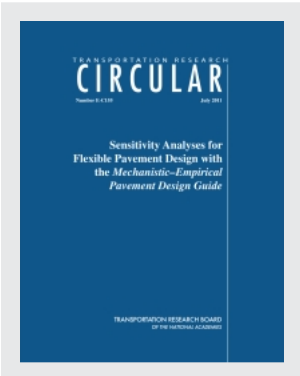

Sensitivity Analyses for Flexible Pavement Design with the þÿMechanistic Empirical Pavement Design Guide

DETAILS

0 pages | null | PAPERBACK
ISBN 978-0-309-43048-7 | DOI 10.17226/22867

AUTHORS

TRANSPORTATION RESEARCH

CIRCULAR

Number E-C155 July 2011

Sensitivity Analyses for Flexible Pavement Design with the *Mechanistic–Empirical Pavement Design Guide*

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

TRANSPORTATION RESEARCH CIRCULAR E-C155

Sensitivity Analyses for Flexible Pavement Design with the *Mechanistic–Empirical Pavement Design Guide*

Flexible Pavement Design Committee

July 2011

Transportation Research Board
500 Fifth Street, NW
Washington, DC 20001
www.TRB.org

TRANSPORTATION RESEARCH CIRCULAR E-C155
ISSN 0097-8515

Transportation Research Board
500 Fifth Street, NW
Washington, DC 20001
www.TRB.org

Glenda J. Beal, Production Editor; Regina Reid, Proofreader and Layout

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NOTE

This circular was developed from Workshop 143, Flexible Pavement Design Sensitivity Analysis with *Mechanistic–Empirical Pavement Design Guide*, held at the Transportation Research Board's 89th Annual Meeting in January 2010. The seven workshop presentations were provided by the workshop's moderator, Leslie Myers McCarthy, Villanova University, who also wrote an introduction to the material.

Introduction

LESLIE MYERS MCCARTHY
Villanova University

This workshop was developed to provide information for transportation agencies in the process of, or considering the implementation of, the interim AASHTO *Mechanistic–Empirical Pavement Design Guide* (MEPDG). The workshop shared experiences from transportation agencies that have performed various sensitivity analyses using the MEPDG software, primarily related to flexible pavement analysis. The goal for the workshop was to communicate which input factors are important to the final pavement designs, so that agencies can focus their research accordingly during the implementation process.

Sensitivity Analysis for Flexible Pavement Design Using the Mechanistic–Empirical Pavement Design Guide

LESLIE MYERS MCCARTHY
JIANG LIANG
Villanova University

Over the last few years, transportation agencies have had the opportunity to use AASHTO's interim *Mechanistic–Empirical Pavement Design Guide* (MEPDG) software. This software allows users to assess the impacts of traffic, climate, materials properties, etc. on the predicted pavement performance. Several transportation agencies have begun the process of implementing the design process. However, many agencies are just starting the implementation process or are waiting to see the results from other states. As such, the TRB Flexible Pavement Design (AFD60) committee requested assistance from state agencies in collecting and disseminating information and results related to sensitivity analysis of flexible pavement designs performed by transportation agencies. A survey similar to the FHWA MEPDG survey used earlier in the decade was circulated via electronic mail during the summer of 2009. The survey questions and summary of responses are provided in this circular.

Overall, there were a total of 52 agencies that participated in the study, including 48 out of the 50 U.S. states. The other agencies were District of Columbia Department of Transportation, Puerto Rico, FHWA Federal Lands Division, and Ontario Ministry of Transportation. A remarkable response rate of 98% was attained.

GENERAL QUESTIONS

Question 1 asked each agency about their level of involvement with the interim AASHTO MEPDG (see Figure 1). Note that each agency was allowed to select all choices that were applicable. Workshops or presentations have been attended in the last 5 years by 46 of the agencies, comprising 53% of responses. Joint Task Force on Pavements or NCHRP panels were participated in by 22 of the agencies, and 17 agencies have participated as a member of the Lead State Group. Only a couple of agencies fall into the category of "heard the term, but knew very little" about the interim AASHTO MEPDG.

Question 2 asked agencies what design procedure was currently being used for flexible pavements in their state (see Figure 2). Each agency could select multiple answers. The design procedure specified by AASHTO 1993 was used by 27 of the agencies, and AASHTO 1972 was used by seven of the agencies. None of the agencies that participated in the survey used AASHTO 1986. Individual state design procedures were used by nine of the agencies. A combination of AASHTO and a state procedure was used by 12 agencies. A combination of AASHTO 1972/86/93 and MEPDG procedure was used by six agencies. Only two agencies used a combination of a state procedure and the MEPDG procedure.

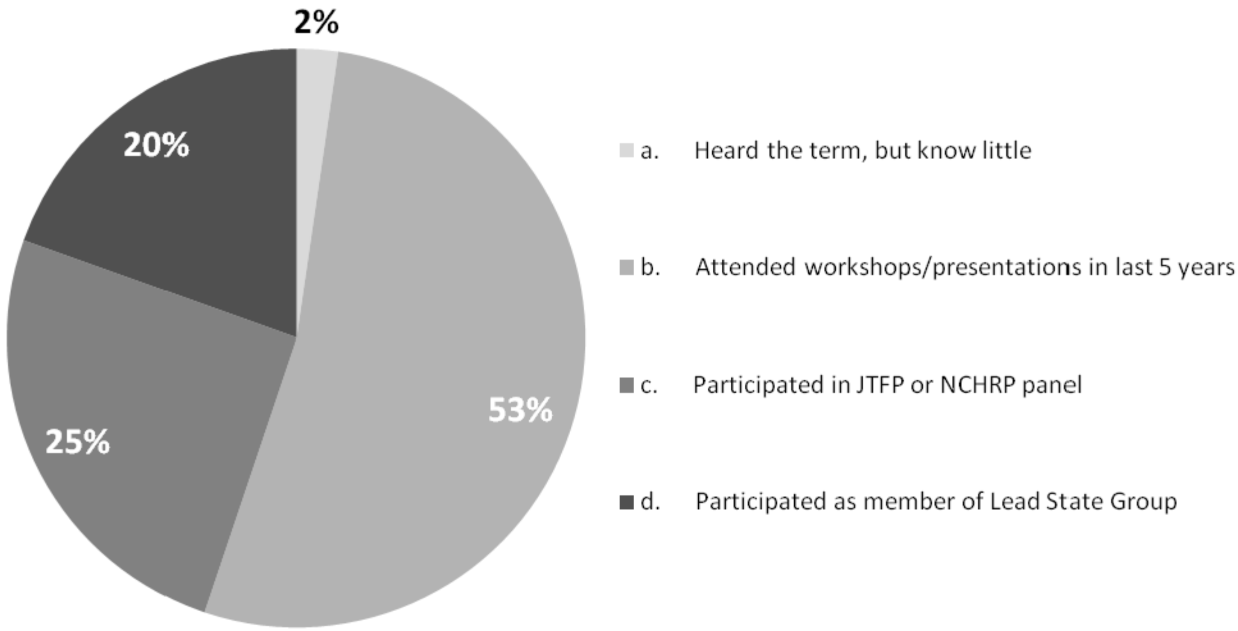


FIGURE 1 Responses to Survey Question 1.

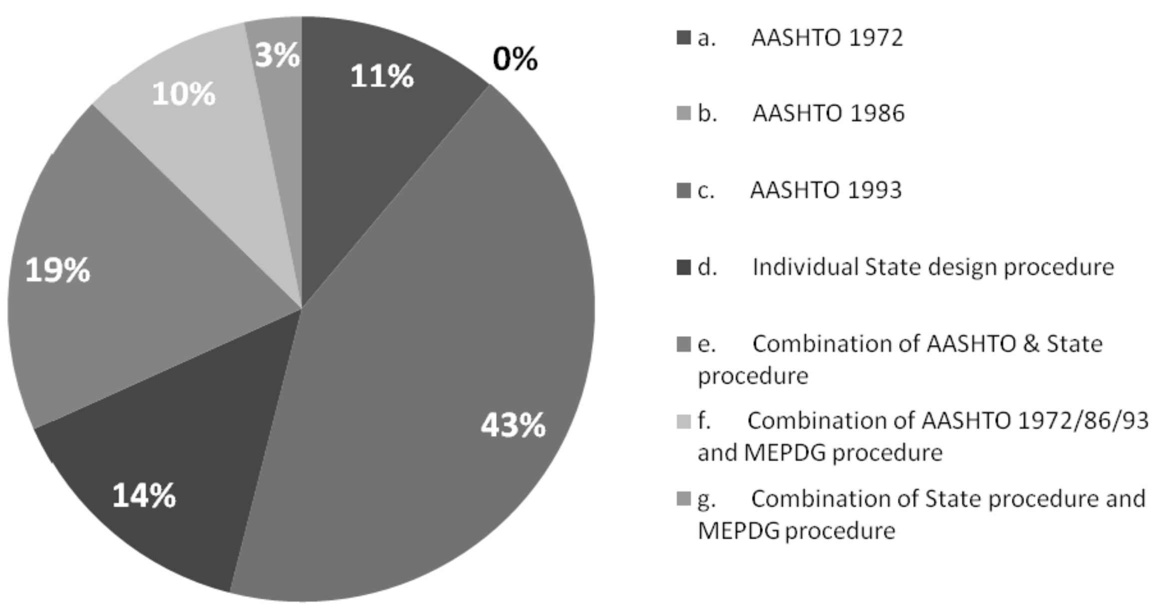


FIGURE 2 Responses to Survey Question 2.

Question 3 asked whether the agency currently had an implementation plan in place for MEPDG. The majority of the agencies (62%) did have a plan in place, while 38% of the agencies did not already have an implementation plan.

Question 4 asked whether the agency currently had a local calibration plan in place for MEPDG. About half of the agencies (54%) did, while 46% of respondents did not.

Question 5 asked how the agency would describe its receptiveness to adopting the MEPDG (see Figure 3). A total of 13 agencies were completely in favor of adopting MEPDG. Of the 59 total responses to the question, 32% were interested but still needed additional confidence in accuracy of predictions, while 22% were interested but needed to identify appropriate applications for its use. Eight agencies were neutral and wanted to see how other agencies were implementing it before they invested their time and resources. Five agencies were not ready to adopt MEPDG until it comes out as a complete AASHTO (postinterim) product. One agency was not receptive to adopting MEPDG.

Question 6 queried agencies as to how they were currently using MEPDG (see Figure 4). Agencies were able to select more than one response Of the 76 responses, 7% were using MEPDG for routine flexible pavement designs, 17% were using MEPDG for a few unique flexible pavement designs, 9% were using MEPDG for evaluating and setting calibration factors, and 24% were using MEPDG for forensic or exploratory analysis purposes. A total of 36% of the respondents were not using MEPDG for designs but were evaluating it for calibration factors, analysis, etc. The study found that 8% of respondents were not using or evaluating MEPDG at all.

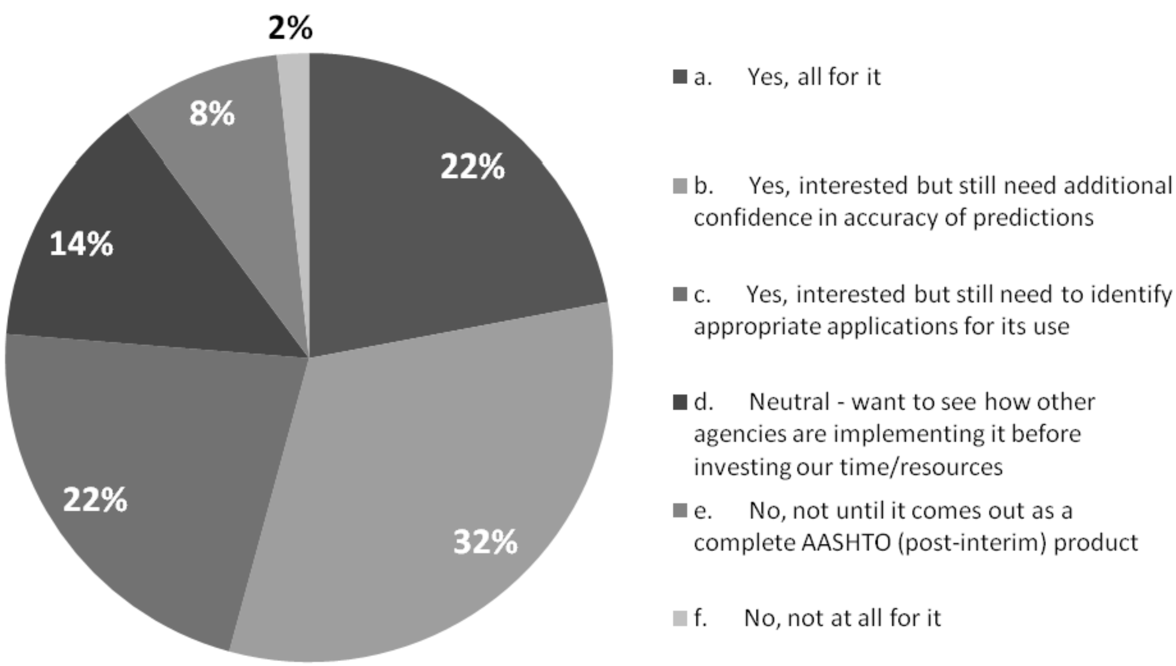


FIGURE 3 Responses to Survey Question 5.

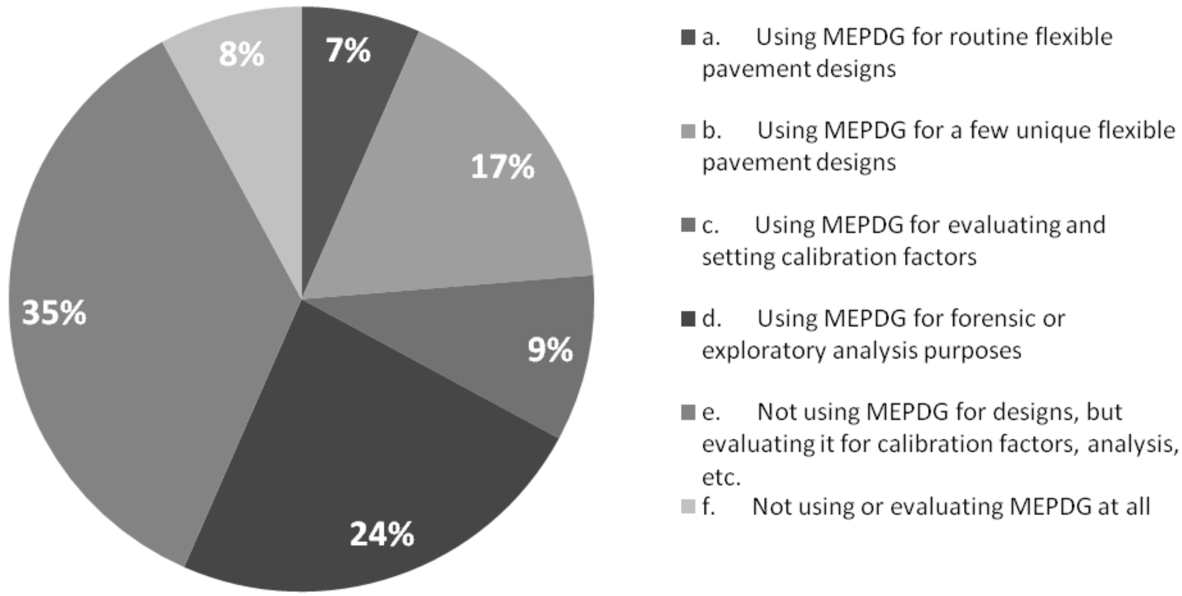


FIGURE 4 Responses to Survey Question 6.

Most agencies were collecting some sort of information for use in MEPDG, whether it was collecting traffic data, geotech data, pavement management data, compiling materials properties catalogs for typical asphalt mixes used in the state, or performing materials tests in laboratories. Only six of the agencies were currently not collecting any data for use in MEPDG. Question 7 showed that out of the 154 responses, 22% were compiling a materials properties catalog for typical asphalt mixes used in the state, 21% were performing materials tests (dynamic modulus, dynamic shear rheometer, indirect tensile test, etc.) in the laboratory, 21% were collecting traffic data (specific sites, traffic data catalog, etc.), 17% were collecting geotech data (specific sites, soils data catalog, etc.), and 15% were collecting pavement management data (specific sites, pavement management system data catalog, etc.) for rehabilitation design in MEPDG (see Figure 5).

In Question 8, agencies reported on how they were conducting implementation activities for MEPDG (see Figure 6). Many agencies were doing multiple activities. Of the 88 total responses, 22% of agencies were doing research and implementation activities internally, while 16% were doing these activities as a "pooled effort" with other agencies. About 38% of responses indicated a joint effort between the agency and consultant or university contracts, while 17% are completely contracting these activities out to consultants or a university. Florida and Oklahoma Departments of Transportation (DOT) have research and implementation activities conducted as a partnership between the agency and industry partners (i.e., paving contractors, state Asphalt Paving Association, etc.). Alabama, Colorado, Florida, Kansas, and Oregon reported that they also conduct research and implementation activities through partnerships between agency, university, consultants, and industry.

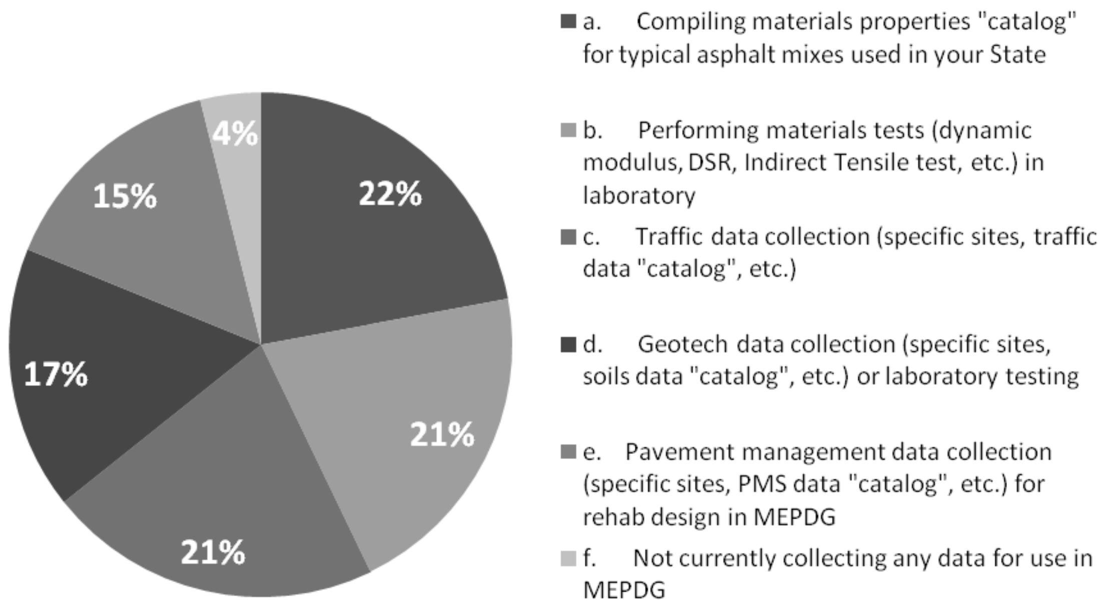


FIGURE 5 Responses to Survey Question 7.

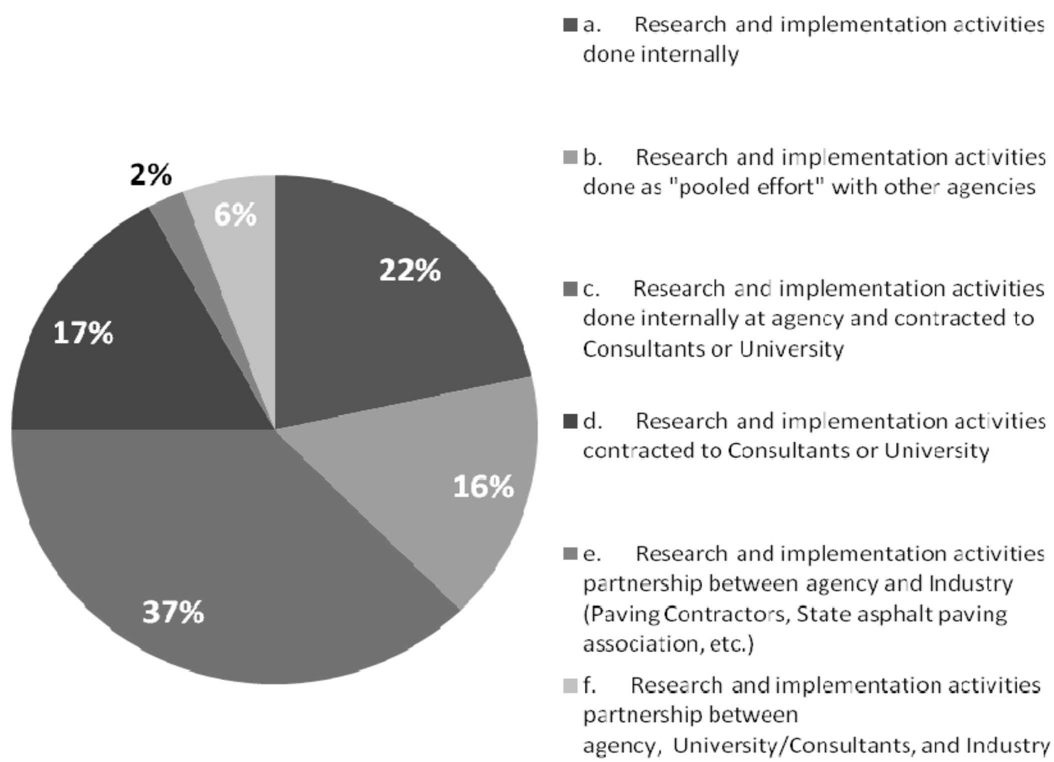


FIGURE 6 Responses to Survey Question 8.

PAVEMENT SPECIFIC QUESTIONS

Question 9

Agencies were asked to provide a brief description of what they have done in terms of hot-mix asphalt (HMA) testing (mix, binder) for MEPDG. At the time of the query, 19% had not done any HMA testing while 81% of respondents had various ongoing projects that included HMA testing (see Table 1).

Detailed examples from states are summarized and presented in the following sections.

Colorado

Colorado DOT reported it is in the process of collecting values for resilient modulus, tensile strength, creep compliance, effective asphalt content, air voids, aggregate specific gravity, gradation, unit weight, and voids filled for mix properties on new HMA projects constructed in 2009. Colorado DOT planned on collecting data on the performance grade (PG), complex shear modulus, phase angle, and Brookfield viscosity for binder properties on projects constructed in 2009. In addition, Colorado DOT is obtaining values for the backcalculated layer modulus, resilient modulus, unit weight, asphalt content gradation, air voids, and asphalt cement content on in-place HMA.

Georgia

Georgia DOT reported that it completed research work entitled Determination of Georgia DOT Design Inputs for ME Pavement Design. The research objectives were to measure the dynamic modulus of commonly used Superpave® (SP) and stone matrix asphalt (SMA) mixes, measure the resilient modulus of typical soils and aggregate base course materials, compare measured moduli with default MEPDG for a range of subgrade and aggregate base materials, and evaluate the sensitivity of the MEPDG and Per ROAD Design Software to changes in HMA moduli. The research conclusions were that the MEPDG Level 3 inputs for resilient modulus of soils and aggregates tested were significantly higher than values obtained from test results, use of actual

TABLE 1 HMA Testing Practices of Responding Agencies

Implementation Practice	Agencies
Superpave mix design	Alabama, Illinois
Varied research projects	Alaska, New Hampshire, Oklahoma, South Carolina, Wisconsin
Working with E^* (dynamic modulus) information	Arkansas, Connecticut, Hawaii, Idaho, Illinois, Iowa, Maine, Missouri, Nebraska, Nevada, New Hampshire, New Jersey, New Mexico, North Carolina, Oklahoma, Oregon, Virginia
Binder Testing	Arkansas, Arizona
Mechanistic–empirical pavement design calibration	California, South Dakota
Collecting mix property values on HMA and/or binder	Colorado, Montana, New Jersey, Ohio, Washington State, West Virginia, Wyoming
Characterizing paving mixes	Kansas, Louisiana, Mississippi

materials properties resulted in significantly greater structures being recommended than when default values were used, and the dynamic modulus may not adequately capture the improved performance experienced with polymer modified SP and SMA mixes. A design could not be determined at 90% reliability for one of the scenarios of this study, revealing a limitation of the software. National default values were used to compare a pavement structure designed using MEPDG to the current Georgia DOT design method as part of a presentation. The structural thickness derived from the AASHTO–state procedure is typical of in-service pavements in Georgia experiencing high traffic volumes and high truck percentages with no significant distresses. The structural thickness used in the last trial was approximately 67% greater than that of the structural thickness derived from the AASHTO–state procedure and never satisfactorily converged to a solution at the specified reliability (90% was used). Excessive rutting was being predicted as the failure mechanism, but Georgia pavements rarely rut to failure.

Hawaii

About 80 lab prepared/lab-compacted mix specimens have been tested for dynamic modulus (E^*) and permanent deformation, including variations in air voids and asphalt content for two gradations and three binder types. A few other tests were performed with plant mix and laboratory-compacted specimens. Beam fatigue testing of unmodified and polymer-modified asphalt (PMA) mixes have also been performed on several dozen specimens. Dynamic shear rheometer (DSR) testing has been performed, including determination of dynamic shear moduls (G^*) and phase angle (δ), as well as repeated creep-recovery tests for unmodified and polymer-modified asphalts. Brookfield viscosity testing has also been performed. Software was developed for development of master curves (outside MEPDG) to develop the inputs for MEPDG simulations in some extreme cases of interest for research (such as mixes with very high air voids, which have very low moduli at high temperatures and low frequencies). The software is able to obtain the information to meet the requirements in MEPDG and still obtain the same master curve. The software also has a module for permanent deformation analysis, which automates the flow number determination (using an approach developed by their research), trims the data above the flow number, computes the permanent-to-resilient strain ratio ($\varepsilon_p/\varepsilon_r$) as a function of number of cycles (N), and finally fits a power model to the resultant curve. The results from the permanent deformation tests have then been used to alter some of the calibration parameters for permanent deformation to account for some effects of interest, such as the use of polymer-modified asphalt.

New Mexico

A research proposal has been submitted for next fiscal year. Since New Mexico DOT will soon have the dynamic modulus testing equipment in fall 2009. Statewide soils will be catalogued by resilient modulus. Statewide asphalt mixes will be catalogued for E^*. A research project is currently underway to develop the MEPDG database. A research proposal has been submitted to look at endurance limits of asphalt.

Oklahoma

Universities in Oklahoma are conducting research on dynamic modulus and binder properties. They have two instrumented sections at National Center for Asphalt Technology evaluating perpetual pavement concepts, and they are participating in pooled fund studies evaluating warm mix asphalt, increased recycled HMA, and the use of shingles in asphalt. They also have an instrumented section on I-35 evaluating minimal HMA thickness on an unbound aggregate base.

South Dakota

South Dakota Research Project on HMA and Subgrade Material: Mechanistic–Empirical Pavement Design: Materials Testing of Resilient and Dynamic Modulus Study SD2008-10. Project objectives include obtaining resilient modulus and dynamic modulus values for construction materials on HMA paving projects through tests performed with a simple performance tester (SPT) at South Dakota School of Mines and Technology (SDSM&T) to correlate, calibrate, and validate these results from the new SPT through comparative analyses with similar work performed at the UNR for the South Dakota DOT. Another objective is to obtain resilient modulus and dynamic modulus values of construction materials through tests performed with the SPT at SDSM&T on other HMA paving projects and typical soil types around the state to validate resultant data relative to the criteria defined for mechanistic–empirical pavement design processes and ultimate incorporation of the data into a mechanistic–empirical pavement design database. The last objective is to gain an assessment, jointly with South Dakota DOT Technical Implementation Group, on the possible need for acquisition of SPT or other materials testing equipment by the department.

Utah

In Utah, a number of projects were tracked by their field performance and compared to predicted performance. Local calibration factors were produced. All of these projects were in the category of long-term pavement performance (LTPP) type materials. The agency also sought high-modulus HMA and subgrade designs and predicted thin structure performance with the MEPDG. These highly stiffened mixes were tested at the Western Superpave Center using controlled-stress tests beginning with the initial stress set, so as to produce less than 50 microstrain. These mixes produced very good resistance to fatigue. When installed in the field, all of the thin pavement designs failed in fatigue and thermal cracking. This experience has made Utah DOT uncertain about relying only on a stiffness model to predict fatigue performance. The agency also contracted with a consultant to run a sensitivity analysis on binder stiffness, and found that within a single grade and relatively insensitive to change in binder stiffness through one or even two grades.

Question 10

In Question 10, agencies were asked whether the flexible pavement designs were sensitive to the changes made in the software, as compared to the national defaults in the program, based on the agency's HMA testing results. Of the 52 agencies, 69% have not yet done sensitivity evaluation, while 31% had the evaluation done and reported a difference. Some extended responses have been provided below as examples.

Hawaii

Hawaii DOT reported that in its experience, the guide was not sensitive to the use of polymer-modified asphalt when only *E** values from dynamic modulus testing were considered. Since mixes prepared with polymer-modified asphalt have moduli that under some conditions are lower than the moduli of mixes with unmodified asphalts, the unmodified mixes were predicted to perform better. Based on their fatigue tests, the polymer-modified asphalt mixes also had between 30 to 50% longer fatigue life than the unmodified mixes. Thus, it is also giving some credit (conservatively) to polymer-modified asphalt mixes by adjusting the k_1 parameter in the fatigue model.

Kentucky

They have performed some informal sensitivity studies considering the range of values for asphalt mixture volumetric properties. Preliminarily, they have concluded that gradation variations for base mixtures do not significantly affect pavement performance as predicted by MEPDG. There is continuing evaluation on other volumetrics and properties of asphalt mixes produced in Kentucky.

Missouri

Missouri DOT reported that its primary finding from in-service pavement section data used in the local calibration study verified the suspected bias in the total rutting models. The model was recalibrated to eliminate the bias to the extent possible. The dynamic modulus test results confirmed the accuracy of the Witzcak correlation model using volumetrics, gradations, and asphalt cement content. This led them to believe it may not have to perform comprehensive *E** testing on all of its mixes.

Montana

Generally, Montana's pavement deterioration rate is slower than the rest of the nation. This results in its local calibration factors predicting less pavement distress when compared to the national default values.

New Jersey

Flexible pavement designs conducted with collected asphalt input properties were only found to be significantly different with respect to top-down cracking. Pavement rutting and bottom-up cracking were not found to be significantly different. Based on the MEPDG evaluations conducted, thermal cracking has yet to be seen in any of the simulations conducted in MEPDG. Precision analysis research was also conducted with respect to the dynamic modulus test. Eight different laboratories tested six different samples, three samples of a 9.5-mm mix and three samples of a 25-mm mix. Both mixes contained a PG 64-22 asphalt binder. Extremely large variations in the modulus values were found between the eight different laboratories. However, only large differences in the top-down cracking were found in the MEPDG simulations, with minor variations found in the rutting and bottom-up cracking.

Oregon

The research was performed on HMA mixtures without recycled asphalt pavement (RAP) material. However, a large majority of Oregon DOT projects use 20% and up to 30% RAP in the mixture. Therefore, the current direction has been to use the MEPDG defaults and perform the design at Level 3.

Utah

Based on LTPP type projects, national standards were quite close to observed performance by UDOT. When looking at highly stiffened mix designs, performance was well below national standards. When observing mixes produced with elastomeric modifiers, pavements outperformed nearly twice the national calibrated standards.

Washington State

Washington State DOT has conducted very detailed sensitivity analysis on structure thickness design, material properties of all layers and soil, climate stations (national or statewide), and traffic inputs. The results matched well with Washington State DOT expectations and indicated that the MEPDG pavement distress models are reasonable.

Question 11

Question 11 asked whether the agency intended to incorporate the testing results into the MEPDG software by modifying the material performance models. Many of the agencies mentioned that it was difficult to estimate at the time and a more concrete answer would likely depend on the results of current research. General statistics on this question include that 39% of the agencies won't modify material performance models, 29% reported that it's too early to decide, and 32% modified (or will modify) material performance. Some detailed answers to Question 11 are shown below.

Hawaii

At this point, one of its major uses for the guide would be for analysis of alternatives (polymer-modified asphalt versus unmodified mixes, asphalt-treated base versus recycled foamed asphalt base, etc.). Although it is recognized that MEPDG is not calibrated for some of the previous combinations, it is a tool that (with careful analysis of its inputs and calibration factors) can provide estimates of potential differences between alternatives. It would also like to incorporate other research results related to the permanent deformation of recycled materials as well as some testing (dynamic modulus, permanent deformation, etc.) for mixes of RAP, foamed asphalt, and cement.

Mississippi

The calibration factors will be modified using the HMA test data. A consultant will be hired to perform this task. Mississippi DOT is still gathering requisite construction and materials data for the selected pavement management analysis sections being used for calibrating the performance models.

New Jersey

The local calibration that was recently initiated will incorporate materials sampled at the asphalt plant to help modify the material performance models. It is envisioned that different performance models will most likely be required for asphalt materials containing a PG 64-22 and a PG 76-22. This will most likely be the case NCHRP projects 9-30A (rutting) and 1-42A (top-down cracking) are finalized and implemented in MEPDG.

Oregon

Oregon DOT is working toward better definition of mix properties by participating in a pooled-fund study for the use of the SPT. Anticipated delivery of equipment is 2010 and it is also collecting data on the binder grade of the production of HMA mixtures (including RAP), for warm-mix asphalt, and some existing aged pavements.

Washington State

Washington State DOT calibrated the MEPDG flexible pavement portion in 2008 on Version 1.0 of the software, and the rigid pavement part in 2005 on Version 0.603 of the software. Both calibrations were conducted for new pavement designs, but not for pavement rehabilitation.

Question 12

Question 12 asked the agencies what materials they typically use for flexible pavements and provided the option to check multiple answers (see Figure 7). Of the 161 total responses, 30% of respondents use dense-graded mixes with less than 20% RAP and 16% use dense graded mixes with more than 20% RAP. About 14% use stone matrix asphalt and gap-graded mixes or substitute gap-graded mixes, and the same percent use open-graded mixes. The survey revealed that 26% use modified asphalt binders in any mix.

As an example, Arizona DOT is just finalizing their RAP specifications, which will allow a maximum of 25% RAP. It may assign to RAP the same structural coefficient as used for new asphalt concrete (AC). However, this process has not been finalized. Its rubber-modified AC mix (known as AR-AC) is a gap-graded mix. Its widely used friction courses, regular mix (AR-AC), and rubber-modified mix (AR-ACFC), are both open-graded. Its rubberized mixes (ARAC and AR-ACFC) contain rubber-modified binders (virgin binder and about 20% crumb rubber hot-mixed). It also uses the Terminal Blend (TR+) binders that are modified with a minimum of 8% crumb rubber and 2% SBS polymer in regular dense-graded and open-graded mixes.

The last question queried agencies as to whether they would include the materials from Question 12 in the MEPDG implementation plan. A total of 43 agencies responded affirmatively.

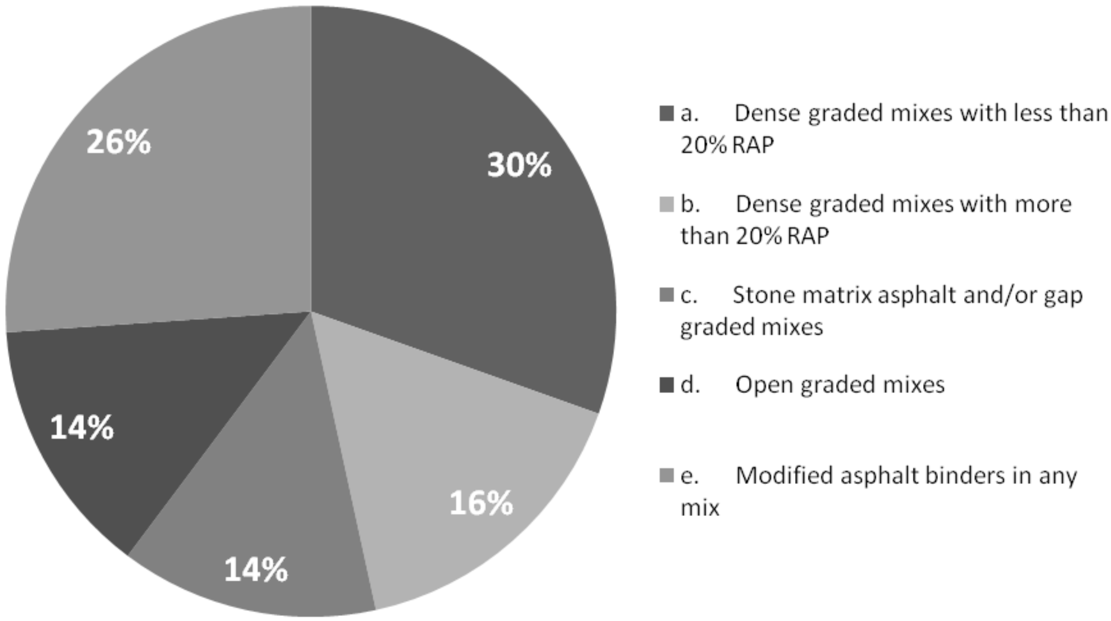


FIGURE 7 Responses to Survey Question 12.

SUMMARY

- Just about all states are receptive and have knowledge of MEPDG. However, only 62% have an implementation plan in place for it.
- A lot of agencies were interested in adopting MEPDG, (76%) but far less were completely in favor of adopting it (22%).
- While almost every agency was collecting supplementary information for use in MEPDG and logistically conducting research and implementation activities for MEPDG, 43% of the agencies were not currently using MEPDG for designs.

Summary of Mechanistic–Empirical Pavement Design Guide Regional User-Group Meetings

MICHAEL HEITZMAN
National Center for Asphalt Technology

In 2007, nine states in the north-central region proposed to meet and share their expertise, challenges and accomplishments toward successful implementation of the *Mechanistic–Empirical Pavement Design Guide* (MEPDG). FHWA's Design Guide Implementation Team (DGIT) agreed to sponsor the meeting, and the National Center for Asphalt Technology (NCAT) and the Concrete Preservations Technology (CPTech) Center facilitated the February 2008 2-day event. Based on the success of the north-central meeting, FHWA's DGIT sponsored four additional regional meetings in late 2008 and early 2009 to cover the balance of the country.

All five meetings were planned independently, but a common agenda emerged. Each meeting started with a general overview of individual states' MEPDG implementation plans. The second session examined general implementation issues, like "how to calibrate" the performance models (empirical transfer functions) and "how to coordinate" the effort of multiple department of transportation (DOT) offices. The third session allowed the participants to examine more specific technical details regarding traffic and material inputs. The meeting ended with a discussion of software limitations and regional challenges and opportunities.

The limitations, challenges, and opportunities identified by the participants were divided into nine general topics:

1. Traffic—getting quality traffic data is a struggle for most agencies;
2. Materials—most states are building materials data libraries;
3. Climate—more climate files are needed to adequately cover each state;
4. Performance models—research efforts are underway to improve the models;
5. Rehabilitation—effort is needed to improve the use of falling weight deflectometer (FWD) and pavement management system (PMS) data;
6. Pavement management—most PMS lack adequate data for MEPDG input;
7. Resources and training—support from management is essential, but varies;
8. Software—improve flexible design run time and access to output data; and
9. Sensitivity and reliability—share studies and improve the reliability approach.

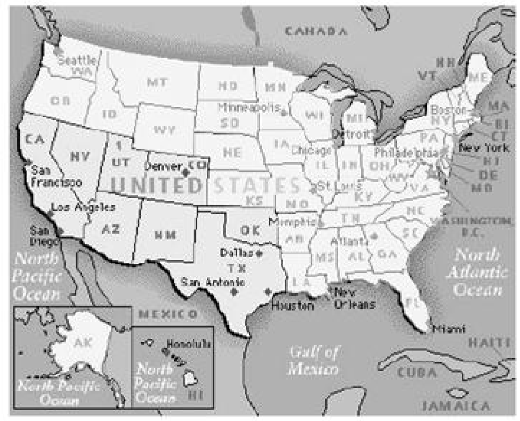
Specific asphalt topics discussed at the regional meetings were building materials databases, improving the performance models, and the need for better materials and flexible pavement design expertise at the agency level.

Implementation of MEPDG will be slow for most states. Some are waiting for AASHTO's DARWin ME version before initiating their plans. It is clear that the agencies will need to develop databases for the MEPDG inputs to successfully use it. The performance models will continue to improve. Implementation of MEPDG for new construction will precede its use for pavement rehabilitation.

Summary of MEPDG Regional User-Group Meetings

Michael Heitzman, NCAT
Tom Cackler, CPTech Ctr
Gary Crawford, FHWA DGIT

TRB 2010 Workshop 143 Flexible Pavement Design Sensitivity Analysis with MEPDG



Workshop Schedule

- **North-Central**
  - **February 19-20, 2008, Iowa**
- **North-East**
  - **December 18-19, 2008, New Jersey**
- **North-West**
  - **March 9-10, 2009, Oregon**
- **South-West**
  - **March 23-24, 2009, Nevada**
- **South-East**
  - **March 25-26, 2009, Tennessee**

Common Agenda

- Day-1 1:00 PM – 8:00 PM
  - General Implementation Plan Overviews
  - General Technical Issues
- Day-2 8:00 AM – 2:00 PM
  - Detailed Technical Issues
  - Closing and Future Direction

Closing and Future Direction

- Regional challenges and barriers
- Identify specific MEPDG limitations and issues
- Need for regional pooled fund studies

Challenges, Limitations and Regional Studies

Topic	NW	SW	NC	SE	NE
Traffic		X	X	X	X
Materials	X	X	X	X	X
Climate		X			X
Performance Models	X	X	X	X	
Rehabilitation	X	X	X	X	X
Pavement Management	X	X		X	X
Resources / Training	X	X	X	X	X
Software		X	X	X	X
Sensitivity / Reliability		X	X	X	X

Challenges, Limitations and Regional Studies

Topic	NW	SW	NC	SE	NE
Traffic		X	X	X	X

- Getting traffic data
- Quality of traffic data
- Weigh-in-motion (WIM)
- Regional database
- Software interface

Challenges, Limitations and Regional Studies

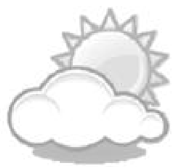
Topic	NW	SW	NC	SE	NE
Materials	X	X	X	X	X

- Getting materials data
- Non-standard materials
- Recycled materials
- Regional database
- Test standardization

Challenges, Limitations and Regional Studies

Topic	NW	SW	NC	SE	NE
Climate		X			X

- Verify the EICM
- More climate files
- Better climate files



Challenges, Limitations and Regional Studies

Topic	NW	SW	NC	SE	NE
Performance Models	X	X	X	X	

- Improve HMA rutting model
- Improve HMA fatigue model
- Improve HMA T-crack model
- Model for thin HMA
- Calibration on regional data
- Other models

Challenges, Limitations and Regional Studies

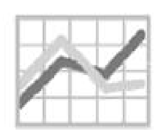
Topic	NW	SW	NC	SE	NE
Rehabilitation	X	X	X	X	X

- FWD input – back calculation
- Reflective cracking models
- Using PMS data

Challenges, Limitations and Regional Studies

Topic	NW	SW	NC	SE	NE
Pavement Management	X	X		X	X

- Lack of performance data
- Modify PMS databases
- Improve PMS data collection
- Top-down cracking
- Regional data for calibration



Challenges, Limitations and Regional Studies

Topic	NW	SW	NC	SE	NE
Resources / Training	X	X	X	X	X

- Funding for implementation
- Funding for improvements
- Agency staff experience
- Training
- Regional collaboration

Challenges, Limitations and Regional Studies

Topic	NW	SW	NC	SE	NE
Software		X	X	X	X

- Flexible pavement run time
- Stress & strain output
- Access to software code

Challenges, Limitations and Regional Studies

Topic	NW	SW	NC	SE	NE
Sensitivity / Reliability		X	X	X	X

- Sharing sensitivity studies
- Improve the approach to reliability

Challenges, Limitations and Regional Studies

Topic	NW	SW	NC	SE	NE
Traffic		X	X	X	X
Materials	X	X	X	X	X
Climate		X			X
Performance Models	X	X	X	X	
Rehabilitation	X	X	X	X	X
Pavement Management	X	X		X	X
Resources / Training	X	X	X	X	X
Software		X	X	X	X
Sensitivity / Reliability		X	X	X	X

Asphalt topics

- **Developing materials databases**
  - Mix properties with RAP
  - Mixes with modified binders
  - Lab performance measures (E*, FN)
- **Improving performance models**
  - New construction (rutting, fatigue, T-cracking)
  - Rehabilitation (reflective cracking)
- **Resources / training**
  - HMA materials expertise
  - Flexible pavement design expertise

Proceedings of the

North-Central States M-E PDG User Group Meeting

This document captures the information shared by the nine north-central States on M-E PDG implementation efforts. The meeting was held in Ames, Iowa on February 19-20, 2008.

Will be available through FHWA DGIT, NCAT, and CPTech Ctr

Summary

- Implementation will be slow for most States
- DARWin ME ver 2.0 January 2011
- States need data to use MEPDG
- Performance prediction models will continue to improve
- Pavement rehabilitation implementation will lag new construction implementation

Calibration of Rutting Models for Hot-Mix Asphalt Structural and Mix Design

Update on NCHRP Project 9-30A

HAROLD VON QUINTUS
Applied Research Associates

This presentation includes an overview and comparison of different rut depth transfer functions that were included in a modified version of the *Mechanistic–Empirical Pavement Design Guide* (MEPDG) software identified as Version 9-30A, prepared under NCHRP project 9-30A. The presentation was grouped into four areas: (1) overview of the project objectives and rut depth transfer functions, (2) comparison of predicted and measured rut depths using the different transfer functions, (3) assessment and effectiveness of the transfer functions, and (4) a summary of the observations and findings from the project. The five rut depth transfer functions that were investigated and compared in the study included

1. MEPDG elastic vertical strain–temperature transfer function (included in Version 1.0 of MEPDG) and the NCHRP 1-40B mixture adjustment parameters based on mixture volumetric properties;
2. WesTrack shear strain, shear stress transfer function;
3. Verstraeten deviator stress transfer function;
4. Asphalt Institute elastic vertical strain, deviator stress-temperature transfer function; and
5. Modified Leahy elastic vertical strain, deviator stress transfer function.

Three laboratory tests were used to determine the permanent deformation parameters and inputs to the above transfer functions. These tests included: dynamic modulus test, confined repeated load triaxial test, and the repeated load constant height shear test. Results from these tests were used to determine the field adjusted values in terms of the exponents and coefficients to the above transfer functions. The rut depths were predicted using the field calibrated values for each transfer function. The assessment and effectiveness of the rut depth transfer functions were determined from a benefit–cost analysis. A summary of the benefit–cost analysis was included in the presentation for different threshold values of rut depths, reliability levels, and size of project. The final part of the presentation was a listing and overview of the observations and findings from the data, which included

1. Confined repeated load triaxial tests were recommended for the plastic vertical strain and deviator stress based transfer functions.
2. Repeated load permanent deformation tests (both triaxial and shear tests) significantly reduced the bias and error for the transfer functions, suggesting a benefit to conduct laboratory tests. It was found that dynamic modulus testing by itself did not significantly reduce the bias and error.
3. The shear and vertical strain–based transfer functions can be used with similar accuracy after calibration.
4. All calibrated rut depth transfer functions were found to provide reasonably accurate prediction of the measured rut depths and the evolution of rutting.
5. The benefit–cost analyses found that the reduced error based on repeated load tests was cost effective, or the benefit exceeded the cost of testing.

Update on NCHRP 9-30A

Harold L. Von Quintus, P.E.

TRB Annual Meeting
Session #143
January 10, 2010

NCHRP 9-30A Calibration of Rutting Models for HMA Structural & Mix Design

Outline

1. Overview of Project & Rut Depth Transfer Functions
2. Predicted & Measured Rut Depths
3. Assessment & Effectiveness of Transfer Functions
4. Summary: Observations & Findings

Draft final report will be submitted next month.

Project Objective

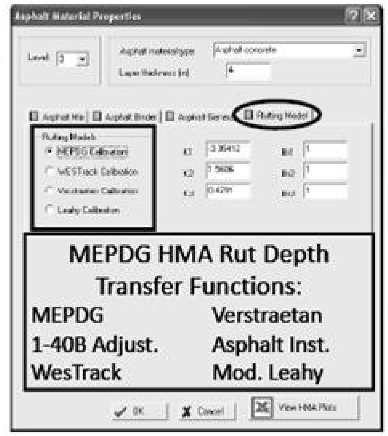
Recommend revisions to the HMA rut depth transfer function in the MEPDG software.

- ★ Short-term revisions.
  - ☑ Other rut depth transfer functions
  - ☑ Computational methodology
- ★ Longer-term revisions – Advanced mechanistic-based prediction system.

Rut Depth Transfer Functions from Facilitated Workshop

1. MEPDG—Elastic Strain/Temp. Equation
2. NCHRP 1-40B Mix Adjustment Parameters
3. WesTrack—Shear Strain & Stress Equation
4. Verstraeten—Deviator Stress Equation
5. Asphalt Institute—Elastic Strain & Deviator Stress Equation (Original Leahy Equation)
6. Modified Leahy Model—Elastic Strain & Deviator Stress Equation

MEPDG 9-30A Version



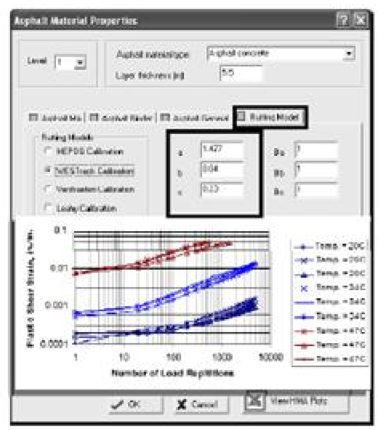
Specimen Testing Summary

Triaxial
- 10 psi Confinement
- 70 psi Deviatoric
- Up to 10,000 Cycles
- Three Replicates

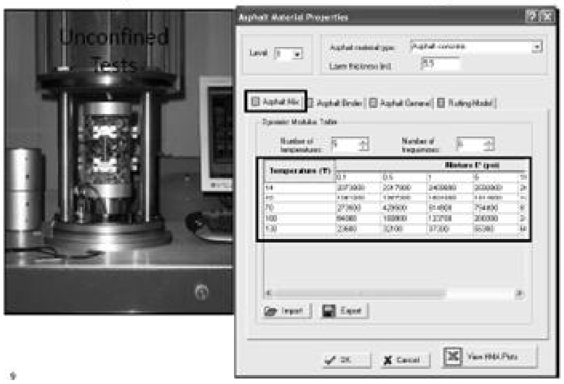
Shear
- Per AASHTO T320
- 5,000 Cycles
- Three Replicates

Three Test Temperatures
- 20 C
- Intermediate
- 7 Day Avg. Max. From LTPPBind

Repeated Load Constant Height Shear or Triaxial Testing



Dynamic Modulus Testing



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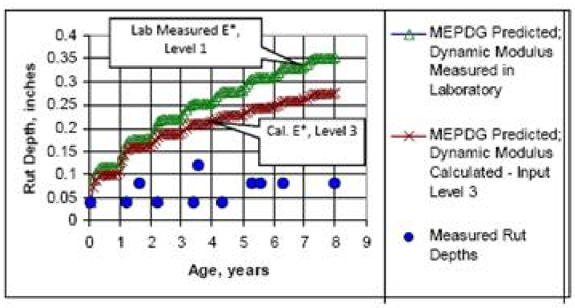
Data Interpretation: Predicted and Measured Rut Depths

Calibration completed in accordance with the NCHRP 1-40B Local Calibration Guide

515P ARA0127-10

Dynamic Modulus Testing



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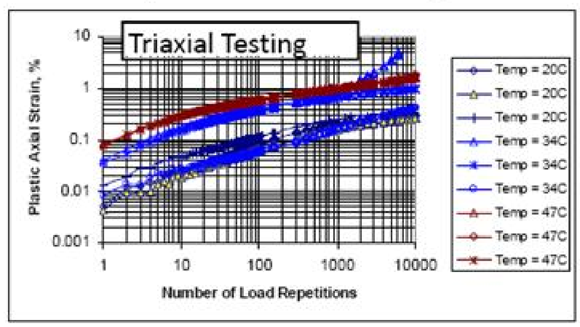
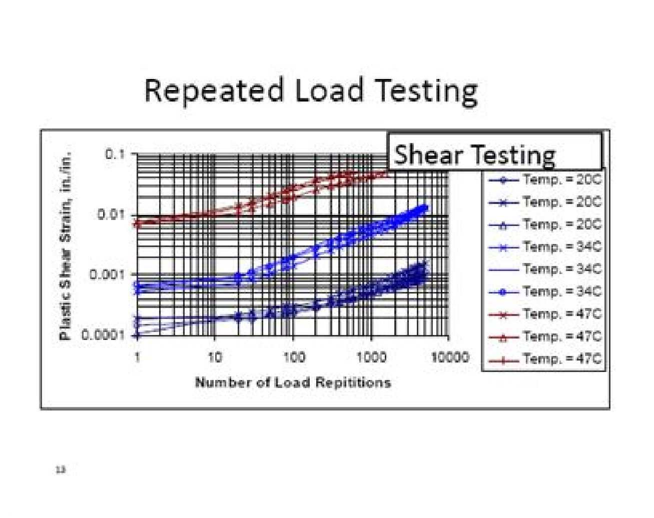
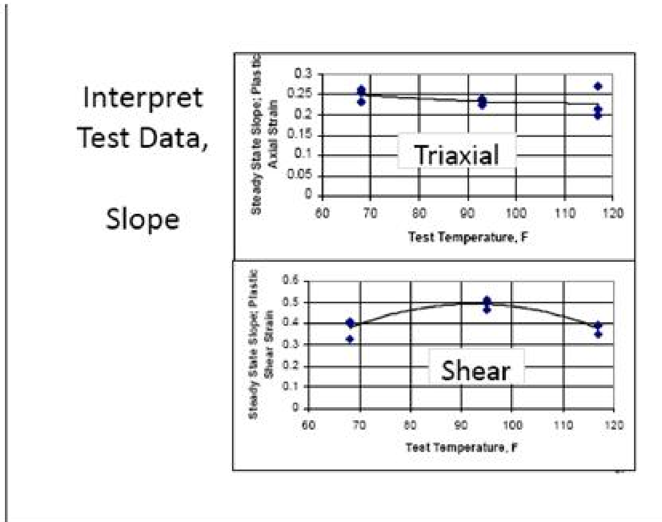
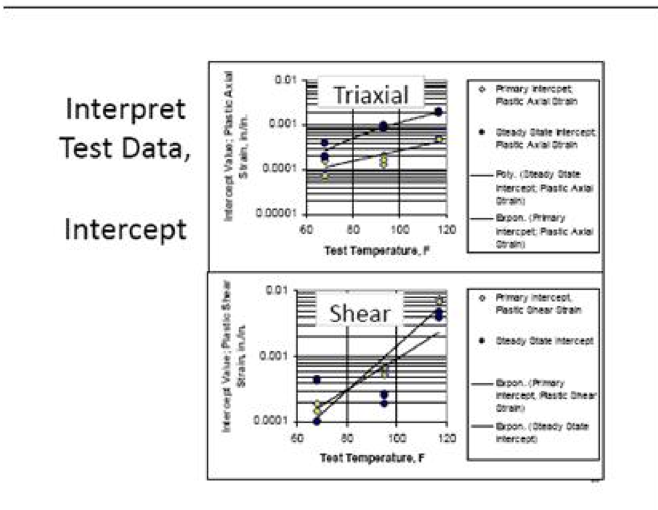
Repeated Load Testing

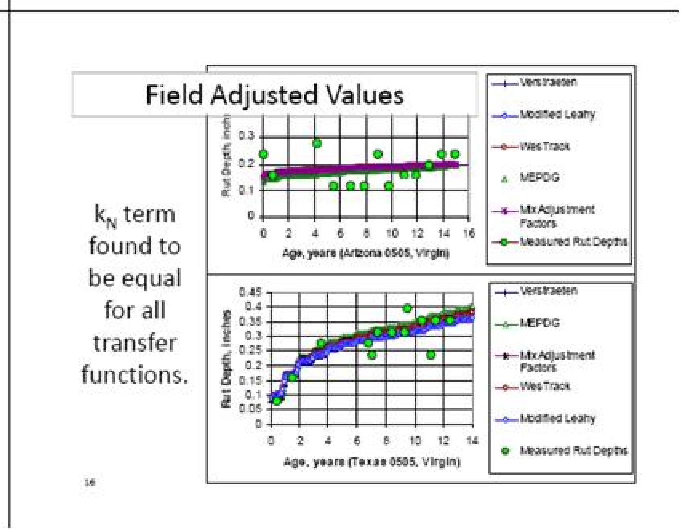


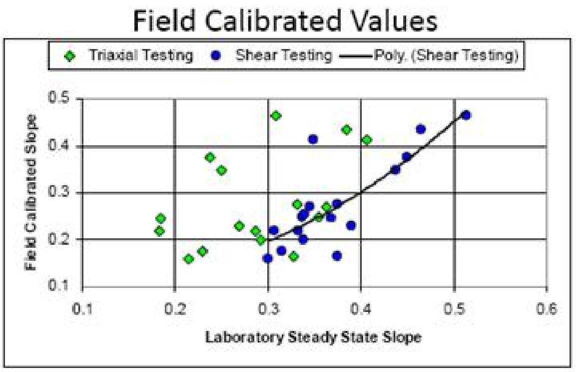
12


Repeated Load Testing
Shear Testing
Plastic Shear Strain, in./in.
Number of Load Repititions
Temp. = 20C
Temp. = 34C
Temp. = 47C


Interpret Test Data,
Slope
Triaxial
Shear
Test Temperature, F


Interpret Test Data,
Intercept
Triaxial
Shear
Test Temperature, F


Field Adjusted Values
k_N term found to be equal for all transfer functions.
Verstraeten
Modified Leahy
WesTrack
MEPDG
MixAdjustment Factors
Measured Rut Depths
Age, years (Arizona 0505, Virgin)
Age, years (Texas 0505, Virgin)
Rut Depth, inches



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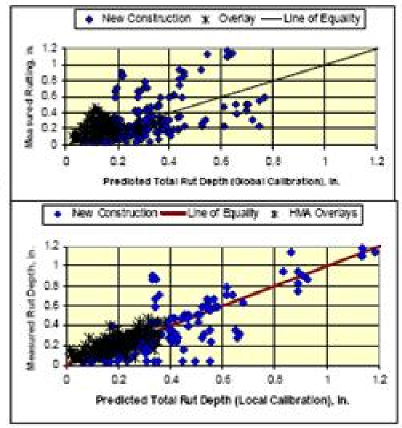
Summary:

Lab Adjusted to Field



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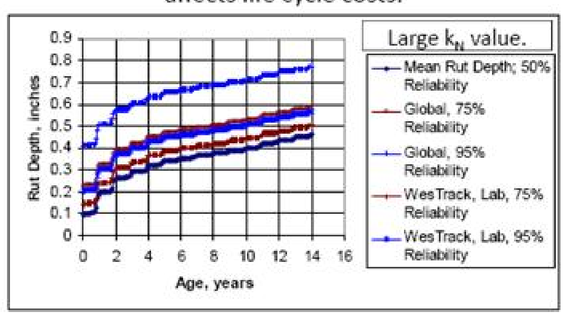
Assessment and Effectiveness of Rut Depth Transfer Functions; Benefit/Cost Analysis

S1SP ARA0127-19

Benefit/Cost Analysis – Reduction in service life affects life cycle costs.



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Summary of Benefit/Cost Analysis

Trigger Value, in.	Reliab. Level, %	HMA Overlay Project		
		Small Project, <$1M	Medium Size Project	Large Project, $5M
0.25	75			
	85			B/C>1.0
	95		B/C>1.0	
0.5	75	B/C>1.0	B/C>1.0	B/C>1.0
	85			
	95			
0.75	75	B/C>1.0	B/C>1.0	B/C>1.0
	85			
	95			

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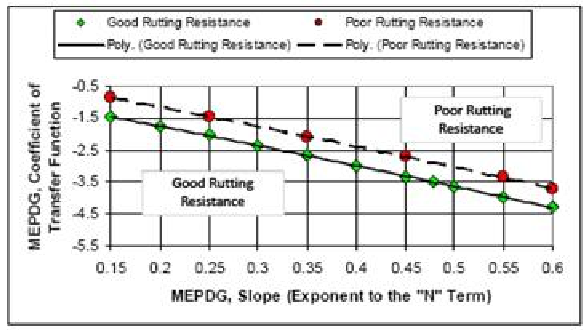
Mixture Assessment to Rutting



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Summary Observations/Findings and Final Report

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Summary Observations

1. Use confinement – important for plastic vertical strain & deviator stress transfer functions.
2. Repeated load permanent deformation tests (vertical strain and shear strain) significantly reduces bias and error.
   – Modulus differences alone do not adequately explain differences in rutting.
3. Shear and vertical strain transfer functions can be used with similar accuracy after calibration.

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Summary Observations

4. All calibrated rut depth transfer functions were found to provide reasonably accurate predictions of the measured rut depths (evolution of rutting).
5. Benefit/Cost Analysis – The benefit of reduced error for repeated load testing exceeds the cost of testing.

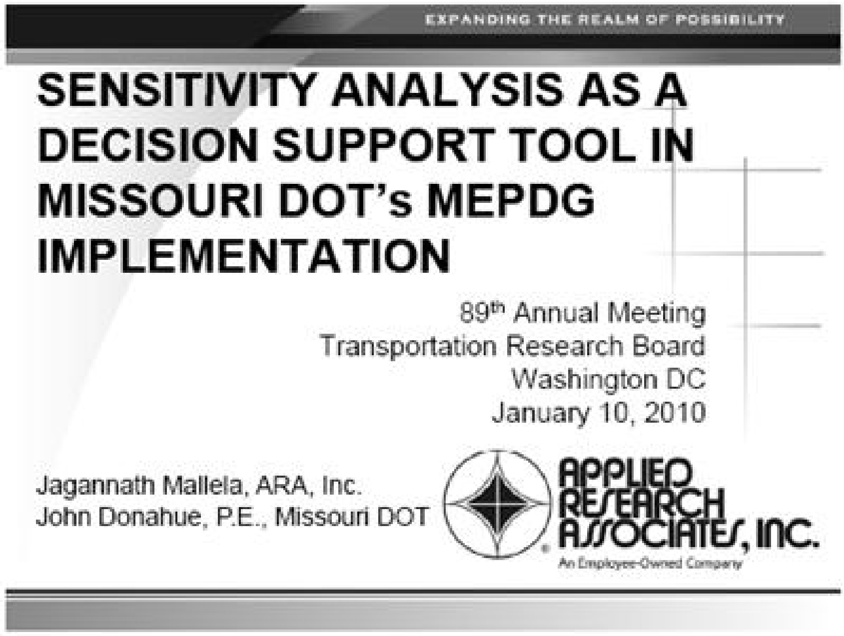
Sensitivity Analysis as Decision Support Tool for Missouri Department of Transportation MEPDG Implementation

JAGANNATH MALLELA
Applied Research Associates

JOHN DONAHUE
Missouri Department of Transportation

The general intent of this presentation is to overview the concepts of sensitivity analysis and applications of the results in guiding decisions during state-specific implementation of AASHTO's interim *Mechanistic–Empirical Pavement Design Guide* (MEPDG). The results from the sensitivity studies performed during the local calibration of the MEPDG models for the Missouri Department of Transportation (DOT) are specifically referenced. The presentation underscores the importance of sensitivity analysis as a decision support tool in locally calibrating the MEPDG performance models and illustrates an approach for setting up a successful sensitivity study. Results from the sensitivity analysis conducted for new jointed plain concrete pavements and asphalt concrete pavements are presented. In addition, a discussion of how the results were used by Missouri DOT was provided that included

- Assessing the quality of the prediction models and model deficiencies,
- Identifying factors that contribute most to the output variability,
- Assessing the impact of Missouri DOT–specific site and design inputs on key design types and distress types of interest,
- Identifying the region in the space of input factors for which the model variation is maximum, and
- Selecting the appropriate input level to characterize key inputs.


EXPANDING THE REALM OF POSSIBILITY
SENSITIVITY ANALYSIS AS A DECISION SUPPORT TOOL IN MISSOURI DOT's MEPDG IMPLEMENTATION
89th Annual Meeting
Transportation Research Board
Washington DC
January 10, 2010
Jagannath Mallela, ARA, Inc.
John Donahue, P.E., Missouri DOT
APPLIED RESEARCH ASSOCIATES, INC.
An Employee-Owned Company


Design of Experiments
Uncertainty Analysis
Sensitivity Analysis
ARA
Expanding the Realm of Possibility

Definition

> Sensitivity analysis is the study of how the variation (uncertainty) in the output of a mathematical model can be apportioned, qualitatively or quantitatively, to different sources of variation in the input of a model
>
> -Cacuci , 2005

ARA

Expanding the Realm of Possibility

Application of Sensitivity Analysis

- Sensitivity analysis was used to identify
  - Quality of the model definition
  - Factors that mostly contribute to the output variability
  - The region in the space of input factors for which the model variation is maximum
  - Optimal - or instability - regions within the space of factors for use in a subsequent calibration study
  - Interactions between factors

ARA

Expanding the Realm of Possibility

MEPDG Model Sensitivity Studies—Important Considerations

- Is it needed?
- How is it done?
- How to use results?

ARA

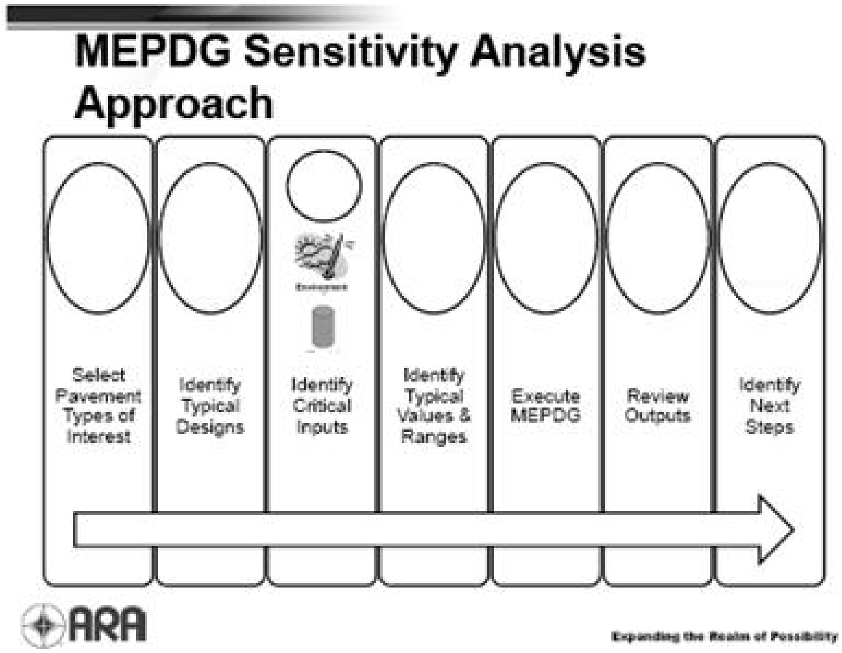
Expanding the Realm of Possibility

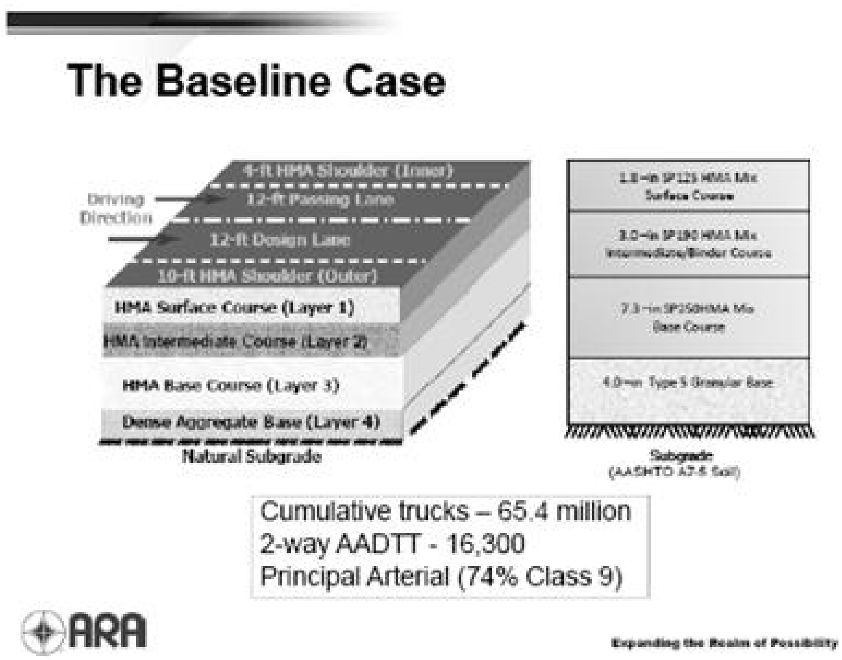
Is it Needed?

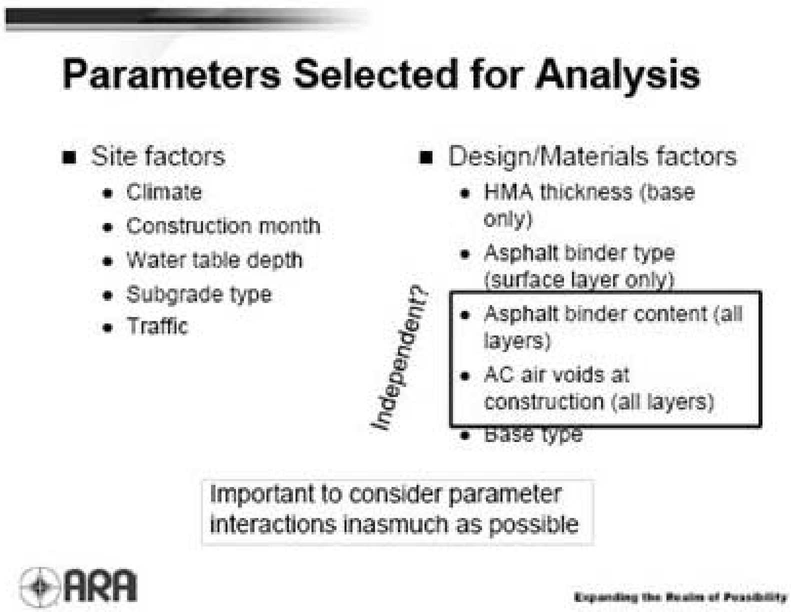
- Sensitivity is a part of model development
  - Extensive sensitivity and model verification runs performed during MEPDG development
- Sensitivity analysis still needed to verify
  - Model behavior over local factor space
  - Identify local calibration issues

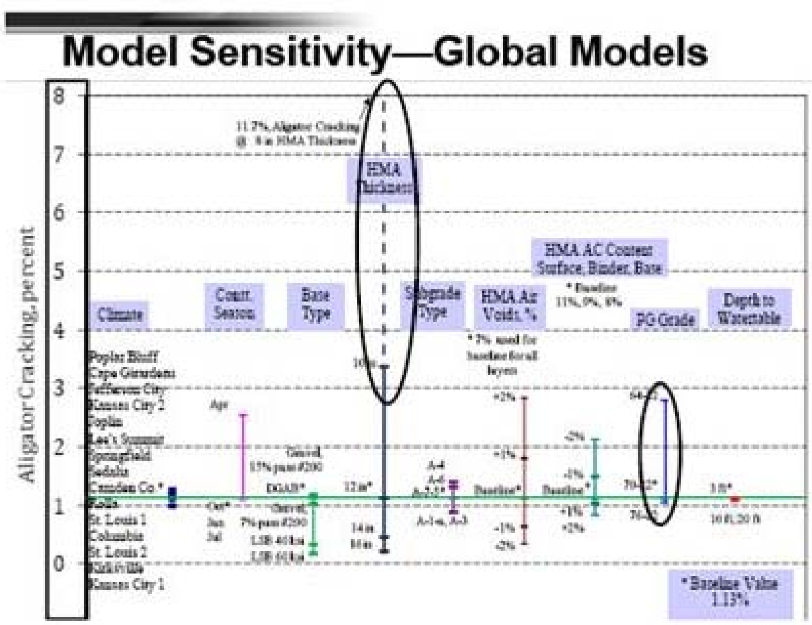
ARA

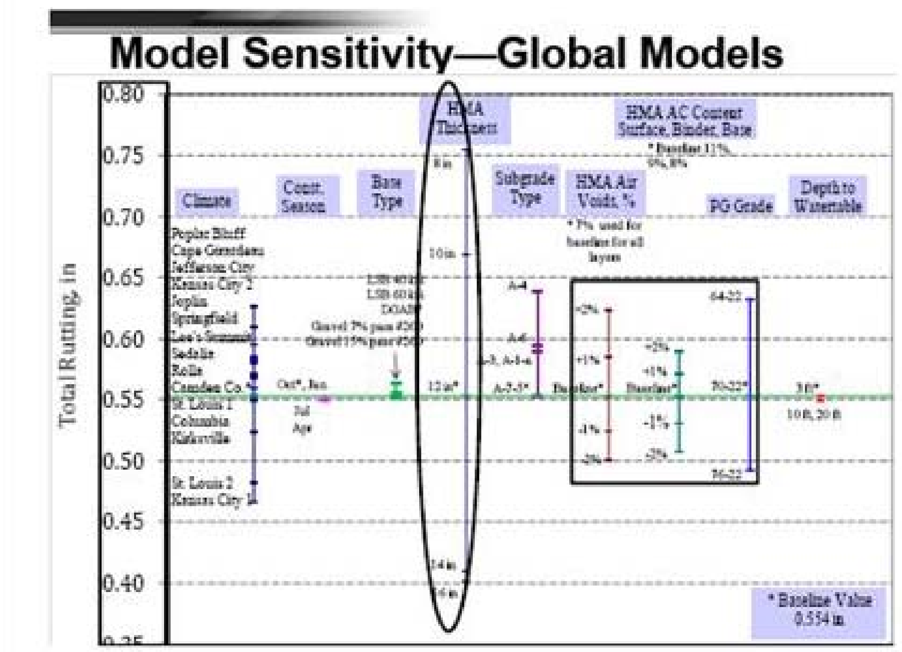
Expanding the Realm of Possibility

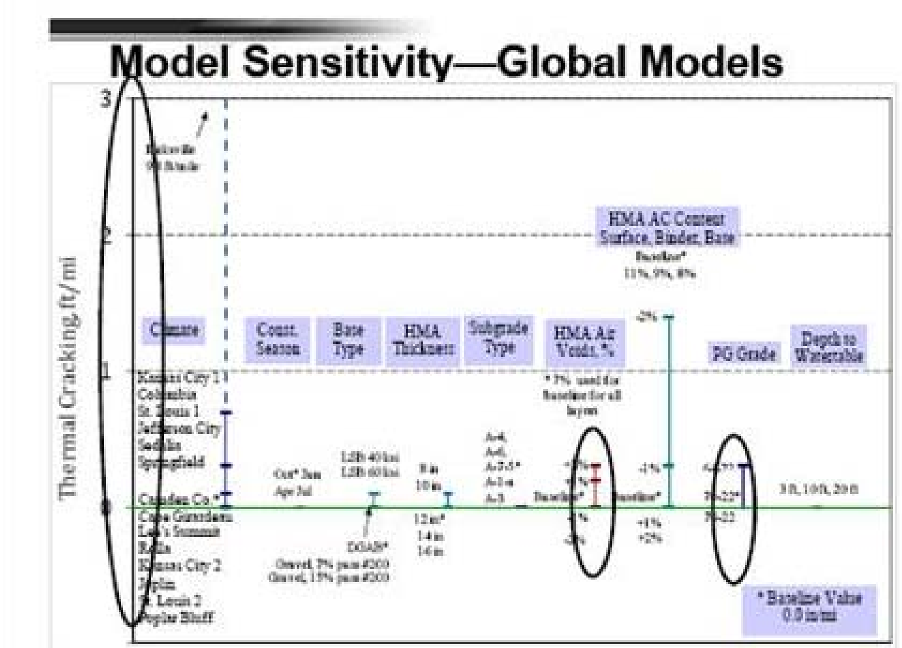

MEPDG Sensitivity Analysis Approach
Select Pavement Types of Interest
Identify Typical Designs
Identify Critical Inputs
Identify Typical Values & Ranges
Execute MEPDG
Review Outputs
Identify Next Steps
ARA
Expanding the Realm of Possibility


The Baseline Case
Driving Direction
4-ft HMA Shoulder (Inner)
12-ft Passing Lane
12-ft Design Lane
10-ft HMA Shoulder (Outer)
HMA Surface Course (Layer 1)
HMA Intermediate Course (Layer 2)
HMA Base Course (Layer 3)
Dense Aggregate Base (Layer 4)
Natural Subgrade
Surface Course
Base Course
Subgrade
(AASHTO A7-6 Soil)
Cumulative trucks – 65.4 million
2-way AADTT - 16,300
Principal Arterial (74% Class 9)
ARA
Expanding the Realm of Possibility


Parameters Selected for Analysis
Site factors
Climate
Construction month
Water table depth
Subgrade type
Traffic
Design/Materials factors
HMA thickness (base only)
Asphalt binder type (surface layer only)
Asphalt binder content (all layers)
AC air voids at construction (all layers)
Base type
Independent?
Important to consider parameter interactions inasmuch as possible
ARA
Expanding the Realm of Possibility


Model Sensitivity—Global Models
Alligator Cracking, percent
8
7
6
5
4
3
2
1
0
Climate
Const. Season
Base Type
HMA Thickness
Subgrade Type
HMA Air Voids, %
HMA AC Content Surface, Binder, Base
PG Grade
Depth to Watertable
*Baseline Value 1.13%


Model Sensitivity—Global Models
Total Rutting, in
Climate
Const. Season
Base Type
HMA Thickness
Subgrade Type
HMA Air Voids, %
HMA AC Content Surface, Binder, Base
PG Grade
Depth to Watertable
* Baseline Value 0.554 in


Model Sensitivity—Global Models
Thermal Cracking, ft/mi
Climate
Const. Season
Base Type
HMA Thickness
Subgrade Type
HMA Air Voids, %
HMA AC Content Surface, Binder, Base
PG Grade
Depth to Watertable
* Baseline Value 0.0 in/mi

Recap: Observations Needing Further Action

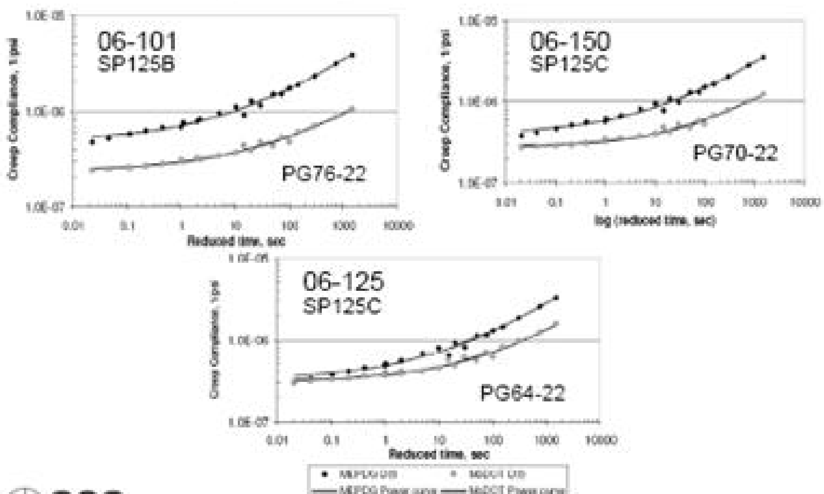
- Alligator cracking
  - Very sensitive when thickness is less than 10 inches; otherwise low sensitivity
- Rutting
  - Thickness sensitivity not intuitive; highly sensitive for HMA thickness less than 14 in
- Thermal cracking
  - Not very sensitive to inputs

Triggered investigation of default inputs/functions to determine inputs, more detailed dependency studies of models, local calibration where performance data were available.

ARA

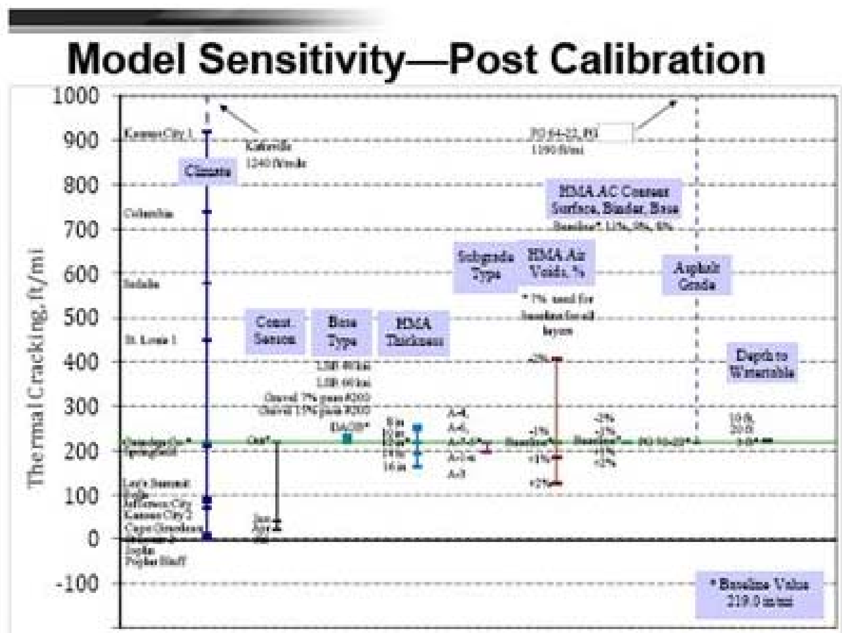
Expanding the Realm of Possibility

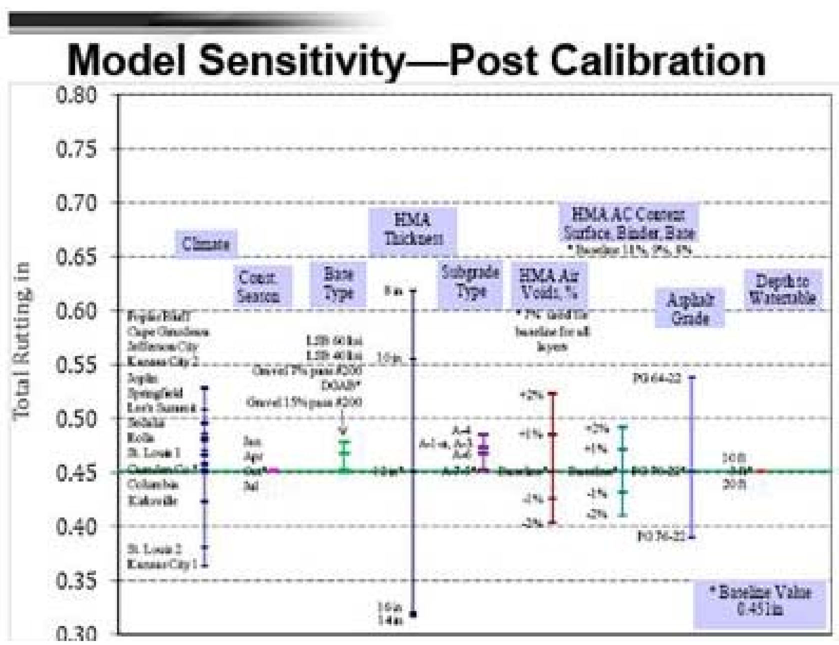
HMA Creep Compliance

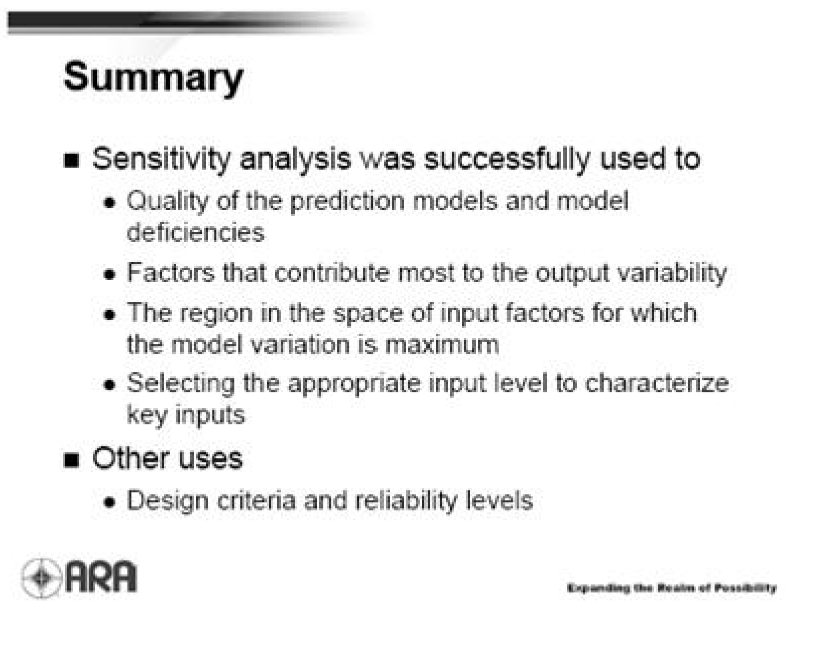


ARA

Expanding the Realm of Possibility


Model Sensitivity—Post Calibration
Thermal Cracking, ft/mi
1000
900
800
700
600
500
400
300
200
100
0
-100
Climate
Const. Season
Base Type
HMA Thickness
Subgrade Type
HMA Air Voids, %
HMA AC Content Surface, Binder, Base
Asphalt Grade
Depth to Watertable
* Baseline Value 219.0 in/mi


Model Sensitivity—Post Calibration
Total Rutting, in
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
Climate
Const. Season
Base Type
HMA Thickness
Subgrade Type
HMA Air Voids, %
HMA AC Content Surface, Binder, Base
Asphalt Grade
Depth to Watertable
* Baseline Value 0.451in


Summary
Sensitivity analysis was successfully used to
Quality of the prediction models and model deficiencies
Factors that contribute most to the output variability
The region in the space of input factors for which the model variation is maximum
Selecting the appropriate input level to characterize key inputs
Other uses
Design criteria and reliability levels
ARA

New Jersey's Efforts to Implement the Mechanistic–Empirical Pavement Design Guide

YUSUF MEHTA
Rowan University

THOMAS BENNERT
Rutgers University

The presentation provided an overview of the effort conducted by the State of New Jersey towards implementation of the AASHTO *Mechanistic–Empirical Pavement Design Guide* (MEPDG). New Jersey Department of Transportation is one of the lead states in implementing MEPDG. Leading up to the implementation, Rutgers University conducted an extensive evaluation of the materials in the state of New Jersey and developed a materials database. The database included resilient modulus of subgrades and base–subbase materials. In addition, a dynamic modulus database of mixtures was also developed. Rutgers University assisted in conducting Design Guide Implementation Workshops. Beginning fall 2008, Rowan University conducted Level 3 input verification of all distresses. Rowan University also calibrated and validated the fatigue cracking model based on 29 field pavement sections in New Jersey. Then a pavement catalog was developed in the form of a user-friendly Microsoft Access database. This catalog will help to identify candidate pavement structures that will meet failure criteria during the design life, based on MEDPG Level 3 inputs.

New Jersey's Effort to Implement the MEPDG

Yusuf Mehta, Ph.D., P.E.

Thomas Bennert, Ph.D.

Rutgers University

Implementing MEPDG in New Jersey - Overview

- Materials Input Databases
  - Started from the Ground Up!
    - Subgrade Soils
    - Base/Subbase Aggregates
    - HMA
    - PCC
- MEPDG Training Classes
  - DGIT Materials Input Class
  - DGIT Traffic Input Class
  - In-house Training for NJDOT and Consultants
- Initiating Local Calibration sites (started Fall 2009)
  - Primarily focusing on flexible rehabilitation first
  - Asphalt over asphalt (5 Sites Selected)
  - Asphalt over PCC (6 Locations Planned for 2010)

MEPDG Materials Inputs – Unbound Materials

- Resilient Modulus (M_R)
  - Used to define the stress-state dependent properties of unbound materials (subgrade soils and base/subbase aggregates)
  - Testing conducted in accordance with LTPP Test Protocol P46
  - Final results described as material specific coefficients (k_1, k_2, and k_3) in the MEPDG Resilient Modulus Equation

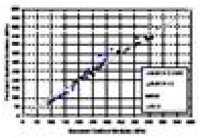
$$M_r = k_1 P_a \left(\frac{\theta}{P_a}\right)^{k_2} \left(\frac{\tau_{oct}}{P_a} + 1\right)^{k_3}$$

Unbound Materials

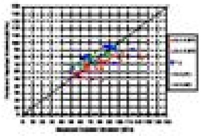
- **Subgrade Soils**
  - Sampled 10 different subgrade soils prominent in New Jersey
  - Compacted in lab to densities simulating field conditions
  - Tested at optimum moisture content, optimum + 2%, and optimum – 2%
- **Base/Subbase Aggregates**
  - Sampled base (dense graded aggregate base course - DGABC) and subbase (bank run river gravel – NJDOT I-3) from three different quarries
  - Sampled recycled concrete (RCA) and recycled asphalt pavement (RAP) from two suppliers
    - Varied gradation to determine influence of NJDOT specifications
    - Also conducted CBR, permeability, cyclic and static triaxial

Resilient Modulus Prediction Evaluation

- Evaluated prediction equations generated from LTPP data for base/subbase aggregates and subgrade soils (Yau and Von Quintus, 2000, *FHWA-RD-02-051*)



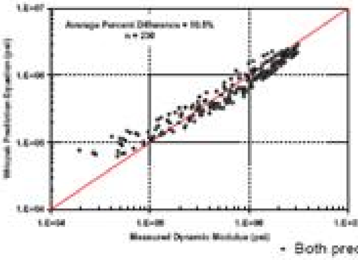
- General fit was initially good but found after slight local calibration, predicted values matched measured values well for aggregates better than subgrade soils



HMA Materials Catalog

- Collected 22 plant produced mixes from across the state – plant produced selected so effects of RAP included
  - Dynamic modulus (E*) determined using modified procedure with AMPT (Bonaquist and Christensen TRR 1929; Bennert and Williams, TRB 2009)
    - Database generated for use with MEPDG (Used for initial design – "Level 1B")
    - Database also used to evaluate Witczak Prediction Equation and Hirsch Model
  - Creep Compliance and Low Temp IDT conducted on selected surface course mixtures
- Asphalt binder properties (Superpave and Conventional) determined for typical asphalt binders supplied in state

Dynamic Modulus Prediction Equations



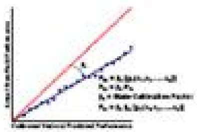
- Both prediction equations provided good comparisons
- Witczak slightly better than Hirsch at intermediate and low temps
- Hirsch better at higher temps

MEPDG Training

- **May 2005** – hosted DGIT Team and Materials Input Course
  - Attendees: NJDOT and their consultants
- **June 2006** – hosted and conducted refresher class on Materials Input Course
  - Attendees: NJDOT and their consultants
- **August 2007** – hosted DGIT Traffic Inputs course
  - Attendees: NJDOT and their consultants
- **February 2009** – conducted Materials Input Course at NJDOT
  - Attendees: NJDOT and NJ FHWA representatives
  - 1st use of HMA Materials Catalog during course

Regional Calibration of Distress Models

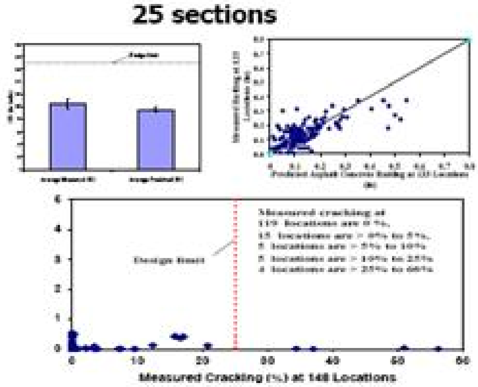
- NJDOT not constructing new pavements
  - Primary need is for rehabilitation
    - HMA over HMA
    - HMA over PCC
- 2009 – established test sections for HMA over HMA
  - Information collected
    - FWD – unbound material modulus
    - Cores – E* testing, volumetrics, binder properties
    - Traffic data – portable WIM/AVC for site specific data
      - Difficulty finding state WIM's within immediate location
      - Traffic data collected for 2 weeks (no seasonal variation being assumed in model calibration)
- 2010 – establishing test sections for HMA over PCC



Verification of asphalt concrete performance prediction using level 2 and level 3 inputs

- To evaluate the accuracy of the pavement performance predicted in the state of New Jersey with level 2 and level 3 inputs

Measured and predicted performance for 25 sections

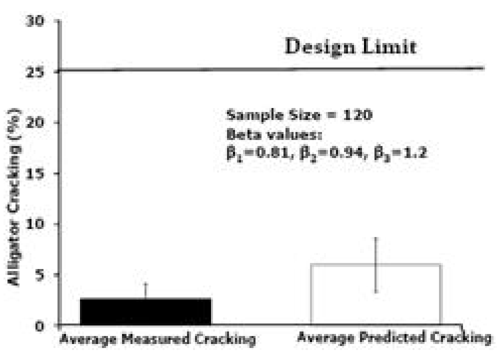


Sensitivity Analysis and Calibration of the Alligator Cracking Model Using Regional Data

Calibration sections	Validation section
Route 183 S	Route 124 E
Route 94	Route 159
Route 23 S (LTPP 1030)	Route 15 N (LTPP 1003)
Route 139 W	Route 64 S
Route I-195 W (LTPP 0508)	Route I-195 E (LTPP 1011)
Route 202 S (LTPP 1033)	Route 95 S (LTPP 6057)
Route 35 S	Route 70 W
Route 31 S	Route 31 S
Route 29 N	Route 29 N
Route 29 S	Route 29 S
Route 55 N (LTPP 1638)	Route 55 S (LTPP 1034)
Route 55 N (LTPP 1031)	Route 9 S
Route 322 W	Route 322 W
Route 49 W	Route 70 E
	Route 40 E

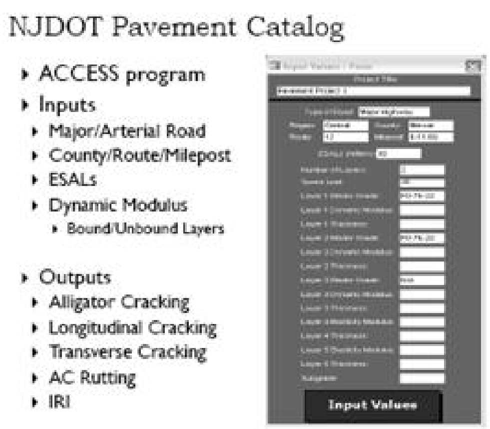
Percent Difference between measured and predicted	Number of data points	Percent of sections
Greater than 15 %	9	7.5
10 – 15%	6	5
5 -10%	14	11.7
Less than 5%	91	75.8

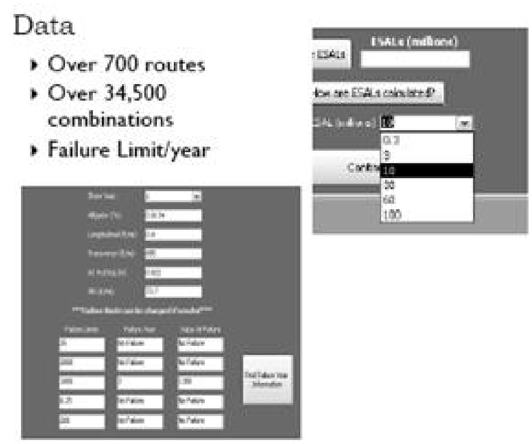
Percent Difference between measured and predicted	Value of Measured Data (% of alligator cracking)
Greater than 15 %	0 - 56
10 – 15%	0-3
5 -10%	0 -12

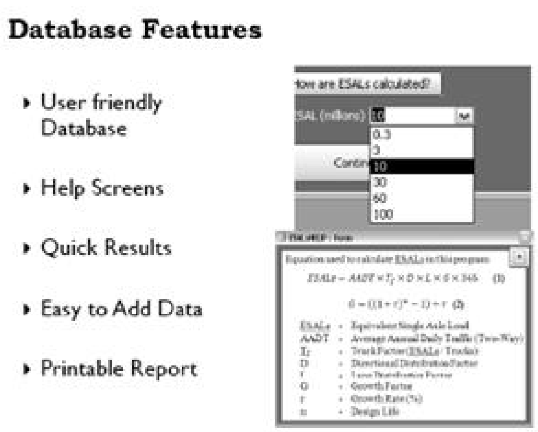


Comparison with other Studies

States	Values Before Calibration					Values after Calibration				
	β_{f1}	β_{f2}	β_{f3}	C_1	C_2	β_{f1}	β_{f2}	β_{f3}	C_1	C_2
North Carolina (Muthadi, et. al., 2008)	1	1	1	1	1	1	1	1	0.44	0.15
Wisconsin (Kang, et. al.,2007)	1	1	1	1	1	1	1.2	1.5	1	1
Wisconsin (Mallela, et al., 2008)	1	1	1	1	1	1	1	1	1	1
Washington Li, et al., 2009)	1	1	1	1	1	0.96	0.97	1.03	1.07	1
New Jersey (Our Study)	1	1	1	1	1	0.81	0.94	1.2	1	1


NJDOT Pavement Catalog
ACCESS program
Inputs
Major/Arterial Road
County/Route/Milepost
ESALs
Dynamic Modulus
Bound/Unbound Layers
Outputs
Alligator Cracking
Longitudinal Cracking
Transverse Cracking
AC Rutting
IRI
Input Values


Data
Over 700 routes
Over 34,500 combinations
Failure Limit/year
ESALs (millions)
0.3
3
10
30
60
100


Database Features
User friendly Database
Help Screens
Quick Results
Easy to Add Data
Printable Report
How are ESALs calculated?
0.3
3
10
30
60
100

Hawaii's Efforts to Implement the Mechanistic–Empirical Pavement Design Guide

ADRIAN R. ARCHILLA
University of Hawaii

This presentation includes an overview of several efforts directed to aid in the implementation of the AASHTO *Mechanistic–Empirical Pavement Design Guide* (MEPDG) in the state of Hawaii. The presentation discusses a few issues with existing software designed for manipulating traffic loading information (TRAFLOAD). An important problem identified is that in some situations the derived number of axles per vehicle is erroneous. A summary of research aimed at developing models for characterization of pavement material behavior, including unbound materials and hot-mix asphalt (HMA), is provided. In addition, the presentation also discusses some locally developed pavement management system (PMS) tools that could provide useful information for the local calibration of the MEPDG.

Hawaii's efforts to implement the MEPDG

TRB 89th Annual Meeting Workshop:
Flexible Pavement Design Sensitivity Analysis with Mechanistic-Empirical Pavement Design Guide

Dr. Adrian Ricardo Archilla
Associate Professor
University of Hawaii at Manoa
January 10, 2010

Acknowledgement

- Financial support of the State of Hawaii Department of Transportation (HDOT) in cooperation with the Federal Highway Administration (FHWA) is greatly appreciated and acknowledged.
- The contents of this presentation reflect the presenter's views, who is responsible for the facts and accuracy of the data presented herein.

Main efforts to date

1. Traffic loading input
   - Derivation of MAF, ALS, and number of axles per vehicle.
2. Material characterization
   - HMA dynamic modulus model and permanent deformation models
   - Resilient modulus models for fine grained soils and limited characterization of coarse graded materials and some reclaimed materials
3. Development of PMS tools with potential relevance to MEPDG calibration
   - Development of a historical structural information database from as-built plans and a software tool for its analysis
   - Software for analysis of the roughness information for the HDOT network
4. Some basic training (at introductory level)

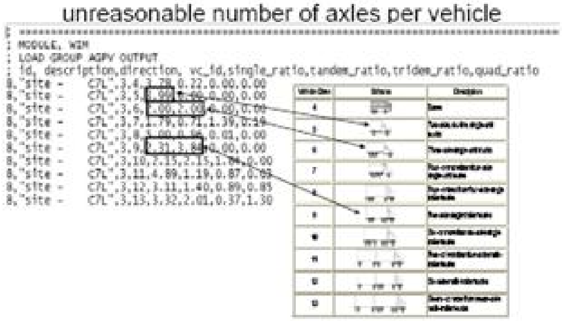
Traffic loading input

Options considered for traffic loading analysis

- TrafLoad
  - Advantages:
    - Very rational approach for weighing observations based on well documented procedures (NCHRP 1-39, Report 538)
    - Software is free
  - Concerns:
    - The program is not always easy to use
    - It requires a thorough understanding by the user of AVC and WIM station classification levels
    - A few results were suspect
- Own program

Inconsistencies in Trafload results

- In some situations TrafLoad produces unreasonable number of axles per vehicle



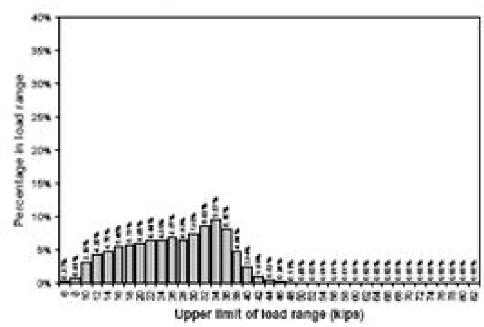
WIM data analysis

- A program was developed to analyze the WIM data directly and provide number of axles per vehicle and ALS.
- MAF were derived separately

Number of axle types per truck Station 3 – Queen Kaahumanu, Hawaii

Vehicle class	Direction 1 – North				
	No. of vehicles counted	Single	Tandem	Tridem	Quad
4	8,129	1.596	0.404	0.000	0.000
5	590,081	2.000	0.000	0.000	0.000
6	24,551	1.000	1.000	0.000	0.000
7	432	1.516	0.606	0.394	0.000
8	2,615	2.298	0.702	0.000	0.000
9	23,663	1.420	1.788	0.001	0.000
10	1,177	1.000	1.023	0.977	0.000
11	37	2.162	0.486	0.514	0.000
12	554	1.007	1.980	0.020	0.000
13	142	1.007	1.092	1.021	0.021

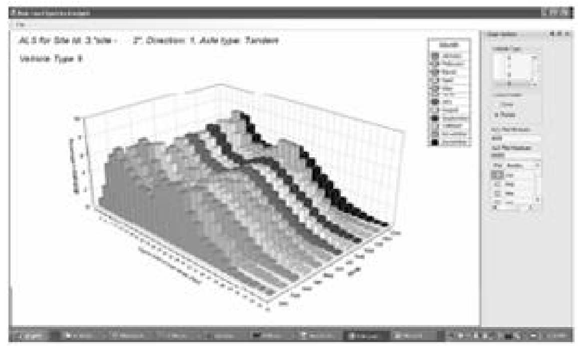
Developed ALS for Sand Island Access Road, Vehicle Class 9, Tandem Axle



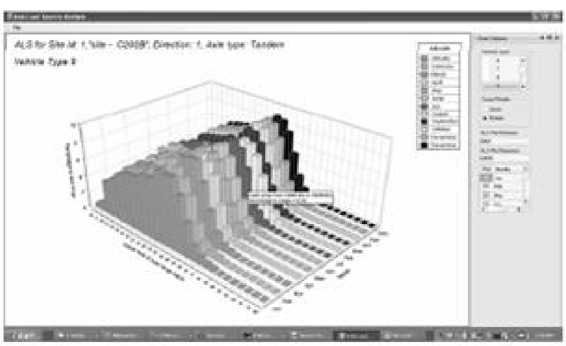
Traffic Loading Tool

- Allows the comparison of monthly distributions (as obtained with TrafLoad) for a given WIM station with the help of 3D graphs.

Patterns were generally quite similar



Another traffic loading pattern



Main efforts to date

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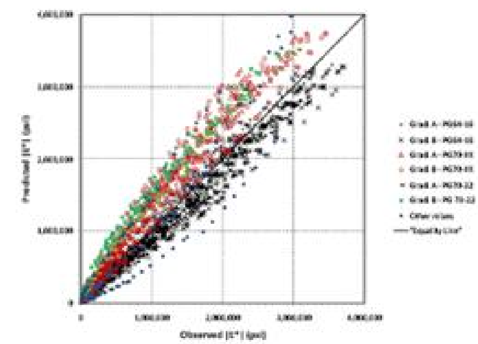
DYNAMIC MODULUS AND PERMANENT DEFORMATION

- One source of aggregate,
- Two different gradations (Superpave 12.5 mm NMAS gradations)
- Three binders (one unmodified and two polymer modified binders)
- Several combinations of air voids and asphalt content.
- DM testing was performed at several temperatures and frequencies of loading (data for 84 specimens, producing 2,447 data points.)
- PD tests were performed at 54°C (close to the highest temperatures for HMA in Hawaii.)

Observed vs. Predicted |E*| in linear scale - NCHRP 1-37A model



DYNAMIC MODULUS MODEL

$$\log_{10}|E^*| = \delta + \frac{\alpha}{1+e^{\beta-\gamma\log_{10} f_r}}$$

$$\log_{10}|E^*| = \delta_1 + \delta_2 V_a + \delta_3\left(\frac{V_{beff}}{V_{beff}+V_a}\right) + \delta_4 D_E + \delta_5 D_W + \delta_6 D_{N3} + \delta_7 D_F$$

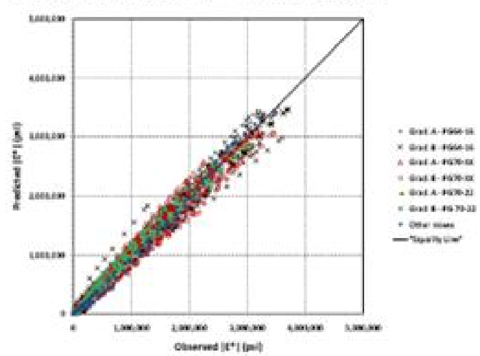
$$+ \frac{\alpha_1 + \alpha_2\left(\frac{V_{beff}}{V_{beff}+V_a}\right) + \alpha_3 D_E + \alpha_4 D_W + \alpha_5 D_{N3} + \alpha_6 D_F}{1+e^{\left(\beta_1+\beta_2 V_a+\beta_3\left(\frac{V_{beff}}{V_{beff}+V_a}\right)+\beta_4 D_E+\beta_5 D_W+\beta_6 D_{N3}+(\gamma_1+\gamma_2 D_F)\log_{10}(f_r)\right)}}$$

$$\log(a(T)) = \log\left(\frac{t}{t_r}\right) = A + BT + CT^2$$

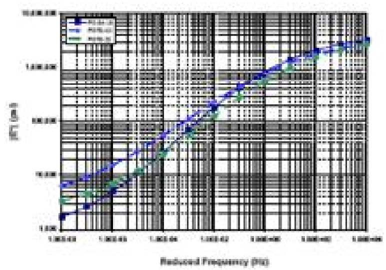
$A = A_1 + A_2 D_E$ $\quad B = B_1 + B_2 D_E$ $\quad C = -70(70A + B)$

These results will be presented in the 2010 AAPT annual meeting.

Observed versus fitted dynamic modulus values – linear scale



Effect of binder type in the HMA Master Curve



Models for permanent deformation parameters k_1 and k_3

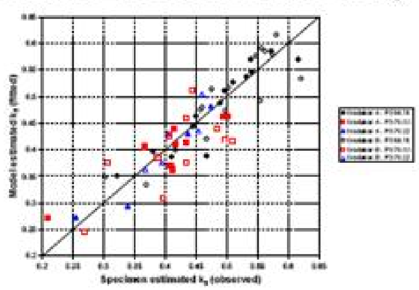
$$\frac{\varepsilon_p}{\varepsilon_r} = 10^{k_1} T^{k_2} N^{k_3}$$

$$\log_{10}(k_3) = \beta_1 + \beta_2 D_{B6416} + \beta_3 D_{A70XX} + \beta_4 D_{B70XX} + \beta_5 D_{A7022} + \beta_6 D_{B7022} + \beta_7 \log(Va) + \beta_8 \log(P_{beffVol}) + \beta_9 \log(Va)\log(P_{beffVol})$$

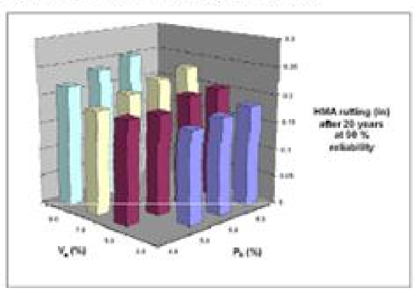
where,

- D_{B6416} = 1 if gradation B and binder is PG64-16 and zero otherwise,
- D_{A70XX} = 1 if gradation A and binder is PG70-XX and zero otherwise,
- D_{B70XX} = 1 if gradation B and binder is PG70-XX and zero otherwise,
- D_{A7022} = 1 if gradation A and binder is PG70-22 and zero otherwise,
- D_{B7022} = 1 if gradation B and binder is PG70-22 and zero otherwise,
- V_a = air voids (%), and
- $P_{beffVol}$ = effective binder content by volume (%).

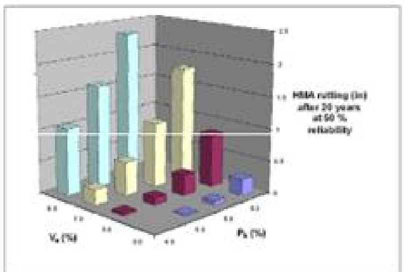
ESTIMATED VS. OBSERVED k_3



Evaluation of mixture volumetrics effects under a given scenario through |E*| alone



Evaluation of mixture volumetrics effects under a given scenario changing PD parameters



Sensitivity

- The sensitivity to mixture volumetrics through |E*| alone is relatively low.
- However, when their effect on PD parameters are also considered, the sensitivity is high.
- The guide does not appear to give enough credit to polymer modified mixes, unless calibration parameters (PD and fatigue) are adjusted.

Main efforts to date

1. Traffic loading input
   - Derivation of MAF, ALS, and number of axles per vehicle.
2. Material characterization
   - HMA dynamic modulus model and permanent deformation models
   - HMA master curve and permanent deformation analysis software
   - Resilient modulus models for fine grained soils and limited characterization of coarse graded materials and some reclaimed materials
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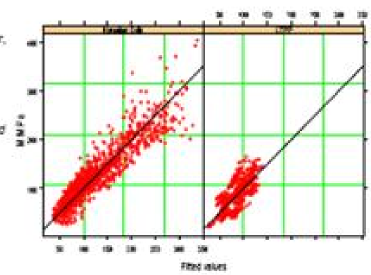
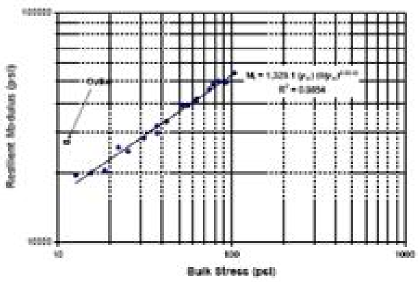
Fine-Grained Soil Model

Archilla, A.R., Ooi, P.S.K., and Sandefur, K.G. (2007). *Estimation of a Resilient Modulus Model for Cohesive Soils Using Joint Estimation and Mixed Effects*, ASCE Journal of Geotechnical and Geoenvironmental Engineering, Vol. 133, No 8, pp. 984-994.



ALA KINOIKI RECLAMATION PROJECT



Main efforts to date

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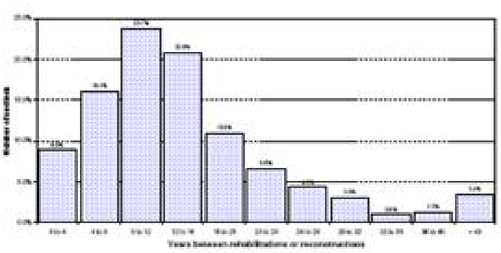
DISTRIBUTION OF PERIODS BETWEEN REHABILITATIONS OR RECONSTRUCTIONS FOR ALL LANES FOR BIG ISLAND



Pavement inventory tool

Main efforts to date

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2. Material characterization
   - HMA dynamic modulus model and permanent deformation models
   - Resilient modulus models for fine grained soils and limited characterization of coarse graded materials and some reclaimed materials
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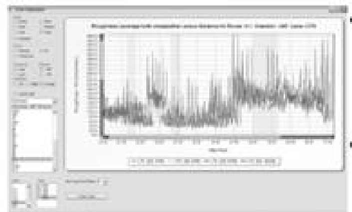
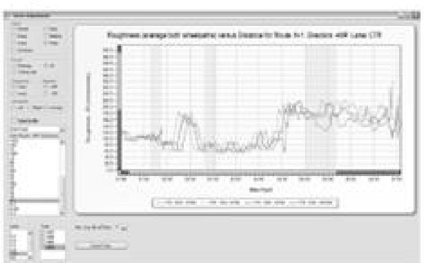
Roughness Processing Tool



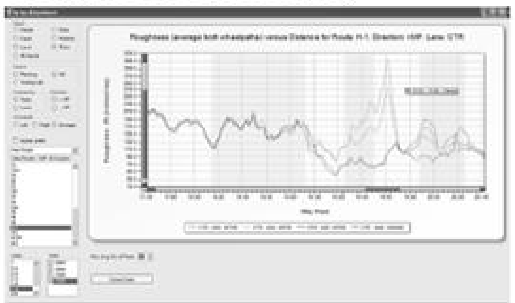
- Raw data (IRI over 0.01-mi segments) are very noisy and difficult to compare for different years
- Distance Measurement Instruments not always properly calibrated → need for series correction

Smoothing allows a better comparison of series over time



Series Correction

Roughness Processing



Summary

- Significant progress has been achieved
- However, obtaining good quality data for local calibration of deterioration models is still challenging

Utah's Efforts to Implement the Mechanistic–Empirical Pavement Design Guide
Asphalt Binder Uniformity Study

RAJ DONGRÉ
Dongré Laboratory Services, Inc.

In this study, the effect on pavement performance of day-to-day production uniformity of asphalt binder supply during construction was determined. The latest available version (0.900, August 2006) of the newly developed NCHRP project 1-37A, AASHTO's *Mechanistic–Empirical Pavement Design Guide* (MEPDG), was used for this purpose, and results are described in this report. Utah Department of Transportation (DOT) engineers wanted to limit the amount of performance grade (PG) variation of the asphalt binder supply during construction if the results showed significant effects on predicted pavement performance. Two existing pavement structures (weak and strong) were selected by Utah DOT for this study. Original asphalt binder grades for each structure were recreated along with additional formulations that simulated variation in grades. Two suppliers were asked to formulate six PG binders each, (three each for strong and weak structures) giving a total of 12 asphalt binders. Aggregates from the same quarry as the original aggregates were collected and hot-mix samples were compacted in the gyratory compactor using the appropriate mix designs. From these compacted samples, smaller simple performance test (SPT) specimens were cored and tested to obtain dynamic modulus (E^*) values for MEPDG analysis. Binder properties required for MEPDG were also determined in the laboratory. Traffic and climate data was obtained from Utah DOT. A total of 366 different designs were analyzed to complete the MEPDG portion of this study. All levels of MEPDG (Level 1, Level 2, and Level 3) were used in the analysis.

Analysis showed that PG uniformity of the asphalt binder supply does not show a significant sensitivity to predicted performance of regular or value engineered pavements. This finding is based on evaluation of all distresses predicted by MEPDG, such as, but not limited to, rutting, fatigue and thermal cracking. Consequently there was no justification found to develop limits on uniformity of PG of the asphalt binder supply. New hot-mix asphalt (HMA) mix-design requirement cannot be justified for the within-PG variation of asphalt binder supply observed at Utah DOT in the past 4 years.

UTAH's Efforts to Implement the MEPDG
"Asphalt Binder Uniformity Study"

Raj Dongré
Dongre Laboratory Services Inc.

Acknowledgements

- Cameron Petersen – Retired UDOT
- Tim Biel – Ex UDOT
- Kevin VanFrank – UDOT
- Ray Bonaquist – AAT
- Gregg Larson – MEPDG Support

Outline

- What is "Asphalt Binder Uniformity"?
- Why Worry About it?
  - Problem statement
- Approach – Use of MEPDG
  - Materials and Methods
- Findings
- Implications and Implementation

Asphalt Binder Uniformity

- The day to day variation in "true PG Grade" of production asphalt binder during a pavement construction project (w.r.t mix-design)
- For Example: Project Binder: PG 64-28
- A PG 64-28 binder can have "true PG grade" in the range: PG 64.0 – 28.0 to PG 69.9 – 33.9
- There is a 6°C range between different climate zones

Why Worry About It?

- Effect on Performance
- Value Engineered Pavements

Problem Statement

- UDOT wants to establish variation limits on the project binder PG Grade with respect to the mix-design binder PG Grade.
- Variation limits shall be determined by considering
  - Sensitivity to performance
    - Regular UDOT Pavement Structures
    - Thickness reduction (Value Engineering)

Approach

- Use the New MEPDG Software
  - Level 1
    - Hot-Mix SPT Data
    - Binder G* Data
    - Low-Temperature Compliance (3 temperatures)
  - Level 2
    - Hot-Mix Volumetric Info + Witczak Model
    - Binder G* Data
    - Low-Temperature Compliance (1 temperature)
  - Level 3
    - Hot-Mix Volumetric Info + Witczak Model
    - Binder PG Grade

Approach……

- Use UDOT Performance Threshold Limits
- Compute No. of Years (Life) to Reach Threshold
- Determine Acceptable Variation in Life
- Determine Binder Uniformity Limits

Interstate Pavements
Strong Rehab

Years to (in UDOT Units)						
Rutting	Fatigue Longitudinal Cracks/500 ft			Alligator ft/500 ft	Thermal cracks/500 ft	IRI
0.4 in	30	200	600	100	20	130
Years to (in MEPDG Units)						
Rutting	Fatigue Longitudinal Cracks/500 ft			Alligator %	Thermal cracks ft/mi	IRI
0.4	316.8	2112	6336	20	211.2	130

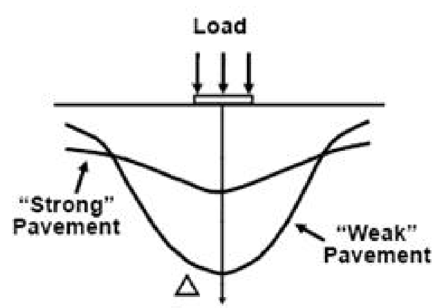
State Route Pavements
Weak New Construction

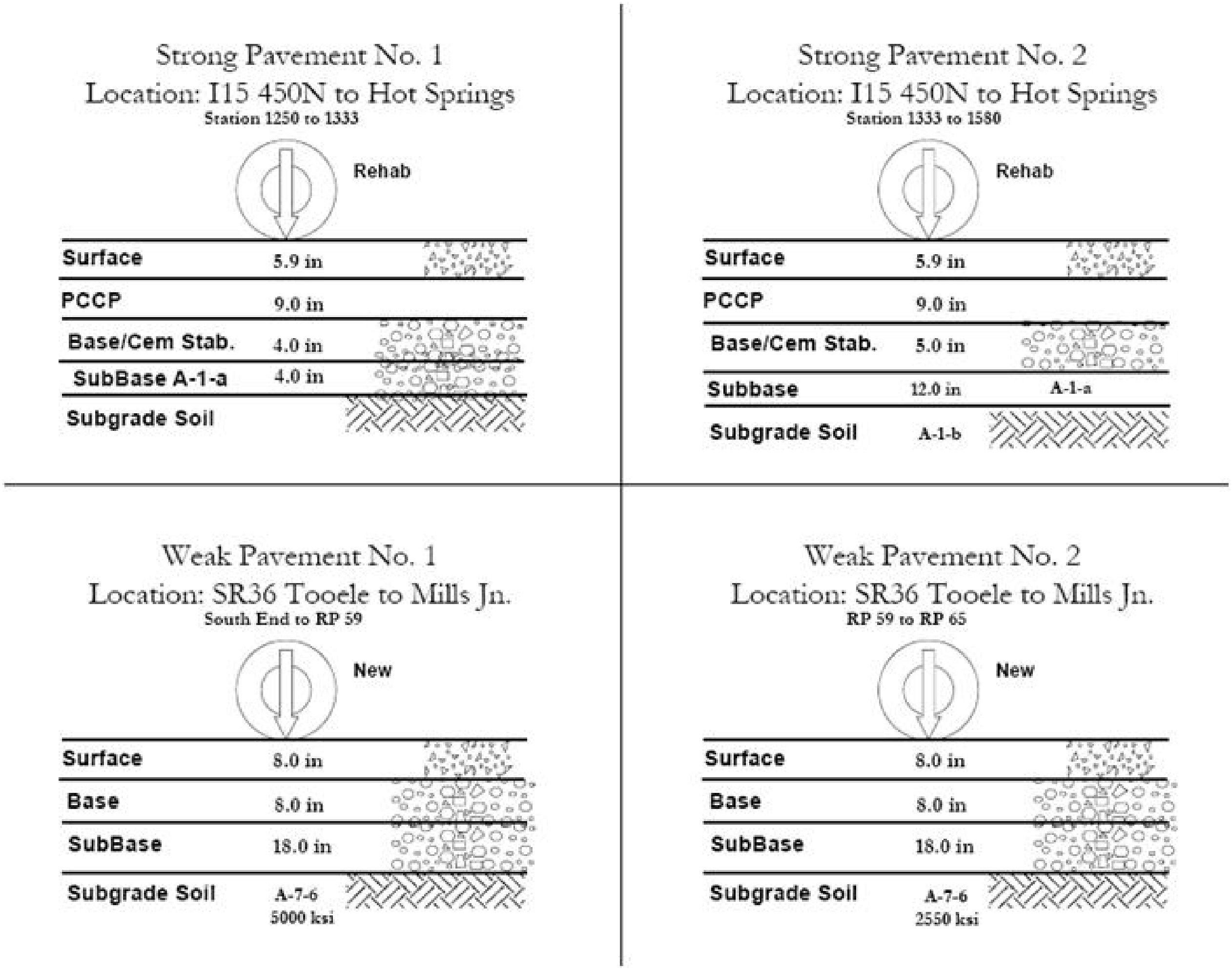
Years to (in UDOT Units)						
Rutting	Fatigue Longitudinal Cracks/500 ft			Alligator ft/500 ft	Thermal cracks/500 ft	IRI
0.5 in	40	250	650	100	20	140
Years to (in MEPDG Units)						
Rutting	Fatigue Longitudinal Cracks/500 ft			Alligator %	Thermal cracks ft/mi	IRI
0.5 in	422.4	2640	6864	20	211.2	140

Materials and Methods

- Two Suppliers
- Six Specially Formulated Asphalt Binders
  - PG 64.1-34, PG 67-34, PG 69.9-34
  - PG 64.1-28, PG 67-28, PG 69.9-28
- Two Mix Designs with 15% RAP
- Two Existing UDOT Pavement Structures
  - Strong
  - Weak

Strong vs. Weak Pavement




Strong Pavement No. 1
Location: I15 450N to Hot Springs
Station 1250 to 1333
Rehab
Surface
5.9 in
PCCP
9.0 in
Base/Cem Stab.
4.0 in
SubBase A-1-a
4.0 in
Subgrade Soil
Strong Pavement No. 2
Location: I15 450N to Hot Springs
Station 1333 to 1580
Rehab
Surface
5.9 in
PCCP
9.0 in
Base/Cem Stab.
5.0 in
Subbase
12.0 in
A-1-a
Subgrade Soil
A-1-b
Weak Pavement No. 1
Location: SR36 Tooele to Mills Jn.
South End to RP 59
New
Surface
8.0 in
Base
8.0 in
SubBase
18.0 in
Subgrade Soil
A-7-6
5000 ksi
Weak Pavement No. 2
Location: SR36 Tooele to Mills Jn.
RP 59 to RP 65
New
Surface
8.0 in
Base
8.0 in
SubBase
18.0 in
Subgrade Soil
A-7-6
2550 ksi

Value Engineering

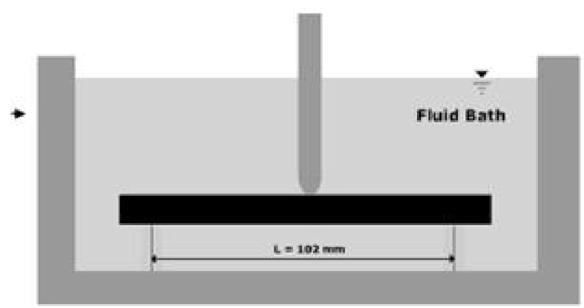
- Strong No. 1 and No. 2
  - 5.9, 4.9, 3.9, 2.9 inches AC Surface
- Weak No. 1 and No. 2
  - 8.0, 7.0, 6.0, 4.0 inches AC surface

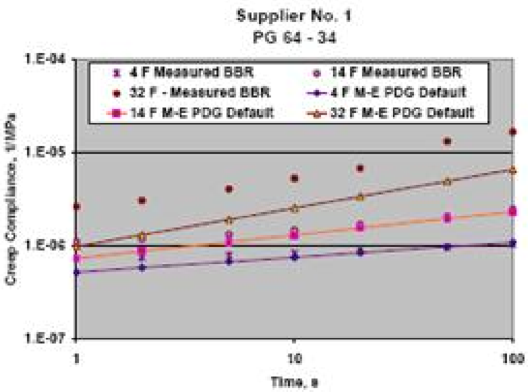
Testing Required

- MEPDG Level 1 Inputs
  - Hot-Mix Asphalt (AMPT)
    - Mix Designs
    - E* Master Curves and Creep Compliance
    - Variability
  - Binder Properties (DSR)
    - Level 1 and Level 2 Inputs
- MEPDG Analysis – Levels 1, 2, and 3
  - A total of 366 MEPDG analysis runs!
  - A lot of Analysis Plots!

Low Temp. Creep Compliance

- In Level 1
  - MEPDG requires IDT at 4, 14, and 32 °F
  - This project – Hot-Mix Slivers (0.5" X 0.25" X 5")
  - Used BBR (from binder low temp PG grading!)
- In Level 2
  - MEPDG requires IDT at only 14 °F
  - This project – Hot-Mix Slivers (0.5" X 0.25" X 5")
  - Used BBR (from binder low temp PG grading!)
- In Level 3
  - MEPDG uses default Creep Compliance Values at 4, 14, and 32 °F





Low Temp. Strength

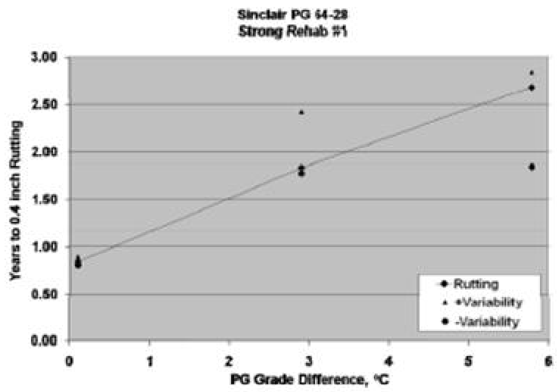
- In all Levels
  - MEPDG requires IDT at only14 °F
  - This project – Hot-Mix Slivers (0.5" X 0.25" X 5")
  - Used BBR (from binder low temp PG grading!)
- Mihai Marasteanu from Univ. of MN
- Comparison!!
  - At 14 °F
    - Measured BBR Sliver Strength = 123 psi
    - <u>MEPDG Default strength = 442.5 psi</u>
      - <u>This project has 15 % RAP</u>
      - <u>M-E PDG Default assumes no RAP</u>

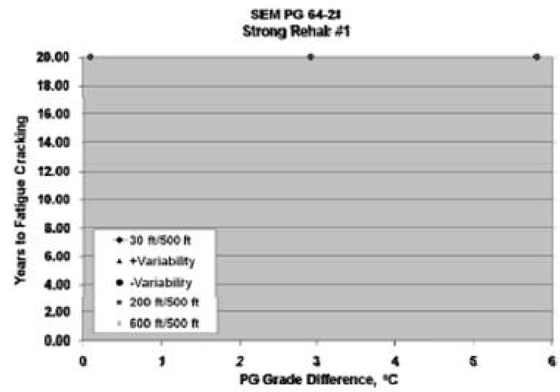
MEPDG Analysis

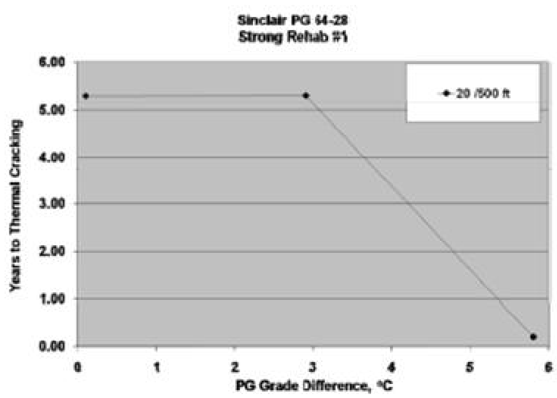
Results

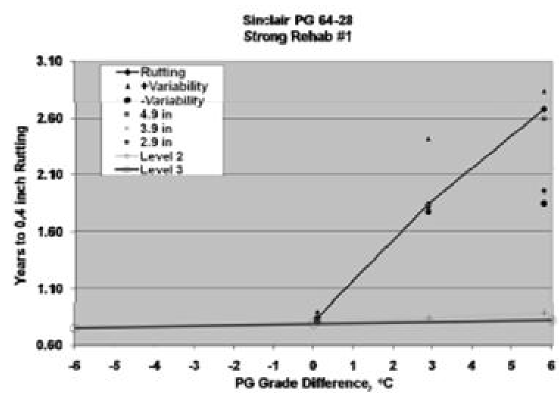
Findings

- The variation within six degrees of the PG Grading system does not show a significant sensitivity to performance of regular or value engineered pavements
  - Rutting, Fatigue and Thermal Cracking
- The above statement is based on
  - M-E PDG analysis of four UDOT pavement structures:
    - 2 strong pavement structures - rehabs
    - 2 weak pavement structures – new construction


Sinclair PG 64-28
Strong Rehab #1
Years to 0.4 inch Rutting
PG Grade Difference, °C
Rutting
+Variability
-Variability


SEM PG 64-28
Strong Rehab #1
Years to Fatigue Cracking
PG Grade Difference, °C
30 ft/500 ft
+Variability
-Variability
200 ft/500 ft
600 ft/500 ft

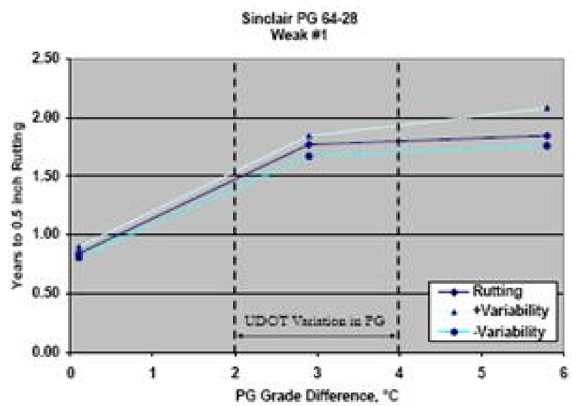

Sinclair PG 64-28
Strong Rehab #1
Years to Thermal Cracking
PG Grade Difference, °C
20 /500 ft


Sinclair PG 64-28
Strong Rehab #1
Years to 0.4 inch Rutting
PG Grade Difference, °C
Rutting
+Variability
-Variability
4.9 in
3.9 in
2.9 in
Level 2
Level 3

Parameter	UDOT Spec. Value 0% Penalty	Mixed Weibull		Normal Distribution			
		lower 2.5%	upper 2.5%	Mean	std dev	lower bound	upper bound
ORG G*, kPa	1.25	1.28	2.75	1.65	0.39	0.90	2.41
phase angle 92 rule	75	75	64	70	3	76	65
phase angle 98 rule	72	71	62	70	3	75	65
RTFO G*, kPa	2.2	2.8	7.9	4.3	1.2	1.9	6.8
Example - PG 64-34	PG 63.9-33.5	PG 63.95	PG 70			PG 61.5	PG 69.0

More Often

PG 67 - PG 68



Conclusions

- MEPDG is not sensitive to within grade (6 °C) changes in high temperature PG
- Reduction in HMA layer thickness (Value Engineering) is unaffected by within grade (6 °C) variation in high temperature PG

Recommendations

- Need local MEPDG calibration values for Utah
- Re-run the 366 files (in batch mode!!) using new calibrations
- The analysis database generated in this study may be used as part of sensitivity study needed to do local calibrations
- Based on this Study
  - No justification to trigger new HMA mix-design for the within grade variation observed at UDOT in the past four years

More Information on UDOT's MEPDG Implementation Efforts

- UDOT MEPDG User's Guide
  - Report No. UT-09.11a: Draft User's Guide for UDOT Mechanistic-Empirical Pavement Design .
- Calibration and Validation Studies
  - Report No. UT-09.11: Implementation of the Mechanistic-Empirical Pavement Design Guide In Utah: Validation, Calibration, and Development of the UDOT MEPDG User's Guide .
- Staff Training -- Pavement Design using MEPDG

Virginia Mechanistic–Empirical Pavement Design Guide Research

Influence of Traffic and Materials Research

BRIAN DIEFENDERFER
Virginia Transportation Research Council

This presentation gives an overview of the research underway at the Virginia Transportation Research Council related to traffic and materials inputs for use with the *Mechanistic–Empirical Pavement Design Guide* (MEPDG). The presentation lists and shows examples of those traffic and materials inputs that are considered significant with respect to the MEPDG-predicted pavement conditions. Various methods to determine the significance of the inputs (by statistical or practical consideration of the predicted pavement conditions) are discussed. Two methods of calculating a normalized difference statistic are presented along with a brief description of regression analyses that could serve as examples for statistical-based analysis. Practical-based methods were suggested to include consideration of the time to failure as it relates to the timing of pavement maintenance activities. The presentation discussed preliminary findings in terms of a comparison of the predicted pavement condition to expected values based on field experience. The need for local calibration was discussed as a future need.

(Editor's Note: Virginia Transportation Research Council is now the Virginia Center for Transportation Innovation and Research.)

VTRC
Virginia Transportation Research Council

Virginia MEPDG Research:
Influence of Traffic & Materials Inputs

Brian Diefenderfer, PhD, PE January 10, 2010

A partnership of the Virginia Department of Transportation and the University of Virginia since 1948

Presentation Outline

- Introduction to MEPDG *(very brief)*
- Description of current studies
  - HMA materials inputs
  - Traffic inputs
- Significance of different inputs
- Some findings
- Next steps

Acknowledgements

- Bryan Smith
  - South Carolina DOT (former graduate student at University of Virginia)
- Alex Apeagyei & Stacey Diefenderfer
  - Virginia Transportation Research Council
- Mohamed Elfino, Trenton Clark, Affan Habib, F. Hamlin Williams
  - Virginia Department of Transportation

Introduction – MEPDG 101

- Analysis software
- Mechanistic and empirical
- Mechanistic
  - pavement response from environmental and traffic loading
- Empirical
  - predicts pavement condition from response to loading through distress transfer functions

VDOT MEPDG Input Studies

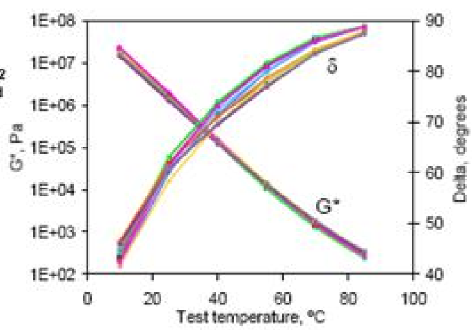
- HMA mixture and binder data
  - default vs. mixture specific |E*|
  - |G*| and δ vs. PG binder grading
  - influences from gradation, binder grade, aggregate type

VDOT MEPDG Input Studies

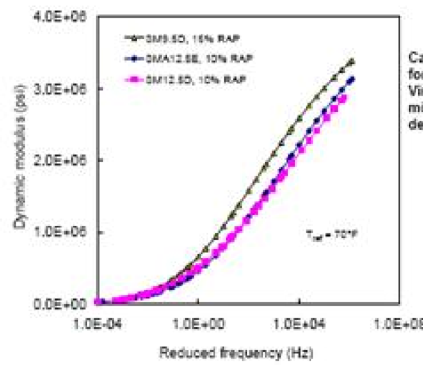
- Traffic data
  - default vs. site specific
    - axle-load spectra, monthly adjustment factor, class distribution factor, number of axles per truck class
  - local WIM stations (level 1 data)
    - 8 interstate
    - 7 primary
    - calibrated, ASTM Type 1

Binder Data

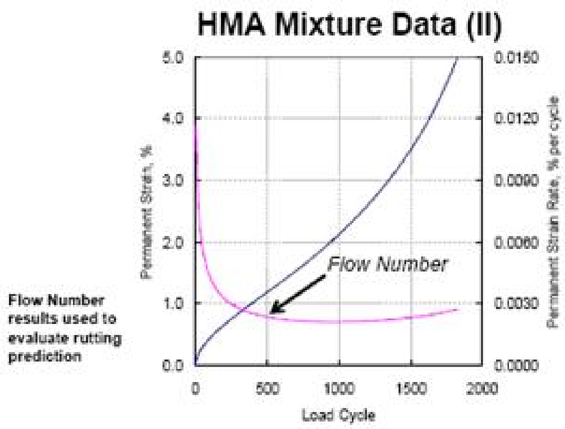
11 PG 64-22 RTFO-aged binders

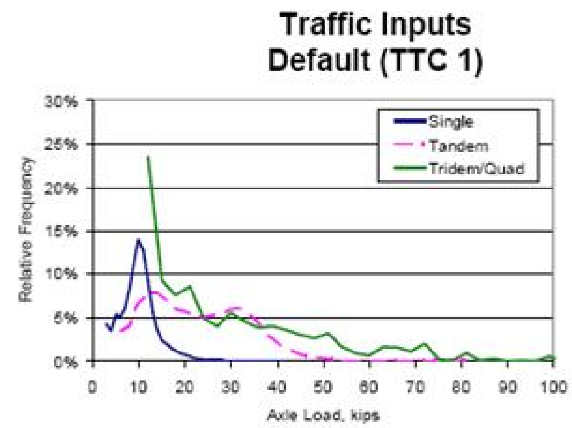


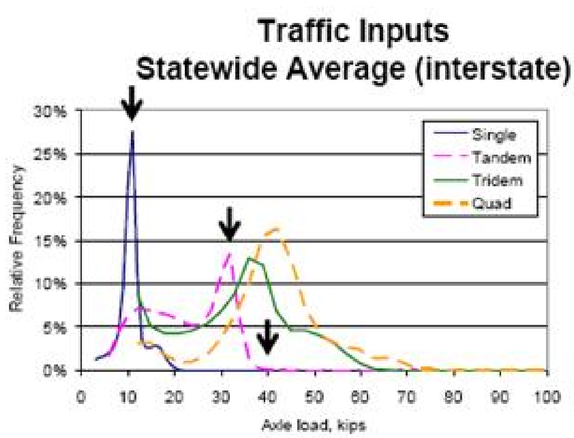
HMA Mixture Data (I)



Catalogue of E* for typical Virginia HMA mixtures is being developed







Significance of Inputs

- Evaluating predicted distresses
  - statistical vs. practical
- Other thoughts…
  - definition of failure
  - deterioration model variability

Significance of Inputs

- **Statistical methods**
  - **Normalized difference**
    - Tran and Hall (2007), TRR 2037 (2 papers)
      - traffic data

$$ND = \frac{|x_{default} - x_{statewide}|}{x_{default}} \times 100$$

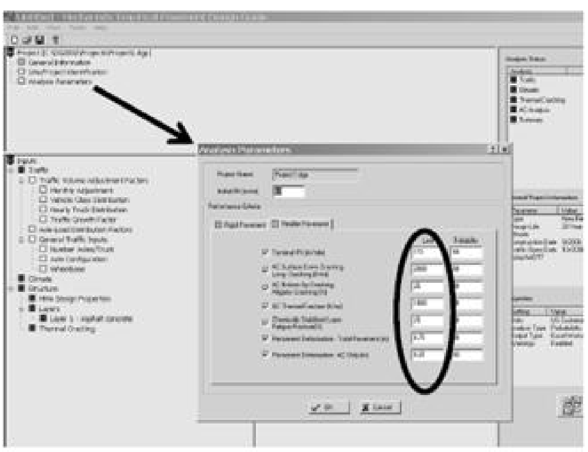
- $X_{default}$ = prediction using default traffic inputs
- $X_{statewide}$ = prediction using statewide traffic inputs

Significance of Inputs

- **Statistical methods**
  - **Normalized difference**
    - *Smith and Diefenderfer (paper 10-1288)*
      - considers user-defined performance criteria (or definition of failure)

$$ND = \frac{x_{default} - x_{site}}{x_{perf}} \times 100$$

- $X_{default}$ = prediction using default traffic inputs
- X_{site} = prediction using site-specific traffic inputs
- X_{perf} = user-defined performance criteria

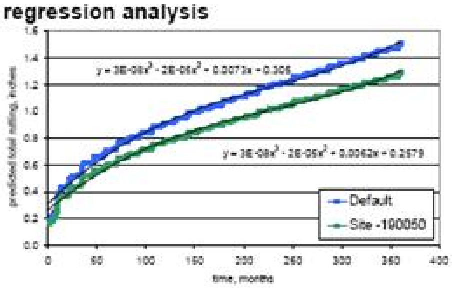


Significance of Inputs

- **Statistical methods**
  - **considering deterioration model variability**
    - calculate normalized difference, including the user-defined performance criteria (UDPC)
    - compare with the calculated coefficient of variation of the distress prediction model
      - SD / UDPC
  - **what indicates the inputs are statistically different?**
    - ND > CoV, others?

Significance of Inputs

- Statistical methods
  - regression analysis



Significance of Inputs

- Practical methods
  - time to failure
    - what difference in predicted time to failure indicates the inputs are practically different?
      - a few months, a year, more?

Where are we now?

- Traffic inputs
  - site-specific values (flexible pavement)
    - see paper 10-1288 "Analysis of Virginia-Specific Traffic Data for Use with the MEPDG"
    - session 620, Wednesday 8AM
- Materials inputs
  - ongoing…
  - evaluating the results of using different input levels and materials data

Preliminary Findings

- Traffic inputs
- As compared to local experience
  - rigid pavements
    - less predicted distress (high MOR)
  - flexible pavements
    - more predicted rutting
    - less predicted fatigue cracking

Next Steps

- **Local calibration**
  - **current work shows where efforts are needed for certain deterioration and pavement types**

disclaimer: may not be the same for everyone!

Conclusion

TRENTON CLARK
Virginia Department of Transportation

This workshop's mission was to inform the pavement engineering community on the completed and on-going efforts related to assessing the sensitivity of the *Mechanistic–Empirical Pavement Design Guide* (MEPDG). Specifically, the workshop was concerned with those parameters that had an impact on flexible pavement analysis and design. Many transportation agencies have been involved in various studies to look at particular parts of the MEPDG, but much of this work had not been compiled into a single document. As such, a workshop was proposed by the Flexible Pavement Design (AFD60) committee and approved by TRB to look at the flexible pavement sensitivity analysis in the MEPDG. Once accepted, a planning team was established to develop the workshop by collecting and disseminating the work done by transportation agencies.

The workshop planning team had two primary goals:

1. Take a snapshot of the current implementation status of transportation agencies through a questionnaire and reporting on workshops hosted by FHWA and
2. Invite transportation agencies based on their responses to the questionnaire to present on a specific subject or overall research implementation effort.

Additionally, the planning team wanted to capture and present current NCHRP research related to flexible pavement analysis and performance. Workshop Session 143, held in January 2010, met these goals by providing presentations on various efforts related to understanding the sensitivity of flexible pavement performance using the MEPDG inputs.

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