. A number of trench tests on typical pavement structures are recommended.

ACRONYMS, ABBREVIATIONS, AND SYMBOLS

AADTT	Average Annual Daily Truck Traffic
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
AC	asphalt concrete
ANOVA	analysis of variance
e_r	residual error
EICM	enhanced integrated climate model
ESAL	equivalent single axle load
FHWA	Federal Highway Administration
ft.	foot (feet)
HMA	hot mix asphalt
in.	inch(es)
IRI	international roughness index
LADOTD	Louisiana Department of Transportation and Development
LA-PMS	Louisiana pavement management system
lb.	pound(s)
LTPP	Long-term Pavement Performance
LTRC	Louisiana Transportation Research Center
MATT	Material Testing System
MEPDG	Mechanistic-Empirical Pavement Design Guide
mi.	mile(s)
M_r	resilient modulus
NCDC	National Climate Data Center
NCHRP	National Cooperative Highway Research Program
PCC	Portland cement concrete
pcf	pound per cubic foot (feet)
PMS	pavement management system
psi	pound per square inch
RPCC	rubblized Portland cement concrete
S_e	standard error of estimate
SSE	sum of squared errors
SSV	soil support value
TAND	Highway Need System
TATV	Traffic Count ADT

TOPS	Tracking of Projects
TRB	Transportation Research Board
TTC	truck traffic classification
WIM	weigh-in-motion
USGS	US Geology Survey
VCD	vehicle class distribution

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APPENDIX

APPENDIX A

Default Axle Load Distribution Factors for Louisiana

Axle load spectra (also called axle load distribution) are important traffic inputs for the MEPDG. It has a direct impact on the amount of predicted distresses (and IRI) of the MEPDG. In the MEPDG design software, users have the options to either input the distribution of axle load of each axle type in each month of a year (level 1) or accept the national default axle load spectra (level 3). To better represent the local traffic conditions, many states chose to develop their local axle load spectra, often based on WIM station data.

In a previous study, Ishak et al. analyzed the axle load data from about 200 WIM stations in Louisiana. He grouped the WIM data based on the truck traffic classification (TTC) and developed the default axle load spectra for each typical TTC in Louisiana. In this study, the design vehicle class distribution of the selected project can be categorized as either TTC 1, TTC 3, or TTC 12. Thus the Louisiana default axle load spectra for these three TTC groups are used in this study. Louisiana default axle load spectra and the national default axle load spectra are plotted in Figures 45 to 47. The number of axle per truck inputs (shown in Table 31) were also modified based on the Louisiana default axle load spectra.

Table 31
Number of axles per truck in Louisiana

	Single	Tandem	Tridem	Quad
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0	1.09	0
Class 8	3.05	0	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.61	0	0	0
Class 12	3.52	1.2	0	0
Class 13	2.15	2.48	0	0

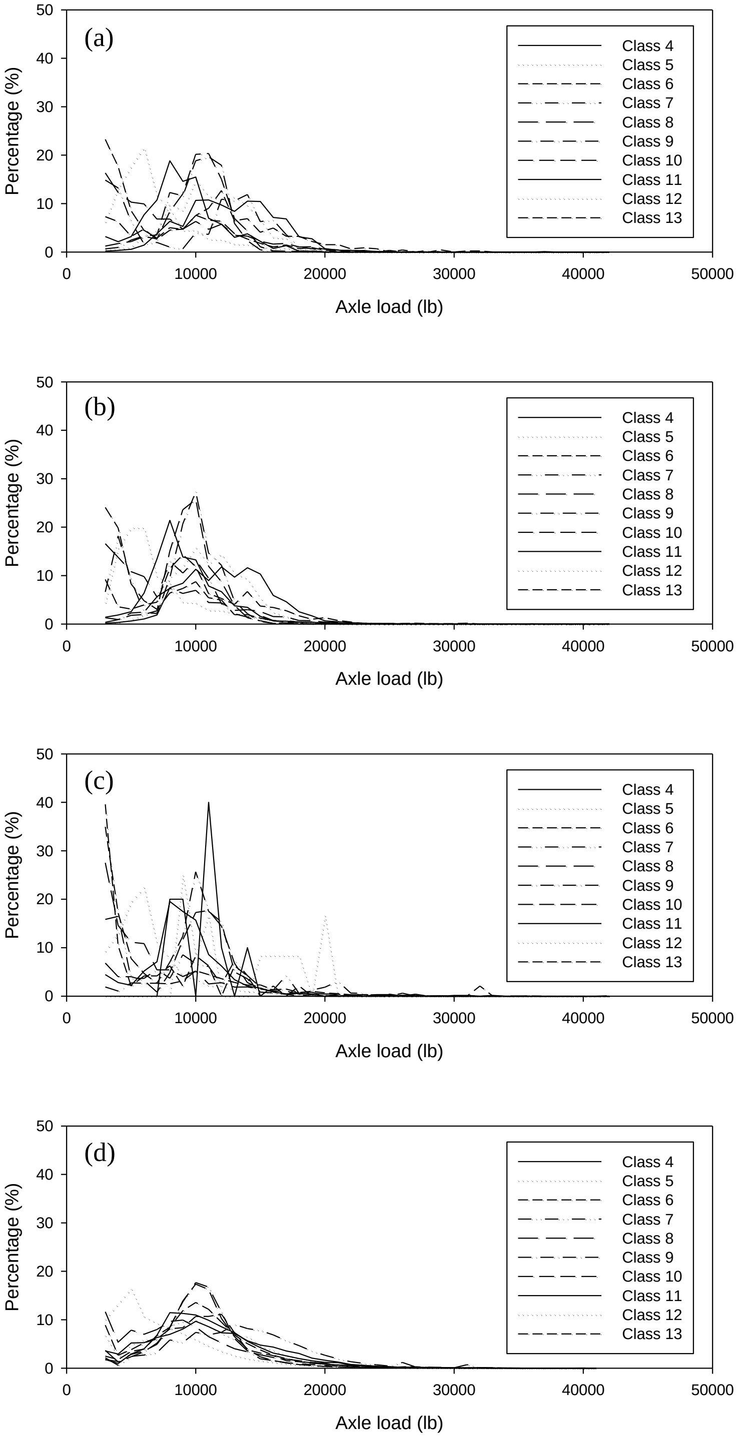


Figure 45
Single axle load spectrum: (a) TTC1, (b) TTC3, (c) TTC12, (d) MEPDG default

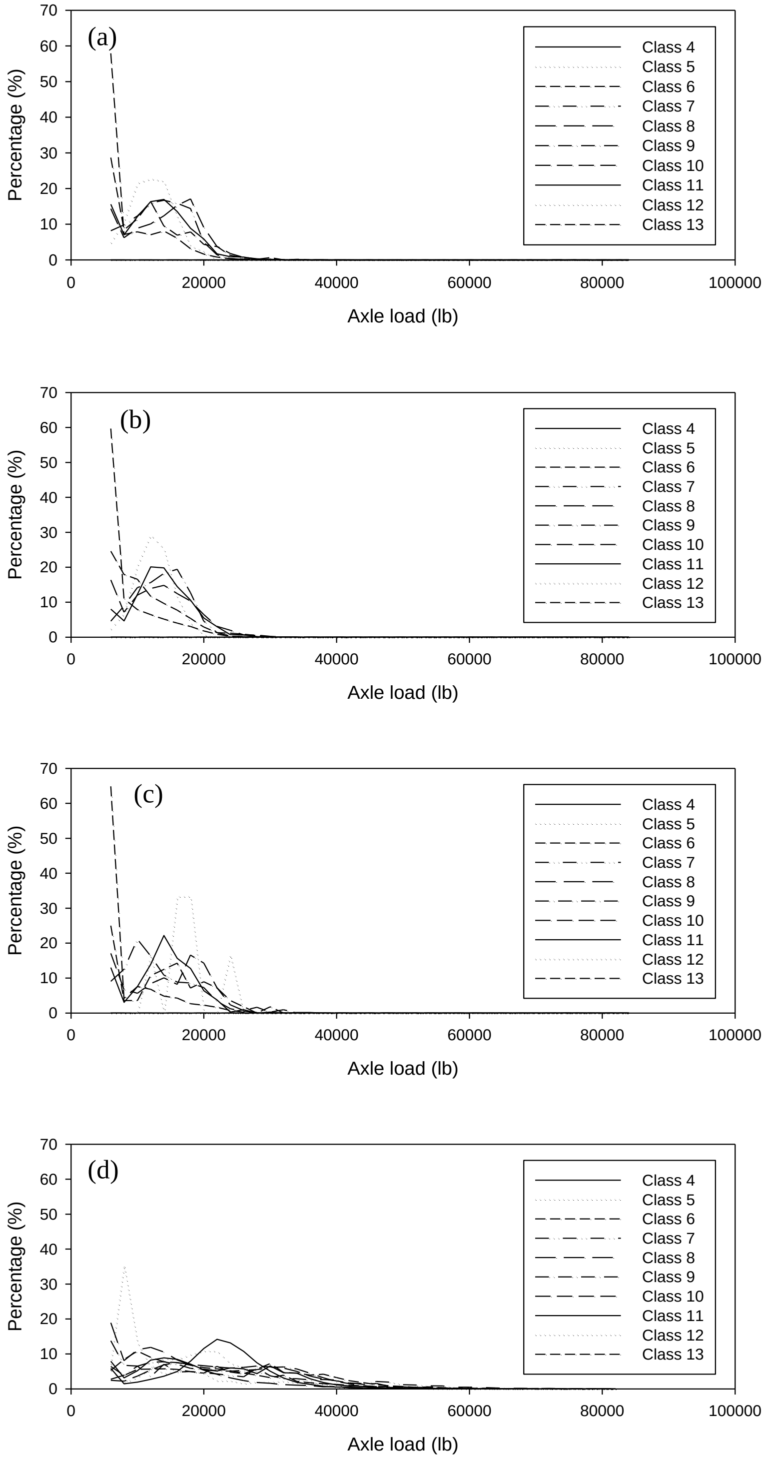


Figure 46
Tandem axle load spectrum: (a) TTC1, (b) TTC3, (c) TTC12, (d) MEPDG default

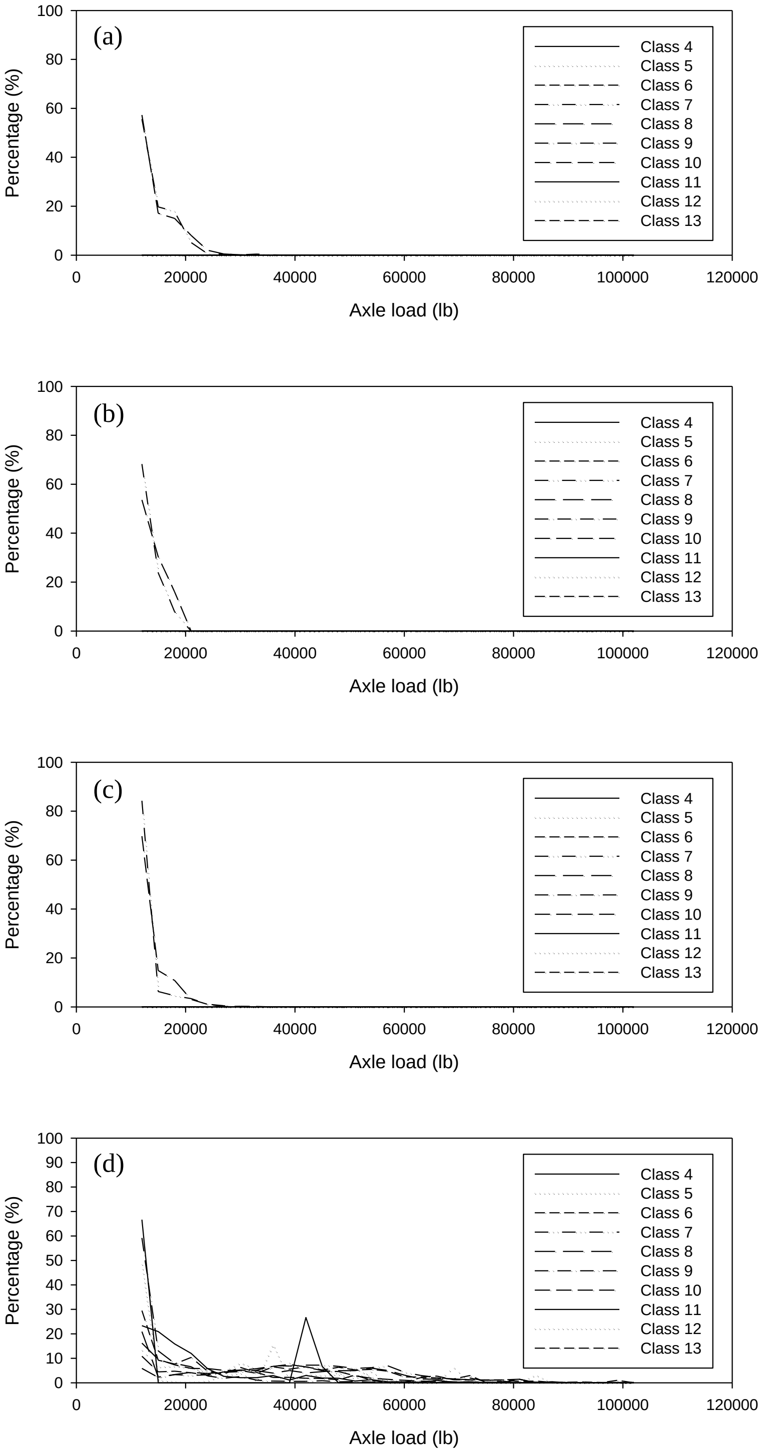


Figure 47
Tridem axle load spectrum: (a) TTC1, (b) TTC3, (c) TTC12, (d) MEPDG default

APPENDIX B

Default AC Materials Inputs for Louisiana

The visco-elastic behavior of AC is characterized by the master curve in the MEPDG. For Level-1 input, the design software constructs the master curve directly from the dynamic modulus *E** test data. For Level-2 and Level-3 inputs, the design software predicts the master curve based on an empirical model. In this study, Level-3 inputs (i.e., aggregate gradation, binder type, and volumetric properties of AC mixture as built) were used since they are available in the LADOTD database (Mainframe/MATT). Louisiana has a detailed record of AC properties for each lot of AC mixture for each highway project. This is more than required since the same type of AC mixture (e.g., Type 5 base course) in different projects may have similar properties. In order to simplify the input strategy, it is desirable to construct the representative master curve(s) for typical AC mixtures used in Louisiana. Before constructing the representative master curve, a sensitivity analysis was conducted to see how the variation of input AC properties may influence the predicted master curve. Variables studied in the sensitivity analysis are listed in Table 32. The predicted master curves were shown in Figures 48 to 54. It is shown that within the practical range of variation, most parameters do not have a significant influence on the shape of the predicted master curve. Asphalt binder type is the only influential factor in the model. Thus in this study, representative master curves were developed based on the asphalt binder type. The material properties corresponding to each representative master curve were used as the AC material inputs in the MEPDG analysis.

Table 32
Level-3 input parameters for AC

Parameters	Baseline	Variation
Cumulative % retained ¾ inch sieve	5	5, 10, 15
Cumulative % retained 3/8 inch sieve	30	20, 30, 40
Cumulative % Retained #4 sieve	50	40, 50, 60
% passing #200 sieve	5.5	3.0, 5.5, 8.0
Asphalt Binder	PG 70-22	PG 64-22, PG 70-22, PG 76-22
Effective binder content (%) (by vol)	9.5	8.0, 9.5, 11.0
In-place air void (%)	7.0	7.0, 8.0, 9.0

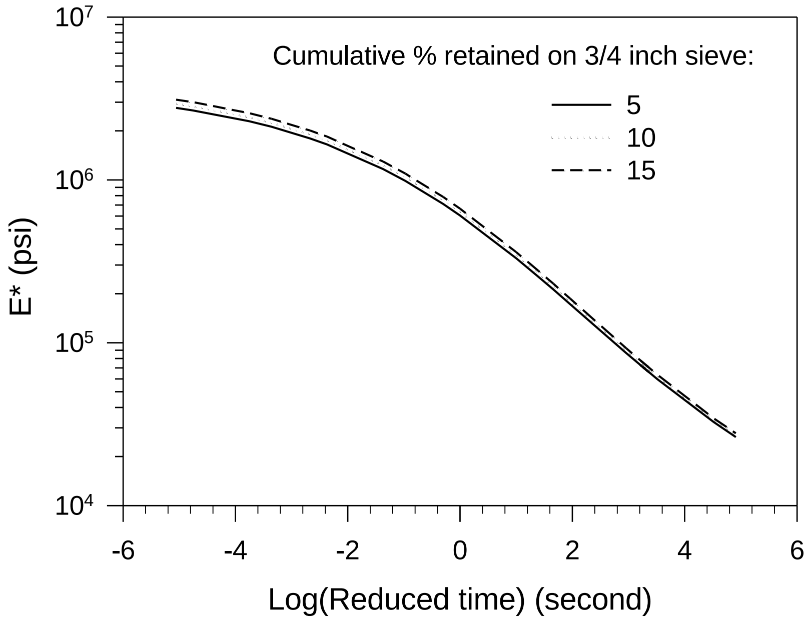


Figure 48
Changing the cumulative % retained on ¾ in. sieve

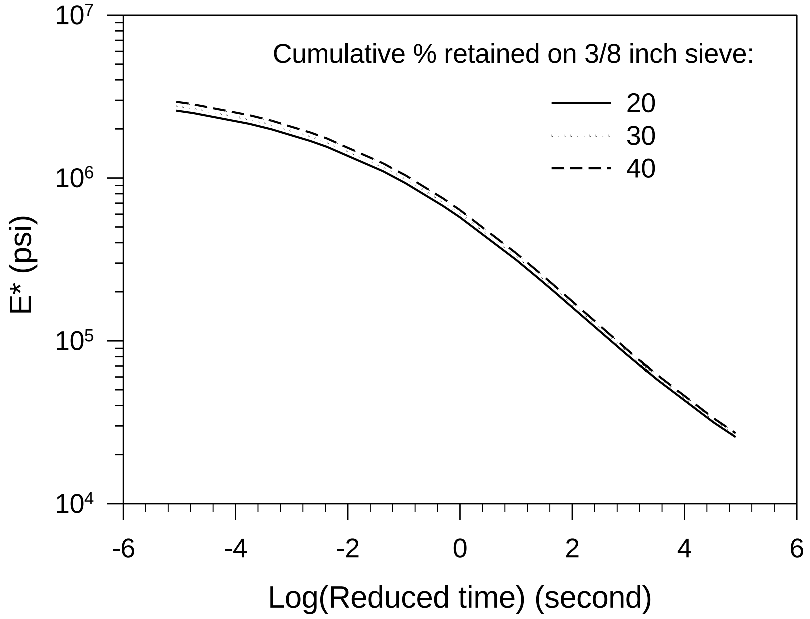


Figure 49
Changing the cumulative % retained on 3/8 in. sieve

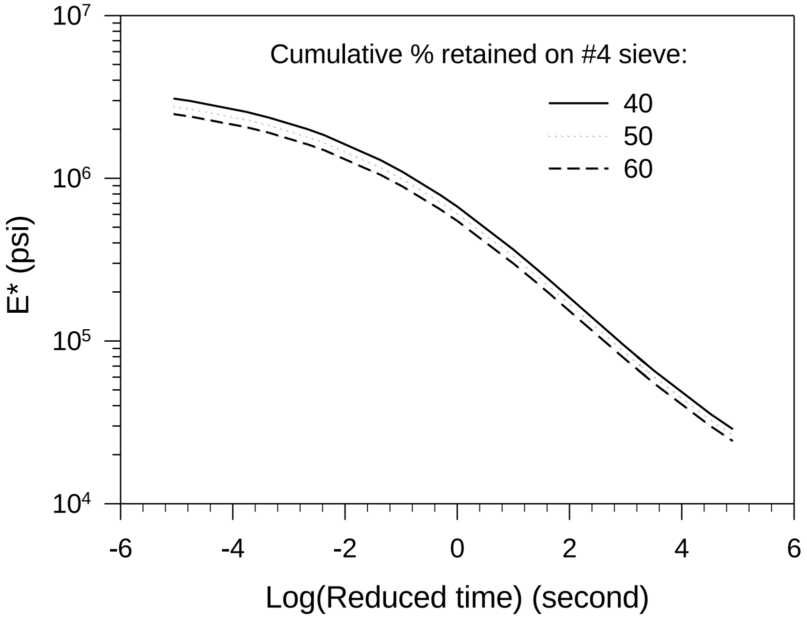


Figure 50
Changing the cumulative % retained on #4 sieve

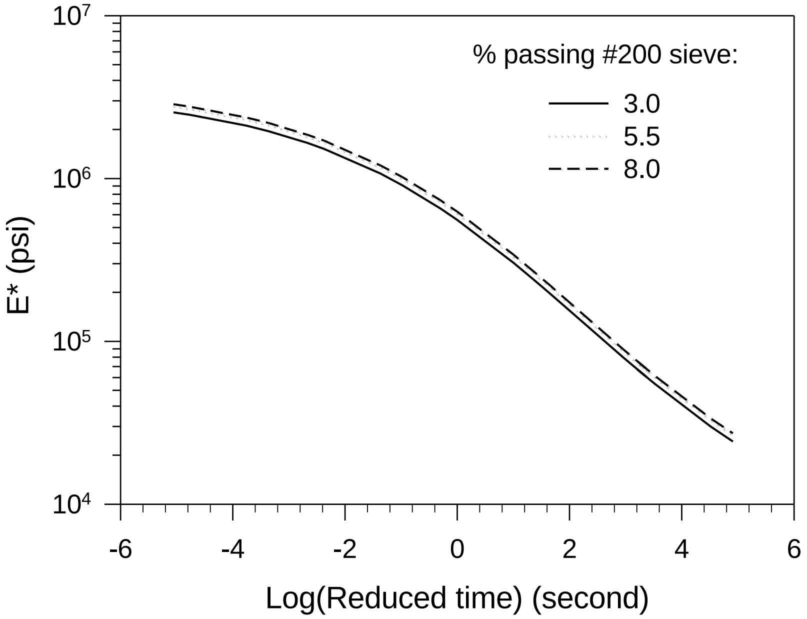


Figure 51
Changing the cumulative % passing #200 sieve

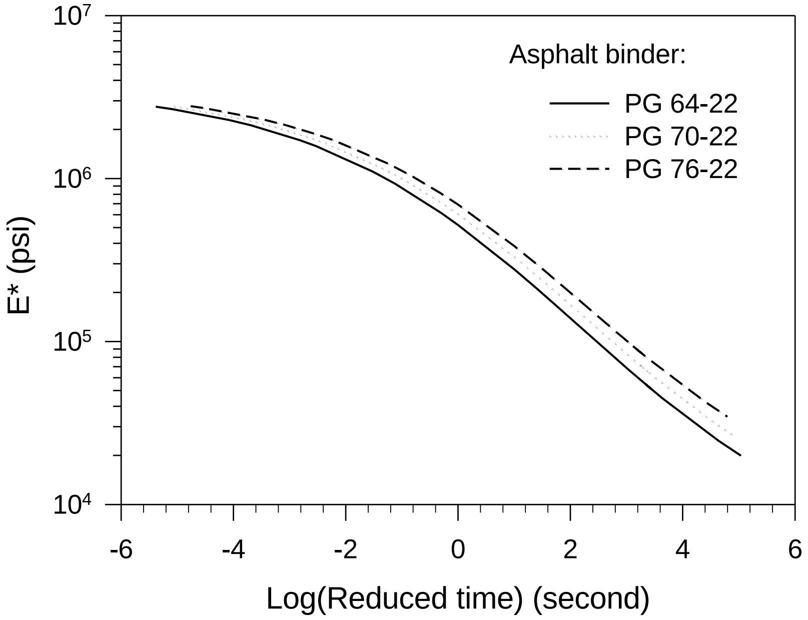


Figure 52
Changing the asphalt binder type

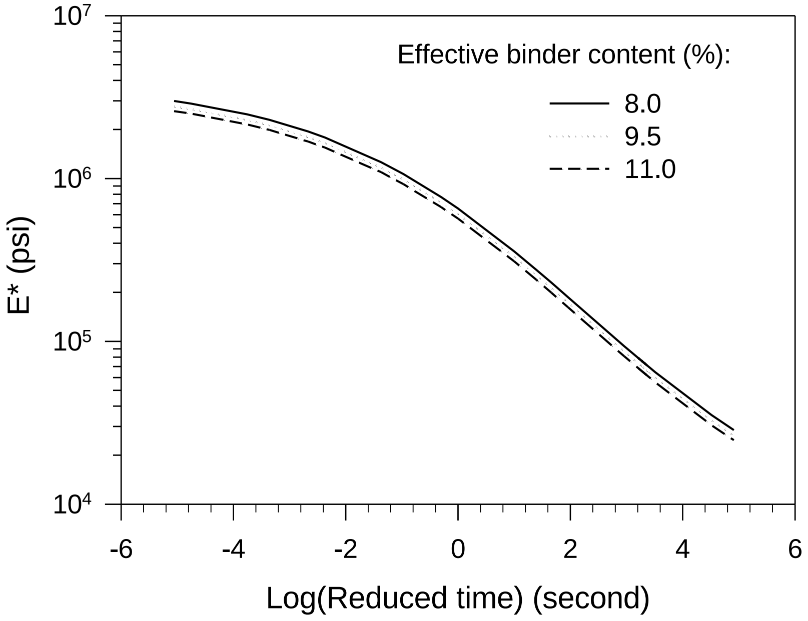


Figure 53
Changing the effective binder content

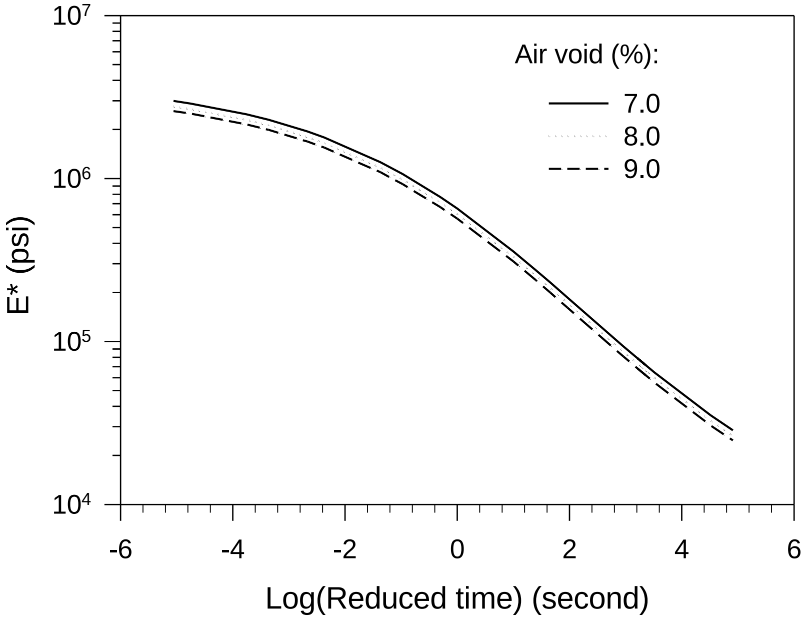


Figure 54
Changing the air void

For each binder type, two plant mix test records were randomly selected from each district, one wearing course mix and one binder course mix. PG 64-22 and AC-30 binders are almost exclusively used for base courses. Thus only one record was selected for these types of mixture. The collected plant mix test records were used to generate master curves with the MEPDG software. The average value of each parameter was used to develop the representative master curve (shown in Figures 55 to 59) for each type of AC mixture.

Table 33 lists the default AC material input parameters for typical AC mixtures in Louisiana. Note that the total unit weight of the mixture is not used in the predictive model for master curve, thus it is taken as 144 pcf (average of all records collected) for simplicity.

Table 33
Default AC material input parameters for typical AC mixtures in Louisiana

Conventional/Superpave	Superpave	Superpave	Superpave	Conventional	Conventional
Asphalt Binder	PG 76-22	PG 70-22	PG 64-22	PAC-40	PAC-30, AC-30
Use (WC = wearing course, BC = binder course)	Level 2 WC Level 2 BC	Level 1 WC Level 1 BC	Level 1 BS	Type 8 WC Type 8 BC	Type 5 BS
Cumulative % retained 3/4 inch sieve	5	4	11	5	11
Cumulative % retained 3/8 inch sieve	31	28	28	30	26
Cumulative % retained #4 sieve	52	48	46	49	44
% passing #200 sieve	5.1	5.6	5.3	5.2	5.5
Effective binder content (%)	9.49	9.46	9.17	10.04	9.42
In-place air void (%)	6.95	6.90	6.94	6.92	6.86
Total unit weight (pcf)	144	144	144	144	144

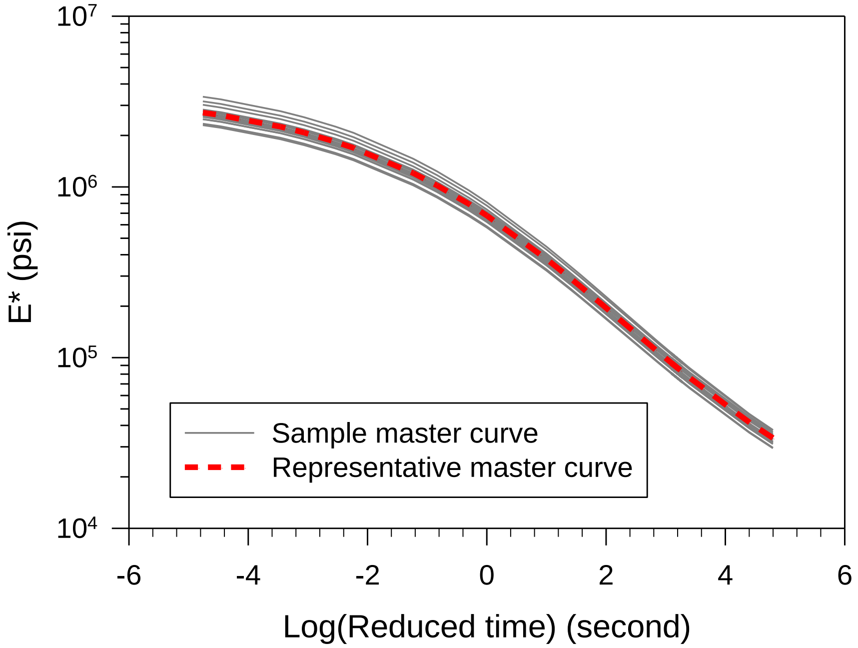


Figure 55
Representative master curve for PG 76-22 AC (based on 16 sample master curves, including 8 wearing course mixtures and 8 binder course mixtures)

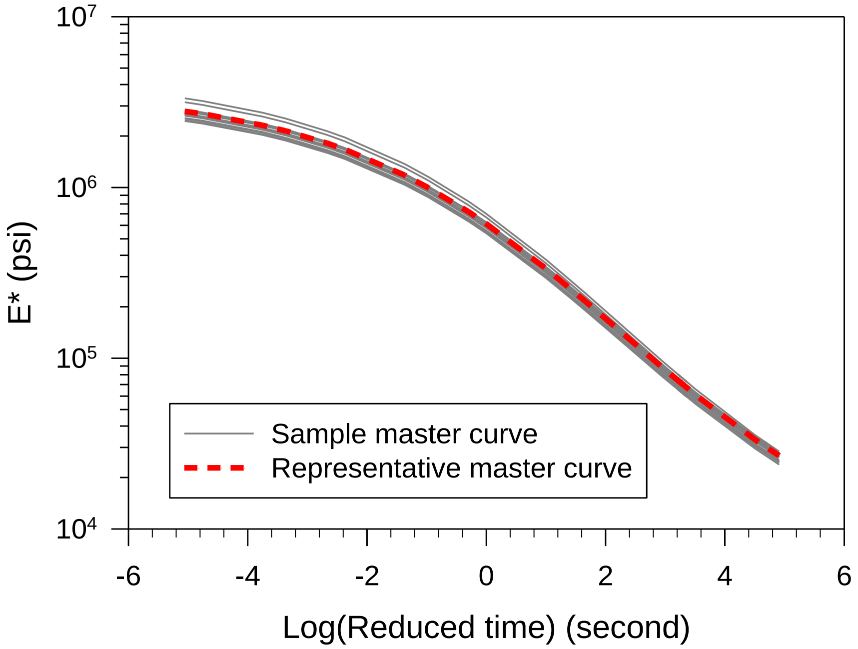


Figure 56

Representative master curve for PG 70-22 AC (based on 15 sample master curves, including 8 wearing course mixtures and 7 binder course mixtures)

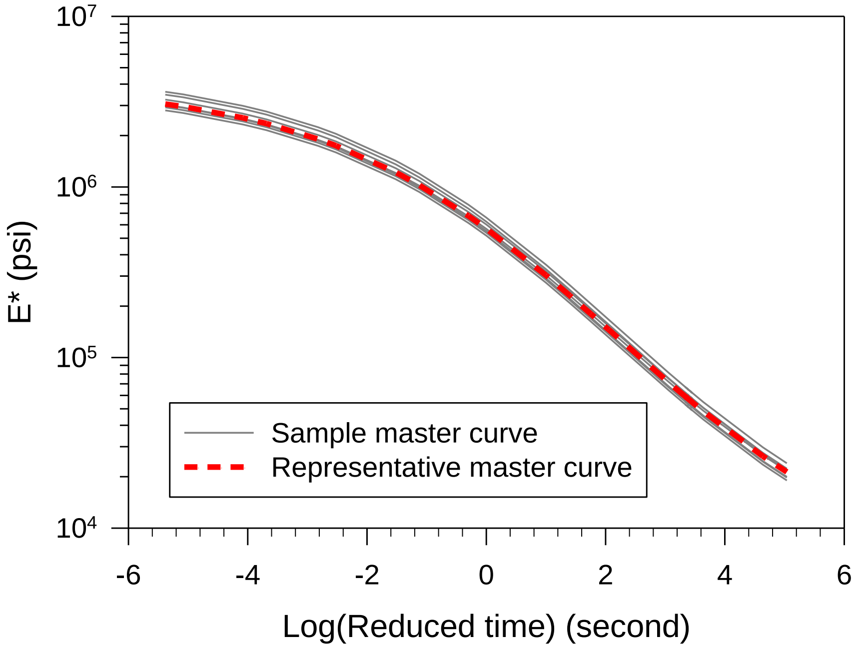


Figure 57

Representative master curve for PG 64-22 AC (based on 7 sample master curves, all from base course mixtures)

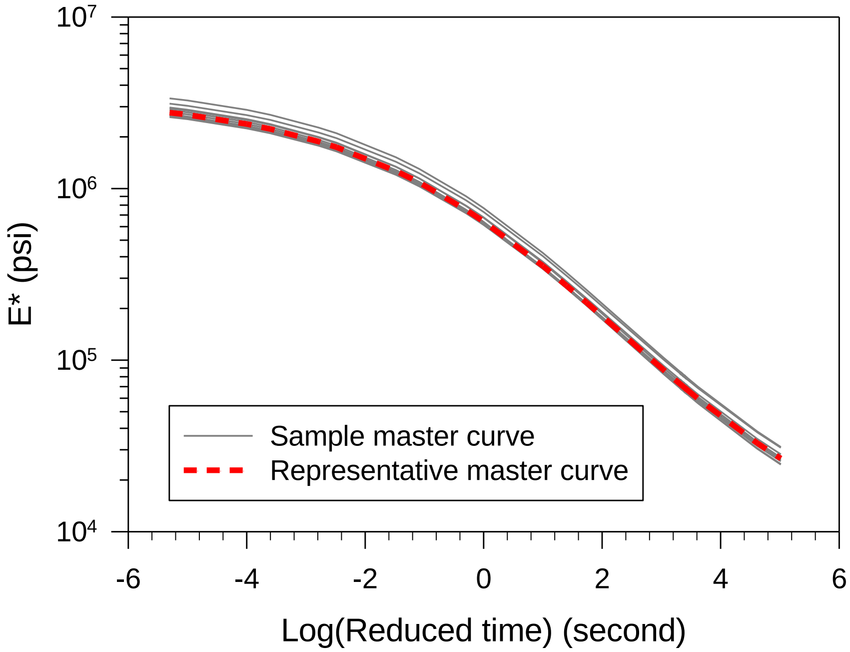


Figure 58
Representative master curve for PAC-40 AC (based on 18 sample master curves, including 9 wearing course mixtures and 9 binder course mixtures)

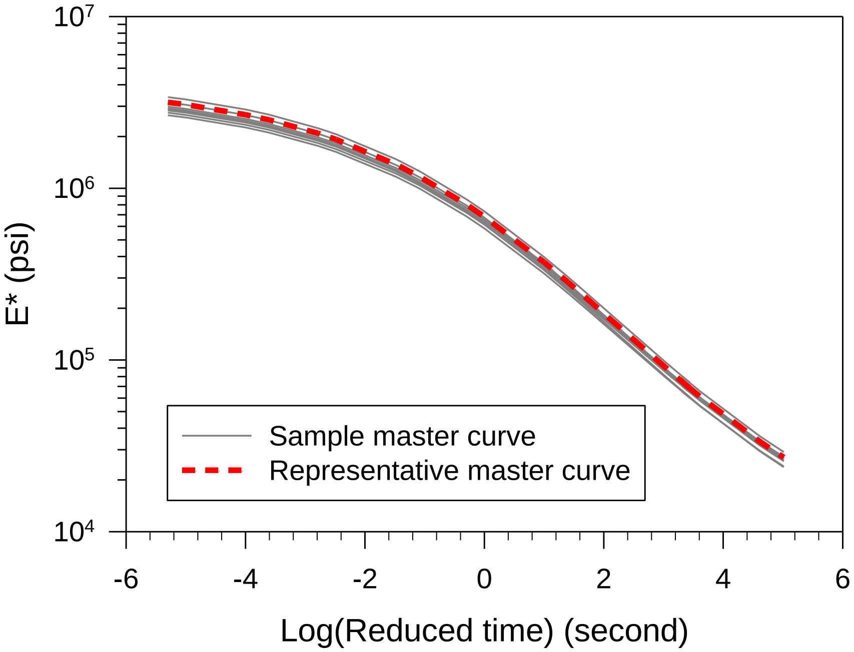


Figure 59
Representative master curve for AC-30 (and PAC-30)

APPENDIX C

LA-MEPDG Database

This study utilized a number of LADOTD databases: Mainframe, Content Manager, LA-PMS, etc. These databases are maintained separately by different offices in LADOTD. There is a need to link these databases together so that researchers can easily collect, manage, and analyze the data. For example, researchers want to find the general information, traffic data, and subgrade soil properties of a specific project by simply typing-in the project ID (xxx-xx-xxxx).

To fulfill this requirement, a database (named LA-MEPDG) was created in Access 2007 format. This database linked a number of LADOTD databases (TOPS, TAND_NEEDS, TATV, and MATT/SOILS) together. The structure of the database is illustrated in Figure 60. The tables in the database are introduced in Table 34. A number of useful queries were created to facilitate data collection and data management. The functions of the queries are introduced in Table 35. Unfortunately, pavement structure (material and thickness) information in Louisiana is stored in image format. This information has to be input manually into the database. Note that LA-PMS is not automatically linked to the LA-MEPDG database because manual inspection must be made to check the abnormal trends and errors in the pavement condition data. The interpretation of the LA-PMS data will be described later.

Table 34
Tables in LA-MEPDG database

Table	Description
DOTD_TOPSPROJS	This table stores inventory information about the LADOTD projects. It is converted (into Access format) from the TOPS database in Mainframe.
PLAN	This table stores the pavement design information collected from the plan files and DARWIN design sheets. Each record in this table represents a selected project in this study. Data in this table are input manually. This is the only table in the LA-MEPDG database that needs manually input. Remarks about a project are also input in this table.
MATT_SOILS	This table stores boring/sampling information on each LADOTD projects. It is converted from the MATT/SOILS database in Mainframe.
LA_ADT	This table stores the two-way ADT information from the traffic stations in Louisiana. It is converted from the TATV database in Mainframe.
TAND_NEEDS	This table contains some traffic input information such as lane width, operation speed, truck factor, growth factor, etc. It is converted from the TAND database in Mainframe.
PMS_VS_MEPDG	This table contains the measured distresses from LA-PMS and the predicted distresses from the MEPDG. Data in this table are input manually.

Table 35
Queries in LA-MEPDG database

Table	Description
FIND_PROJECT	This is a multi-table query based on the DOTD_TOPSPROJS table. It used to find projects with specific criteria (e.g., work type, year of construction, cost per mile, traffic volume, location, function class, etc.)
SELECTED_PROJECT	This is a multi-table query to gather information that is related to the MEPDG input from each table. This table is also a list of the selected projects. Each entry in this table corresponds to an entry in the PLAN table.
SOIL_AVERAGE	This a multi-table query. For each project in the PLAN table, this query finds all the subgrade soil boring/sampling records of this project, group them by soil classification, and calculated the average values of liquid limit, plastic index and sieve analysis result for each type of soil.
TAND_QUERY	This is a multi-table query to list all the sub-sections within a project with different traffic levels.
PMS_VS_ME_QUERY	This is a multi-table query to filter the comparisons between measured and predicted pavement performance by specific project properties (e.g., location, pavement type, traffic volume, etc.)

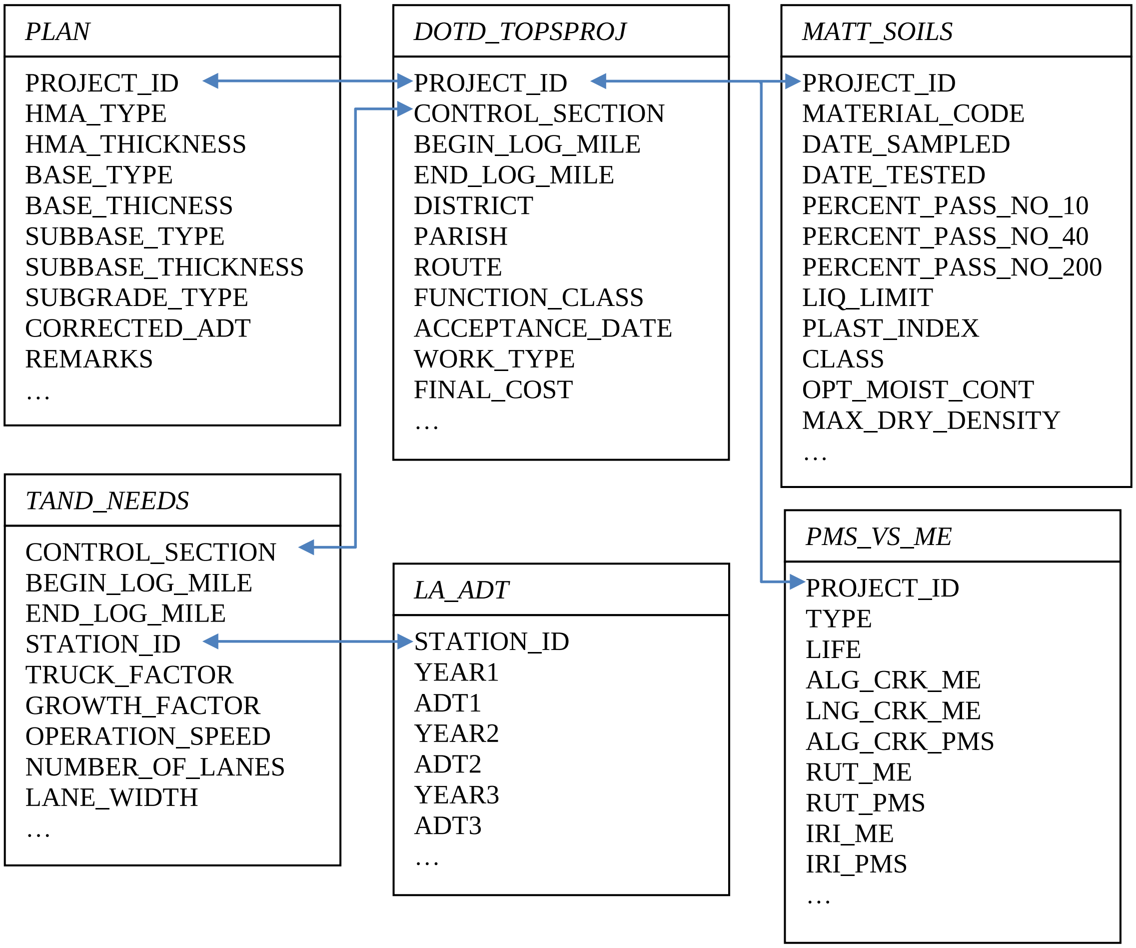


Figure 60
Structure of the LA-MEPDG database

The step-by-step procedure of working with LA-MEPDG database is described below:

1. Run the “FIND_PROJECT” query. An example set of criteria is: WORK_TYPE = “C2,” “C3,” “A1,” “A2,” “A3,” “A4,” “A5,” “A6,” “A7,” “A8,” and “ZA”; ACCEPTANCE_DATE between “1/1/1997” and “12/31/2005”; and Length ≥ 0.5. This query created a list of 1,839 projects for initial selection. Note that a wide range of work types is used here (from flexible to rigid pavement construction), because researchers found that “work type” is a poor, yet the only, indicator of the pavement structure. For example, an AC over RPCC bass pavement project may be categorized as “A1,” “A4,” “A8,” “C2,” or “C3” in the TOPS database.

2. For each project in the initial selection list, go to the Content Manger and the Intranet Plan Room to find the design file. If typical section design confirmed this project has a pavement structure of interest, go to step 3.

3. Create a new entry in the “PLAN” table. Input the project number and pavement structure/materials information.

4. Run the “TAND_QUERY” query. If a project has more than one sub-section with significantly different traffic levels, the user must choose the traffic inputs from one sub-section and input the traffic sub-section ID into the “PLAN” table. If the project has only one sub-subsection, input “00” in the corresponding field in the “PLAN” table.

5. Run the “SELECTED_PROJECT” query. The MEPDG input information for each project in the “PLAN” table will be collected and displayed.

6. Input the collected input information into the MEPDG design software to analyze a project.

7. Copy the predicted pavement performance from the MEPDG and the measured pavement performance from LA-PMS to the “PMS_VS_MEPDG” table.

8. Keep adding and analyzing more projects.

9. Compare the predicted performance columns to the corresponding measured performance columns in the “PMS_VS_MEPDG” table. If necessary, run the “PMS_VS_ME_QUERY” query to narrow the comparison results by specific criteria.

APPENDIX D

Detailed Information about the Selected Projects

Project ID: **015-05-0038**

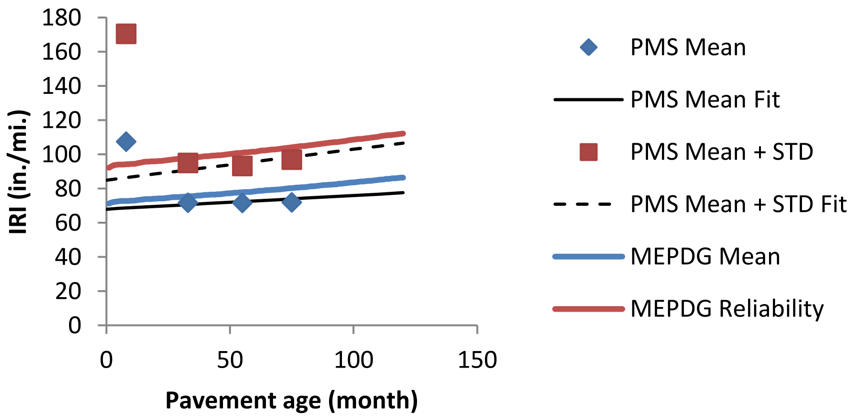
General Information:

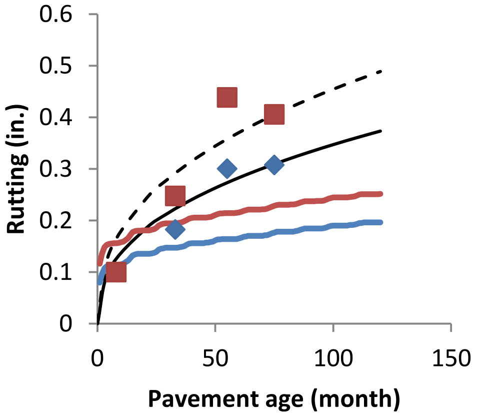
District:	58	Two-Way ADT:	5485
Parish:	30	Number of Lane in Design Direction:	4
Route:	US 165	Growth Factor:	3%
Accept Date:	6/6/2002	Axle Load Spectrum:	Louisiana Default (TTC1)

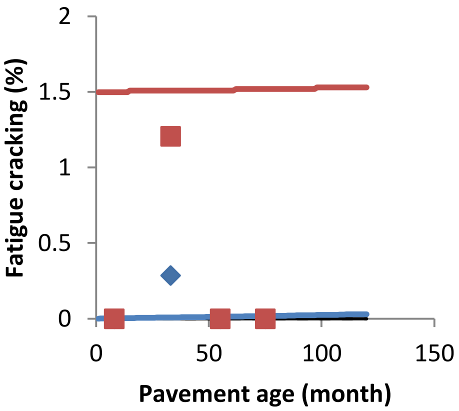
Pavement Structure:

Asphalt Concrete:	2" SMA WEARING COURSE (PG 76-22)+ 4" SUPERPAVE LEVEL 2 BINDER COURSE (PG 76-22)
Base:	6.5" TYPE 5A AC (PG 64-22)
Subbase:	
Subgrade:	A-4 (Mr = 9176 psi)

Predicted vs. Measured Pavement Performance







Project ID: **018-30-0018**

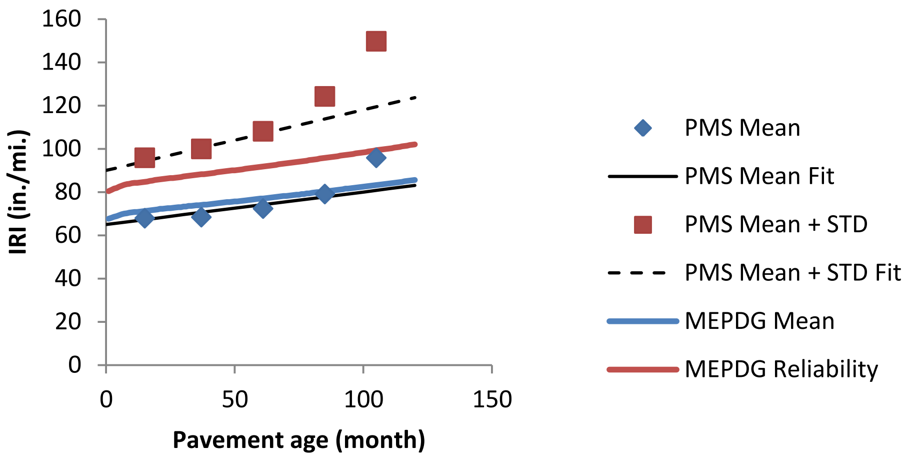
General Information:

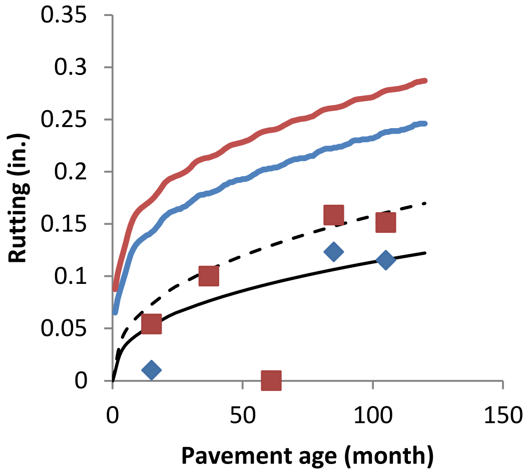
District:	62	Two-Way ADT:	1927
Parish:	52	Number of Lane in Design Direction:	2
Route:	LA 433	Growth Factor:	3%
Accept Date:	1/3/2000	Axle Load Spectrum:	Louisiana Default (TTC12)

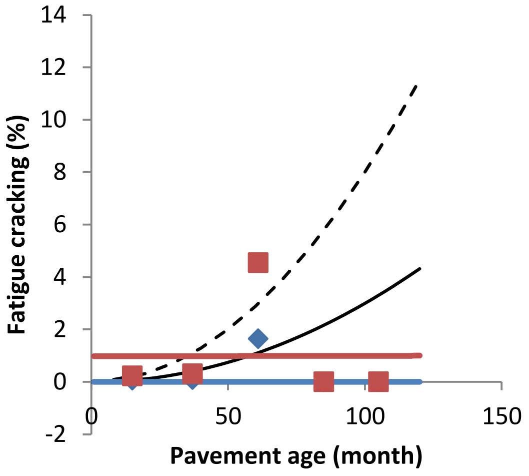
Pavement Structure:

Asphalt Concrete:	1.5" TYPE 8 WEARING COURSE (PG 76-22) + 2" TYPE 8 BINDER COURSE (PG 76-22)
Base:	8.5" CEMENT STABILIZED (Mr = 100 ksi)
Subbase:	
Subgrade:	A-6 (Mr = 9176 psi)

Predicted vs. Measured Pavement Performance







Project ID: **019-05-0025**

General Information:

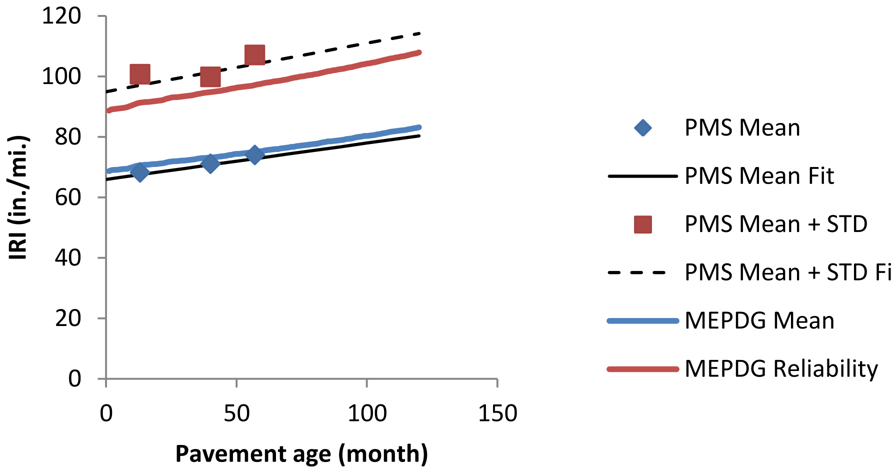
District: 61
Parish: 63
Route: US 61
Accept Date: 9/18/2003

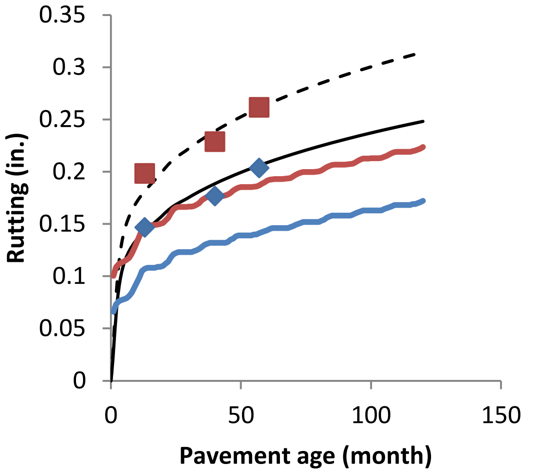
Two-Way ADT: 5996
Number of Lane in Design Direction: 4
Growth Factor: 2.6%
Axle Load Spectrum: Louisiana Default (TTC3)

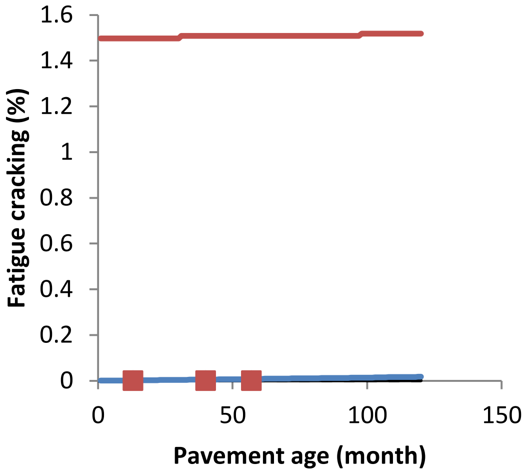
Pavement Structure:

Asphalt Concrete: 1.5" TYPE 8F WEARING COURSE (PG 76-22) + 4" TYPE 8 BINDER COURSE (PG 76-22)
Base: 7.5” TYPE 5A AC (PG 64-22)
Subbase:
Subgrade: A-4, 12” TYPE D LIME TREATED (Mr = 10634 psi)

Predicted vs. Measured Pavement Performance







Project ID: **026-05-0017**

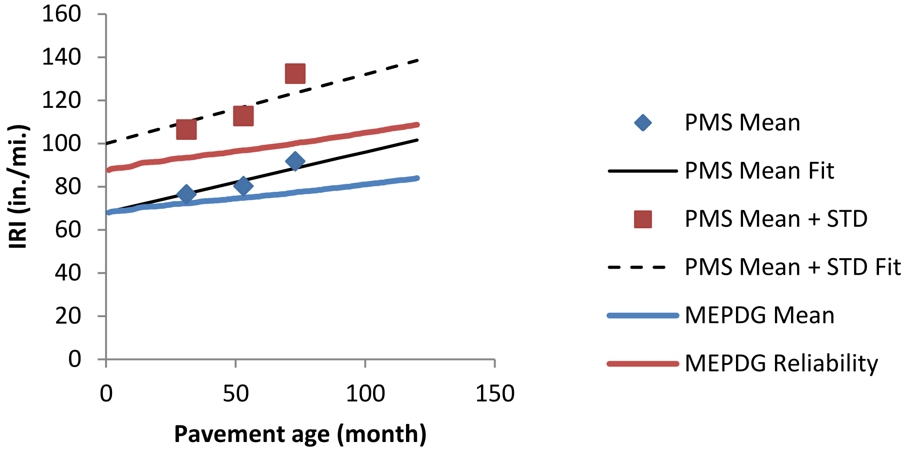
General Information:

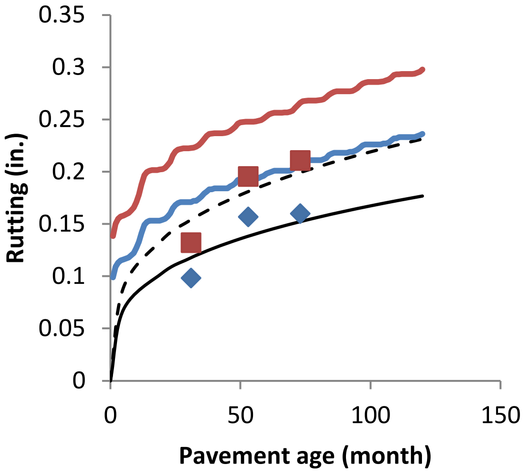
District:	58	Two-Way ADT:	4199
Parish:	13	Number of Lane in Design Direction:	4
Route:	LA 15	Growth Factor:	1.8%
Accept Date:	8/8/2002	Axle Load Spectrum:	Louisiana Default (TTC3)

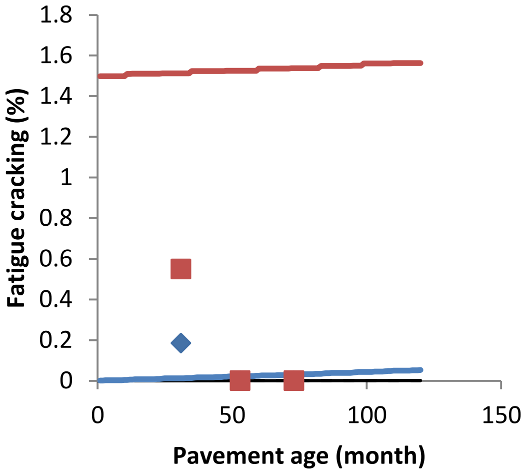
Pavement Structure:

Asphalt Concrete:	1.5" TYPE 8F WEARING COURSE (PG 76-22) + 4" TYPE 8 BINDER COURSE (PG 76-22)
Base:	5.5” TYPE 5A AC (PG 64-22)
Subbase:	
Subgrade:	A-4, 12” TYPE D LIME TREATED (Mr = 8797 psi)

Predicted vs. Measured Pavement Performance







Project ID: **029-07-0055**

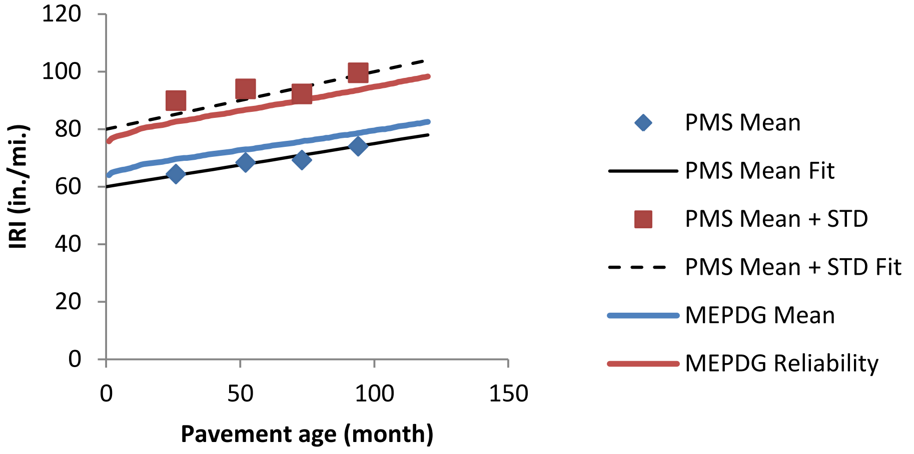
General Information:

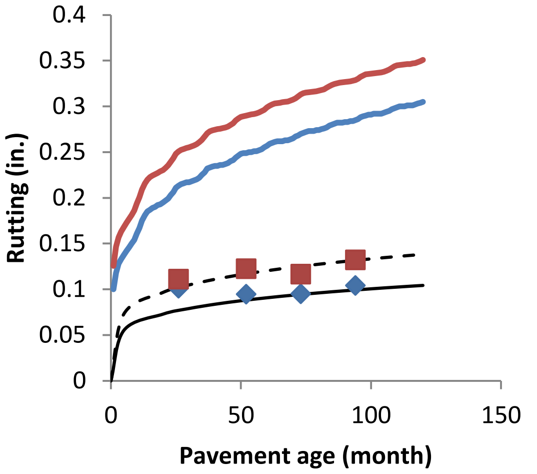
District:	08	Two-Way ADT:	2047
Parish:	40	Number of Lane in Design Direction:	2
Route:	LA 496	Growth Factor:	1%
Accept Date:	9/25/2000	Axle Load Spectrum:	Louisiana Default (TTC12)

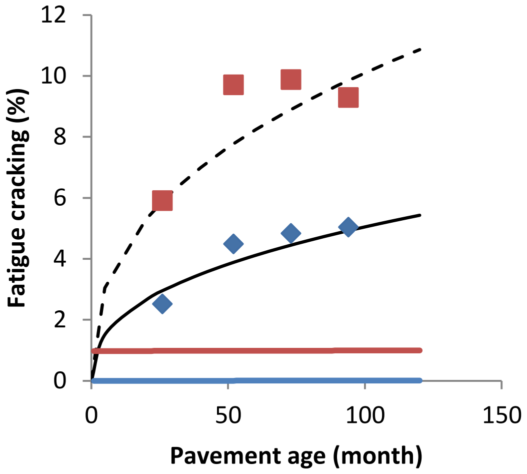
Pavement Structure:

Asphalt Concrete:	1.5" TYPE 3 WEARING COURSE (PG 70-22) + 2" TYPE 3 BINDER COURSE (PG 70-22)
Base:	8.5” CEMENT STABILIZED (Mr = 100 ksi)
Subbase:	
Subgrade:	A-4 (Mr = 9916 psi)

Predicted vs. Measured Pavement Performance







Project ID: **036-03-0016**

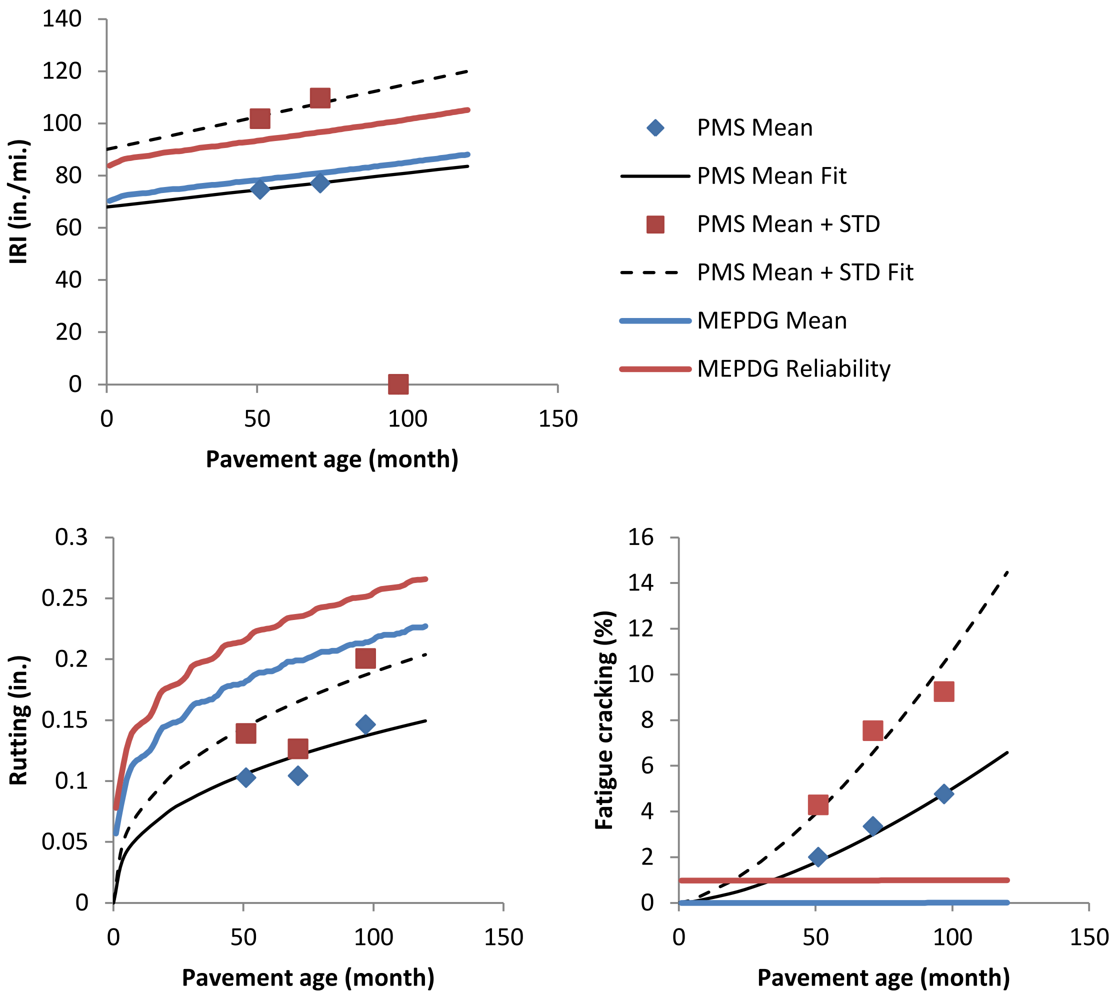
General Information:

District:	58	Two-Way ADT:	3331
Parish:	21	Number of Lane in Design Direction:	2
Route:	LA 4	Growth Factor:	1.1%
Accept Date:	3/20/1997	Axle Load Spectrum:	Louisiana Default (TTC12)

Pavement Structure:

Asphalt Concrete:	1.5" TYPE 8 WEARING COURSE (PAC-40) + 2" TYPE 8 BINDER COURSE (PAC-40)
Base:	8.5” CEMENT STABILIZED (Mr = 100 ksi)
Subbase:	
Subgrade:	A-6, 12” TYPE D LIME TREATED (Mr = 9916 psi)

Predicted vs. Measured Pavement Performance



Project ID: **055-06-0049**

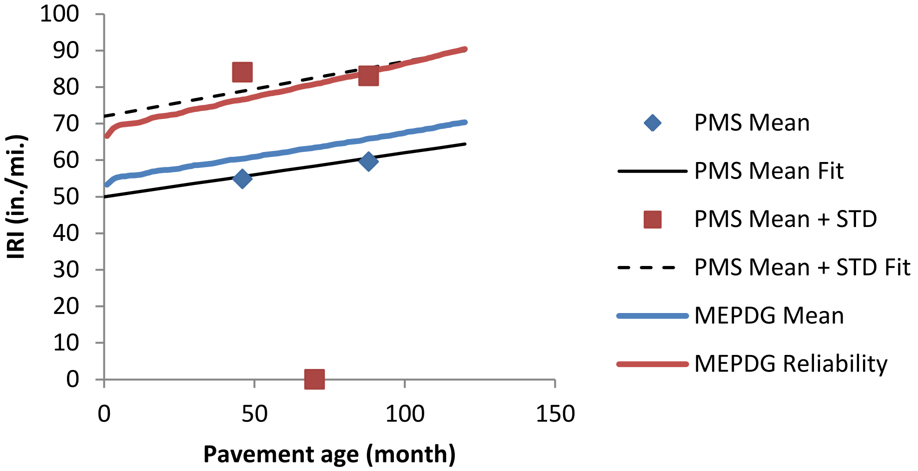
General Information:

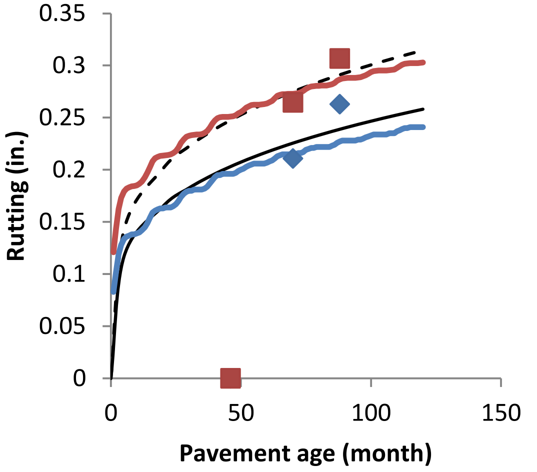
District:	03	Two-Way ADT:	12022
Parish:	57	Number of Lane in Design Direction:	4
Route:	LA 14	Growth Factor:	1%
Accept Date:	5/8/2001	Axle Load Spectrum:	Louisiana Default (TTC12)

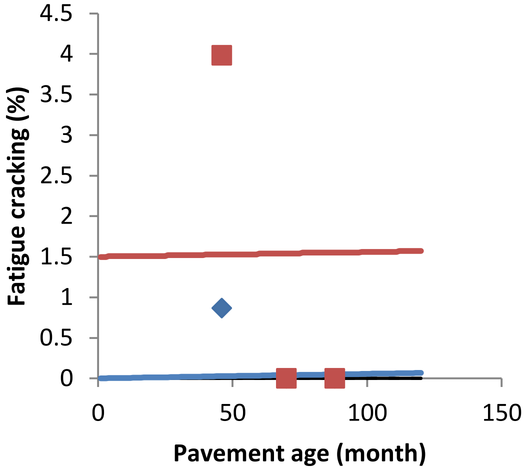
Pavement Structure:

Asphalt Concrete:	1.5" TYPE 8F WEARING COURSE (PG 76-22) + 4" TYPE 8 BINDER COURSE (PG 76-22)
Base:	6.5” TYPE 5A AC (PG 64-22)
Subbase:	
Subgrade:	A-6 (Mr = 7627 psi)

Predicted vs. Measured Pavement Performance







Project ID: **058-02-0009**

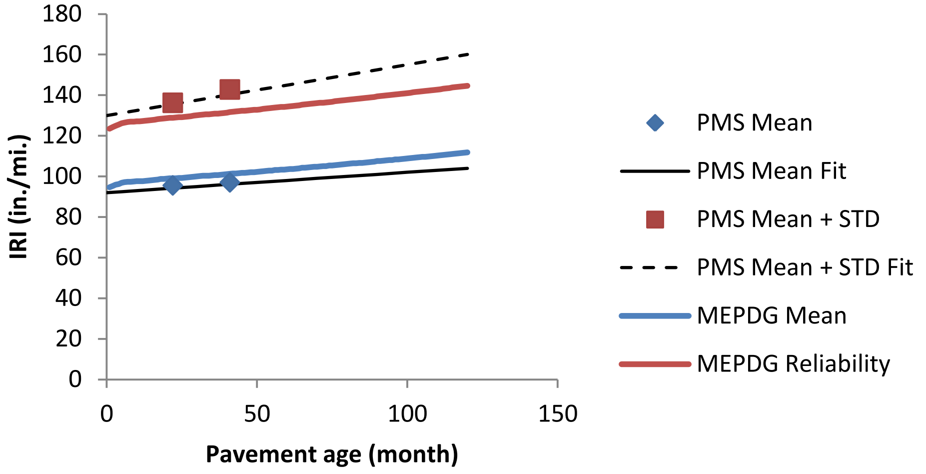
General Information:

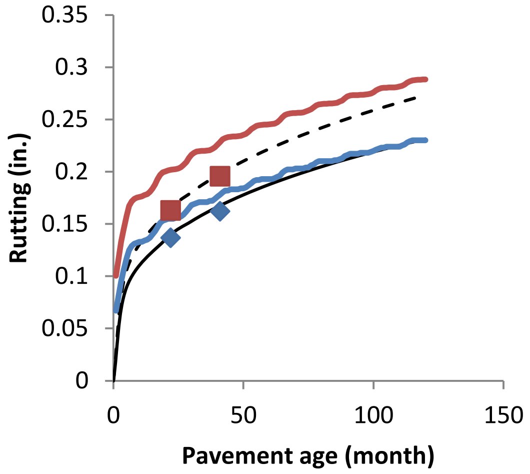
District:	62	Two-Way ADT:	5039
Parish:	52	Number of Lane in Design Direction:	4
Route:	LA 41	Growth Factor:	3%
Accept Date:	5/23/2005	Axle Load Spectrum:	Louisiana Default (TTC12)

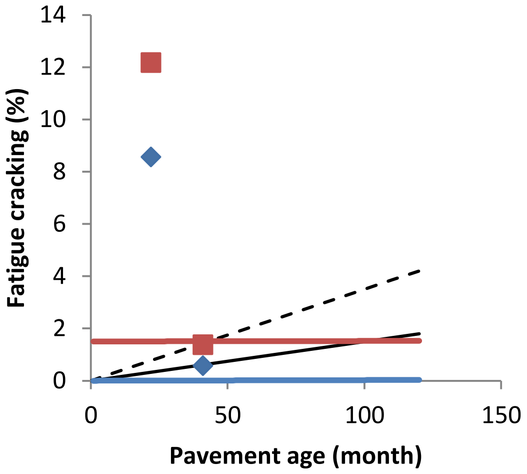
Pavement Structure:

Asphalt Concrete:	2" TYPE 8F WEARING COURSE (PG 76-22) + 3" TYPE 8 BINDER COURSE (PG 76-22)
Base:	5” TYPE 5 AC (PG 64-22)
Subbase:	10” STONE (Mr = 30 ksi)
Subgrade:	A-6, 12” TYPE D LIME TREATED (Mr = 9176 psi)

Predicted vs. Measured Pavement Performance







Project ID: **067-03-0009**

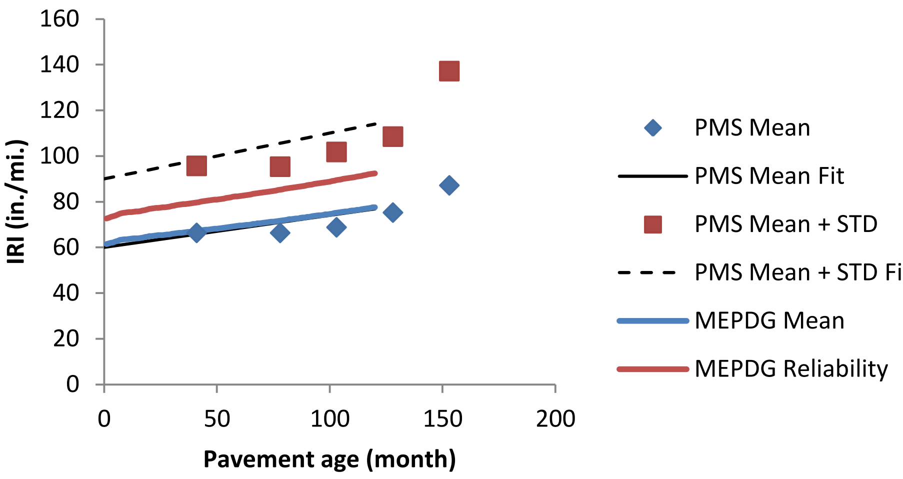
General Information:

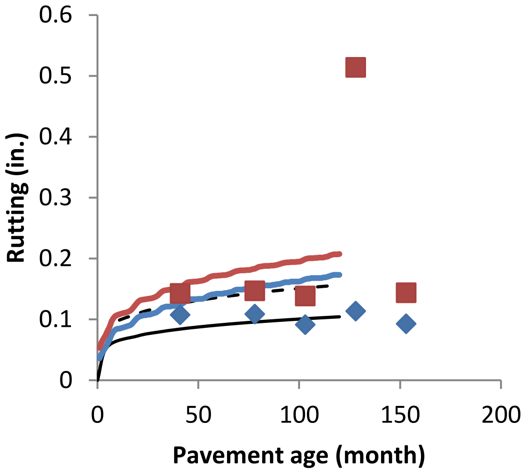
District:	04	Two-Way ADT:	1568
Parish:	7	Number of Lane in Design Direction:	2
Route:	LA 4	Growth Factor:	3%
Accept Date:	1/17/1997	Axle Load Spectrum:	Louisiana Default (TTC12)

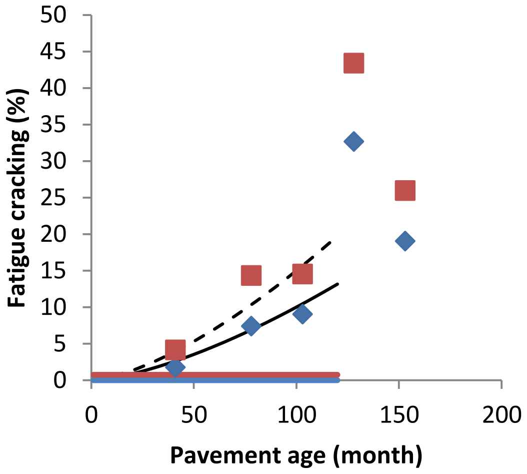
Pavement Structure:

Asphalt Concrete:	1.5" TYPE 3 WEARING COURSE (PAC-40) + 2" TYPE 3 BINDER COURSE (PAC-40)
Base:	10” LIME FLYASH STABILIZED (Mr = 100 ksi)
Subbase:	
Subgrade:	A-6 (Mr = 9916 psi)

Predicted vs. Measured Pavement Performance







Project ID: **077-02-0013**

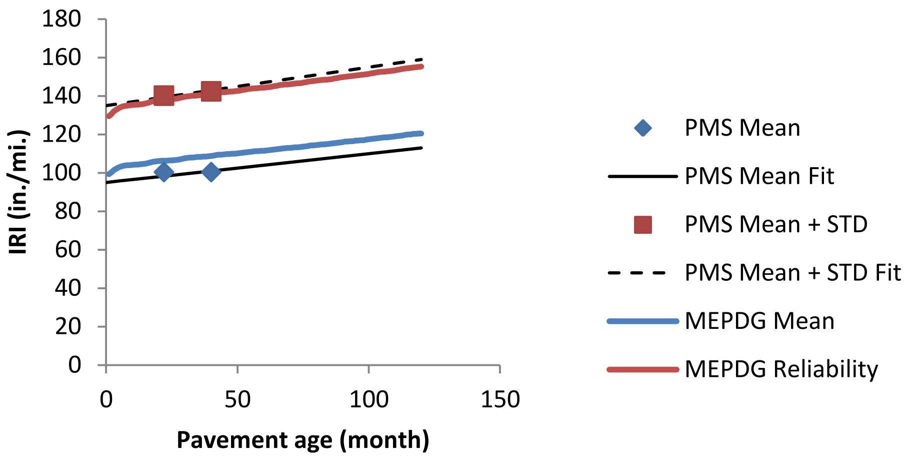
General Information:

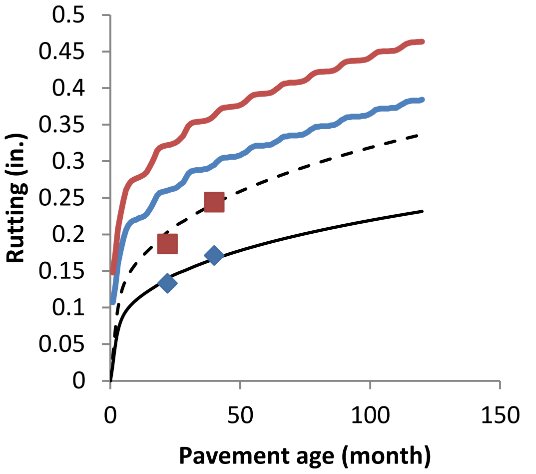
District:	61	Two-Way ADT:	16157
Parish:	3	Number of Lane in Design Direction:	2
Route:	LA 73	Growth Factor:	1%
Accept Date:	3/12/2005	Axle Load Spectrum:	Louisiana Default (TTC12)

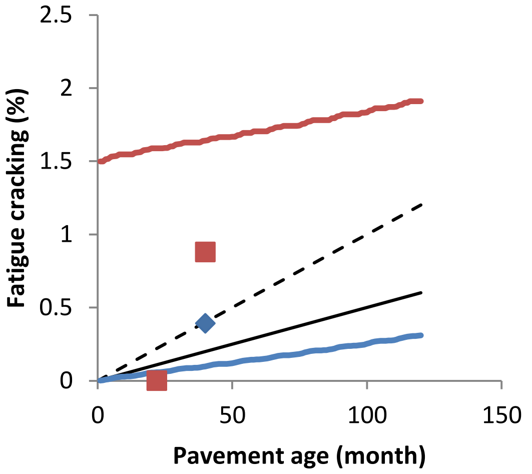
Pavement Structure:

Asphalt Concrete:	1.5" TYPE 8F WEARING COURSE (PG 76-22) + 2" TYPE 8 BINDER COURSE (PG 76-22)
Base:	4.5” TYPE 5 AC (PG 64-22)
Subbase:	8.5“ STONE (Mr = 30 ksi)
Subgrade:	A-4, 12” TYPE D LIME TREATED (Mr = 8413 psi)

Predicted vs. Measured Pavement Performance







Project ID: **139-06-0011**

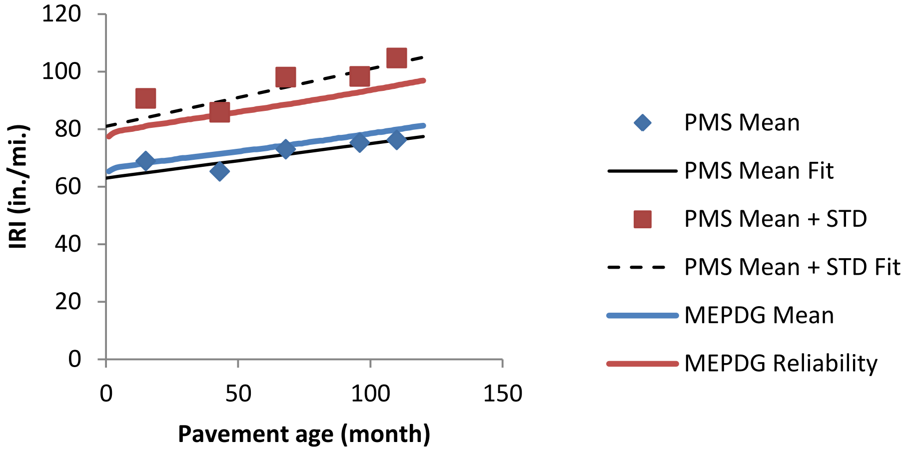
General Information:

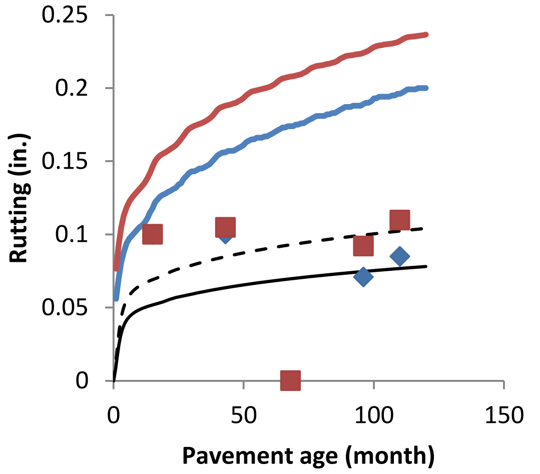
District:	08	Two-Way ADT:	1027
Parish:	58	Number of Lane in Design Direction:	2
Route:	LA 463	Growth Factor:	1%
Accept Date:	5/5/1999	Axle Load Spectrum:	Louisiana Default (TTC12)

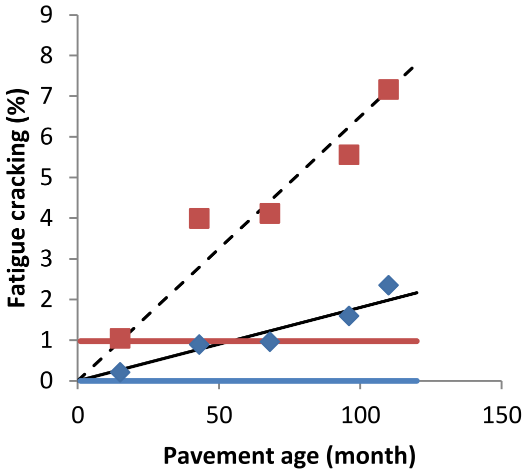
Pavement Structure:

Asphalt Concrete:	1.5" TYPE 8 WEARING COURSE (PAC-40) + 2" TYPE 8 BINDER COURSE (PAC-40)
Base:	12" CEMENT TREATED (Mr = 100 ksi)
Subbase:	
Subgrade:	A-4, 12" TYPE D LIME TREATED (Mr = 8797 psi)

Predicted vs. Measured Pavement Performance







Project ID: **193-02-0039**

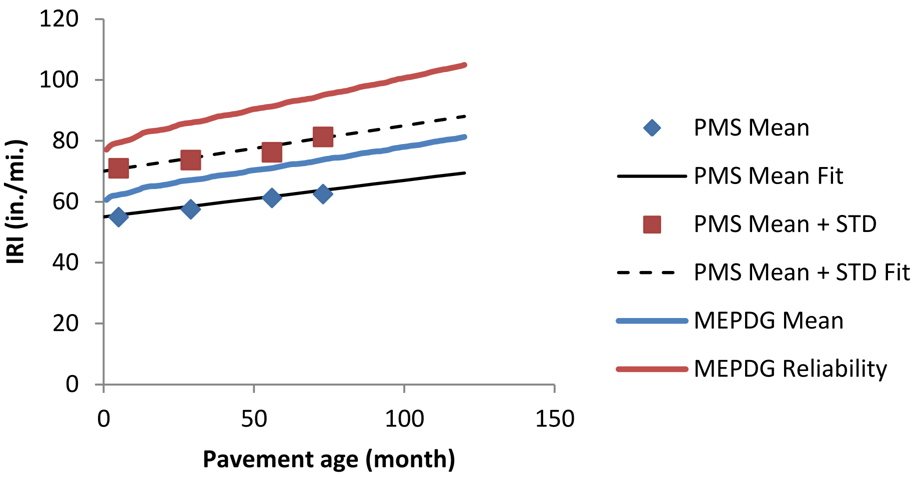
General Information:

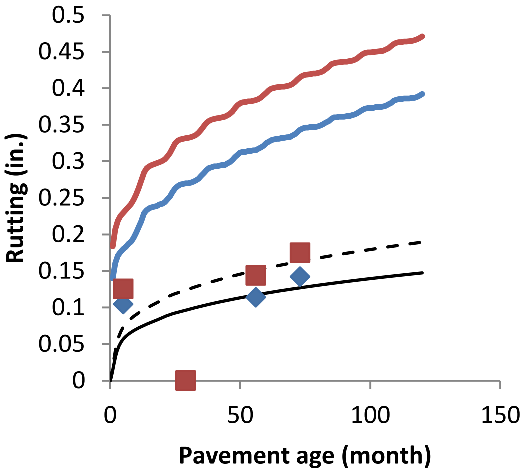
District:	07	Two-Way ADT:	3969
Parish:	12	Number of Lane in Design Direction:	2
Route:	LA 27	Growth Factor:	2.8%
Accept Date:	8/20/2002	Axle Load Spectrum:	Louisiana Default (TTC12)

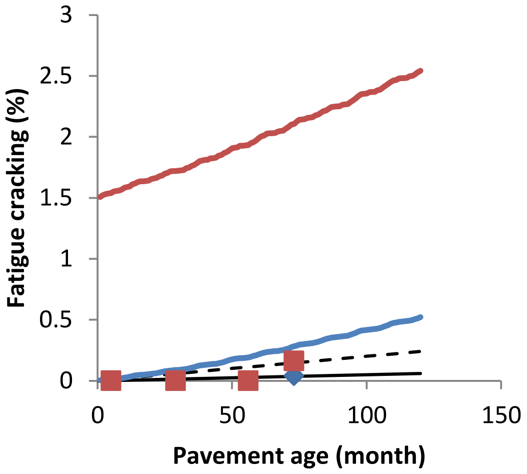
Pavement Structure:

Asphalt Concrete:	1.5" TYPE 8F WEARING COURSE (PG 76-22) + 3" TYPE 8 BINDER COURSE (PG 76-22)
Base:	12” STONE (Mr = 30 ksi)
Subbase:	
Subgrade:	A-4 (Mr = 9176 psi)

Predicted vs. Measured Pavement Performance







Project ID: **211-04-0009**

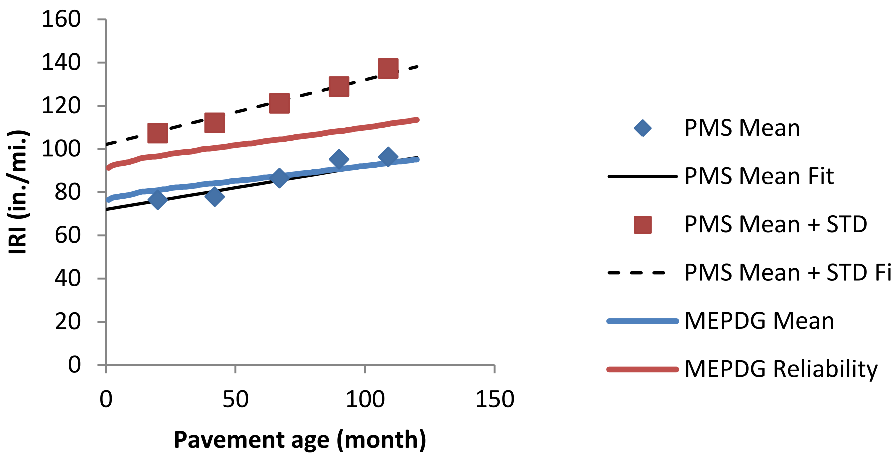
General Information:

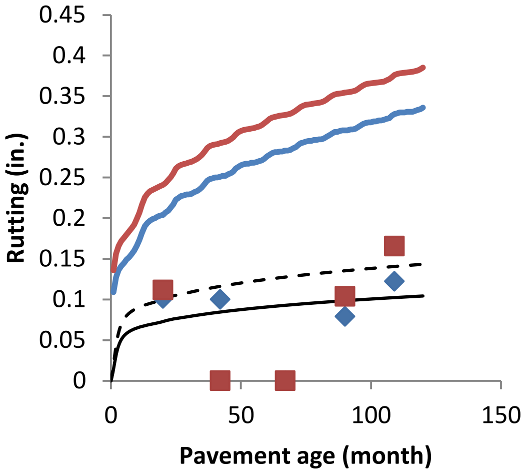
District:	03	Two-Way ADT:	4833
Parish:	1	Number of Lane in Design Direction:	2
Route:	LA 755	Growth Factor:	1.9%
Accept Date:	8/19/1999	Axle Load Spectrum:	Louisiana Default (TTC12)

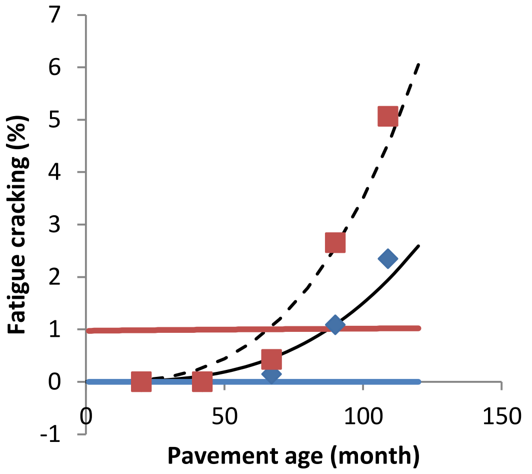
Pavement Structure:

Asphalt Concrete:	1.5" TYPE 8F WEARING COURSE (PAC-40) + 2" TYPE 8 BINDER COURSE (PAC-40)
Base:	8.5" CEMENT STABILIZED (Mr = 100 ksi)
Subbase:	
Subgrade:	A-4, 12" TYPE D LIME TREATED (Mr = 8797 psi)

Predicted vs. Measured Pavement Performance







Project ID: **219-30-0012**

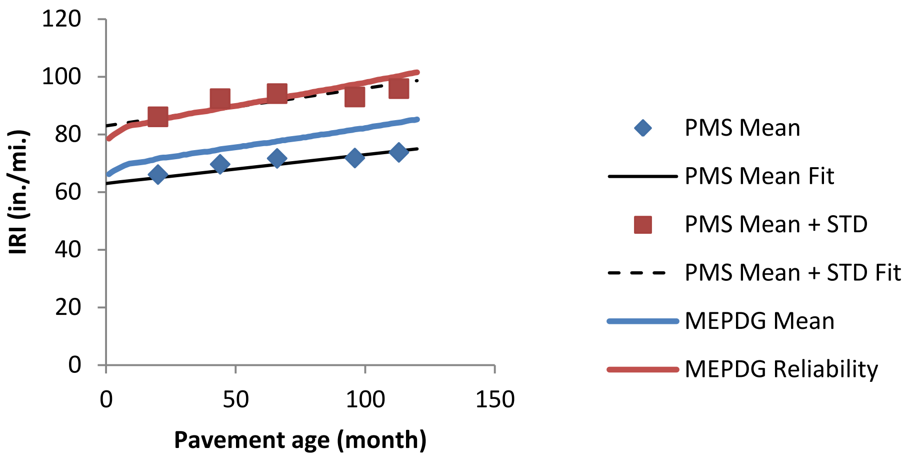
General Information:

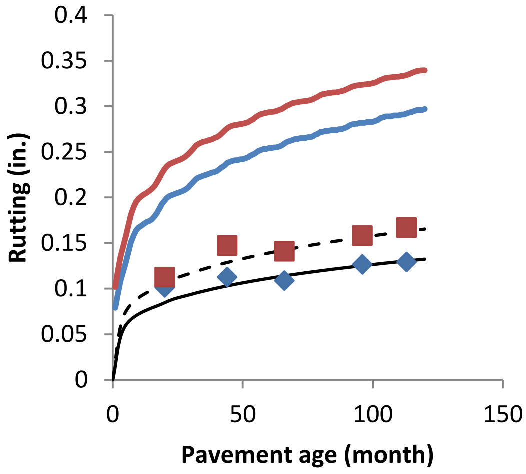
District:	61	Two-Way ADT:	680
Parish:	39	Number of Lane in Design Direction:	2
Route:	LA 10	Growth Factor:	1%
Accept Date:	1/27/1999	Axle Load Spectrum:	Louisiana Default (TTC12)

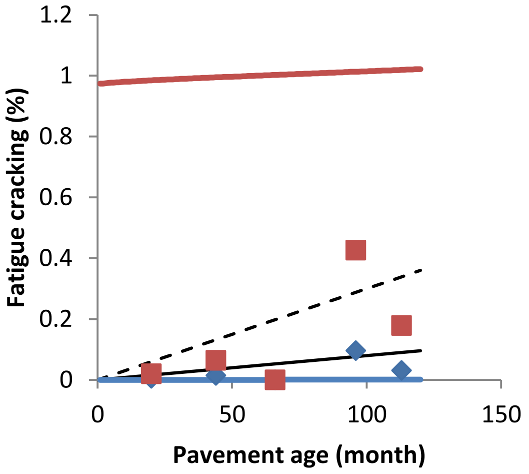
Pavement Structure:

Asphalt Concrete:	1.5" TYPE 3 WEARING COURSE (AC-30) + 2" TYPE 3 BINDER COURSE (AC-30)
Base:	4” STONE (Mr = 30 ksi)
Subbase:	6” CEMENT TREATED (Mr = 100 ksi)
Subgrade:	A-4 (Mr = 9176 psi)

Predicted vs. Measured Pavement Performance







Project ID: **230-03-0022**

General Information:

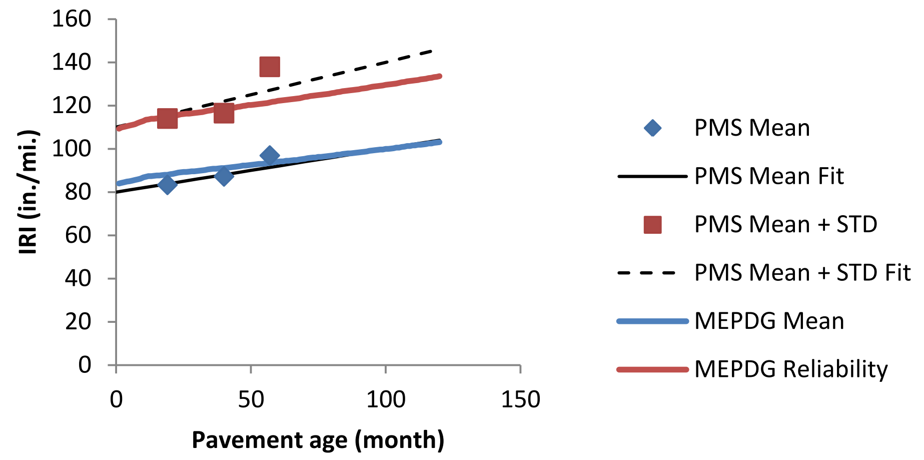
District: 61
Parish: 24
Route: LA 75
Accept Date: 10/17/2003

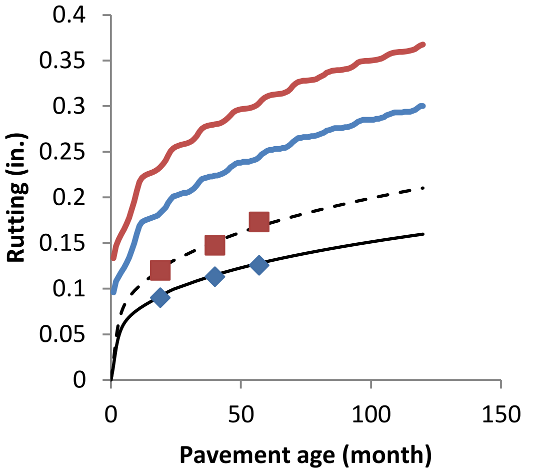
Two-Way ADT: 2065
Number of Lane in Design Direction: 2
Growth Factor: 2.3%
Axle Load Spectrum: Louisiana Default (TTC12)

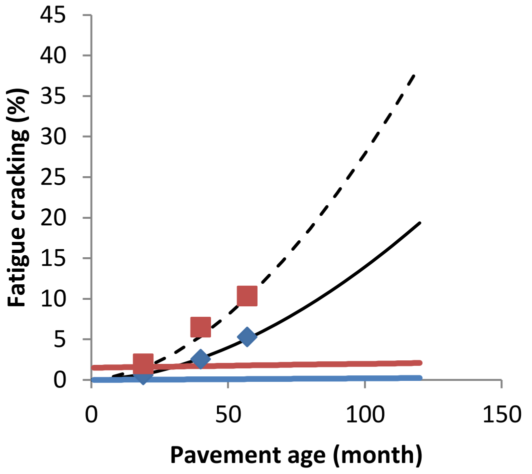
Pavement Structure:

Asphalt Concrete: 1.5" TYPE 3 WEARING COURSE (PG 70-22) + 3.5 TYPE 3 BINDER COURSE (PG 70-22)
Base: 8.5” STONE (Mr = 30 ksi)
Subbase:
Subgrade: A-4 (Mr = 8413 psi)

Predicted vs. Measured Pavement Performance







Project ID: **260-03-0010**

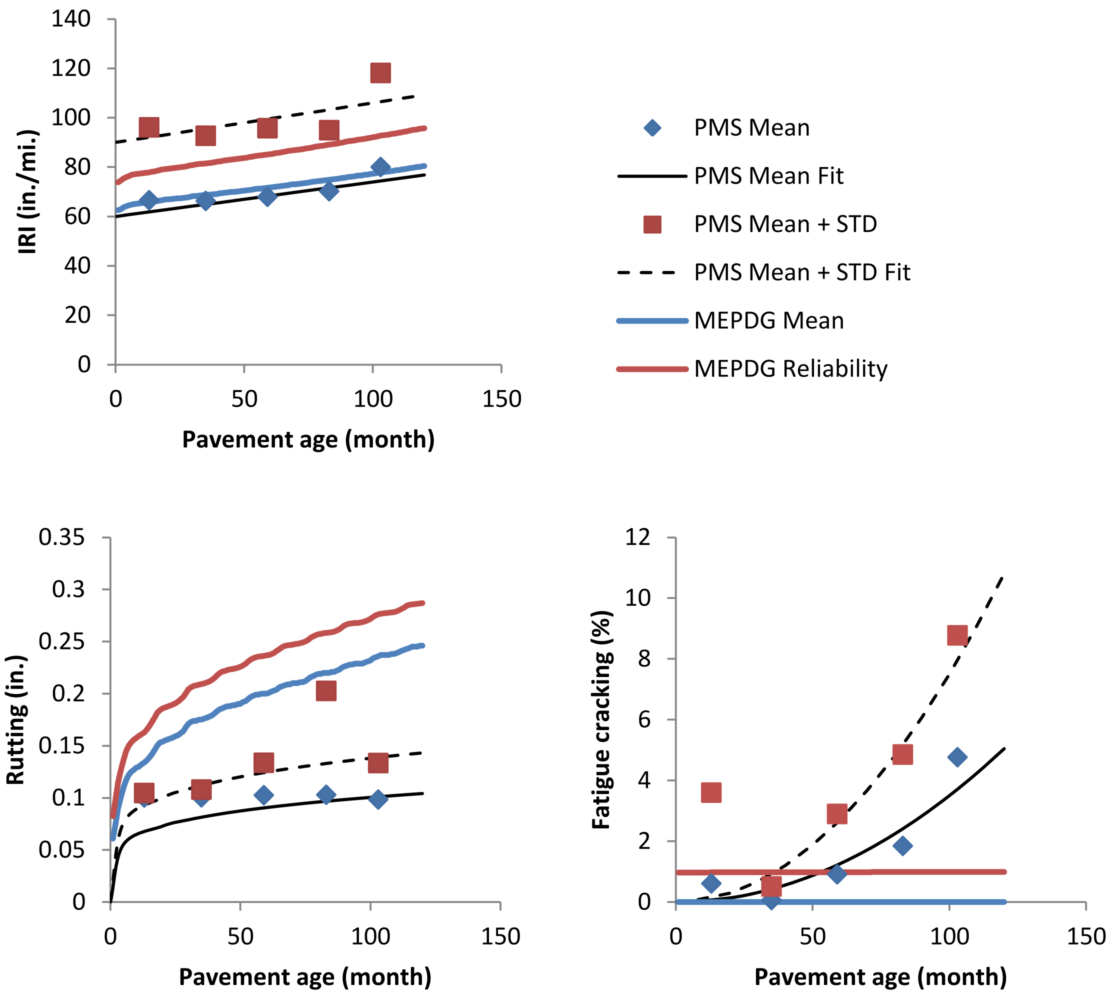
General Information:

District:	62	Two-Way ADT:	3014
Parish:	32	Number of Lane in Design Direction:	2
Route:	LA 22	Growth Factor:	3%
Accept Date:	3/23/2000	Axle Load Spectrum:	Louisiana Default (TTC12)

Pavement Structure:

Asphalt Concrete:	1.5" TYPE 8 WEARING COURSE (PAC-40) + 2" TYPE 8 BINDER COURSE (PAC-40)
Base:	8.5” CEMENT STABILIZED (Mr = 100 ksi)
Subbase:	
Subgrade:	A-6, 15” TYPE D LIME TREATED (Mr = 9549 psi)

Predicted vs. Measured Pavement Performance



Project ID: **261-02-0020**

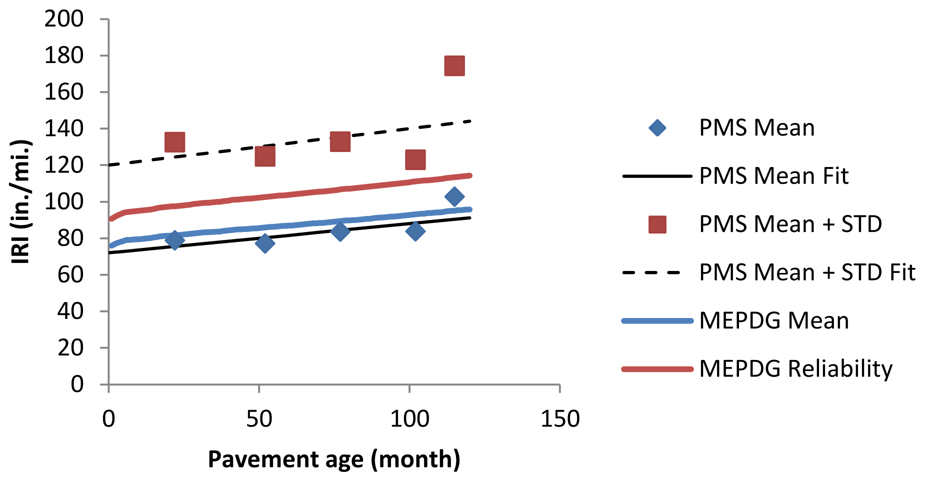
General Information:

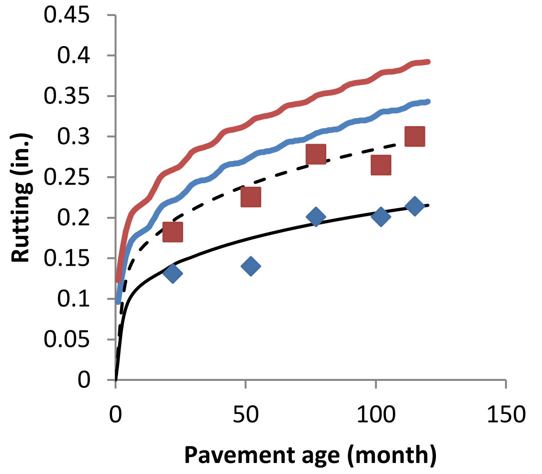
District:	62	Two-Way ADT:	4358
Parish:	32	Number of Lane in Design Direction:	2
Route:	LA 42	Growth Factor:	3%
Accept Date:	4/1/1999	Axle Load Spectrum:	Louisiana Default (TTC12)

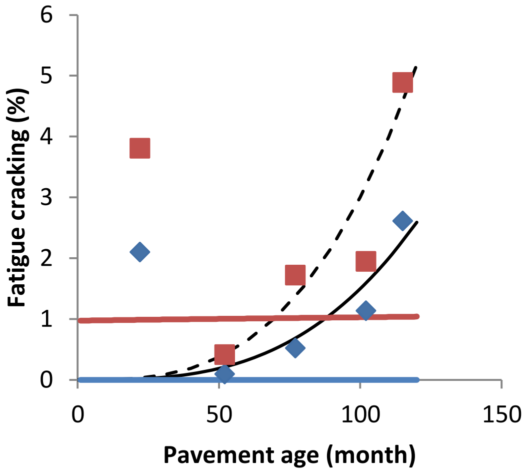
Pavement Structure:

Asphalt Concrete:	1.5" TYPE 8 WEARING COURSE (PAC-40) + 2" TYPE 8 BINDER COURSE (PAC-40)
Base:	8.5" CEMENT STABILIZED (Mr = 100 ksi)
Subbase:	
Subgrade:	A-6 (Mr = 9549 psi)

Predicted vs. Measured Pavement Performance







Project ID: **262-04-0005**

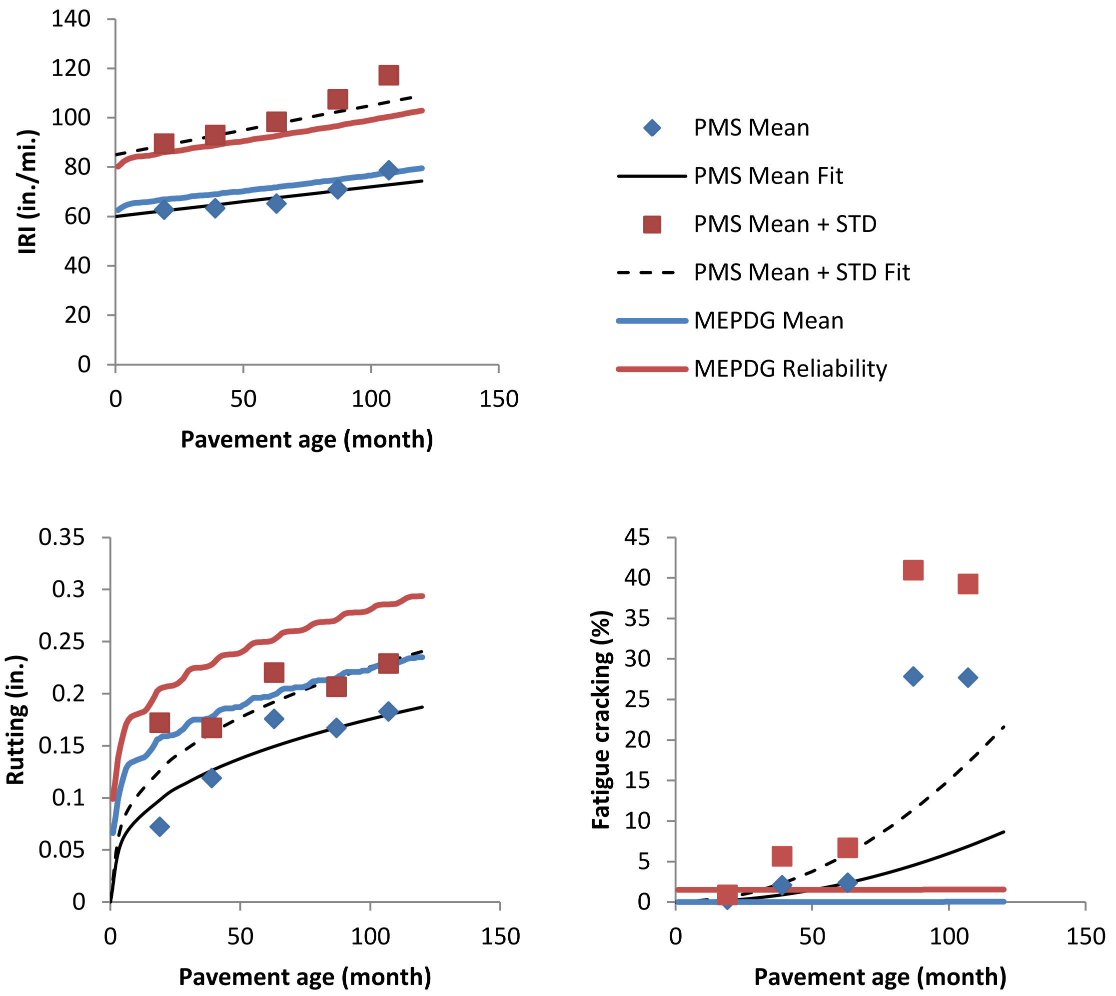
General Information:

District:	62	Two-Way ADT:	6434
Parish:	46	Number of Lane in Design Direction:	2
Route:	LA 16	Growth Factor:	3%
Accept Date:	11/19/1999	Axle Load Spectrum:	Louisiana Default (TTC12)

Pavement Structure:

Asphalt Concrete:	1.5" TYPE 8 WEARING COURSE (PG 76-22) + 4.5" TYPE 8 BINDER COURSE (PG 76-22)
Base:	4.5” TYPE 5B AC (PG 64-22)
Subbase:	8.5” STONE (Mr = 30 ksi)
Subgrade:	A-4 (Mr = 9549 psi)

Predicted vs. Measured Pavement Performance



Project ID: **267-02-0022**

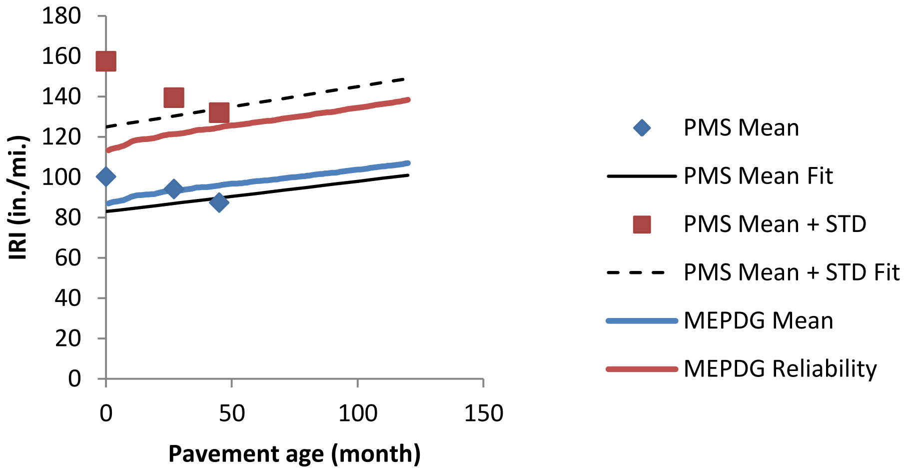
General Information:

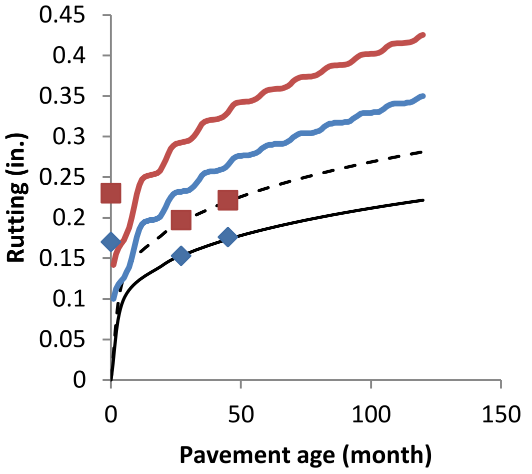
District:	61	Two-Way ADT:	7017
Parish:	3	Number of Lane in Design Direction:	2
Route:	LA 431	Growth Factor:	3%
Accept Date:	10/20/2004	Axle Load Spectrum:	Louisiana Default (TTC12)

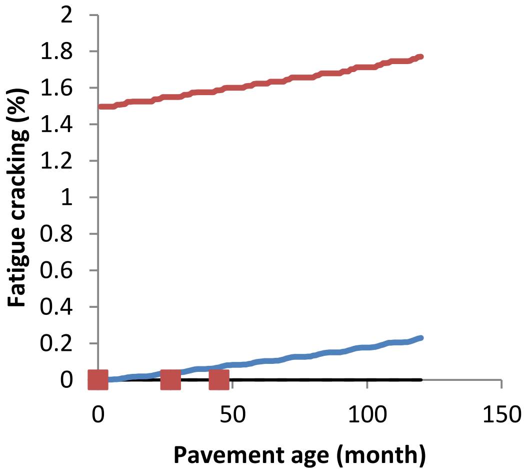
Pavement Structure:

Asphalt Concrete:	2.0" TYPE 8 WEARING COURSE (PG 76-22) + 3.0" TYPE 8 BINDER COURSE (PG 76-22)
Base:	5” TYPE 5 AC (PG 64-22)
Subbase:	
Subgrade:	A-4, 12” TYPE D LIME TREATED (Mr = 8413 psi)

Predicted vs. Measured Pavement Performance







Project ID: **268-01-0014**

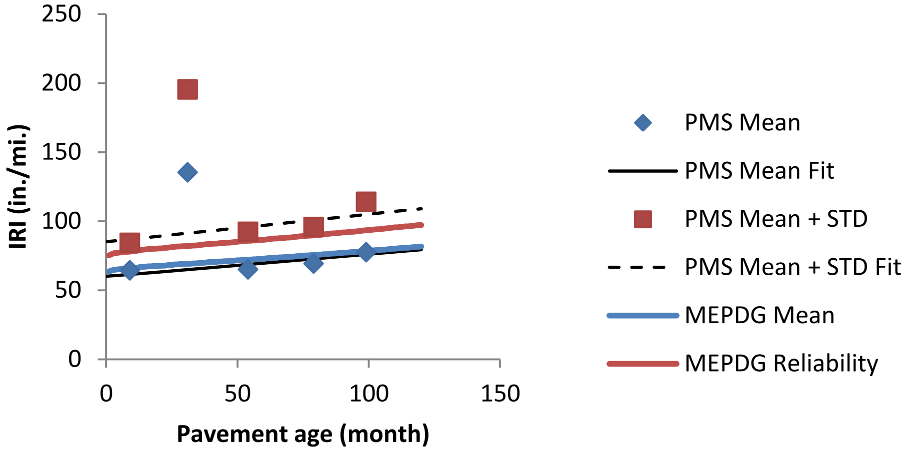
General Information:

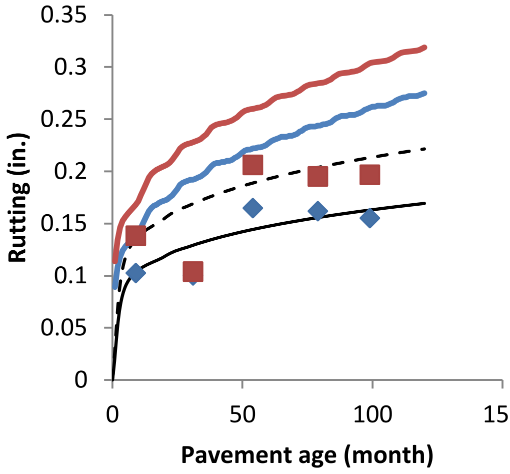
District:	62	Two-Way ADT:	3947
Parish:	32	Number of Lane in Design Direction:	2
Route:	LA 447	Growth Factor:	3%
Accept Date:	7/27/2000	Axle Load Spectrum:	Louisiana Default (TTC12)

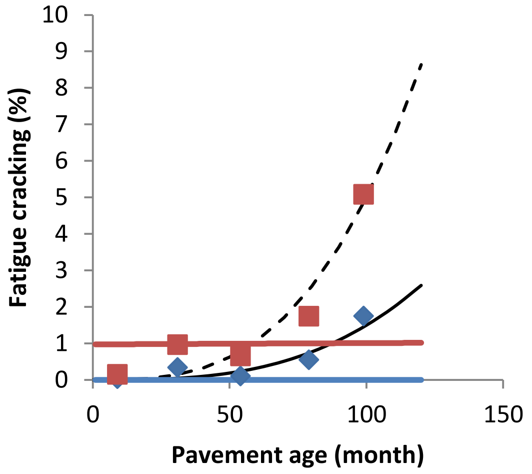
Pavement Structure:

Asphalt Concrete:	2" TYPE 8 WEARING COURSE (AC-30) + 2.5" TYPE 8 BINDER COURSE (AC-30)
Base:	8.5” CEMENT STABILIZED (Mr = 100 ksi)
Subbase:	
Subgrade:	A-6 (Mr = 9549 psi)

Predicted vs. Measured Pavement Performance







Project ID: **397-04-0004**

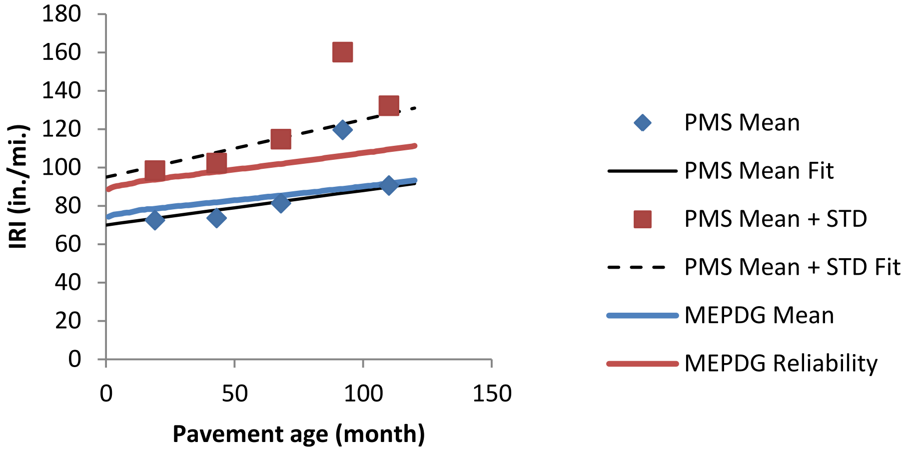
General Information:

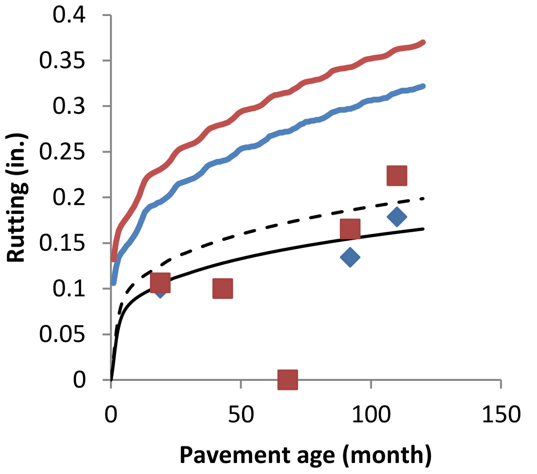
District:	03	Two-Way ADT:	3023
Parish:	57	Number of Lane in Design Direction:	2
Route:	LA 89	Growth Factor:	3%
Accept Date:	7/19/1999	Axle Load Spectrum:	Louisiana Default (TTC12)

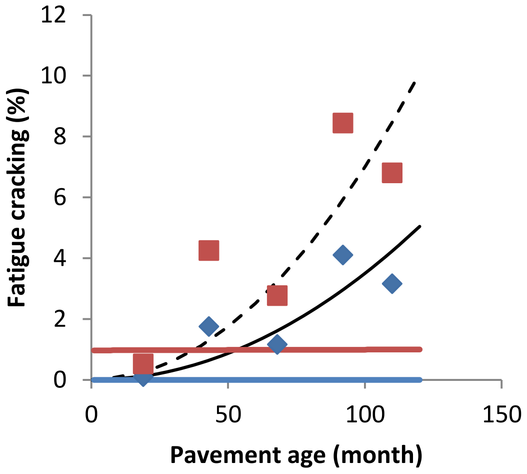
Pavement Structure:

Asphalt Concrete:	1.5" TYPE 8 WEARING COURSE (PAC-40) + 2" TYPE 8 BINDER COURSE (PAC-40)
Base:	8.5” CEMENT STABILIZED (Mr = 100 ksi)
Subbase:	
Subgrade:	A-4 12” TYPE D LIME TREATED (Mr = 7627 psi)

Predicted vs. Measured Pavement Performance







Project ID: **432-01-0018**

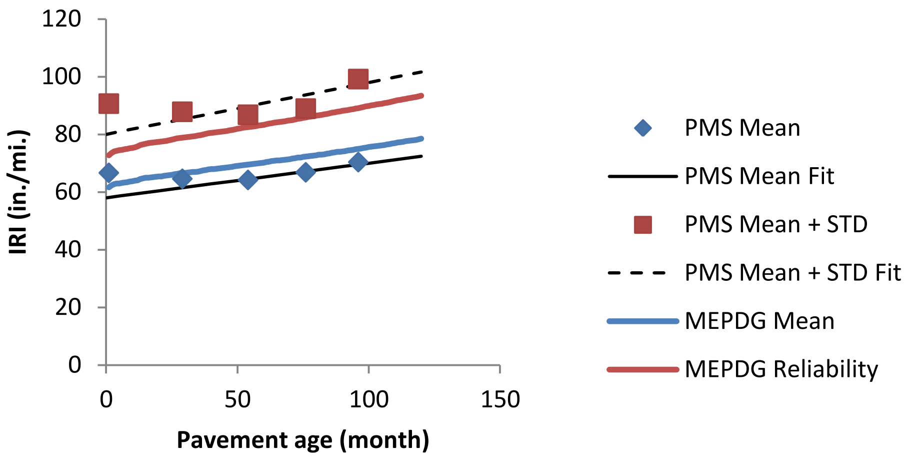
General Information:

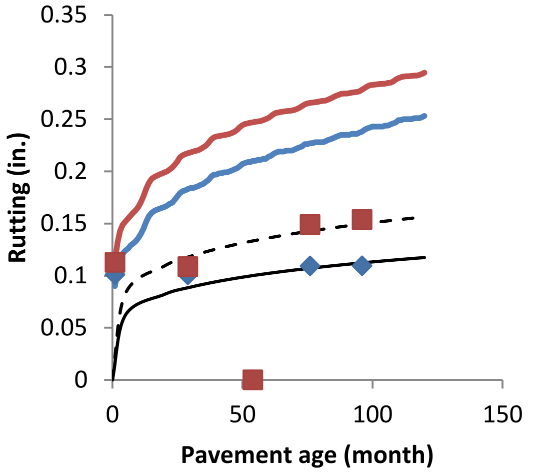
District:	08	Two-Way ADT:	3363
Parish:	43	Number of Lane in Design Direction:	2
Route:	LA 191	Growth Factor:	1%
Accept Date:	7/24/2000	Axle Load Spectrum:	Louisiana Default (TTC12)

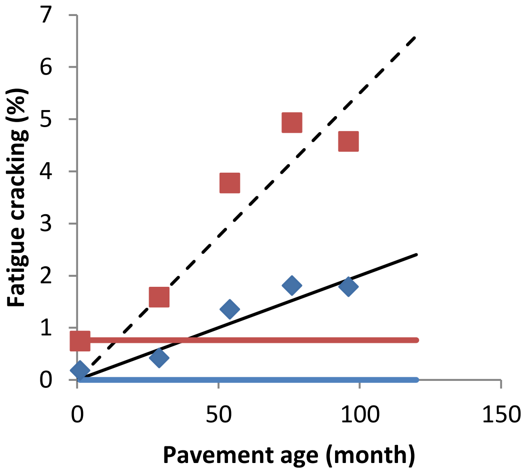
Pavement Structure:

Asphalt Concrete:	2" TYPE 8 WEARING COURSE (PAC-40) + 2.5" TYPE 8 BINDER COURSE (PAC-40)
Base:	8.5” CEMENT STABILIZED (Mr = 100 ksi)
Subbase:	
Subgrade:	A-4 12” TYPE D LIME TREATED (Mr = 9549 psi)

Predicted vs. Measured Pavement Performance







Project ID: **450-03-0037**

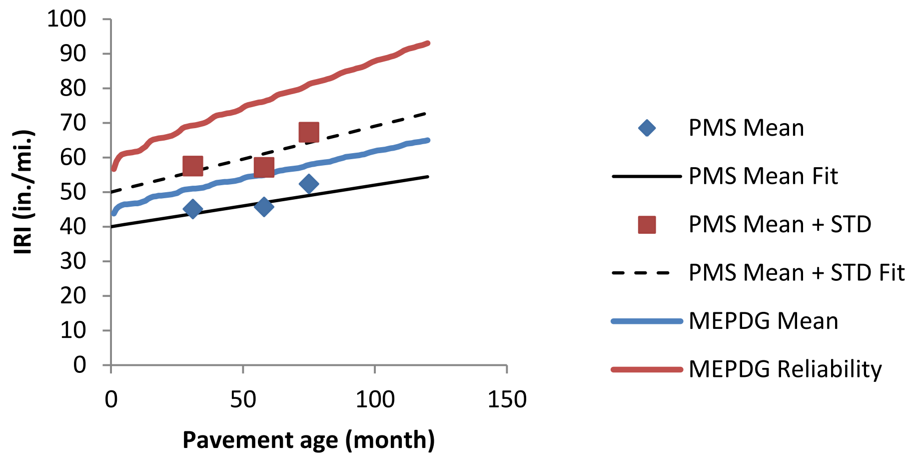
General Information:

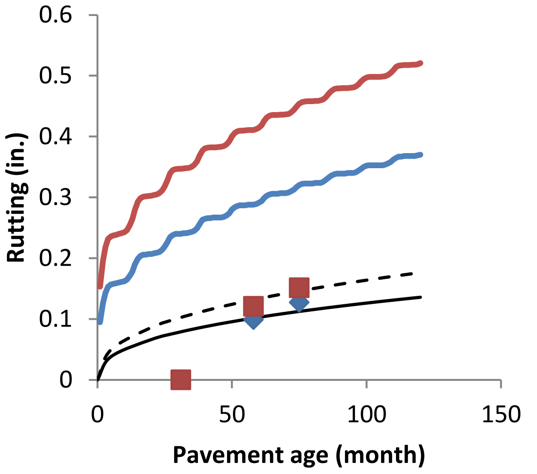
District:	07	Two-Way ADT:	33325
Parish:	27	Number of Lane in Design Direction:	4
Route:	I-10	Growth Factor:	1%
Accept Date:	6/6/2002	Axle Load Spectrum:	Louisiana Default (TTC3)

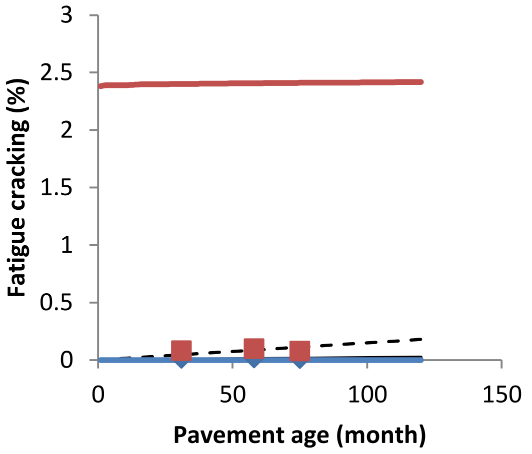
Pavement Structure:

Asphalt Concrete:	2" SUPERPAVE WEARING COURSE (PG 76-22) + 5.5" SUPERPAVE BINDER COURSE (PG 76-22)
Base:	10” RUBBLIZED PCC (Mr = 500 ksi)
Subbase:	6” EXISTED SOIL CEMENT (Mr = 30 ksi)
Subgrade:	A-4 12” TYPE D LIME TREATED (Mr = 8413 psi)

Predicted vs. Measured Pavement Performance







Project ID: **450-03-0064**

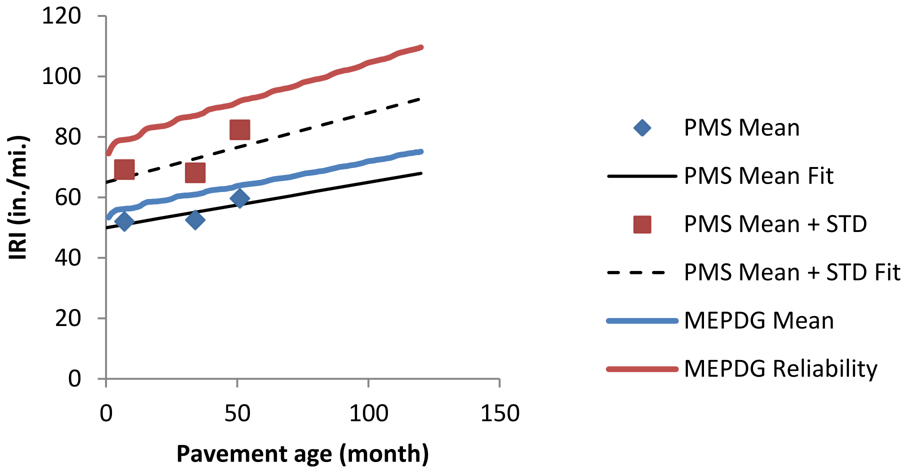
General Information:

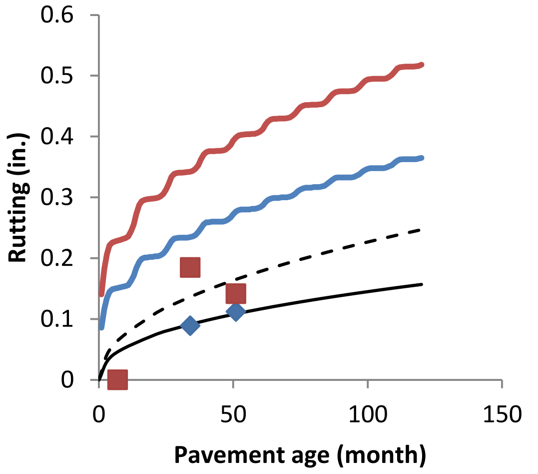
District:	07	Two-Way ADT:	35744
Parish:	27	Number of Lane in Design Direction:	4
Route:	I-10	Growth Factor:	1%
Accept Date:	6/7/2004	Axle Load Spectrum:	Louisiana Default (TTC3)

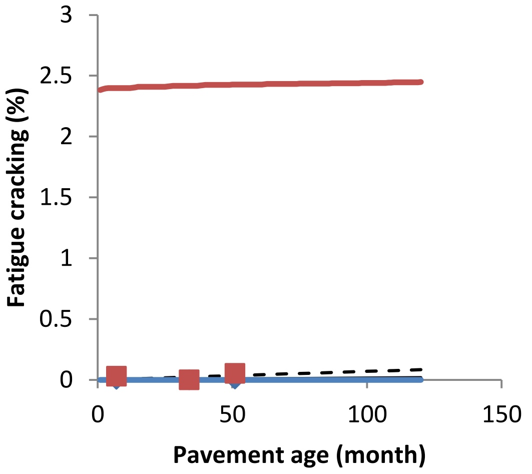
Pavement Structure:

Asphalt Concrete:	2" SUPERPAVE LEVEL 3 WEARING COURSE (PG 76-22) + 6" SUPERPAVE LEVEL 3 BINDER COURSECOURSE (PG 76-22)
Base:	10” RUBBLIZED PCC (Mr = 500 ksi)
Subbase:	6” EXISTED SOIL CEMENT (Mr = 30 ksi)
Subgrade:	A-7-6 (Mr = 8413 psi)

Predicted vs. Measured Pavement Performance







Project ID: **450-04-0065**

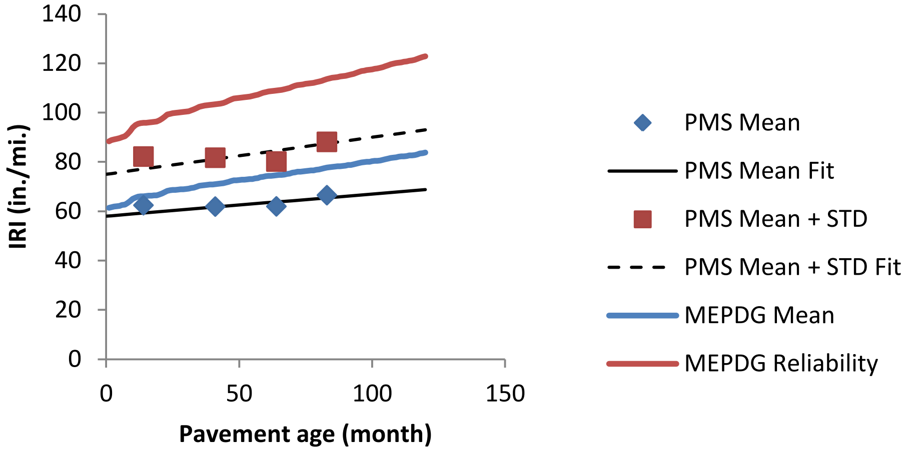
General Information:

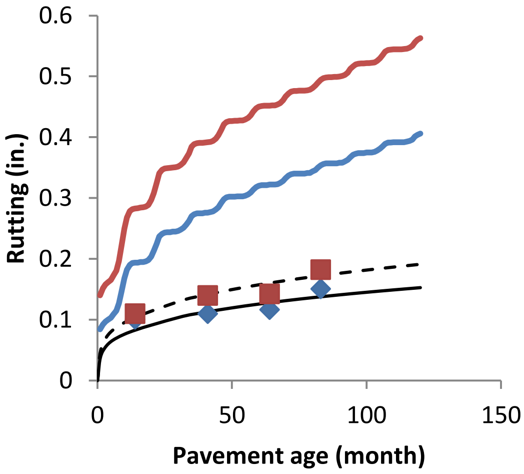
District:	03	Two-Way ADT:	40998
Parish:	1	Number of Lane in Design Direction:	4
Route:	I-10	Growth Factor:	1%
Accept Date:	10/9/2001	Axle Load Spectrum:	Louisiana Default (TTC3)

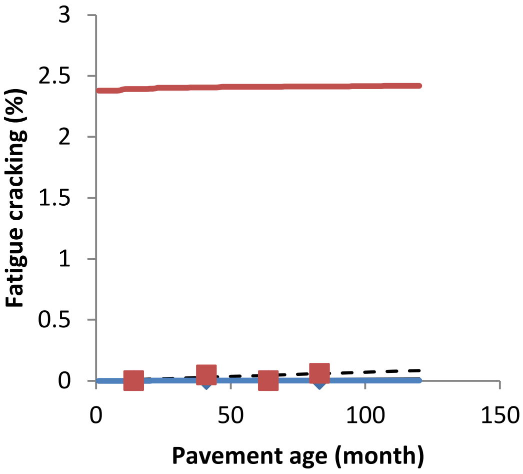
Pavement Structure:

Asphalt Concrete:	2" SMA WEARING COURSE (PG 76-22) + 5.5 TYPE 8 BINDER COURSE (PG 76-22)
Base:	10" RUBBLIZED PCC (Mr = 500 ksi)
Subbase:	6" EXISTED SOIL CEMENT (Mr = 30 ksi)
Subgrade:	A-4 (Mr = 8797 psi)

Predicted vs. Measured Pavement Performance







Project ID: **450-04-0084**

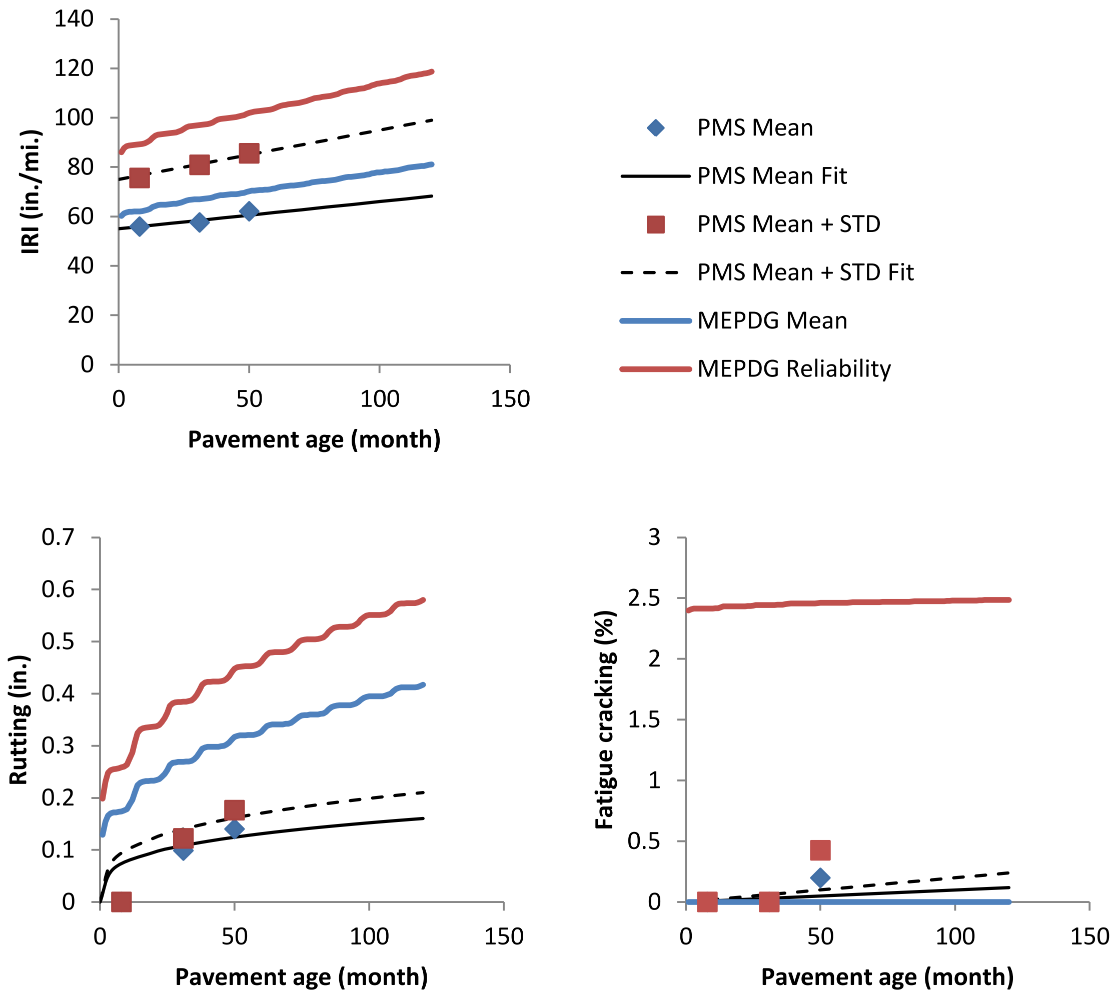
General Information:

District:	03	Two-Way ADT:	33055
Parish:	1	Number of Lane in Design Direction:	4
Route:	I-10	Growth Factor:	1%
Accept Date:	7/19/2004	Axle Load Spectrum:	Louisiana Default (TTC3)

Pavement Structure:

Asphalt Concrete:	2" SUPERPAVE LEVEL 3 WEARING COURSE (PG 76-22) + 6" SUPERPAVE LEVEL 3 BINDER COURSE (PG 76-22)
Base:	10" RUBBLIZED PCC (Mr = 500 ksi)
Subbase:	6" EXISTED SOIL CEMENT (Mr = 30 ksi)
Subgrade:	A-4 (Mr = 8797 psi)

Predicted vs. Measured Pavement Performance



Project ID: **450-05-0046**

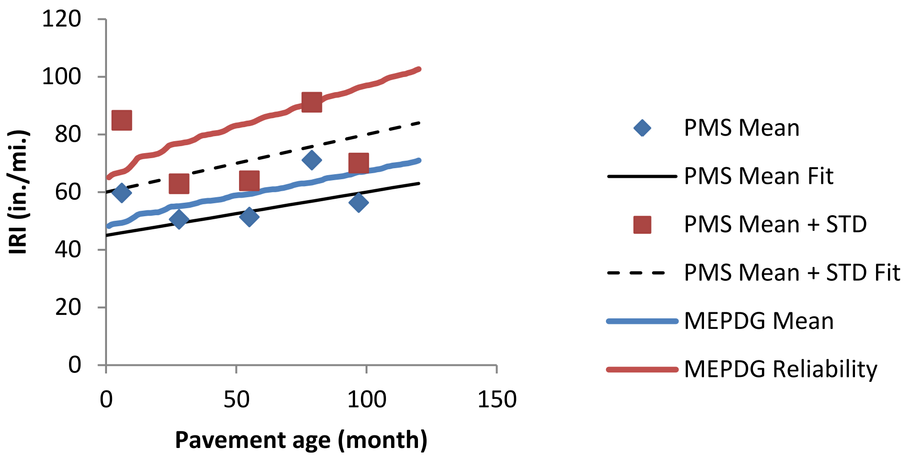
General Information:

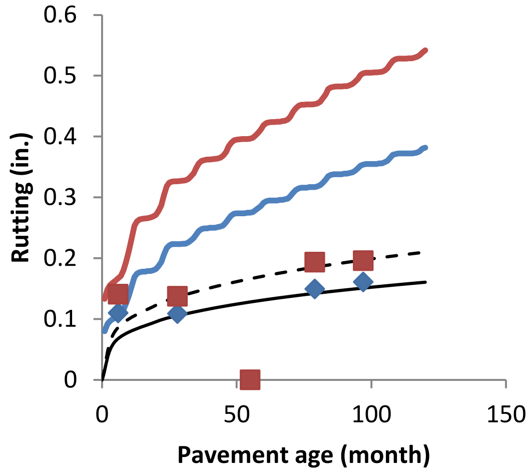
District:	03	Two-Way ADT:	41310
Parish:	28	Number of Lane in Design Direction:	4
Route:	I-10	Growth Factor:	1%
Accept Date:	9/1/2000	Axle Load Spectrum:	Louisiana Default (TTC3)

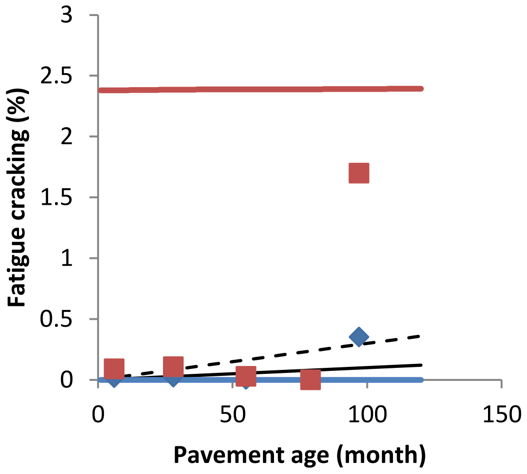
Pavement Structure:

Asphalt Concrete:	2" SMA WEARING COURSE (PAC-40) + 4" TYPE 8 BINDER COURSE (PAC-40)
Base:	10" RUBBLIZED PCC (Mr = 500 ksi)
Subbase:	6" EXISTED SOIL CEMENT (Mr = 30 ksi)
Subgrade:	A-7-6 (Mr = 9916 psi)

Predicted vs. Measured Pavement Performance







Project ID: **450-91-0076**

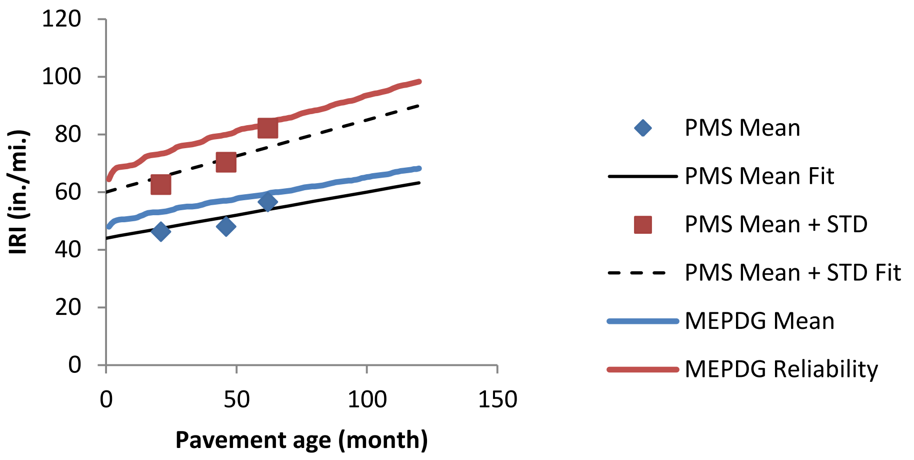
General Information:

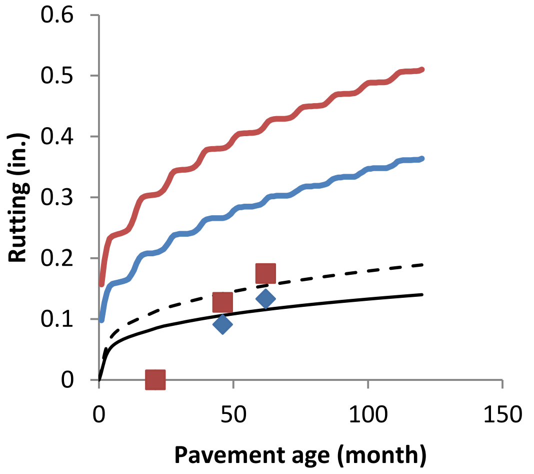
District:	07	Two-Way ADT:	34847
Parish:	10	Number of Lane in Design Direction:	4
Route:	I-10	Growth Factor:	1%
Accept Date:	6/17/2003	Axle Load Spectrum:	Louisiana Default (TTC3)

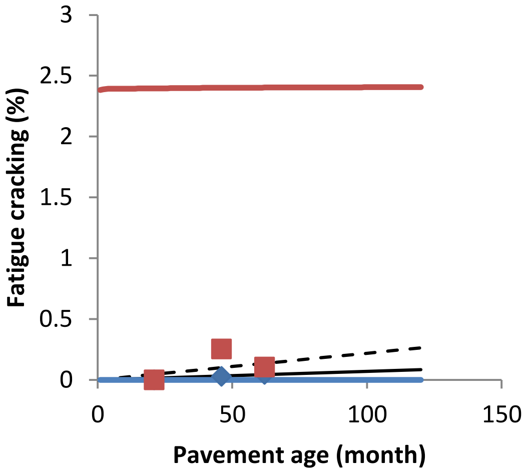
Pavement Structure:

Asphalt Concrete:	2" SMA WEARING COURSE (PG 76-22) + 5.5" SUPERPAVE LEVEL 3 BINDER COURSE (PG 76-22)
Base:	10" RUBBLIZED PCC (Mr = 500 ksi)
Subbase:	6" EXISTED SOIL CEMENT (Mr = 30 ksi)
Subgrade:	A-4 (Mr = 9176 psi)

Predicted vs. Measured Pavement Performance







Project ID: **451-01-0083**

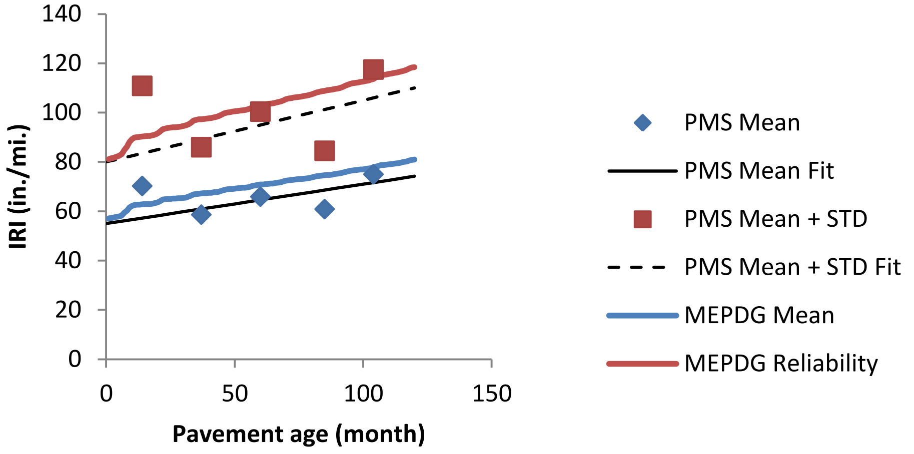
General Information:

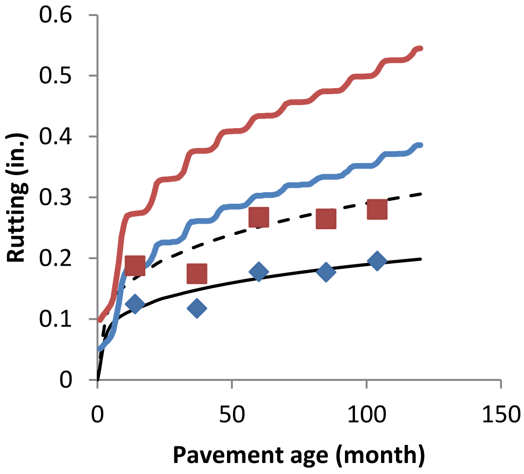
District:	04	Two-Way ADT:	33505
Parish:	9	Number of Lane in Design Direction:	4
Route:	I-20	Growth Factor:	1%
Accept Date:	11/29/1999	Axle Load Spectrum:	Louisiana Default (TTC3)

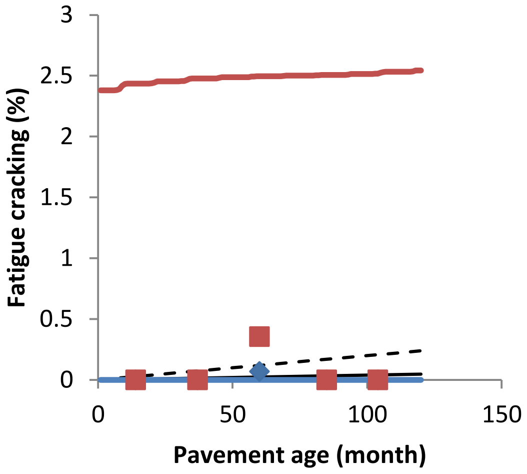
Pavement Structure:

Asphalt Concrete:	2" SMA WEARING COURSE (PAC-40) + 6" TYPE 8 BINDER COURSE (PAC-40)
Base:	10" RUBBLIZED PCC (Mr = 500 ksi)
Subbase:	6" EXISTED SOIL CEMENT (Mr = 30 ksi)
Subgrade:	A-4 (Mr = 10278 psi)

Predicted vs. Measured Pavement Performance







Project ID: **451-05-0075**

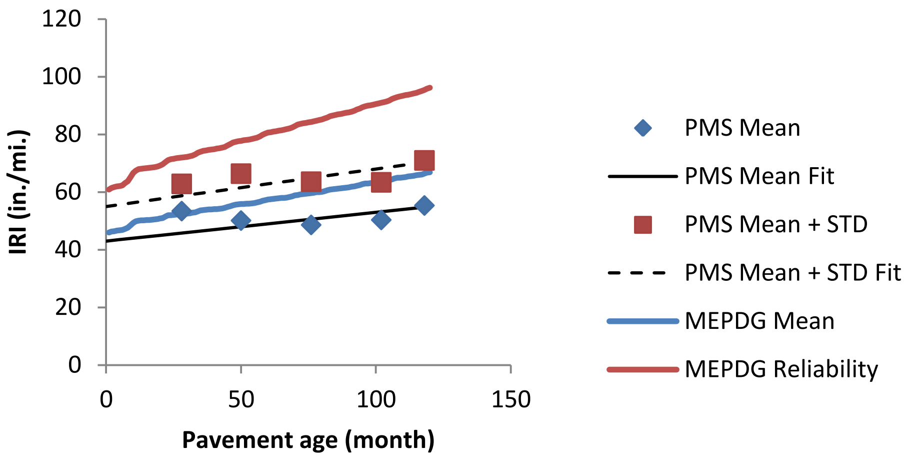
General Information:

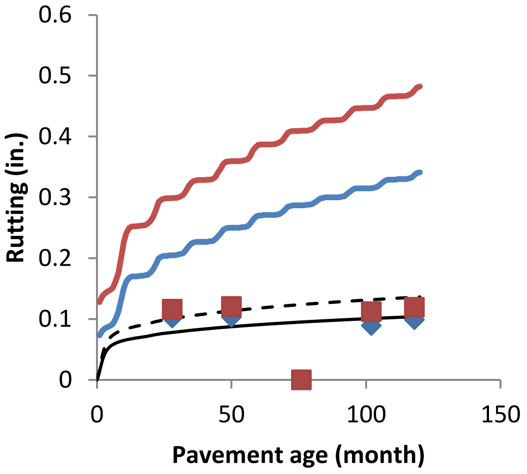
District:	05	Two-Way ADT:	21490
Parish:	31	Number of Lane in Design Direction:	4
Route:	I-20	Growth Factor:	1%
Accept Date:	10/29/1998	Axle Load Spectrum:	Louisiana Default (TTC3)

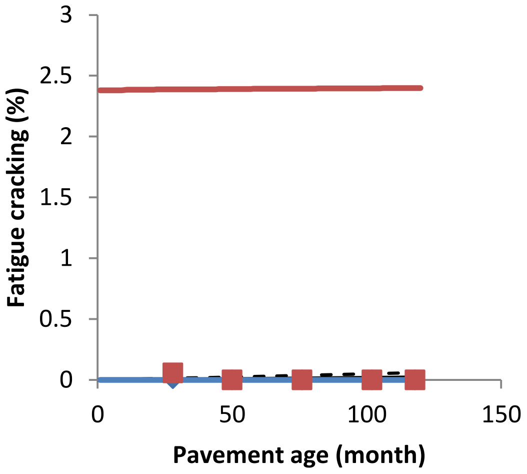
Pavement Structure:

Asphalt Concrete:	2" SMA WEARING COURSE (PAC-40) + 4" SUPERPAVE LEVEL 3 BINDER COURSE (PAC-40)
Base:	10" RUBBLIZED PCC (Mr = 500 ksi)
Subbase:	6" EXISTED SOIL CEMENT (Mr = 30 ksi)
Subgrade:	A-2-4 (Mr = 10278 psi)

Predicted vs. Measured Pavement Performance







Project ID: **451-06-0092**

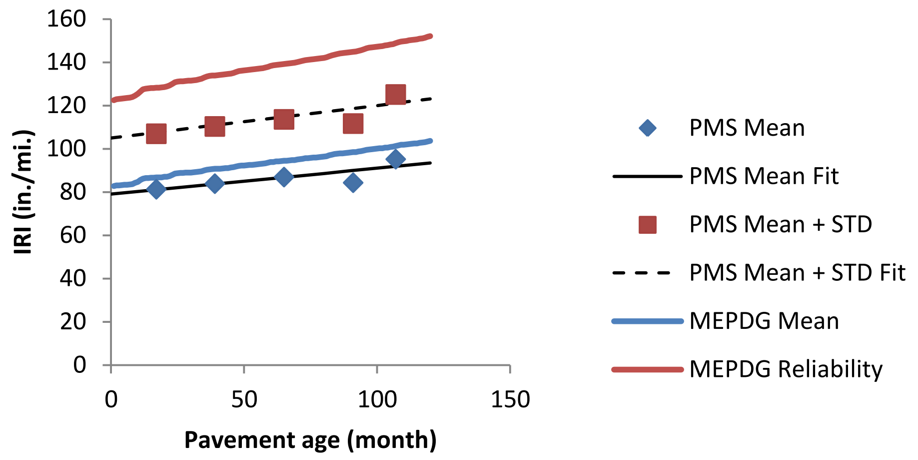
General Information:

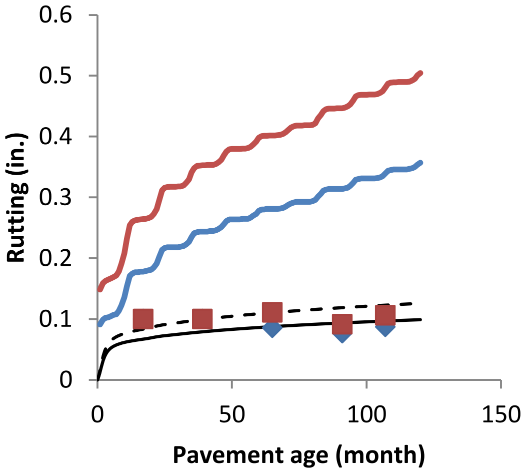
District:	05	Two-Way ADT:	25702
Parish:	37	Number of Lane in Design Direction:	4
Route:	I-20	Growth Factor:	1%
Accept Date:	9/23/1999	Axle Load Spectrum:	Louisiana Default (TTC3)

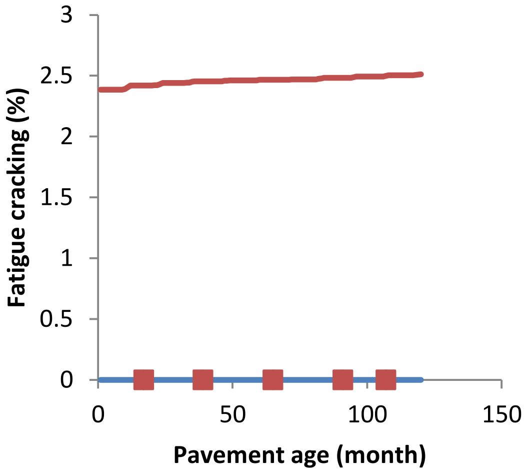
Pavement Structure:

Asphalt Concrete:	2" SMA WEARING COURSE (PAC-40) + 6" TYPE 8 BINDER COURSE (PAC-40)
Base:	10" RUBBLIZED PCC (Mr = 500 ksi)
Subbase:	6" EXISTED SOIL CEMENT (Mr = 30 ksi)
Subgrade:	A-4 (Mr = 9916 psi)

Predicted vs. Measured Pavement Performance







Project ID: **454-02-0026**

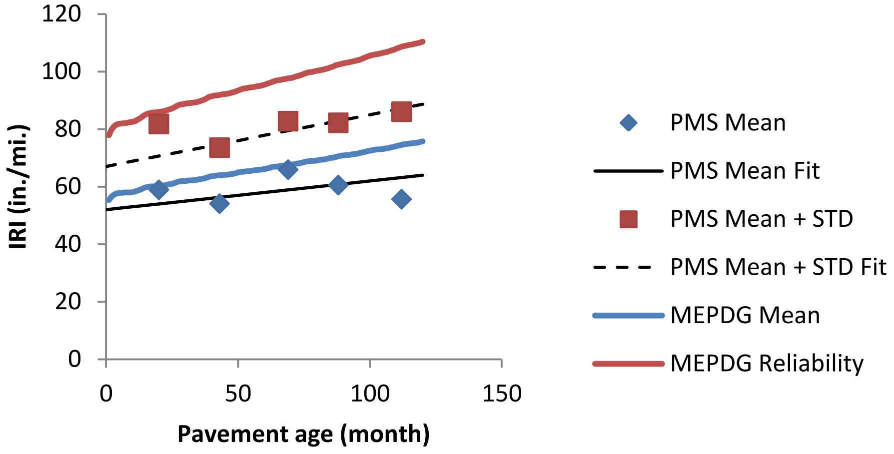
General Information:

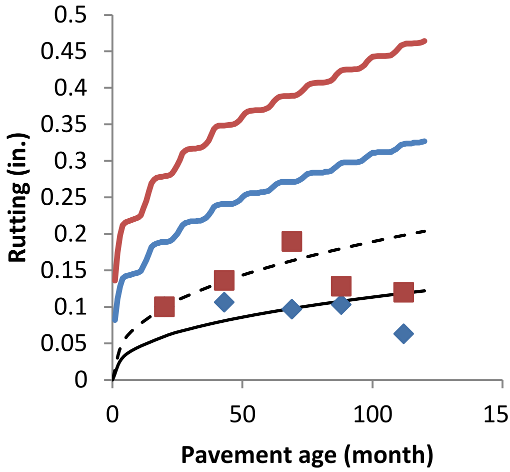
District:	62	Two-Way ADT:	33062
Parish:	32	Number of Lane in Design Direction:	4
Route:	I-12	Growth Factor:	1%
Accept Date:	6/18/2001	Axle Load Spectrum:	Louisiana Default (TTC3)

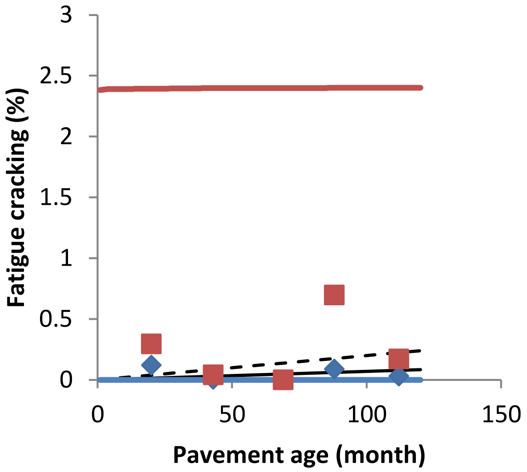
Pavement Structure:

Asphalt Concrete:	4" SUPERPAVE LEVEL 3 WEARING COURSE (PG 76-22) + 4" SUPERPAVE LEVEL 3 BINDER COURSE (PG 76-22)
Base:	10" RUBBLIZED PCC (Mr = 500 ksi)
Subbase:	6" EXISTED SOIL CEMENT (Mr = 30 ksi)
Subgrade:	A-7-6 (Mr = 9549 psi)

Predicted vs. Measured Pavement Performance







Project ID: **454-02-0043**

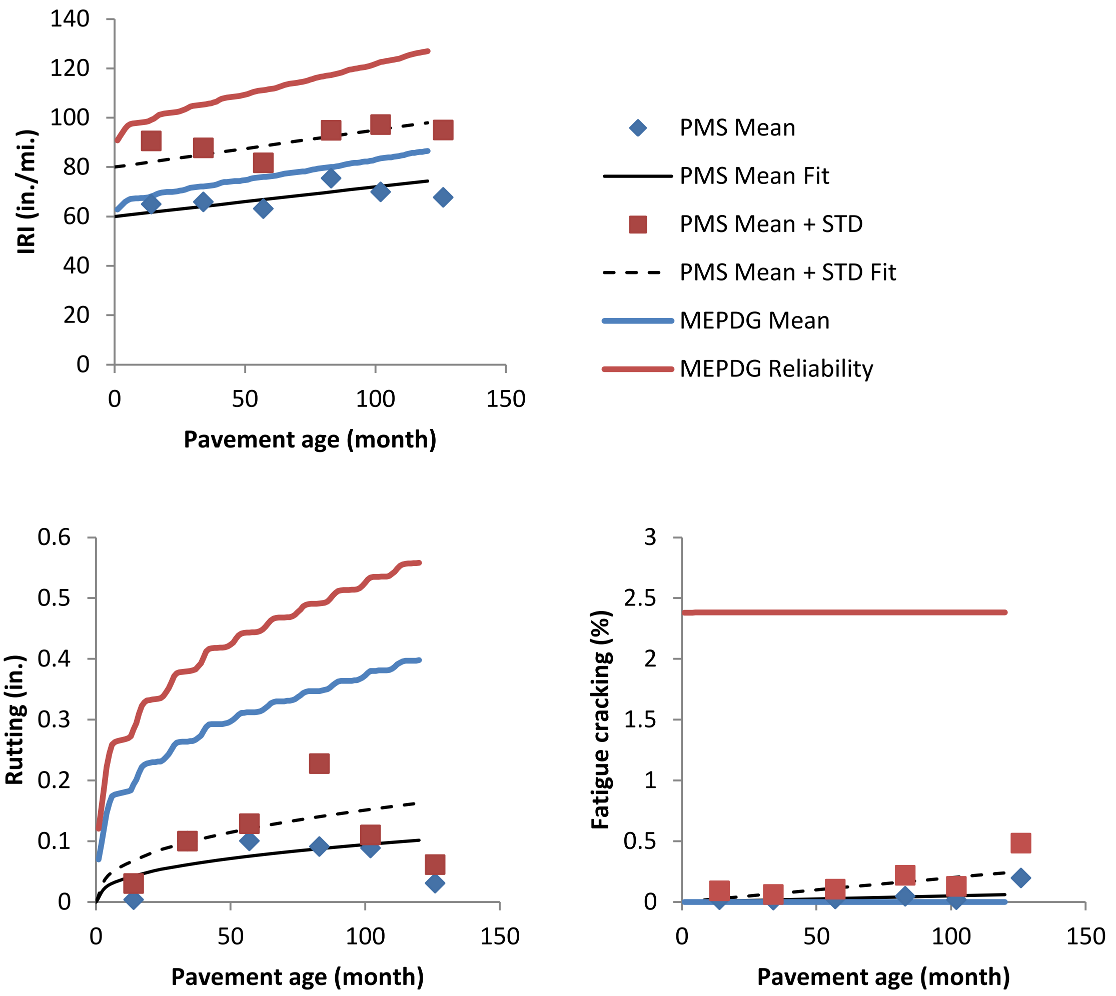
General Information:

District:	62	Two-Way ADT:	42857
Parish:	32	Number of Lane in Design Direction:	4
Route:	I-12	Growth Factor:	1%
Accept Date:	4/12/2000	Axle Load Spectrum:	Louisiana Default (TTC3)

Pavement Structure:

Asphalt Concrete:	2" SUPERPAVE LEVEL 3 WEARING COURSE (PG 76-22) + 4" SUPERPAVE LEVEL 3 BINDER COURSE (PG 76-22)
Base:	10" RUBBLIZED PCC (Mr = 500 ksi)
Subbase:	6" EXISTED SOIL CEMENT (Mr = 30 ksi)
Subgrade:	A-7-6 (Mr = 9549 psi)

Predicted vs. Measured Pavement Performance



Project ID: **454-03-0028**

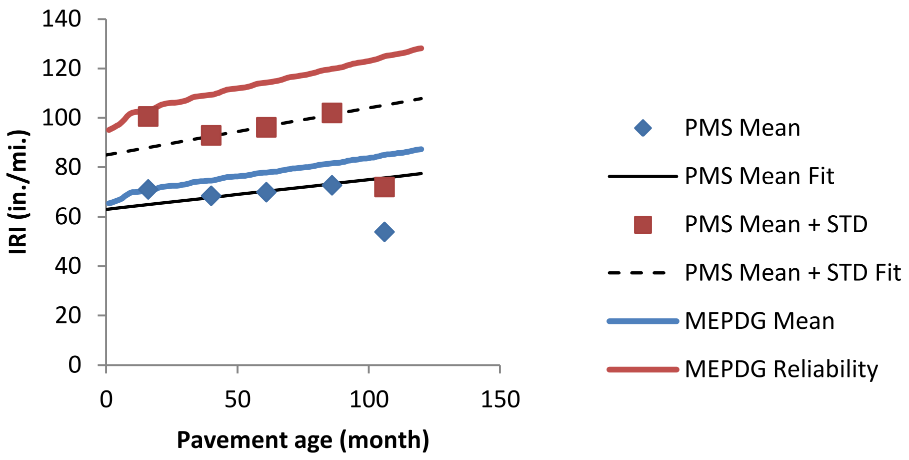
General Information:

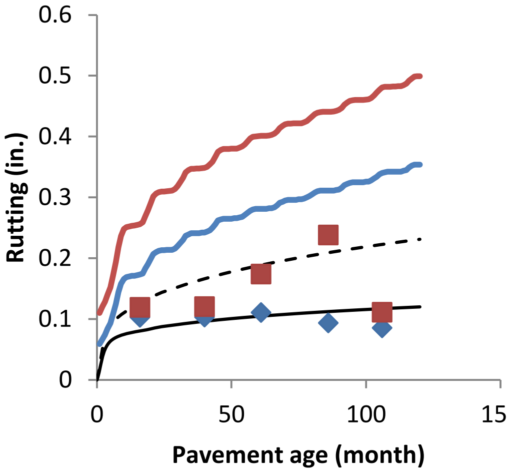
District:	62	Two-Way ADT:	39985
Parish:	53	Number of Lane in Design Direction:	4
Route:	I-12	Growth Factor:	1%
Accept Date:	12/21/1999	Axle Load Spectrum:	Louisiana Default (TTC1)

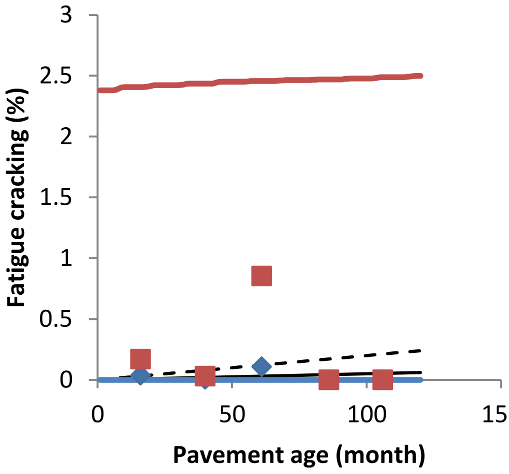
Pavement Structure:

Asphalt Concrete:	2" SMA WEARING COURSE (PAC-40) + 4" TYPE 8 BINDER COURSE (PAC-40) + 3" TYPE 5A BASE COURSE (AC-30)
Base:	10" RUBBLIZED PCC (Mr = 500 ksi)
Subbase:	6" EXISTED SOIL CEMENT (Mr = 30 ksi)
Subgrade:	A-4 (Mr = 10634 psi)

Predicted vs. Measured Pavement Performance







Project ID: **803-32-0001**

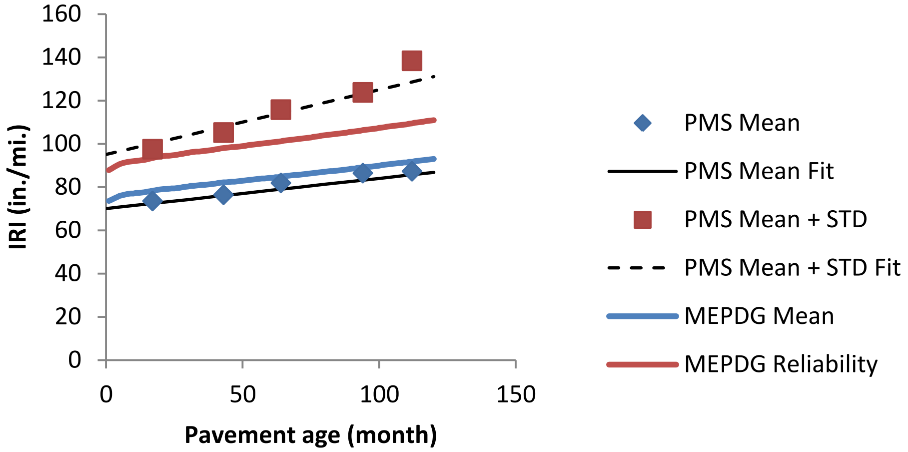
General Information:

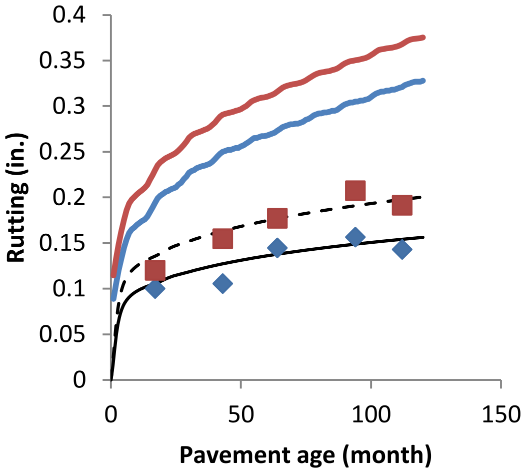
District:	61	Two-Way ADT:	2500
Parish:	3	Number of Lane in Design Direction:	2
Route:	LA 938	Growth Factor:	3%
Accept Date:	3/4/1999	Axle Load Spectrum:	Louisiana Default (TTC12)

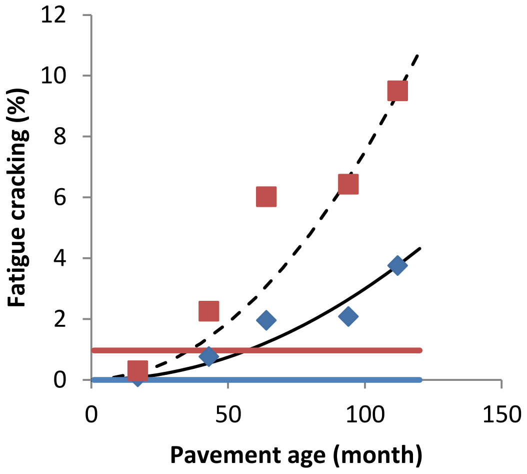
Pavement Structure:

Asphalt Concrete:	1.5" TYPE 3 WEARING COURSE (AC-30) + 2" TYPE 3 BINDER COURSE (AC-30)
Base:	12" CEMENT TREATED (Mr = 100 ksi)
Subbase:	
Subgrade:	A-4 (Mr = 8413 psi)

Predicted vs. Measured Pavement Performance







Project ID: **810-07-0014**

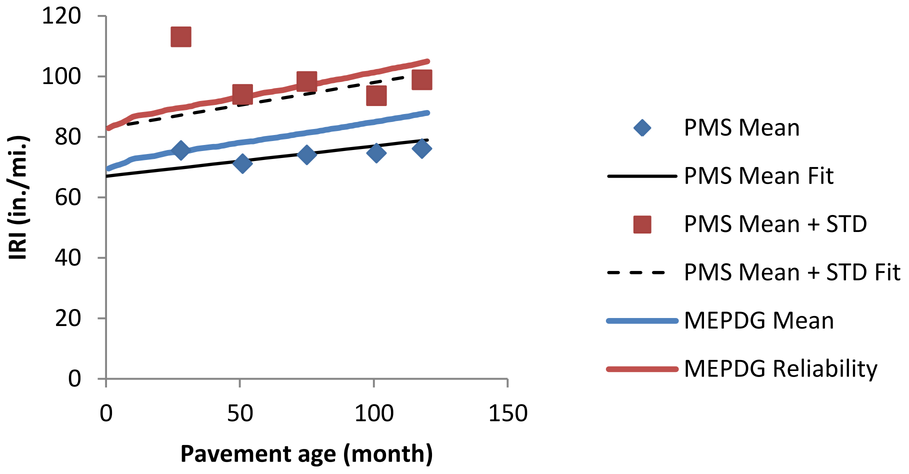
General Information:

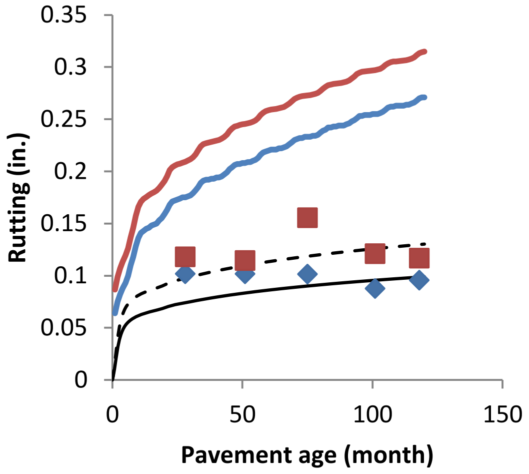
District:	07	Two-Way ADT:	3890
Parish:	10	Number of Lane in Design Direction:	2
Route:	LA 3020	Growth Factor:	2.4%
Accept Date:	11/23/1998	Axle Load Spectrum:	Louisiana Default (TTC12)

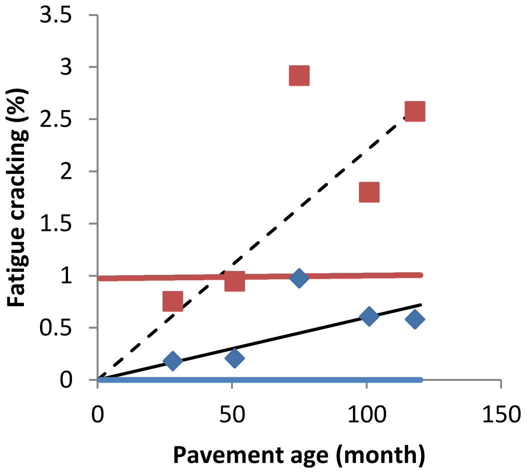
Pavement Structure:

Asphalt Concrete:	1.5 TYPE 8 WEARING COURSE (PAC-40) + 2" TYPE 8 BINDER COURSE (PAC-40)
Base:	8.5" CEMENT STABILIZED (Mr = 100 ksi)
Subbase:	
Subgrade:	A-6 15” TYPE D LIME TREATED (Mr = 9176 psi)

Predicted vs. Measured Pavement Performance







Project ID: **828-15-0012**

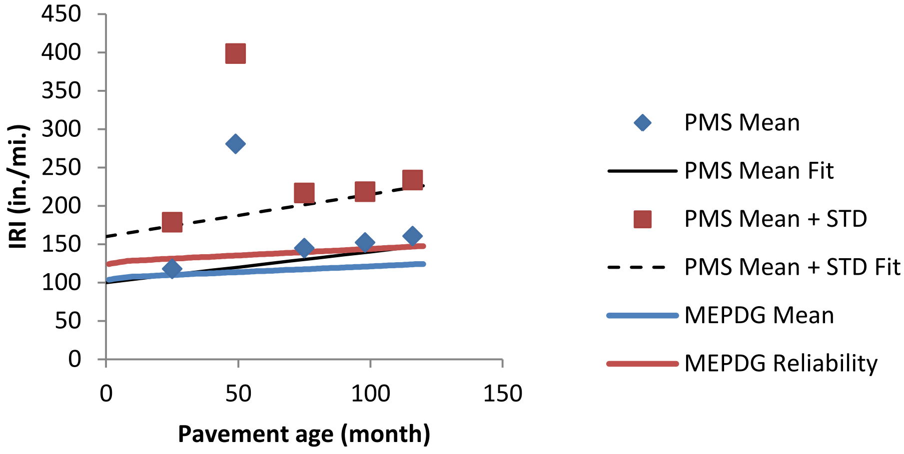
General Information:

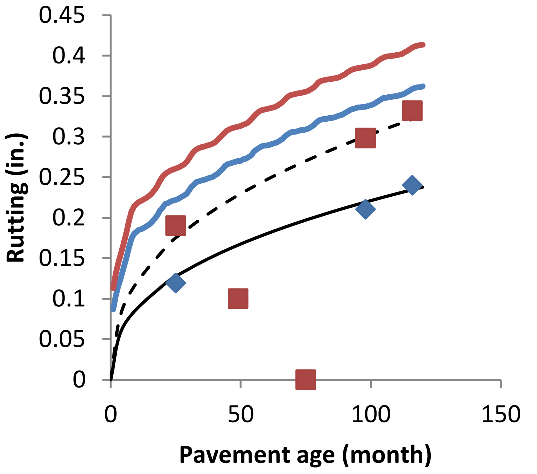
District:	03	Two-Way ADT:	6515
Parish:	28	Number of Lane in Design Direction:	2
Route:	LA 93	Growth Factor:	3%
Accept Date:	1/5/1999	Axle Load Spectrum:	Louisiana Default (TTC12)

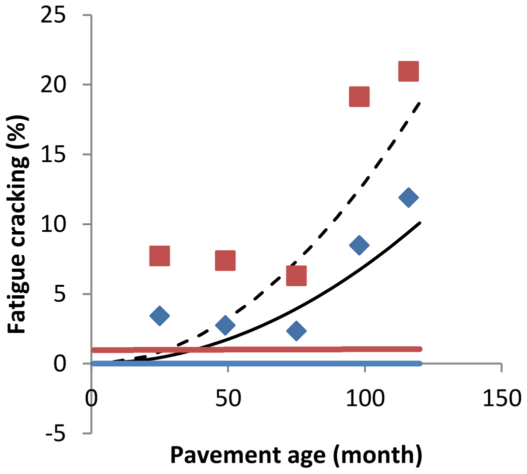
Pavement Structure:

Asphalt Concrete:	1.5 TYPE 8 WEARING COURSE (PAC-40) + 2" TYPE 8 BINDER COURSE (PAC-40)
Base:	8.5" CEMENT STABILIZED (Mr = 100 ksi)
Subbase:	
Subgrade:	A-4, 12” TYPE D LIME TREATED (Mr = 9916 psi)

Predicted vs. Measured Pavement Performance







Project ID: **839-02-0016**

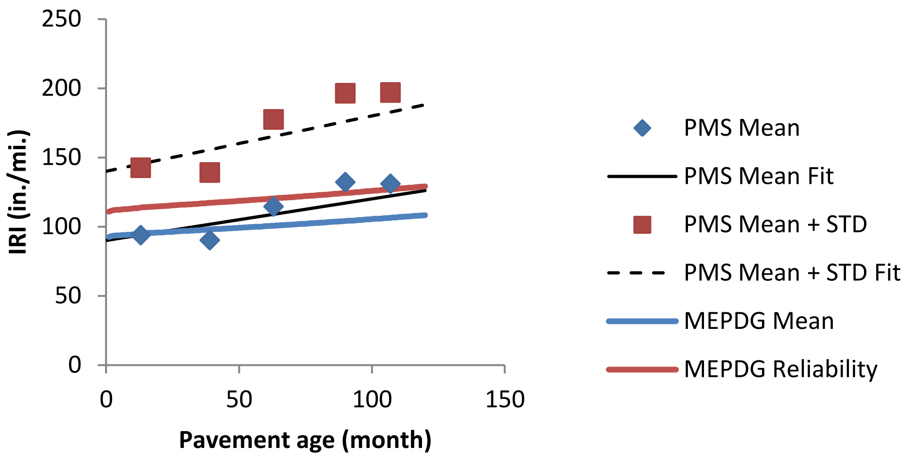
General Information:

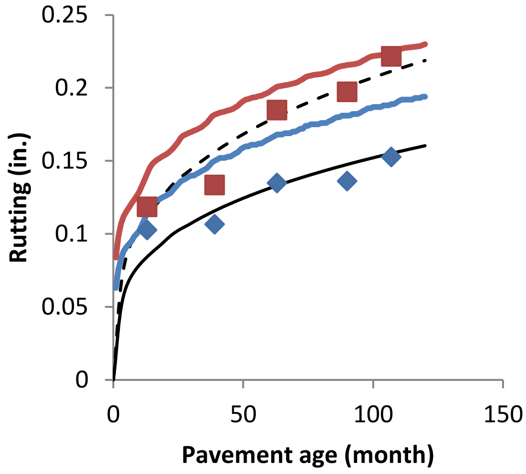
District:	61	Two-Way ADT:	806
Parish:	39	Number of Lane in Design Direction:	2
Route:	LA 419	Growth Factor:	1%
Accept Date:	7/19/1999	Axle Load Spectrum:	Louisiana Default (TTC12)

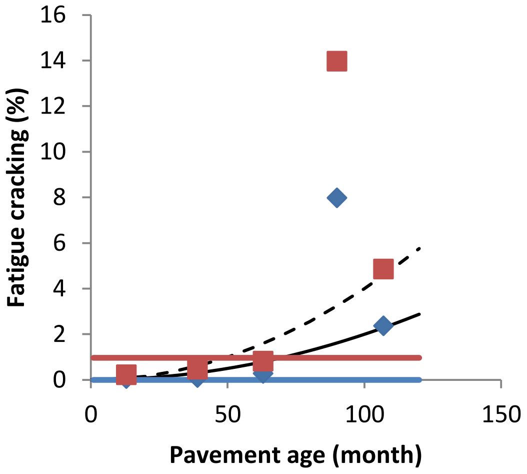
Pavement Structure:

Asphalt Concrete:	1.5 TYPE 3 WEARING COURSE (AC-30) + 2" TYPE 3 BINDER COURSE (AC-30)
Base:	12" CEMENT TREATED (Mr = 100 ksi)
Subbase:	
Subgrade:	A-4 (Mr = 9176 psi)

Predicted vs. Measured Pavement Performance







Project ID: **847-02-0019**

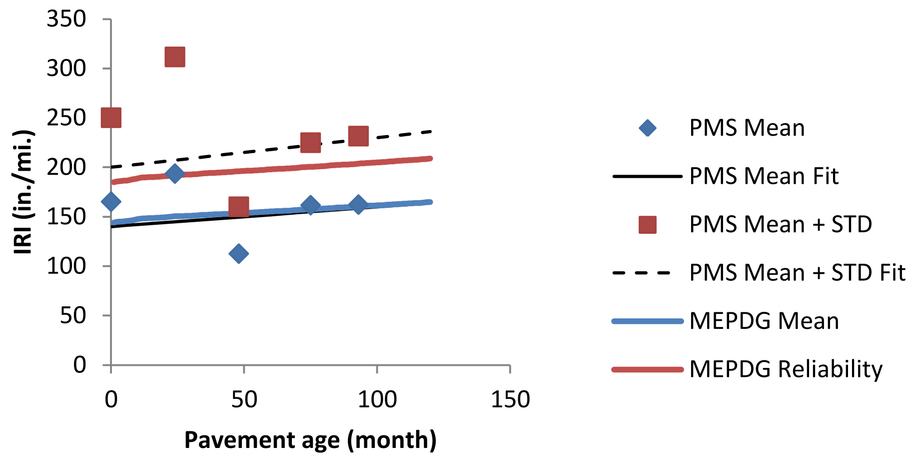
General Information:

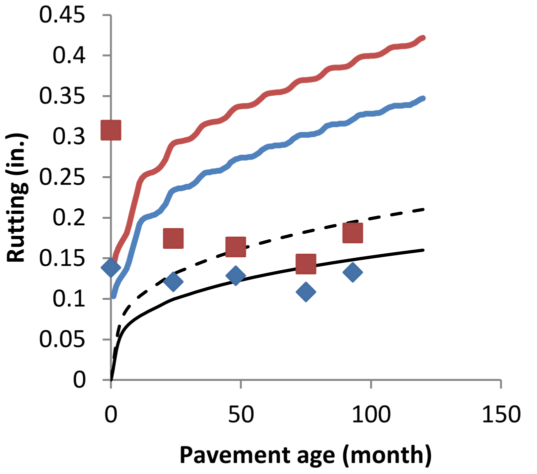
District:	61	Two-Way ADT:	6626
Parish:	47	Number of Lane in Design Direction:	2
Route:	LA 641	Growth Factor:	1%
Accept Date:	10/12/2000	Axle Load Spectrum:	Louisiana Default (TTC12)

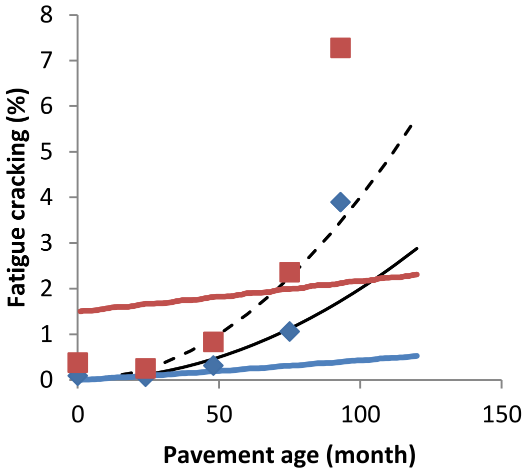
Pavement Structure:

Asphalt Concrete:	1.5" TYPE 8F WEARING COURSE (PAC-40) + 4.5" TYPE 8 BINDER COURSE (PAC-40)
Base:	8.5” STONE (Mr = 30 ksi)
Subbase:	
Subgrade:	A-7-6, 12” TYPE D LIME TREATED (Mr = 8023 psi)

Predicted vs. Measured Pavement Performance







Project ID: **852-03-0009**

General Information:

District:	62	Two-Way ADT:	7025
Parish:	52	Number of Lane in Design Direction:	2
Route:	LA 1077	Growth Factor:	3%
Accept Date:	1/31/2003	Axle Load Spectrum:	Louisiana Default (TTC12)

Pavement Structure:

Asphalt Concrete:	2" TYPE 8F WEARING COURSE (PG 76-22) + 2" TYPE 8 BINDER COURSE (PG 76-22)
Base:	12” CEMENT TREATED (Mr = 100 ksi)
Subbase:	
Subgrade:	A-7, 15” TYPE D LIME TREATED (Mr = 9176 psi)

Predicted vs. Measured Pavement Performance