# AASHTO PAVEMENT ME NATIONAL USERS GROUP MEETINGS

## TECHNICAL REPORT: FIRST ANNUAL MEETING—INDIANAPOLIS, IN DEC 14-15, 2016

**Prepared For:**
Federal Highway Administration
Office of Acquisition and Grants Management
1200 New Jersey Ave., SE
Washington, DC 20590


**Submitted By:**
Applied Pavement Technology, Inc.
115 West Main Street, Suite 400
Urbana, IL 61801
217-398-3977
www.appliedpavement.com


**Submission Date:**
February 8, 2017

applied pavement TECHNOLOGY

providing engineering solutions to improve pavement performance

# TABLE OF CONTENTS

# LIST OF TABLES



# LIST OF FIGURES

# 1. INTRODUCTION

## Background

In 2008, the American Association of State Highway and Transportation Officials (AASHTO) published an interim edition of the *Mechanistic-Empirical Pavement Design Guide (MEPDG): A Manual of Practice*. That groundbreaking document presented the first mechanistic-empirical (ME) pavement design procedure based on nationally calibrated pavement performance prediction models (AASHTO 2008). A second edition of the *Manual* containing updated information, additional guidance, and improved nationally calibrated models was published in 2015 (AASHTO 2015).

An accompanying software program, AASHTOWare *Pavement ME Design*, was developed and released in 2011. Multiple updates have been made to the software since its initial release, with the latest version (v2.3) made available in 2016. Together, the MEPDG and the AASHTOWare software provide an improved process for conducting pavement analysis and for developing designs based on M-E principles.

Implementation of the MEPDG has been proceeding throughout North America since its release. A 2014 synthesis conducted by the National Cooperative Highway Research Board (NCHRP) reported that three States had fully implemented the procedure and that 30 additional States and several Canadian provinces had planned to implement it within 5 years (Pierce and McGovern 2014). A 2015 FHWA report on the AASHTO MEPDG Regional Peer Exchange Meetings put the number of implementing agencies at 11 and the number of agencies evaluating the procedure at 33 (Pierce and Smith 2015). The number of adopting agencies continues to grow, but many are still working on key parts of the process, including developing appropriate design inputs, establishing material and traffic databases, and training staff or consultants in the proper use of the procedure. Additionally, while the AASHTO *Guide for the Local Calibration of the MEPDG* was published in 2010, most agencies are actively engaged in calibrating the ME performance models to local conditions, policies, and materials.

In September 2013, the Wisconsin Department of Transportation (WisDOT) initiated an outreach program to conduct an MEPDG implementation peer exchange meeting with state highway agencies (SHAs) in AASHTO Region 3 (covering Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Missouri, Ohio, and Wisconsin). The intent of that peer exchange was to share experiences with five key aspects of MEPDG implementation: calibration, materials testing, traffic data, design acceptance, and deployment (WisDOT 2013). The Wisconsin peer exchange meeting proved successful in providing SHAs with a platform for exchanging and sharing ideas, experiences, tips, and concerns in relation to implementing the MEPDG.

## FHWA Peer Exchange Meetings

In 2014, FHWA in conjunction with AASHTO and others sponsored four Wisconsin-like peer exchange meetings to foster the sharing of SHA experiences and to facilitate ME implementation effort. These meetings were held at the following locations and dates:

- Southeast AASHTO Region 2, Atlanta, Georgia, November 5-6, 2014.
- Southwest AASHTO Region 4, Phoenix, Arizona, January, 20-22, 2015.

- Northwest AASHTO Region 4, Portland, Oregon, April 14-15, 2015.
- Northeast AASHTO Region 1, Albany, New York, May 13-14, 2015.

The results of the four peer exchange meetings were summarized in an FHWA technical report titled *AASHTO MEPDG Regional Peer Exchange Meetings* (Pierce and Smith 2015). This report can be accessed at https://www.fhwa.dot.gov/pavement/dgit/hif15021.pdf.

## National Users Group Meetings

To promote the formation of a national ME users group that can facilitate the more rapid adoption of the MEPDG and the AASHTOWare *Pavement ME Design* software, Transportation Pooled Fund study TPF-5(305) (Regional and National Implementation and Coordination of ME Design) is now sponsoring three ME implementation meetings to be held annually at the national level. The first of these meetings took place on December 14-15, 2016 in Indianapolis, Indiana.

This report documents the results of the first meeting and includes all pertinent materials and information shared in the meeting and covers the various technical topics presented and discussed by the participants. It also discusses key take-aways from the meeting and the proposed next steps for aiding and facilitating the implementation of ME pavement design within highway agencies.

### Meeting Goals

The overall goal of the AASHTO Pavement ME National Users Group meetings is to provide SHAs, Provincial Highway Agencies (PHAs), and other stakeholders with a forum for the exchange of information and ideas. Specific goals include updating participants on enhancements to the ME design procedure and software, providing participants with an opportunity to discuss issues related to the procedure and software, providing demonstration-based training on the latest version of the software, and identifying future training, software, and research needs.

### Participants

A total of 68 attendees participated in the first annual Pavement ME Users Group meeting, including representatives from 30 states, four Canadian provinces, FHWA, AASHTO, five consulting firms, and two universities. The meeting participants are listed in Appendix A.

### Agenda

The meeting agenda is provided in Appendix B.

### Speakers and Presenters

In addition to introductory and opening remarks by Mr. Chris Wagner (FHWA ME Pooled Fund Manager), and informational messages from Mr. John Donahue (Missouri DOT, Vice-Chair of AASHTO Joint Technical Committee on Pavements [JTCOP] and AASHTOWare Pavement ME Design Task Force) and Mr. Felix Doucet (Quebec MOT, Canadian liaison to the Pavement ME Design Task Force), the meeting featured presentations from 20 participants. The presentations materials are provided in chronological order in Appendix C.

# 2. PRE-MEETING SURVEY

One week before the ME Users Group meeting, SHA/PHA participants were asked to complete a short on-line survey pertaining to their agency's ME design practices. The intent of the survey was to stimulate thoughts in preparation for the meeting and to generate information to help guide the meeting discussions. Responses were received from a total of 25 agencies (22 SHAs, 3 PHAs) and a summary of the results are presented in tables 1 through 10. Although the number of respondents represent only about half of the U.S. states, it is clear that several agencies have already implemented *Pavement ME Design* or are getting close to doing so. Key challenges include the characterization of materials, including the use of backcalculation data, and local calibration and validation. A major concern is the ability to handle or adjust to dynamic changes in software releases.

Table 1. Implementation status.

| Question | Total Responses | Yes | No |
|---|---|---|---|
| *1a. Has your agency implemented Pavement ME Design for the design of asphalt pavements and overlays?* | 25 | 7 | 18 |
| *1b. If No, does your agency intend to implement it and if so, by what year?* | 18 | 2017 (7)<br>2018 (4)<br>2020 or later (3)<br>Not sure (1) | 3 |
| *2a. Has your agency implemented Pavement ME Design for the design of concrete pavements and overlays?* | 25 | 6 | 19 |
| *2b. If No, does your agency intend to implement it and if so, by what year?* | 19 | 2017 (7)<br>2018 (5)<br>2020 or later (3)<br>Not sure (1) | 3 |

Table 2. Implementation status by pavement type.

| Question | Total Responses | Implemented | Planning to Implement |
|---|---|---|---|
| *3. For which types of asphalt pavements has your agency implemented or plan to implement Pavement ME Design?* | | | |
| • New Conventional (Thin or Nominal HMA on unbound base) | 22 | 7 | 15 |
| • New Deep-Strength (Thick HMA on unbound aggregate base) | 22 | 8 | 14 |
| • New Full-Depth (HMA on stabilized or unstabilized subgrade) | 19 | 7 | 12 |
| • New Semi-Rigid (HMA on stabilized base/subbase) | 16 | 5 | 11 |
| • HMA Overlay on Existing Asphalt Pavement | 22 | 4 | 18 |
| • HMA Overlay on Existing Intact or Fractured Concrete Pavement | 20 | 2 | 18 |
| *4. For which types of concrete pavements has your agency implemented or plan to implement Pavement ME Design?* | | | |
| • New Jointed Plain Concrete (JPC) | 22 | 8 | 14 |
| • New Continuously Reinforced Concrete (CRC) | 8 | 2 | 6 |
| • JPCP Overlay on Existing Pavement | 16 | 2 | 14 |
| • CRCP Overlay on Existing Pavement | 4 | 1 | 3 |

Table 3. Implementation challenges.

| Question | Total Responses |
|---|---|
| *5. What has been the most difficult or challenging technical aspect of implementation (select top two)?* | |
| • Compatibility of performance measures and threshold criteria | 5 |
| • Availability of data to adequately characterize inputs | 8 |
| • Characterization of traffic | 3 |
| • Characterization of climate | 1 |
| • Characterization of subgrade, subbase, and/or base material properties | 4 |
| • Characterization of HMA material properties | 3 |
| • Characterization of PCC material properties | 0 |
| • Backcalculation analysis for characterizing existing pavement and subgrade properties | 1 |
| • Sensitivity testing of key design inputs | 2 |
| • Availability of performance data to adequately perform local calibration and verification | 7 |
| • Local calibration and verification of performance model coefficients | 12 |
| • Other:<br>➢ Data collected and available is not in a compatible format for input into *Pavement ME Design* software.<br>➢ The distress models need to be updated. | 2 |

Table 4. Hierarchical input levels.

| Question | Total Responses | Level 1 | Level 2 | Level 3 |
|---|---|---|---|---|
| *6. What hierarchical input level does your agency use for the following key input parameters (Level 1=site/project specific, Level 2=estimated from correlations or regional-specific, Level 3=global/default)* | | | | |
| • Truck Volume Distribution | 24 | 10 | 10 | 4 |
| • Lane and Directional Distributions | 24 | 11 | 9 | 4 |
| • Axle Load Distributions (single, tandem, tridem) | 24 | 8 | 6 | 10 |
| • Subgrade Resilient Modulus | 24 | 6 | 12 | 6 |
| • Unbound Base/Subbase Modulus | 24 | 4 | 14 | 6 |
| • Chemically Stabilized Layer Modulus | 21 | 1 | 10 | 10 |
| • HMA Dynamic Modulus | 23 | 4 | 10 | 9 |
| • HMA Creep Compliance and Indirect Tensile Strength | 23 | 3 | 6 | 14 |
| • HMA Volumetric Properties | 23 | 4 | 10 | 9 |
| • PCC Elastic Modulus | 23 | 2 | 10 | 11 |
| • PCC Flexural Strength | 23 | 1 | 9 | 13 |
| • PCC Coefficient of Thermal Expansion | 23 | 4 | 8 | 11 |
| • Existing Pavement Moduli | 20 | 2 | 7 | 11 |

Table 5. Condition threshold levels.

| Question | Total Responses | Default Thresholds | Agency Thresholds/Values |
|---|---|---|---|
| *7a. Does your agency use the Pavement ME Design default threshold levels (table 7.1 of 2015 MEPDG Manual of Practice) for distress and smoothness or agency-selected values?* | 24 | 5 | 19 |
| *7b. If agency-selected values, what are the values used for high-type Interstate/Freeway facilities?* | | | |
| • HMA smoothness (IRI), in/mi | 17 | | <50 (1)<br>51-100 (1)<br>101-125 (2)<br>126-150 (3)<br>151-175 (6)<br>176-200 (2)<br>TBD or Varies (2) |
| • HMA alligator (bottom-up) cracking, % lane area | 16 | | 0-5% (2)<br>6-10% (7)<br>15% (2)<br>20% (2)<br>25 ft/mile (1)<br>TBD or Varies (2) |
| • HMA total rut depth, in | 17 | | 0.00-0.25 (2)<br>0.26-0.50 (9)<br>0.51-0.75 (4)<br>TBD or Varies (2) |
| • HMA transverse thermal cracking, ft/mi | 16 | | 15 (1)<br>700 (2)<br>1000-1188 (7)<br>1500 (3)<br>N/A (1)<br>TBD or Varies (2) |
| • JPC / CRC smoothness (IRI), in/mi | 16 | | 50-100 (2)<br>101-150 (3)<br>151-175 (6)<br>176-200 (3)<br>TBD or Varies (2) |
| • JPC mean joint faulting, in | 15 | | 0.118 (2)<br>0.12 (6)<br>0.125 (3)<br>0.15 (1)<br>0.2 (1)<br>TBD or Varies (2) |
| • JPC transverse slab cracking, % | 16 | | 1.5 (1)<br>5-9 (3)<br>10 (6)<br>15 (3)<br>30 (1)<br>TBD or Varies (2) |

Table 6. Local calibration and use of locally or nationally calibrated models.

| Question | Total Responses | No | Yes, but use default values | Yes |
|---|---|---|---|---|
| *8. Has your agency conducted a local calibration?* | 25 | 11 | 3 | 11 |
| | **Total Responses** | **National** | **Locally Calibrated** | **Not Applicable (model not used)** |
| *9. Does your agency use the nationally or locally calibrated performance prediction models?* | | | | |
| • HMA smoothness (IRI) | 24 | 9 | 11 | 4 |
| • HMA longitudinal (top-down) cracking | 24 | 11 | 6 | 7 |
| • HMA alligator (bottom-up) cracking | 24 | 9 | 11 | 4 |
| • HMA transverse thermal cracking | 24 | 10 | 7 | 7 |
| • HMA reflective cracking | 24 | 11 | 6 | 7 |
| • HMA rutting (asphalt layer only) | 24 | 7 | 12 | 5 |
| • HMA rutting (total) | 24 | 8 | 11 | 5 |
| • JPC smoothness (IRI) | 23 | 10 | 10 | 3 |
| • JPC transverse slab cracking | 23 | 11 | 9 | 3 |
| • JPC mean joint faulting | 23 | 10 | 10 | 3 |
| • CRC smoothness (IRI) | 23 | 7 | 2 | 14 |
| • CRC punchouts | 21 | 6 | 2 | 13 |

Table 7. Incorporation of MERRA.

| Question | Total Responses | Yes | No |
|---|---|---|---|
| *10a. Has your agency incorporated MERRA weather data into Pavement ME Design?* | 24 | 3 | 21 |
| *10b. If Yes, has your agency evaluated or sensitivity-tested the effect of using MERRA data versus ground-based weather data on ME performance predictions?* | 3 | 1 | 2 |

Table 8. Traffic database status.

| Question | Total Responses | Yes | No |
|---|---|---|---|
| *11a. Has your agency developed a comprehensive traffic database for use in Pavement ME Design?* | 24 | 12 | 12 |
| *11b. If Yes, does the database include Level 1 project-specific vehicle class distribution inputs and/or Level 2 vehicle class distribution factors (for truck traffic clusters defined by location and highway functional class)?* | | | |
| • Level 1 project-specific vehicle class distribution | 4 | | |
| • Level 2 vehicle class distribution factors for truck traffic clusters | 10 | | |

Table 9. Use of FWD backcalculation.

| Question | Total Responses | Yes | No |
|---|---|---|---|
| *12a. Does your agency use backcalculation of FWD data to characterize the existing pavement and subgrade for rehabilitation design?* | 23 | 10 | 13 |
| *12b. If Yes, what flexible pavement backcalculation programs/methods are used to establish the necessary Pavement ME Design inputs?* | | | |
| • BOUSDEF | 0 | | |
| • ELMOD | 3 | | |
| • ELSDEF | 0 | | |
| • EVERCALC | 2 | | |
| • MODULUS | 2 | | |
| • WESDEF | 0 | | |
| • MODCOMP | 0 | | |
| *12b. If Yes, what rigid pavement backcalculation programs/methods are used to establish the necessary Pavement ME Design inputs?* | | | |
| • AREA method | 2 | | |
| • Best-Fit method | 2 | | |
| *12db If Yes, what composite pavement backcalculation programs/methods are used to establish the necessary Pavement ME Design inputs?* | | | |
| • Outer AREA method | 1 | | |
| • Best-Fit method | 1 | | |

Table 10. Materials database/library status.

| Question | Total Responses | Yes | No |
|---|---|---|---|
| *13. Has your agency developed a materials database or library for quick and reliable establishment of Pavement ME Design inputs?* | | | |
| • Subgrade (including chemically stabilized) | 23 | 17 | 6 |
| • Untreated Base/Subbase | 23 | 15 | 8 |
| • Treated Base/Subbase | 22 | 8 | 14 |
| • HMA | 23 | 18 | 5 |
| • PCC | 24 | 15 | 9 |

Table 11. Evaluation of unbound materials and subgrade.

| Question | Total Responses | Yes | No |
|---|---|---|---|
| *14. Has your agency evaluated or sensitivity-tested the impacts of subgrade, subbase, and base layer resilient moduli on the resulting layer thicknesses?* | | | |
| • Subgrade (including chemically stabilized) | 23 | 15 | 8 |
| • Untreated Base/Subbase | 24 | 14 | 10 |
| • Treated Base/Subbase | 23 | 10 | 13 |

Table 12. HMA material characterization.

| Question | Total Responses |
|---|---|
| *15. Which of the following types of asphalt mixes has your agency developed Level 1 or Level 2 inputs for use in Pavement ME Design?* | |
| • Warm-Mix Asphalt (WMA) | 4 |
| • HMA with Rubber-Modified Binder | 1 |
| • HMA with Reclaimed Asphalt Pavement (RAP) | 6 |
| • HMA with Recycled Asphalt Shingles (RAS) | 1 |

Table 13. PCC design features.

| Question | Total Responses |
|---|---|
| *16. Which of the following JPC design inputs has your agency evaluated or sensitivity-tested to determine the impacts on PCC thickness?* | |
| • Transverse Joint Spacing | 13 |
| • Fixed versus Random Transverse Joint Spacing | 1 |
| • Dowel Bar Size | 13 |
| • Dowel Bar Spacing / Placement Configuration | 7 |
| • Dowel Bar Shape | 1 |
| • Tied versus Untied Shoulders | 11 |
| • Slab Width | 12 |

Table 14. Suggested software improvements, research needs, and training needs.

| **Questions and Responses** |
|---|
| *17. Do you have any suggestions for software improvements?* |
| • Make it easier to keep licensed. Our Computer Services Division seems to have difficulty with this. |
| • Provide better integrated help, and transparent database guidance for input libraries, etc.; provide more robust compatibility for hosting from central server location out to districts (for use by state agencies). |
| • Still encounter different bugs in the latest version of the software. |
| • Better define bottom up versus top down cracking and how data can be collected for input into Pavement ME. In the inputs for subgrade soil, it would be nice if the compacted layers were displayed more obviously. Changing soil type - software does not allow you to revise a soil type. The entire layer needs to be re-done. |
| • Make sure all models make logical sense, best available models are incorporated and most importantly, they are coded correctly in the program. |
| • Specifically, which models have changed - their values and shown in equation format and how this specifically will impact designs - the results and significance change of all inputs. How do the changes impact calibration coefficients? Provide examples. |
| • Not at this time, may have suggestions after discussions next week. |
| • Headings or some resource that clearly identifies data in tables generated in design files. |
| • Please do not make any change in the software user interface. |
| • The top-down alligator cracking model and top-down longitudinal cracking model are needed for flexible pavement. The chip seal cracking model is needed. The JPCP longitudinal cracking model and JPCP multi cracking model are needed. |
| *18. Do you have any research needs requests?* |
| • KDOT will be working over the next year or more to determine these needs. |
| • Perpetual pavement design using *Pavement ME Design*. |
| • Our biggest problem is having to recalibrate with new versions and having to use outside research help to do so. |
| • Initiate regional calibration on concrete pavements. |
| • Same as 17 (The top-down alligator cracking model and top-down longitudinal cracking model are needed for flexible pavement. The chip seal cracking model is needed. The JPCP longitudinal cracking model and JPCP multi cracking model are needed.). Plus, the overlay model may need to be updated. |
| *19. Do you have any specific training needs?* |
| • More understanding the engineering models of the various distress types. The manual of practice does not clearly describe the models. |
| • It depends on the training offered. KDOT staff is familiar with the operation of Pavement ME. If there is training regarding how the software works behind the scenes to run calculations and come up with design thicknesses, that training could be useful. |
| • We would like to know more about the *Pavement ME Design* "black box". In the old DARWin software, we calculated ESAL's of damage (loadings). What does *Pavement ME Design* calculate? |
| • How the software makes calculations of results showing all the models and interworking of the software. |
| • We are in process of getting *Pavement ME Design* in 2017. Training will be needed for efficient use of the software. |
| • We urgently need training on the fundamentals of MEPDG. Arrange help for the agencies struggling with issues. |

# 3. INTRODUCTORY SESSION

Mr. Wagner opened the Introductory Session on Day 1 by welcoming the participants and briefly describing the genesis of the Pavement ME Users Group and its growth and development over time. He presented to the group the latest snapshot of agency implementation status, which indicates that 11 SHAs have adopted the ME design procedure (presentation 1, appendix C). He encouraged participants to continue to be proactive in their implementation efforts and to make the most of the Users Group meeting through learning, sharing, and communicating with peers.

Mr. Donahue followed Mr. Wagner and provided an informative discussion on the purposes and responsibilities of the AASHTO JTCOP and the AASHTOWare *Pavement ME Design* Task Force (presentation 2, appendix C). He described the composition of these groups and discussed their crucial roles in helping achieve the many milestones in the MEPDG and the *Pavement ME Design* software development. He also reported on AASHTO's current reorganization effort to merge the JTCOP and the Subcommittee on Materials, and noted that the effects of this reorganization on ME design development could be significant, but are not currently known.

Lastly, Mr. Doucet provided the audience with an overview of the Transportation Association of Canada (TAC) Canadian User Group and a description of Canadian efforts to implement the MEPDG and the *Pavement ME Design* software (presentation 3, appendix C). He reported on the development of the *Canadian Guide: Default Parameters for AASHTOWare Pavement ME Design*, which is based on the Ontario Guide and input from Canada's Lead implementing agencies (Alberta, Manitoba, Ontario, Quebec, and the City of Edmonton) (TAC 2014). He also reported on the Canadian User Group trials, which began with a basic calibration exercise, expanded into other trials (e.g., subgrade strength, HMA air voids), and now has looking at the conduct of additional trials (e.g., HMA binder content, NARR climate database).

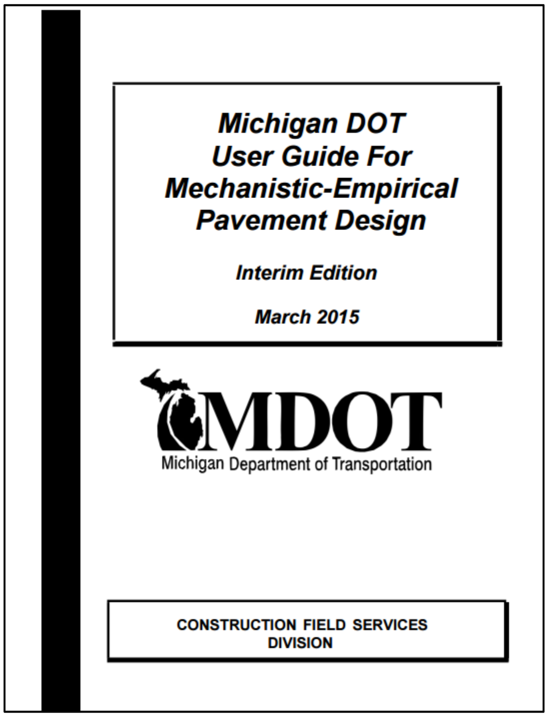
# 4. AGENCY IMPLEMENTATION EXPERIENCES AND STATUS

Sessions 2 and 3 of the meeting focused on agency reporting of ME implementation experiences and status, respectively. In Session 2, representatives of three SHAs gave presentations relating to the level and scope of implementation, notable challenges and successes, and specific lessons learned as part of the implementation process. A summary of these presentations and notable discussions related to each is provided in sequence below. Copies of the presentations are featured as presentations 4 through 6 in appendix C.

1. ***MEPDG to AASHTO Pavement ME: 2004 to Present, Missouri's Experiences* (Mr. Paul Denkler, Missouri DOT)**—This presentation covered the Missouri DOT's timeline for MEPDG implementation, including adoption in 2004, local calibration in 2009, various transitions in software versions, and a second local calibration that is now underway. It also touched upon some of the bases for how the DOT performs ME designs (e.g., they use 50 percent reliability along with established performance criteria for key distresses), key observations about the use of the *Pavement ME Design* software (many good features, compatibility issues with the network server) and about specific designs (e.g., benefits of a widened PCC slab, no benefit to SMA under Level 3 analysis), and areas of emphasis moving forward (e.g., designing with recycled mixes, greater ability to evaluate drainage, incorporating multiple stress creep recovery [MSCR] binder grading).

2. ***Michigan DOT – ME Oversight Committee* (Mr. Adnan Iftikhar, Michigan DOT)**—This presentation provided the timeline of MEPDG implementation in Michigan (full implementation in 2014) and focused on the formation of an ME Oversight Committee in 2012 to facilitate and steer the implementation process. It described the makeup of the Committee (key staff from various DOT division offices, HMA and PCC industry representatives, FHWA Division Office representative) and individual subcommittees (traffic, HMA, and PCC), and discussed the responsibilities and goals of the various groups. The details of a key product of the Oversight Committee, a 2015 *Interim Edition ME User Guide* (https://www.michigan.gov/documents/mdot/MDOT_Mechanistic_Empirical_Pavement_Design_User_Guide_483676_7.pdf), were also covered (see figure 1).

3. ***MEPDG Implementation in VDOT: Plan and Challenges* (Mr. Affan Habib, Virginia DOT)**—This presentation summarized the Virginia DOT's implementation activities to date and those that lie ahead toward achieving full implementation by January 1, 2018. It also discussed a range of issues faced by the DOT, including (a) broad issues like waiting for the release of new models developed under NCHRP projects, (b) software-related issues such as incompatibility with the agency's new network server, (c) design input issues identified through testing, and (d) local calibration issues such as insufficient sections and sections with little distress. The presentation closed with a list of DOT needs; most notably, training on the fundamentals of MEPDG and communication from AASHTO on MEPDG issues and developments.


Michigan DOT
User Guide For
Mechanistic-Empirical
Pavement Design

Interim Edition

March 2015

MDOT
Michigan Department of Transportation

CONSTRUCTION FIELD SERVICES
DIVISION

Figure 1. Michigan DOT ME User Guide.

> In response to the stated needs, Mr. Harold Von Quintus (Applied Research Associates, Inc. [ARA]) described the recent development and delivery of two courses for the Pennsylvania DOT—one on implementation and one on theory. He suggested the implementation course would be helpful in terms of the fundamentals of MEPDG. Mr. Habib agreed and also suggested that Users Group participants could meet regularly to help one another learn more about the design procedure and software.

In Session 3, meeting participants were asked to provide a brief update on their agency's MEPDG implementation status. Table 15 summarizes the reporting information provided by each SHA/PHA. A summary of key aspects of MEPDG implementation and use by each agency is provided in table 16.

Table 15. MEPDG implementation status of participating SHAs/PHAs.

| Agency | Status/Update |
|---|---|
| Alabama DOT | • Conducted traffic study.<br>• Completed material characterization of subgrade soils.<br>• Participating in NCAT Asphalt Mixture Performance Tester pooled fund study.<br>• Semi-implemented training course for consultants.<br>• Still in process of implementation. |
| Alberta MOT | • Local calibration has not been conducted.<br>• Traffic data from six WIM sites.<br>• Some materials characterization.<br>• Conducting *Pavement ME Design* since April 2016. They require consultants to do one ME design (using their best judgment) as a design check, and have done about 80 designs so far. |
| Arizona DOT | • Local calibration conducted by ARA (2010-2012).<br>• Draft user guide prepared, but not yet available.<br>• Traffic study completed.<br>• Materials characterization around 2000.<br>• AASHTO 1993 and *Pavement ME Design* parallel designs for new pavement (2012-present).<br>• Plan on recalibrating for new reflection cracking model.<br>• Using *Pavement ME Design* version 2.1 until next software release and calibration are complete.<br>• Design manual does not say to use ME. They are still uncertain about going with full implementation. |
| Arkansas SHTD | • Materials testing and database developed by University of Arkansas. They are trying to get the Materials Division to review and revise the database.<br>• Local calibration of asphalt models performed by University of Arkansas. A similar effort for the concrete models could not be completed due to an insufficient number of concrete pavements.<br>• Currently developing an implementation plan and a new pavement design guide.<br>• Conducting performing parallel designs, but they are having difficulty with Prep-ME accessing other databases. |
| California DOT | • Implementation of concrete pavement design procedure only. Asphalt pavements are designed using Cal-ME.<br>• Use a simplified approach whereby default values are used, except for key inputs.<br>• Conducted sensitivity study in 2006.<br>• Not currently planning to perform a local calibration. They are waiting for two key NCHRP studies—1-51 and 1-53—to be completed.<br>• Need to identify methods/process for modeling rapid strength concrete materials and precast concrete pavements. |
| Colorado DOT | • Conducted local calibration in 2010-2011.<br>• Performed AASHTO 1993 and *Pavement ME Design* parallel designs 2012-2014.<br>• Full implementation on July 1, 2014.<br>• Added 24 climate stations.<br>• Individual rutting models for HMA mixes with different binders (Marshall, Superpave, and polymer-modified).<br>• Completed cold in-place recycling (CIPR) site sampling.<br>• Sensitivity study for SMA is ongoing.<br>• Plan on model recalibration within the next year.<br>• CDOT *Pavement Design Manual* (https://www.codot.gov/business/designsupport/materials-and-geotechnical/manuals/pdm) has ME design procedures for HMA, PCC, and overlays. |
| Florida DOT | • Implementation of PCC design procedure completed, but PCC represents a small portion of Florida roads. HMA design procedure not implemented; they are waiting on this.<br>• Conducting a third local calibration effort. Industry disputed results of second calibration, thus they are currently using the results of the first calibration.<br>• Currently rewriting their design manual (including populating the PCC pavement design tables). |
| Illinois DOT | • IDOT developed their own ME design procedure in the 1980's and updated it in the early 2000's. They have no desire to change from it. |

Table 15. MEPDG implementation status of participating SHAs/PHAs (continued).

| Agency | Status/Update |
|---|---|
| Indiana DOT | • Primarily an asphalt state (90% HMA) and responsible for approximately 10,000 miles of road.<br>• Full implementation in 2009 (first section designed and built that year).<br>• Currently perform ME pavement designs on approximately 500 miles of pavement/year.<br>• ME design procedure is featured in INDOT *Design Manual, Chapter 304, Comprehensive Pavement Analyses* (http://www.in.gov/indot/design_manual/files/Ch304_2013.pdf)<br>• Currently using v2.2.4 of *Pavement ME Design*.<br>• Developed materials database in 2000.<br>• Developed traffic database in 2004.<br>• Conducted sensitivity study in 2004.<br>• Local calibration performed using data from 103 calibration sections.<br>• Currently refining and recalibrating the models based on performance of as-built pavement sections. |
| Iowa DOT | • Developed implementation plan in 2005.<br>• Currently collecting data for materials characterization.<br>• Need to characterize base materials and subgrade soils.<br>• Two local calibrations (one full, one partial) completed.<br>• Both industry groups very interested in ME implementation.<br>• Currently getting comfortable with *Pavement ME Design* by doing parallel design with AASHTO 1993.<br>• Plan for full implementation in 2017. |
| Kansas DOT | • Conducted local calibration using Level 3 data.<br>• AASHTO 1993 and *Pavement ME Design* parallel designs for new full-depth asphalt and PCC.<br>• Evaluating where to put efforts in the future and determining the level of effort needed (lab testing and field investigations). |
| Kentucky Transportation Cabinet | • Currently in process of replacing current design procedure with *Pavement ME Design*.<br>• ME design catalog being developed by University of Kentucky.<br>• Concrete models not yet calibrated due to lack of sufficient pavement sections (currently only 20 concrete sites).<br>• Conducted limited dynamic modulus testing.<br>• Traffic studies not yet performed. |
| Louisiana DOTD | • Material characterization and inputs completed.<br>• Not fully implemented yet; performing AASHTO 1993 and *Pavement ME Design* parallel designs. |
| Maine DOT | • Predominantly an asphalt state.<br>• Good progress on climate database and traffic data from WIM sites.<br>• Less progress on materials characterization and inputs.<br>• Interested in hearing about *Pavement ME Design* implementation for new and major rehabilitation designs. |
| Manitoba Infrastructure | • Traffic data available from 7 WIM sites.<br>• Asphalt binder and mix characterization completed.<br>• Local calibration performed using HMA and some PCC sections.<br>• Currently conducting parallel designs. |
| Maryland SHA | • Completed materials characterization and traffic study.<br>• Local calibration effort by ARA is in progress.<br>• Design parameters available in MDSHA *Pavement Design Guide* (http://www.sha.maryland.gov/OMT/pdguide0616.pdf).<br>• Use of *Pavement ME Design* is not required. |

Table 15. MEPDG implementation status of participating SHAs/PHAs (continued).

| Agency | Status/Update |
|---|---|
| Michigan DOT | • Fully implemented for new HMA and new PCC design since 2014.<br>• Currently, they are on an 8-month hiatus until a new local calibration is performed. Previous calibration resulted in a significant increase in JPC design thickness.<br>• Traffic characterization and climate characterization projects complete.<br>• HMA characterization database completed for Level 1 inputs.<br>• MDOT *User Guide for Mechanistic-Empirical Pavement Design* prepared and available (http://www.michigan.gov/documents/mdot/MDOT_Mechanistic _Empirical_Pavement_Design_User_Guide_483676_7.pdf).<br>• Conducting JPCP, HMA full-depth, and recycled material designs, with AASHTO 1993 as initial and *Pavement ME Design* as final (if results are within 1 in of each other, they use ME).<br>• Working on efforts to include rehabilitation designs.<br>• Evaluating changes in software. They find it difficult to keep up with what has changed. |
| Mississippi DOT | • Completed traffic characterization and climate characterization.<br>• Materials library in development.<br>• Field testing (including coring) will begin in Spring 2017.<br>• Expect full set of data in 1.5 years, with local calibration occurring after that (2018).<br>• Full implementation in 2019. |
| Missouri DOT | • Implementation in 2004 (national models).<br>• Local calibration in 2009.<br>• Completed second local calibration. |
| Nevada DOT | • Full implementation (July 2015).<br>• AASHTO 1993 and *Pavement ME Design* parallel designs (if thickness difference is greater than 2 in, they use the AASHTO 1993 result).<br>• Completed local calibration for some models but not others (e.g., longitudinal and reflection cracking).<br>• Challenges with traffic characterization (nine WIM sites with plans to add an additional three sites) and climate stations.<br>• Question the need to use ME for low-volume roads.<br>• Adopted national calibration values for JPC, but they have had difficulties with CTE testing.<br>• AI Report ER235 on performance differences (no lab testing) between polymer-modified binders and neat binders (*Calibration Factors for Polymer-Modified Asphalts Using M-E Based Design Methods* https://mxo.asphaltinstitute.org/webapps/displayItem.htm?acctItemId=244). |
| New Jersey DOT | • Currently use AASHTO 1993.<br>• Materials characterization completed for Level 1 inputs.<br>• Traffic user's manual under development.<br>• *Pavement ME Design* will be used for new and reconstructed pavements beginning in 2017. |
| New Mexico DOT | • Predominantly asphalt state.<br>• Conducted local calibration for asphalt designs (University New Mexico study). No PCC calibration.<br>• Materials database significant for HMA, but they don't have good subgrade data.<br>• Need study for incorporating recycled materials. They are big into recycling, but not sure how to model these materials in ME. |
| North Carolina DOT | • Implemented *Pavement ME Design* for HMA designs on major projects (2011-2015).<br>• Local calibration was conducted, but it was not perfect. They had concerns with the effort (including effects of aggregate base issues) and there has been numerous model and software updates since the original calibration.<br>• Currently conducting parallel designs, but AASHTO 1993 has been the official procedure since summer 2015. They hope to move back to Pavement ME in the near future.<br>• A project is underway to characterize JPC and CRC materials. |
| North Dakota DOT | • *Pavement ME Design* implemented for concrete pavement design only (primarily using national default values).<br>• Local calibration performed for concrete pavements in 2013-2014.<br>• Starting the process for performing a local calibration for asphalt pavements.<br>• Using South Dakota DOT-determined values for CTE. |

Table 15. MEPDG implementation status of participating SHAs/PHAs (continued).

| Agency | Status/Update |
|---|---|
| Ohio DOT | • Completed a traffic study.<br>• Developed a materials inputs database.<br>• No recent updates on climate characterization; they have 20 weather stations with data back to 2006.<br>• Conducted a local calibration in 2009 using the Long-Term Pavement Performance (LTPP) sites; however, data were inadequate for decent results.<br>• Prepared a calibration database in 2013, but they are waiting for additional years of performance before conduction the calibration (more distress development is needed).<br>• *Pavement ME Design* used only for new construction, unbonded overlays, and rubblization projects (projects requiring LCCA). Deflection-based analysis is performed for all rehab designs. |
| Oklahoma DOT | • AASHTO 1993 and *Pavement ME Design* parallel designs.<br>• Local calibration for concrete pavement design expected in 2017.<br>• Currently in process of implementing asphalt pavement design.<br>• Plan to fully implement *Pavement ME Design* in 3 to 4 years (2019-2020). |
| Ontario MOT | • Implementation has not yet occurred. *Pavement ME Design* was used by a consultant for a high-profile project in Summer 2016.<br>• Local calibration performed only on rutting model in 2015.<br>• Web-based traffic information system good source for traffic characterization.<br>• Climate characterization based on 34 weather stations.<br>• Level 3 materials inputs based on contract specifications. Some resilient modulus testing has been performed.<br>• Currently experiencing internal-based software installation problems. |
| Pennsylvania DOT | • WIM sites for traffic data.<br>• Materials characterization (including SMA and RAP).<br>• In-place concrete is JRCP; however, new designs are JPCP. As a result, they are having issues with calibrating JPCP due to limited historical performance data.<br>• Evaluating long-life concrete design (mix optimization).<br>• Using LTPP and Superpave In-Situ Stress/Strain Investigation (SISSI) sites for local calibration.<br>• Received ARA training in ME theory and *Pavement ME Design* applications.<br>• Use AASHTO 1993 and *Pavement ME Design* parallel designs for truck traffic > 500. |
| Quebec MOT | • Several WIM stations in operation.<br>• Materials testing conducted and materials database developed.<br>• Although no local calibration has been performed, they are well equipped with site-specific performance data. Plan to do a local calibration in 2017.<br>• Currently testing *Pavement ME Design* software. |
| South Carolina DOT | • Early stages of implementation, with dynamic modulus, sensitivity testing, and CTE studies underway.<br>• Clemson University conducting work on subgrade characterization and design catalog development.<br>• Limited use of pavement management data.<br>• AASHTO 1972 is official design procedure in use. They do use the ME PCC module for evaluation of joint spacing and dowel bar issues. |
| Vermont AOT | • Began local calibration in 2012.<br>• Implemented national calibration values in 2015.<br>• Will conduct parallel designs moving forward.<br>• Currently drafting a user manual.<br>• Currently developing a database for default parameters (materials, traffic). |
| Virginia DOT | • HMA characterization completed to Level 1.<br>• Initial local calibration for HMA and CRCP in 2015.<br>• Mix selection guidelines developed.<br>• Need training on basics of *Pavement ME Design*.<br>• Would like to see a more formal update from AASHTO/FHWA on software developments, research studies, etc.<br>• Interest in addressing national industry concerns, rather than individual state industry concerns.<br>• Plan to fully implement *Pavement ME Design* on January 1, 2018. |

Table 15. MEPDG implementation status of participating SHAs/PHAs (continued).

| Agency | Status/Update |
|---|---|
| Washington State DOT | • Primarily an asphalt and chip seal state (50% HMA, 30% chip seal, 20% PCC)<br>• Original calibration effort in 2002.<br>• Traffic data (Level 1) study completed in 2007.<br>• Developed 2013 design catalog based on *Pavement ME Design* and AASHTO 1993.<br>• Currently use AASHTO 1993 with pavement management data check. They are waiting to implement ME once a top-down cracking model is in place. |
| Wisconsin DOT | • Traffic analysis study completed, but now seeking an expanded study.<br>• Materials characterization (primarily for Level 3 inputs) based on LTPP sites and research studies.<br>• Local calibration completed in 2010.<br>• Full implementation in 2014 for new and reconstruction design of asphalt and concrete pavements.<br>• Currently using v2.1 of *Pavement ME Design*.<br>• Developed an original pavement design manual and subsequently updated and streamlined it. Manual is continually being updated. |

Table 16. Summary of key aspects of MEPDG implementation and use.

| Agency | HMA Character-ization | PCC Character-ization | Unbound Base/Subbase and Subgrade Soil Characterization | Local Calibration | Parallel Design | Implementation | User Guide |
|---|---|---|---|---|---|---|---|
| Alabama DOT | — | — | Subgrade soils | — | — | — | — |
| Alberta MOT | Some testing | — | Some testing | Not yet | — | 2016 | — |
| Arizona DOT | Completed | Completed | Completed | 2010-2012 | 2012-current | — | Draft |
| Arkansas SHTD | Completed | — | Completed | HMA only | Yes | — | In progress |
| California DOT | — | — | — | PCC national calibration values | — | PCC only | — |
| Colorado DOT | — | — | — | 2010-2011 | 2012-2014 | 2014 | Yes |
| Florida DOT | — | — | — | On 3rd Round | — | PCC only | Rewriting |
| Illinois DOT | — | — | — | — | — | — | — |
| Indiana DOT | Completed | Completed | Completed | 2009 | — | 2009 | Yes |
| Iowa DOT | Conducting | Underway | Need to do | Partially Complete | Yes | Expected 2017 | — |
| Kansas DOT | — | — | — | Level 3 | full-depth asphalt only | — | — |
| Kentucky Transportation Cabinet | Limited dynamic modulus testing | — | — | HMA only (synthesized factors) | — | Design catalogs | In progress |
| Louisiana DOTD | Completed | — | Completed | — | Yes | — | — |
| Maine DOT | — | — | — | — | — | New and major rehabilitation | — |
| Manitoba Infrastructure | Completed | — | — | Yes | Yes | — | — |
| Maryland SHA | Completed | — | Completed | In progress | — | Yes, but not required | Yes |

Table 16. Summary of key aspects of MEPDG implementation and use (continued).

| Agency | HMA Character-ization | PCC Character-ization | Unbound Base/Subbase and Subgrade Soil Characterization | Local Calibration | Parallel Design | Implementation | User Guide |
|---|---|---|---|---|---|---|---|
| Michigan DOT | Level 1 | — | — | Not yet | — | 2014 (JPCP, HMA, and recycled mtls) | Yes |
| Mississippi DOT | Completed | — | Spring 2017 | Expected 2018 | — | Expected 2019 | — |
| Missouri DOT | | | | 2 rounds | | 2004 | |
| Nevada DOT | — | — | — | HMA only; national calibration values for PCC | Yes (if difference > 2" use AASHTO 1993) | 2015 | — |
| New Jersey DOT | Level 1 | — | — | — | — | Expected 2017 | Traffic user guide |
| New Mexico DOT | Yes | — | — | HMA only | — | — | — |
| North Carolina DOT | Yes | underway | Yes | Yes, but need to recalibrate | Yes; use AASHTO 1993 since 2015 | 2011-2015 | — |
| North Dakota DOT | — | — | — | PCC only; HMA underway | — | PCC (primarily default values) | — |
| Ohio DOT | Yes | Yes | Yes | 2009 using LTPP sites; 2013 calib. database | — | New const., unbonded overlays, and rubbilization | — |
| Oklahoma DOT | — | — | — | PCC only; HMA underway | Yes | Expected 2019-2020 | — |
| Ontario MOT | Level 3 | Level 3 | Level 3; some subgrade characterization | HMA rutting model (2015) | — | High-profile project only | — |
| Pennsylvania DOT | Yes; includes SMA and RAP | Yes | Yes | — | Yes, for truck traffic > 500 vehicles | — | — |
| Quebec MOT | Yes | Yes | Yes | — | — | Expected 2017 | — |
| South Carolina DOT | Dynamic modulus testing underway | CTE study underway | — | — | — | — | — |
| Vermont AOT | Underway | — | Underway | National calibration values (2015) | Will be conducted | — | Draft |
| Virginia DOT | Level 1 | — | — | 2015 | — | Expected 2018 | — |
| Washington State DOT | — | — | — | 2002 | — | Design catalog 2013 | — |
| Wisconsin DOT | Level 3 | Level 3 | Level 3 | 2010 | — | New and reconst. 2014 | Yes (updating) |

# 5. AASHTOWARE PAVEMENT ME DESIGN SOFTWARE UPDATE

Session 4 of the meeting consisted of a briefing from AASHTO about purchasing and licensing of the *Pavement ME Design* software, followed by an overview presentation from the software developer (ARA) regarding the latest enhancements made to the program. Summaries of the information presented and surrounding discussions are provided below. Copies of the presentations are featured as presentations 7 and 8 in appendix C.

1. ***Software Announcements and News* (Ms. Vicki Schofield, AASHTOWare)**—This presentation showcased the new software website (www.aashtoware.org/Pavement/) and provided an overview of the current status of software licensing (38 states, 4 provinces, 14 international agencies). It provided a navigational tour of the website, pointing out the current release of the software (v2.3) and showing key parts of the website, such as where to go for purchasing/licensing, user support, key documents (e.g., software release notes), and bug reporting (Mantis Bug Reporting System). It also touched upon several future software enhancements that are under consideration (e.g., incorporation of Modern-Era Retrospective Analysis for Research and Applications [MERRA] data, customization of reports) and reported on the current membership of the ME Design Task Force.

   Ms. Schofield stated she would like to compile a list of ME users to enhance their connection to the software and resources that are available on the website. This idea was welcomed from the standpoint of a user being able find out the latest research studies and/or tests that will be incorporated into ME design. Additionally, in response to participant desires for more information on software updates and notifications, Mr. Chad Becker (ARA) pointed out that there is an icon on one of the webpages (http://me-design.com/MEDesign/) that provides access to this information (see figure 2).

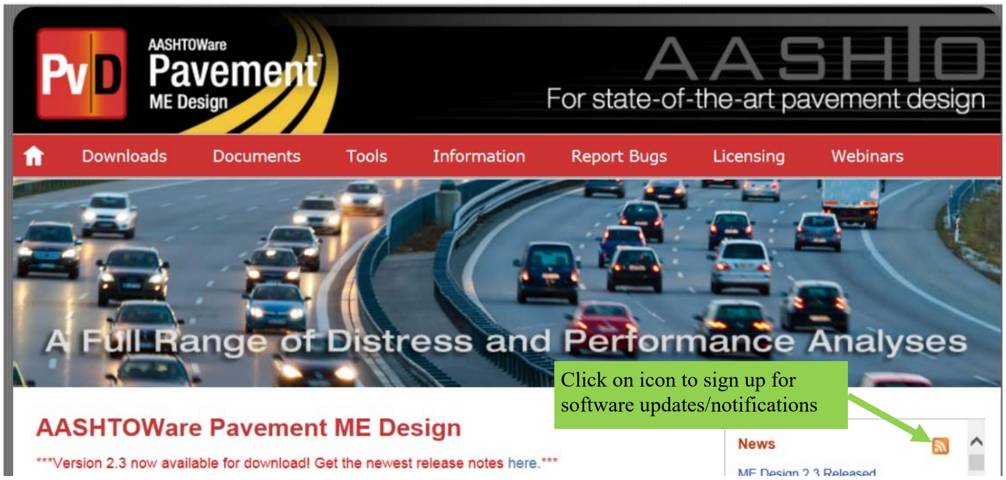



Figure 2. AASHTOWare link to software updates/notifications.

Ms. Schofield also discussed AASHTOWare's intent to provide NCHRP with a standard format that all researchers must adhere to in order to make software upgrades easier. She indicated that research grade programming code and code from third-party developers makes it extremely difficult to perform upgrades to the software. NCHRP projects 1-52 and 1-53 were mentioned as good examples of applying the standard format.

2. ***Software Enhancements*** **(Mr. Chad Becker, ARA)**—The focus of this presentation was on the enhancements and updates made during Fiscal Years 2015 and 2016 (v2.2 and v2.3), respectively. The presentation also briefly touched upon enhancements currently being made that will be available in v2.4, which is targeted for release in July 2017. Key enhancements and new features of each software version are summarized below. Suggestions for process and feature improvements can be submitted through the Mantis Bug Reporting System on the software website (www.me-design.com/MantisBT).

V2.2 Enhancements

- Level 1 and 2 characterization of rehabilitation inputs for PCC overlays of flexible pavements.
- Integration of the mechanistic-based reflection cracking transfer function developed under NCHRP 1-41.
- Incorporation of new global PCC calibration coefficients (based on lab-derived coefficient of thermal expansion [CTE] values).
- Addition of four normalized axle load spectra (NALS) defaults.
- AC layer dependent plastic deformation coefficients. Based on the results of NCHRP 9-30A, separate rutting coefficients for each AC layer (neat, rubber-modified, polymer-modified, RAP) can be assigned. Mr. Von Quintus noted that lab test data must be available to support the different coefficients, otherwise the same coefficient should be used for each layer. He also noted that one can still use the volumetric properties to estimate the plastic flow properties (k coefficients) of the AC mix.

V2.2 New Features

- Supplementation of the *Drainage Requirements in Pavements (DRIP)* program for analyzing subsurface hydraulics.
- Integration of the *MapME* web tool for creating ME project files with Level 4 GIS-referenced climate, traffic, soils, and groundwater data.
- File Application Programmable Interface (API) for JULEA and ICM for incorporating custom functions or applications.

V2.3 Enhancements

- Code modernization and review. Reduction in programming code from 160,000 to 60,000 lines.
- Technical audit to identify and fix programming anomalies.

V2.3 New Features

- Implementation of short-jointed plain concrete pavement (SJPCP) design procedure. This procedure is based on the bonded concrete overlay of asphalt mechanistic-empirical design procedure (BCOA-ME) developed at the University of Pittsburgh. The procedure is governed by only a longitudinal cracking model; it does not include smoothness, transverse cracking, and faulting models. Mr. Von Quintus noted that the longitudinal cracking model could conceivably be applied to conventional PCC pavements.

- Incorporation of North American Regional Reanalysis (NARR) climate data. The original climate data set consisted of 10 years of historical climate date from 1,083 ground-based National Climate Data Center (NCDC) weather stations. The software now provides a link to a 10GB climate datafile containing 37 years of continuous, satellite-based NARR data for the 1,083 gridpoint locations. Mr. Becker indicated that there is generally no bias created using NARR data, but noted the need to be careful in selecting stations and to avoid significant bodies of water when selecting stations. He also recommended downloading only the stations representing the state in question, not the whole 10GB file. It was pointed out that the NARR grid spacing is 19 mi and that NARR is different from the MERRA in that NARR covers North America whereas MERRA covers the world.

V2.4 Enhancements

- Integration of the AASHTO *MEPDG Manual of Practice*.
- Technical audit revisions.

V2.4 New Features

- API for layer modulus and file API for transverse cracking model.
- Incorporation of backcalculation tool. This is being developed in three phases: (1) pre-processing of deflection data, (2) backcalculation of stiffness values using EVERCALC, and (3) post-processing of backcalculation results. Mr. Becker reported that the tool will be outside of the *Pavement ME Design* program and that users will have to get a version of program that provides accessibility to the tool. He also noted that the user will never see the EVERCALC interface. Mr. Von Quintus addressed a concern about EVERCALC yielding high modulus values by highly recommending the use of lab data and cores and making appropriate engineering decisions about the results.

# 6. DESIGN PARAMETERS

Session 5 of the meeting featured presentations associated with the development and/or use of condition threshold limits, hierarchical input levels, and design reliability levels. Summaries of the information presented and subsequent discussions are provided below. Copies of the presentations are featured as presentations 9 and 10 in appendix C.

1. ***Design Parameters* (Mr. Geoff Hall, Maryland SHA)**—Captured in this presentation was information on how the SHA established its initial and terminal performance targets for smoothness and its terminal targets for key distresses (e.g., rutting, fatigue cracking, slab cracking), and how it emphasizes the development of targets that are project-specific and data-driven (where appropriate) and the use of design reliability levels that fit the design type (new versus rehabilitated). A process for establishing terminal targets for resurfacing projects based on the remaining service life (RSL) concept was demonstrated, whereby RSL values are determined for individual smoothness/distress indicators and the lowest RSL value is then used to define the terminal target for each indicator.

   Mr. Hall reported that they only design for bottom-up fatigue cracking (top-down cracking is not considered) in HMA and that they use ME to determine RSL. In addition, while they generally use 90 percent reliability in their designs, they use 50 percent reliability for smoothness for both new and rehabilitated designs (due to a good smoothness specification) and 50 percent reliability for fatigue cracking and thermal cracking in HMA overlays (for accurate assessment of life extension).

   Mr. Hall added that they perform Level 1 designs when they can (i.e., when data are available to support it). However, in some cases, they have to use Level 2 or 3 inputs.

2. ***Kentucky's Design Catalog and Web-Based Program* (Mr. Clark Graves, University of Kentucky and Mr. Joe Tucker, Kentucky Transportation Cabinet)**—The substance of this presentation was the development of a design catalog for Kentucky pavement designers that provides a boundary of values on various input parameters for performing a typical design. Currently, the catalog is only set up for new HMA pavements, but it is expected to be expanded to include other design types such as PCC, composite, and rehabilitated pavements. Additionally, although the catalog is currently based on "synthesized" surrounding-state calibration coefficients, refinements will be made using local calibration results based on several statewide sites.

   Rehabilitation of asphalt pavements in Kentucky is usually necessary to address rutting (fatigue cracking is typically not an issue). However, SuperPave mix designs have greatly reduced rutting. The coefficient development work was led by Mr. Sunil Saha (Kentucky Transportation Cabinet). The design catalog was produced from the results of 343 ME runs conducted using the synthesized coefficients. With very high correlations obtained between the catalog required thickness and the ME predicted thickness (see figure 3), the design catalog provides for a sound and quick way to develop pavement designs in the state.

   Mr. Graves displayed several of the input screens that are part of the web-based design program. He told participants that a report on the design catalog development effort is not available, but that there will likely be a user guide produced in the near future.

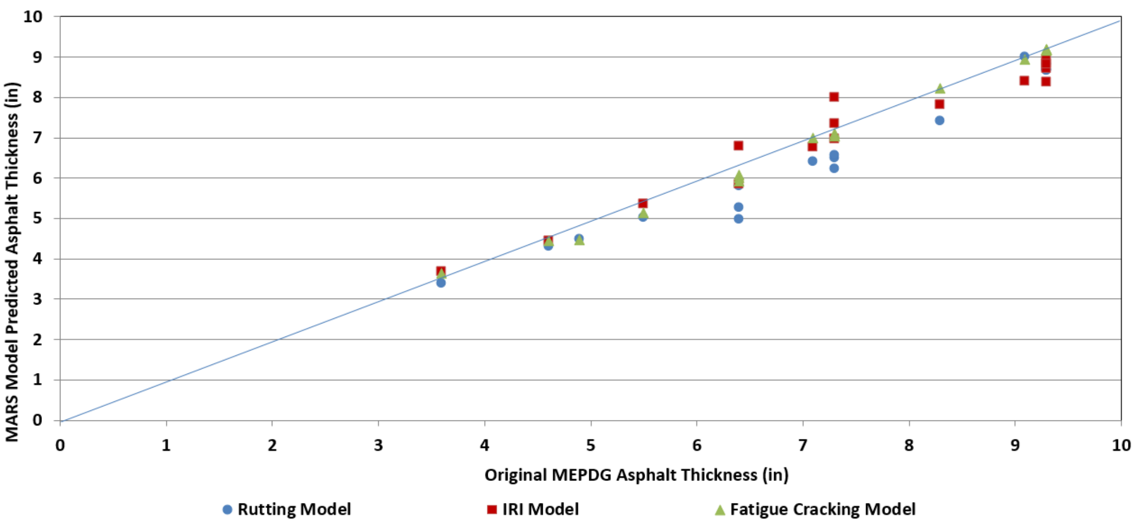



Figure 3. Comparison of HMA thickness requirements obtained using MEPDG and Kentucky design catalog.

# 7. CLIMATE AND TRAFFIC INPUTS

Sessions 6 and 7 of the meeting featured presentations related to the use of climate and traffic data, respectively, in *Pavement ME Design* analysis. Summaries of the information presented and subsequent discussions are provided below. Copies of the presentations are featured as presentations 11 and 12 in appendix C.

1. ***LTPP Climate Tools for ME Design* (Mr. Larry Wiser, FHWA)**—This presentation included an overview of the LTPP InfoPave web-based program (https://infopave.fhwa.dot.gov/) and the LTPP Climate Tool and other ME support tools available within the InfoPave program. The LTPP Climate Tool allows a user to access a wide range of MERRA data (temperature, precipitation, wind, etc.) for varying frequencies (hourly, daily, monthly, etc.) for use in the *Pavement ME Design* software. The data, which are available for the period of 1980 to the present, can be selected and viewed by location (see figure 4), area, or country/state/province, and subsequently extracted for import (in varying formats) into the ME program. Other ME support tools covered in the presentation include one for extracting performance data from selected LTPP test sections to aid the local calibration process (Use LTPP Data for MEPDG Inputs for Local Calibration) and one for extracting MERRA data for use in the ME program (MERRA Climate Data for MEPDG Inputs).

   Mr. Wiser noted that FHWA is considering the adoption of MERRA-2, since it provides more historical information.

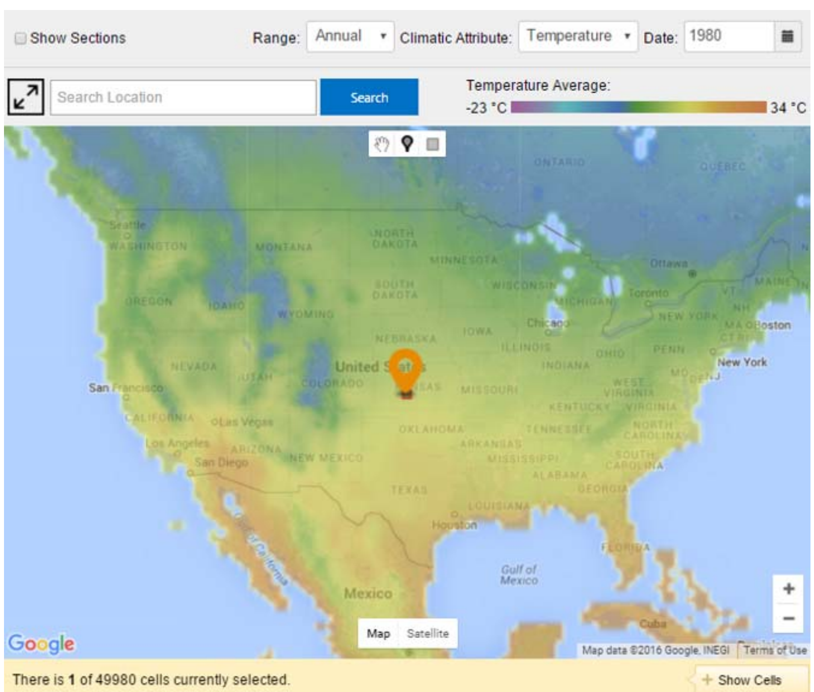



Figure 4. Location selection using the LTPP Climate Tool.

2. ***NJDOT – Status of Traffic Input*** **(Ms. Nusrat Morshed, New Jersey DOT)**—This presentation covered the types of traffic data collected and used by the DOT for pavement design and on the development of a New Jersey DOT *Traffic User Manual for ME Design* by Rutgers University. An example application was given, whereby the projected traffic volumes and truck percentages for a reconstruction project were used in the *Pavement ME Design* program to determine the required pavement thickness. The development of Level 2 and Level 3 traffic inputs based on data from 90 WIM sites throughout the state was also discussed. The DOT plans to continue analyzing traffic and examining the effects of traffic clusters on pavement design.

# 8. FOUNDATION AND BASE MATERIAL INPUTS

Session 8 of the meeting featured presentations related to the characterization of subgrade soils, as well as treated and untreated base/subbase materials, for *Pavement ME Design* analysis. Summaries of the information presented and subsequent discussions are provided below. Copies of the presentations are featured as presentations 13 and 14 in appendix C.

1. ***Subgrade Soils* (Ms. Melody Perkins, Colorado DOT)**—The stiffness of subgrade soil in a pavement system is a key design parameter and is characterized in the MEPDG by the resilient modulus ($M_r$). Because the DOT has historically used the Resistance value (R-value) to characterize soil stiffness, it has developed and refined the correlation between the static R-value and the dynamic $M_r$ for use as a Level 2 input into the ME design procedure. The current correlation (figure 5), as well as Level 3 default $M_r$ values and Level 1 FWD-to-laboratory ratios (i.e., C-factor), are all featured in the latest version (2017) of the DOT's *ME Pavement Design Manual* (https://www.codot.gov/business/designsupport/materials-and-geotechnical/manuals/pdm). The manual also provides guidance on the treatment of expansive subgrade soils that are common in Colorado.

   Ms. Perkins stated that the R-value correlation is only applicable for soils with R-values less than or equal to 50, and that a study is underway to identify a correlation for values greater than 50. She also noted that the Level 3 $M_r$ inputs established for individual AASHTO soil classes are only acceptable for use in preliminary pavement designs.

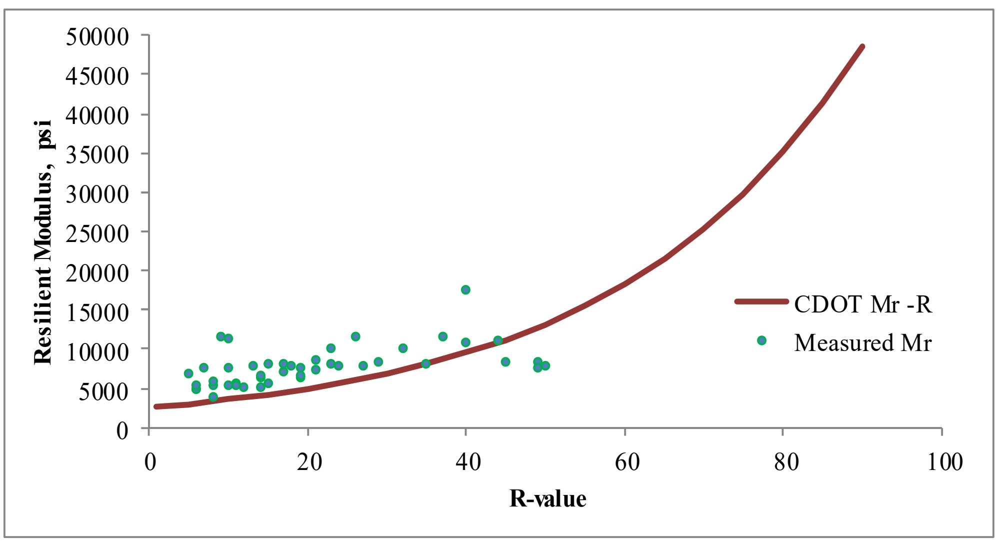



Figure 5. Colorado DOT correlation between R-value and $M_r$ for use in Level 2 ME design.

2. ***Determination of In-place Elastic Layer Moduli through Backcalculation* (Mr. Harold Von Quintus, ARA)**—The basis for this presentation was a 2015 FHWA report titled *Long-Term Pavement Performance Program Determination of In-Place Elastic Layer Modulus: Backcalculation Methodology and Procedures* (https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/ltpp/15036/15036.pdf). The study involved the re-analysis of historical deflection data collected from over 2,400 LTPP test

sections using updated versions of three selected backcalculation methodologies—EVERCALC, MODCOMP, and best-fit—and the incorporation of the resulting most accurate layer moduli into the LTPP database in the form of computed parameter tables (CPTs). The presentation discussed the use of C-factors for unbound material layers and the assessment of damage in existing HMA pavements using FWD data, as currently being defined in the FHWA project, "Characterizing Existing AC Damage for Rehabilitation Design using Pavement ME Design." Additional discussion on the incorporation of the EVERCALC backcalculation tool into *Pavement ME Design* was also provided.

Mr. Von Quintus described the stress-softening characteristics of fine-grained soils and the stress-hardening characteristics of coarse-grained materials, and emphasized the need to use the *in situ* moisture content during FWD testing when converting the backcalculated resilient modulus to a laboratory modulus using a C-factor.

Mr. Von Quintus also pointed out that C-factors are a function of pavement structure; specifically, the layer type (aggregate base or subgrade) and the location of the layer within the structure. Additionally, C-factors are independent of soil type.

# 9. HOT-MIX ASPHALT (HMA) INPUTS

Session 9 started Day 2 of the meeting and featured presentations related to the characterization of HMA materials for use in the design of both new and rehabilitated asphalt pavement structures. Summaries of the information presented and subsequent discussions are provided below. Copies of the presentations are featured as presentations 15 and 16 in appendix C.

1. ***Incorporating Recycled Materials* (Mr. Harold Von Quintus, ARA)**—Resource responsible asphalt mixtures ($R^2$AMs) are asphaltic-based materials containing one or a combination of recycled products, including high (>30 percent) reclaimed asphalt pavement (RAP), recycled asphalt shingles (RAS), ground tire rubber (GTR), and high polymer-modified asphalt. This presentation discussed the up-to-date findings of an FHWA project ("Deployment of Performance Based Technologies for Mechanistic-Empirical Pavement Design") intended to determine if the ME design process adequately captures the behavior of $R^2$AMs, given that the transfer functions are based primarily on standard, neat asphalt mixtures. The study involved an extensive laboratory testing program (dynamic modulus [figure 6], repeated load plastic strain, flexural fatigue strength, creep compliance, indirect tensile strength) applied to HMA mixtures from five states covering the four primary U.S. climatic zones. Test results indicate that $R^2$AMs are mostly within the same ranges of standard, neat asphalt mixtures, and that the calibration shift factors ($k_1$, $k_2$, and $k_3$) between the laboratory and the field are the same.

   Mr. Von Quintus reported that a "Practitioner's Guide" on performance testing of $R^2$AMs is currently being developed and will be made available in 2017. The guide is expected to provide recommendations for sampling and testing of $R^2$AM materials, and guidance on using the test results in *Pavement ME Design*.

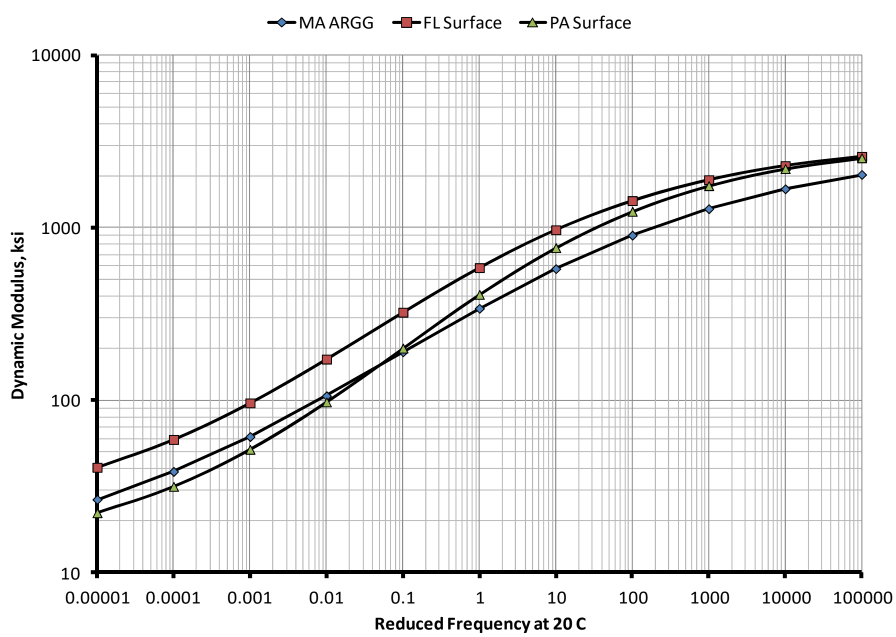



Figure 6. Dynamic modulus master curves for selected rubber-modified asphalt mixes.

2. ***Pavement ME Rutting Calibration for Indiana HMA Full-depth Pavements*** **(Dr. Jusang Lee and Mr. Tommy Nantung, Indiana DOT)**—Since the time the Indiana DOT implemented the MEPDG in 2009, efforts have been made to verify the performance models using actual performance data from Indiana pavement sections. This presentation covered the results of a recent study to verify and calibrate the rutting performance model for full-depth HMA pavements using six accelerated pavement testing (APT) sections and eight in-place pavement sections. Although the global model coefficients produced good agreement between predicted and actual total rutting, poor agreement was seen for the HMA and subgrade rutting components. A local calibration of the three models was successfully performed which resulted in new calibration coefficients for $\beta_{r1}$, $\beta_{r2}$, $\beta_{r3}$, and $\beta_{s1}$ (see figure 7).

   Mr. Lee described in detail the setup and performance monitoring of the APT full-depth HMA sections, and reported that approximately 88 percent of the total rutting occurred in the HMA layers, while only 12 percent occurred in the subgrade. Similar observations were made with the in-place pavement sections.

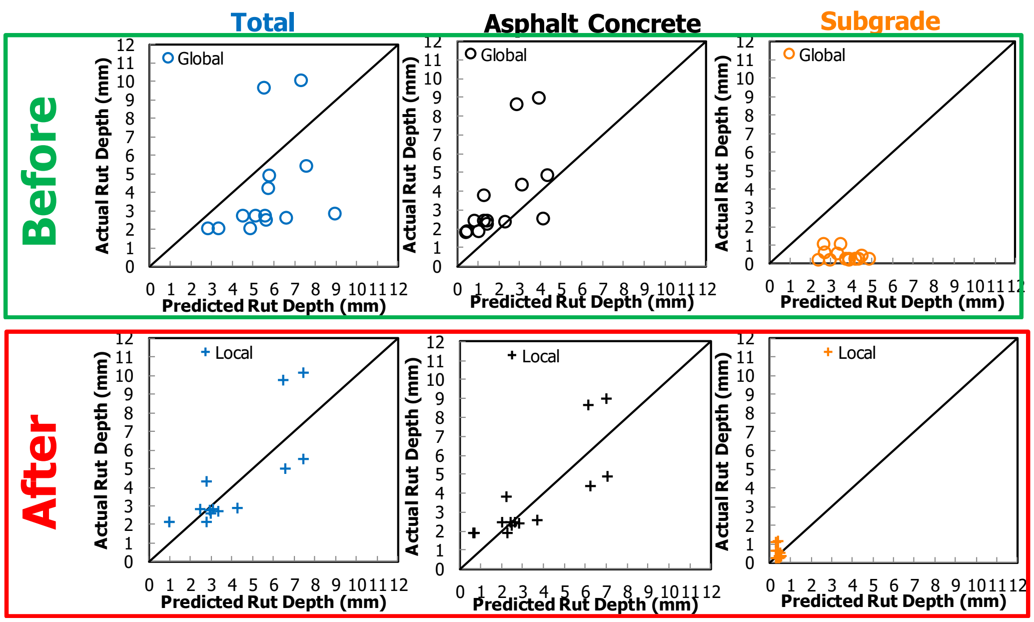



Figure 7. Indiana DOT local calibration results for flexible pavement rutting models.

# 10. PORTLAND CEMENT CONCRETE (PCC) INPUTS

Session 10 of the meeting featured presentations related to the characterization of PCC materials and pavement features for use in the design of both new and rehabilitated concrete pavement structures. Summaries of the information presented and subsequent discussions are provided below. Copies of the presentations are featured as presentations 17 and 18 in appendix C.

1. ***Development of Climatic Regions for Florida Concrete Pavement Design using MERRA Data* (Ms. Rhonda Taylor, Florida DOT)**—At the Florida DOT, pavement designs are performed at the District level using statewide established design tables and are then checked at the Central Office. Because of the high swings in daily temperature throughout the state (particularly in the north), the effects of curling and warping in concrete pavements is a major concern. Although designs to account for these effects can be developed using *Pavement ME Design*, the DOT's past calibration efforts were developed from limited historical ground-based weather data representing five climatic regions for Florida. This presentation spotlighted a study to use satellite-based MERRA data and *Pavement ME Design* to evaluate top-down and bottom-up cracking in concrete pavements throughout the state and examine the impacts on thickness requirements. The analysis involved automated design runs for a standard concrete design subject to a specified traffic level when constructed at each of 47 MERRA cell locations. Results provided the basis for the development of a concrete thickness/climate contour map for Florida (figure 8), which indicate that design thicknesses increase in the northern part of the state and are thinnest in the southeast part of the state.

   Ms. Taylor reported that top-down cracking is dominant in the north, but that bottom-up cracking is equally a concern as top-down cracking in the south. She noted that this confirmed the effects of the more severe night-time temperature gradients in the north.

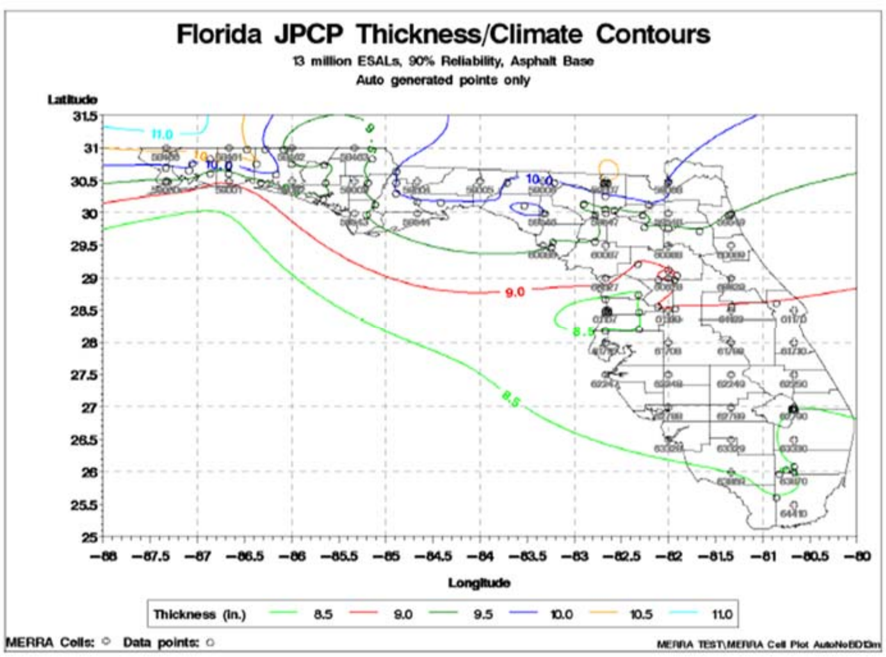



Figure 8. Florida concrete pavement thickness/climate contour map.

Ms. Taylor discussed future efforts including the development of additional design tables that account for truck traffic classification (TTC) clusters that are currently being developed from WIM data. She also indicated that Florida has begun construction of a 2.5-mi concrete test road near Jacksonville, which will provide the basis for updating local calibration coefficients.

2. ***Progress Report of Development of JPCP Design Catalog for New York* (Mr. Chris Brakke, Iowa DOT)**—This presentation provided an update on Pooled Fund Study TPF-5(300), *Performance and Load Response of Rigid Pavement Systems*, being led by the Iowa DOT. Among the study objectives is the development of a JPC pavement design catalog with local validation and calibration of ME models. A total of 23 LTPP test sections from four states (Delaware, Maine, Ohio, Pennsylvania) and one province (Quebec) provided the basis for the performance data used in the validation and calibration effort. Only the slab cracking model required calibration, and that calibration effort produced new $C_4$ and $C_5$ coefficients. Using the validation/calibration results and the *Pavement ME Design* software, a design catalog was developed for New York consisting of PCC thickness tables (see example in table 17) for different climate zones, different subgrade soil moduli, and different ranges of initial AADTT.

Table 17. New York PCC Design Catalog–climate zone 1 design table.

| Subgrade Mr = 4,000 psi (28 MPa) | | |
|---|---|---|
| Initial AADTT | PCC Thickness | |
| | 3.6-m (12-ft) width | 4.2-m (14-ft) width |
| AADTT ≤ 641 | 228.6 mm (9.0 in) | 215.9 mm (8.5 in) |
| 641 < AADTT ≤ 1,049 | 228.6 mm (9.0 in) | 215.9 mm (8.5 in) |
| 1,049 < AADTT ≤ 1,895 | 241.3 mm (9.5 in) | 228.6 mm (9.0 in) |
| 1,895 < AADTT ≤ 2,915 | 254.0 mm (10.0 in) | 241.3 mm (9.5 in) |
| 2,915 < AADTT ≤ 4,809 | 266.7 mm (10.5 in) | 254.0 mm (10.0 in) |
| 4,809 < AADTT ≤ 7,287 | 279.4 mm (11.0 in) | 266.7 mm (10.5 in) |
| 7,287 < AADTT ≤ 11,659 | 292.0 mm (11.5 in) | 266.7 mm (10.5 in) |

# 11. CALIBRATION AND VALIDATION

Session 11 of the meeting featured presentations on agency efforts to calibrate and validate the MEPDG. Summaries of the information presented and subsequent discussions are provided below. Copies of the presentations are featured as presentations 19 and 22 in appendix C.

1. ***Ontario's Local Calibration Effort on Flexible Pavements* (Mr. Warren Lee, Ontario MOT)**—This presentation highlighted the MOT's work on calibrating the flexible pavement distress and smoothness models to Ontario conditions. The process was conducted according to the AASHTO *Guide for the Local Calibration of the MEPDG* and used pavement management and other data on 64 pavement sections located on 20 different highways throughout the province. New calibration factors were developed for rutting ($\beta_{ac}$, $\beta_{gb}$, $\beta_{sg}$) (see figure 9 for calibration plots), alligator cracking ($C_1$, $C_2$), and longitudinal cracking ($C_1$, $C_2$), and IRI ($C_1$, $C_2$, $C_3$, $C_4$). Additional calibration work is needed for the IRI model (a reflection crack calibration must be performed to refine the IRI model coefficients) and the transverse thermal cracking model (the Level 3 calibration performed was inadequate so Level 1 and 2 calibrations are now sought).

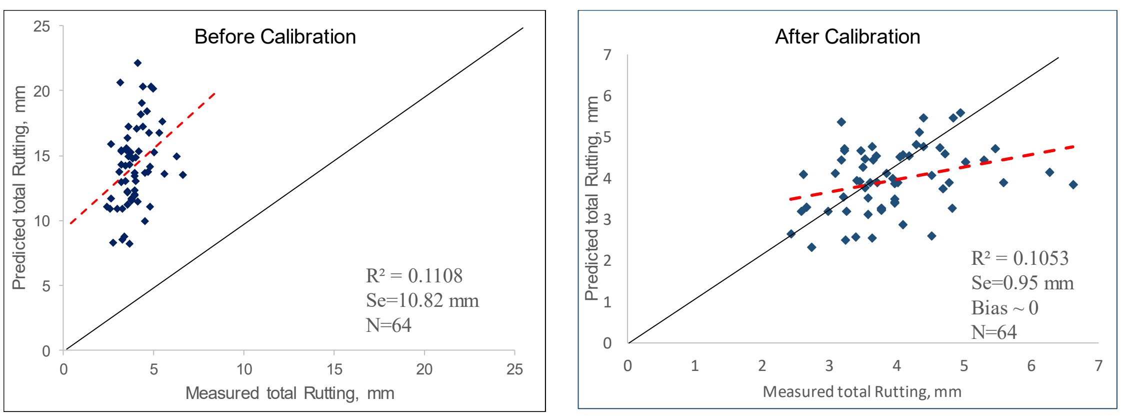



Figure 9. Ontario MOT local calibration results for flexible pavement rutting models.

2. ***The KDOT Experience: Pavement ME Calibration and Validation* (Mr. Ryan Barrett, Kansas DOT)**—Under the overarching goal of saving money under tightening budgets, the DOT undertook a local calibration and validation effort to improve the precision of its pavement designs. This presentation talked about the framework for the study, the results and lessons learned, and recommendations for future calibration activities. A total of 21 flexible pavement sections and 17 rigid pavement sections from across Kansas were used in calibrating the ME performance models, while six additional flexible pavements and five additional rigid pavements were used for validation. Somewhat inconsistent and unexpected results pointed out the need for more testing and research, particularly in the areas of resilient modulus characterization for soils and base materials, HMA characterization, and distress data collection format, and a larger sampling of pavement sections for use in the calibration and validation work.

3. ***Michigan DOT Calibration and User Manual* (Mr. Justin Schenkel, Michigan DOT)**—The focus of this presentation was on Part 3 (Calibration and Validation) of the DOT research project titled "Preparation for Implementation of the MEPDG in Michigan." The calibration study used data from over 160 pavement sections of varying type/structure located on roads throughout Michigan's seven regions. The bootstrapping technique was employed for the calibration and various datasets were considered, including one containing data from surrounding state LTPP sections. Calibrations were performed for the bottom-up cracking, transverse thermal cracking, rutting, and IRI models for flexible pavements and for the slab cracking, faulting, and IRI models for rigid pavements (see table 18 for rigid model coefficients). As an outflow of the above research project, the DOT prepared an interim edition of the *Michigan DOT User Guide for Mechanistic-Empirical Pavement Design* (https://www.michigan.gov/documents/mdot/MDOT_Mechanistic_Empirical Pavement_Design_User_Guide_483676_7.pdf). The guide was developed as a simple and straightforward manual for identifying design inputs and conducting ME analyses.

   Mr. Schenkel stated that the calibration was performed using v2.0 of the *Pavement ME Design* software. He reported that because v2.2 and v2.3 yielded significant changes in the JPC design thicknesses, the DOT suspended the use of ME, pending a re-calibration of the concrete models. This effort is beginning to get underway.

   Mr. Schenkel invited participants to go to the DOT's ME Pavement Design website (http://www.michigan.gov/mdot/0,4616,7-151-9623_26663_27303_27336_63969---,00.html) to view the latest information on their ME implementation efforts.

Table 18. Comparison of Michigan and other agency calibration factors for rigid pavement performance models.

| Model | Coeffi-cients | Global | MI | AZ | CO | FL | MO | WA | | MN | OH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cracking | C1 | 2 | 2 | 2 | 2 | 2.8389 | 2 | 2 | | 2 | 2 |
| | C2 | 1.22 | 1.22 | 1.22 | 1.22 | 0.9647 | 1.22 | 1.22 | | 1.22 | 1.22 |
| | C4 | 1 | 0.23 | 0.19 | 0.6 | 0.564 | 1 | 0.139 | | 0.9 | 1 |
| | C5 | 1.98 | -1.80 | -2.067 | -2.05 | -0.5946 | -1.98 | -2.115 | | -2.64 | -1.98 |
| Faulting | C1 | 1.0184 | 0.4 | 0.0355 | 0.5104 | 4.0472 | 1.0184 | 0.4 | 0.934 | 1.0184 | 1.0184 |
| | C2 | 0.91656 | 0.91656 | 01147 | 0.00838 | 0.91656 | 0.91656 | 0.341 | 0.6 | 0.91656 | 0.91656 |
| | C3 | 0.002848 | 0.002848 | 0.00436 | 0.0147 | 0.002848 | 0.002848 | 0.000535 | 0.001725 | 0.002848 | 0.002848 |
| | C4 | 0.00084 | 0.00084 | 1.10E-07 | 0.008345 | 0.000884 | 0.00084 | 0.000248 | 0.004 | 0.0008837 | 0.000884 |
| | C5 | 250 | 250 | 20000 | 5999 | 250 | 250 | 77.5 | 250 | 250 | 250 |
| | C6 | 0.4 | 0.4 | 2.309 | 0.8404 | 0.079 | 0.4 | 0.0064 | 0.4 | 0.4 | 0.4 |
| | C7 | 1.8331 | 1.8331 | 0.189 | 5.9293 | 1.8331 | 1.8331 | 2.04 | 0.65 | 1.8331 | 1.8331 |
| | C8 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 |
| IRI | C1 | 0.8203 | 1.198 | 0.6 | 0.8203 | 0.8203 | 0.82 | 0.82 | | 0.8203 | 0.82 |
| | C2 | 0.4417 | 3.570 | 3.48 | 0.4417 | 0.4417 | 1.17 | 1.17 | | 0.4417 | 3.7 |
| | C3 | 1.4929 | 1.4929 | 1.22 | 1.4929 | 2.2555 | 1.43 | 1.43 | | 1.4929 | 1.711 |
| | C4 | 25.4 | 25.24 | 45.2 | 25.4 | 25.4 | 66.8 | 66.8 | | 25.4 | 5.703 |

4. ***VDOT Local Calibration for Flexible and Rigid Pavement Design*** **(Mr. Hari Nair, Virginia DOT)**—The DOT's ME implementation efforts trace back to the development of an implementation plan in 2007. Since then, the agency has conducted various studies on ME input parameters and has developed a draft *Pavement ME User Manual*. A continuation of their efforts included a local calibration and validation study (http://www.virginiadot.org/vtrc/main/online_reports/pdf/16-r1.pdf) begun in 2009 and completed in 2015. That study was the basis for this presentation. The calibration centered on HMA and continuously reinforced concrete (CRC) pavements, and utilized data from 53 pavement sections located in eight VDOT districts. The process outlined in the AASHTO *Guide for the Local Calibration of the MEPDG* was followed, which resulted in calibrations of the HMA rutting ($\beta_{r1}$, $\beta_{s1\text{-fine}}$, $\beta_{s1\text{-gran}}$) and bottom-up cracking ($\beta_{f1}$, $C_1$, $C_2$) (see figure 10 for calibration plots) models and the CRC punchout model ($C_4$). Attempts to calibrate the IRI models for HMA and CRC indicated that the global coefficients for those models should be used for the time being, although additional calibrations are planned for the future.

   Mr. Nair noted that Virginia doesn't experience much rutting, and that their suspicion is that the bulk of the rutting that does occur is in the HMA. He also noted that a high percentage of the calibration sections had very low levels of cracking. He stressed the DOT's desire to greatly expand the pool of pavement sections to provide for a more robust calibration. A suggestion was made that agencies seek out more sites that are perpetual design-oriented in order capture a greater performance window. Mr. Von Quintus pointed out that one has to be careful in doing so, citing an example in Georgia whereby eight to 10 sites that had fairly high levels of cracking were selected and it was found that the sites all had used recycled HMA controlled by an older specification.

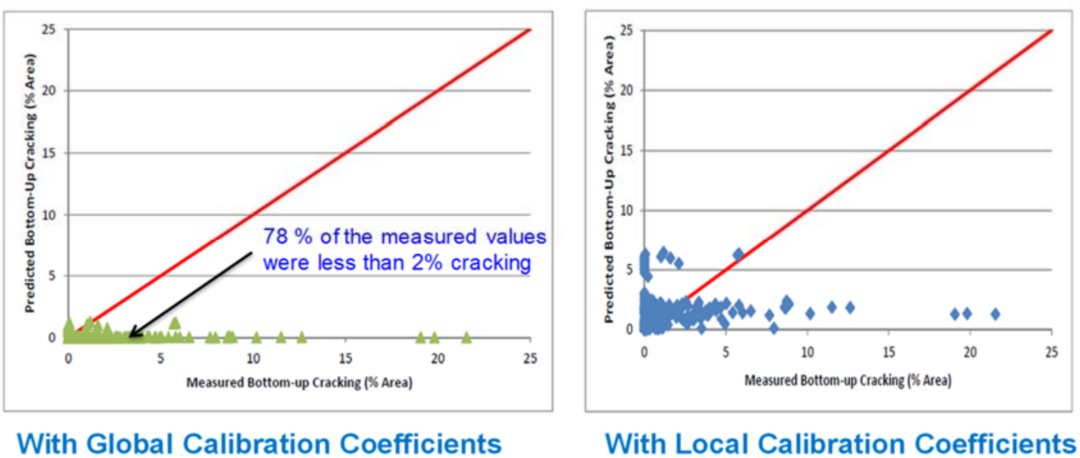



Figure 10. Virginia DOT local calibration results for flexible pavement fatigue cracking models.

At the conclusion of the Calibration and Validation session, it was suggested that a synthesis be developed that summarizes what each agency uses for local calibration factors. Mr. Von Quintus indicated that the National Center for Asphalt Technology (NCAT) has been preparing such a document.

# 12. SOFTWARE TRAINING

Session 12 of the meeting featured demonstration-based training on the use of the *Pavement ME Design* software. Although the original intent of the presentation was to interactively use the software, it was determined that the software screen displays would not be large enough for participants to see. Thus, a presentation with enlarged screen-shots of the software was used. A copy of the software training presentation is featured as presentation 23 in appendix C.

The training session was delivered by Mr. Von Quintus (ARA) and covered four applications: (1) import and use of NARR climatic data, (2) flexible pavement overlay design using SJPCP, (3) flexible pavement overlay design using HMA with damage assessment of in-place asphalt layers, and (4) flexible pavement overlay design using HMA with consideration of reflection cracking. The session concluded with instructional tips on a few of the topics discussed in previous sessions. A summary of each segment of the training is provided below, along with key discussions generated by the presentations.

1. ***Import and Use of NARR Climatic Data***—Both the NCDC and NARR climate data files can be downloaded and imported for use in ME. The key benefits of NARR data, as pointed out in Session 4, are an increase in the number of stations with complete data and an expansion in the number of years of available climate data from 10 to 37. Users are advised that the starting date used for climate data can significantly affect the transverse thermal cracking predictions (see figure 11), and may have an effect on IRI. Rutting and fatigue cracking predictions are not significantly affected.

   In general, there is not a significant bias between using NCDC and NARR data. However, in colder climates (e.g., Canada), there is a bias for HMA pavements, and the bias is driven primarily by transverse thermal cracking. Furthermore, when comparing the NARR and MERRA datasets, there is a bias in PCC cracking and faulting and in HMA transverse thermal cracking. This is mainly attributed to reporting differences in cloud cover.

   Mr. Wiser recommended referring to a study conducted by Dr. Charles Schwartz that looked at MERRA versus LTPP weather stations. Mr. Bill Barstis (Mississippi DOT) inquired if there is a need for a study to determine whether NARR or MERRA data should be used.

   Mr. Von Quintus recommended that users select January 1, 1979 as the start date for NARR data (yielding the full 37 years of data), primarily from the standpoint of consistency of application. A question was raised regarding the effects on past calibration efforts of using a 40-year NARR dataset when the NARR database is updated in 3 years. Mr. Von Quintus suggested that a move from NCDC to NARR data wouldn't necessitate a local calibration, but that a move from NCDC to MERRA data would.

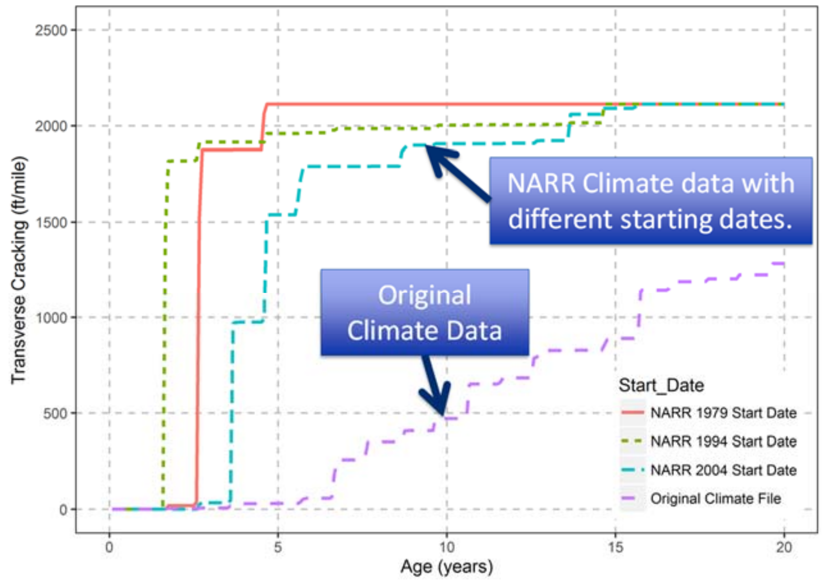
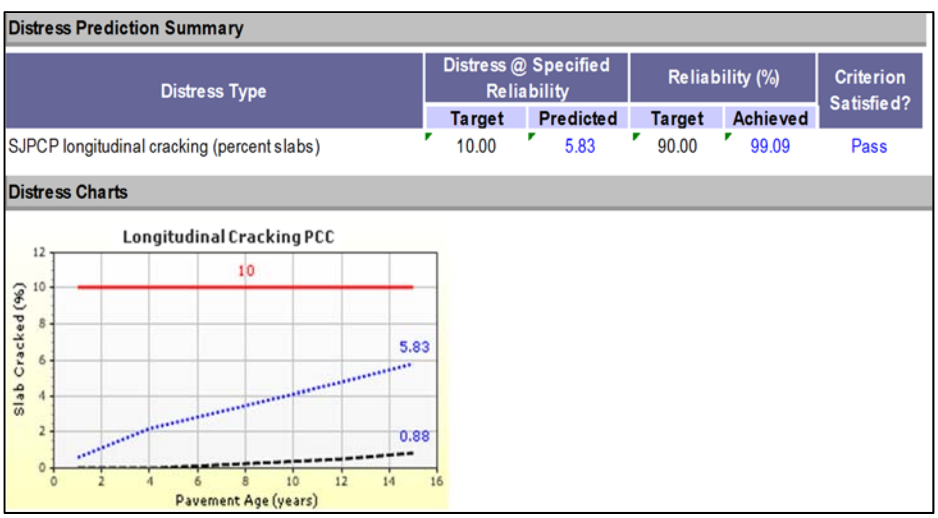



Figure 11. Effects on transverse cracking of using NCDC data and NARR data with different start dates.

2. ***Flexible Pavement Overlay Design Using SJPCP***—SJPCP design is now included as an overlay option for flexible pavements. As discussed in Session 4, the design only considers longitudinal cracking as a performance indicator. Key inputs required include the cracking threshold, the SJPCP slab and material layer properties, and the existing AC layer conditions (fatigue and thermal cracking) and properties (thickness, mix volumetrics, modulus). The design output includes the predicted percentage of cracked slabs as a function of age, as shown in figure 12.



Distress Prediction Summary

| Distress Type | Distress @ Specified Reliability | | Reliability (%) | | Criterion Satisfied? |
|---|---|---|---|---|---|
| | Target | Predicted | Target | Achieved | |
| SJPCP longitudinal cracking (percent slabs) | 10.00 | 5.83 | 90.00 | 99.09 | Pass |

Distress Charts



Figure 12. Distress prediction output for SJPCP design.

3. ***Flexible Pavement Overlay Design using HMA with Damage Assessment of In-place Asphalt Layers***—HMA overlay design also requires an assessment of the existing AC layer conditions (fatigue cracking and transverse cracking for Level 2 analysis, transverse cracking for Level 1 analysis) and properties (backcalculated layer moduli for Level 1 analysis). Milling depth, if included, must be specified, however users are advised not to reset the rut depth to zero for layers below the milled portion. The net thickness of the existing layer (coring depth minus milling depth) is entered as the layer thickness.

   Mr. Von Quintus pointed out that one cannot set the reliability level for AC bottom-up cracking and transverse thermal cracking. The values are automatically set at 50 percent. He explained that the basis for this is in the standard error analysis for reflective cracking, which combined both bottom-up and thermal cracking propagation. He added that the performance criteria limit of 15 percent for bottom-up cracking and 1,500 ft/mi for transverse cracking should also be used as the limits for AC total fatigue cracking (bottom-up plus reflective) and AC total transverse cracking (thermal plus reflective), respectively.

   A question was asked whether the backcalculated layer moduli is used in the rutting calculation. Mr. Von Quintus stated that it is used in the fatigue cracking calculation, but was unsure of its use in the rutting computation.

   Mr. Von Quintus recommended using the BELLS curve process for obtaining a mid-depth temperature for deflection data. This procedure uses the air temperature and the pavement surface temperature to develop a fairly accurate estimate of the mid-depth temperature.

4. ***Flexible Pavement Overlay Design using HMA with Consideration of Reflection Cracking***—The issue of reflection cracking in HMA overlays is an important one. *Pavement ME Design* includes an overlay design option that features an interlayer to help mitigate reflection cracking. Analysis of this design strategy in ME shows minimal benefit.

   Mr. Von Quintus pointed out that some states, such as Arizona, see a significant benefit with the use of an interlayer. He advised agencies to use the ME with caution or to perform a local calibration if their performance data also shows considerable benefit with this strategy.

5. ***Instructional Tips on Noteworthy Topics***—The use of an asphalt-treated permeable base (ATPB) in ME design of HMA pavements yields a high percentage of fatigue cracking, which was not seen in the LTPP sections. The *MEPDG Manual of Practice* recommends that an ATPB be treated as a high-quality aggregate base, with an $M_R$ of 65,000 lbf/in$^2$ (subject to verification). Another suggested modeling alternative is to include a 1-in dense-graded HMA under the ATPB, as the Indiana DOT has done.

   The use of polymer-modified asphalt mixtures in HMA pavements often provides benefits in the way of reduced cracking and rutting. Accounting for this benefit in *Pavement ME Design* requires local calibration to establish separate transfer function coefficients for conventional and polymer-modified mixes.

# 13. CHALLENGES, ISSUES, AND ROADBLOCKS

Session 13 of the meeting provided participants with a forum for discussing key challenges, issues, and roadblocks associated with the implementation of the MEPDG and the *Pavement ME Design* software. It also included a presentation on an ongoing FHWA study to mass assemble information on ME implementation efforts into a clearinghouse database and make it available to agencies as a web-based resource (presentation 24, appendix C). Summaries of each activity are provided below.

1. ***Forum on Implementation Challenges, Issues, and Roadblocks* (Facilitated by Dr. Linda Pierce, NCE)**—Participants were asked to provide any challenges, issues, or roadblocks that may hinder implementation of the MEPDG. The following provides a summary of some of the key responses:
   - There is need for a lot of pavement sections for local calibration and validation, and the need is particularly great for PCC.
   - The age of pavement sections included in local calibration and validation efforts must be looked at carefully to ensure that SuperPave mixes and other relevant designs are adequately captured.
   - The local calibration process is complex and needs some simplification. It is unclear if some states have the capability to perform local calibrations and a collective approach may be needed to help states progress. Automated tools for performing local calibrations would probably be beneficial, but can they be developed? Regional calibrations could also be beneficial, but would likely only work for selected areas (Florida, for example, has many micro-climates). The development of a set of calibration factors to serve as guide for states in a selected area would be helpful.
   - There is a need for a good HMA top-down fatigue cracking model and for the inclusion of a PCC longitudinal cracking model.
   - Polymer-modified asphalt needs more sections for global calibration. Although there are enough sections for rutting calibrations, the number of sections for fatigue cracking are insufficient.
   - The HMA rutting model needs to be fixed immediately. This is being acted on through a global recalibration and the results will be included in the release of *Pavement ME Design* v2.4.
   - AASHTO needs to prepare a road map or strategic plan identifying software development and model updates that will occur over the next 2 to 3 years. Agencies need to know this information in order to determine when they should conduct a local calibration.
   - *Pavement ME Design* should be equipped with a feature to allow the user to choose between "old" and "new" models.
   - Guidance is needed on how to use automated surveys in the local calibration process. Automated distress is rapidly gaining widespread use and acceptance, but there are some aspects of it that require guidance.
   - Recommendations on reasonable ranges for calibration factors are desirable. This would be difficult, however, due to the variability of materials, climate, and performance.

2. ***Clearinghouse of MEPDG Research and Implementation Efforts*** **(Mr. Prashant Ram, APTech)**—Initiated in March 2016, this project has collected information on hundreds of national-, state-, and pooled-fund-sponsored ME studies and recorded key elements of each study in a clearinghouse database. The database will be posted on the FHWA website in January 2017 and will be updated and maintained through February 2019. Agencies were invited to tender information on any new studies not currently included in the clearinghouse database.

# 14. ADDITIONAL NEEDS AND NEXT STEPS

The meeting concluded with a short discussion regarding additional needs relating to ME implementation and some final comments from selected participants. The following is a summary of the identified needs and associated discussion:

- Online training (remote learning) on the operation of the *Pavement ME Design* software is desired. ARA has conducted webinars in the past, but none are currently scheduled.
- Instructor-led training on both the MEPDG and the software is also desired. PennDOT has been very pleased with the training courses (theory and fundamentals/applications) delivered in recent years. The theory course was originated under the AASHTO ME Task Force. The fundamentals/applications course takes longer to conduct, but provides users with a good understanding behind the input parameters and the determination of values to use. Alberta is trying to set up this type of training for the TAC ME User Group. There was an NHI course on ME design, but it is no longer available.

The following a list of final comments made regarding the ME Users Group meeting and efforts to advance ME implementation:

- The people in this meeting are the driving force for ME implementation. Participants are encouraged to launch new initiatives and studies and to share the results with others.
- Lead organizations need to do a better job of communicating what is being done so that implementing agencies and others are aware of the latest developments and advancements.
- Because of its complexity, the process for implementing the MEPDG is long, tedious, and dynamic. Agencies should continue learning and working through the process, and informing others of their findings and lessons.
- Agencies are advised to wait for the new release of the software before performing a re-calibration. October 2017 is the scheduled timeframe for v2.4 of *Pavement ME Design*.
- FHWA appreciates the great participation experienced in this meeting and will work to continually enhance in future meetings.
- AASHTO invites participants to provide feedback and comments, as desired.

# 15. POST-MEETING SURVEY

At the conclusion of the first day of the meeting, SHA/PHA participants were asked to submit their top two choices for the best or most beneficial topic of the meeting. Table 19 provides a ranked listing of the participant responses. As can be seen, the top three topics were Pavement ME Design software updates, agency reporting on implementation status, and agency implementation experiences. These results somewhat dovetail with the pre-meeting survey results, in that agencies are very curious about changes in the software and the progress and experiences of other agencies.

One week after the Users Group meeting, SHA/PHA participants were asked to complete a short on-line survey regarding key takeaways from the meeting and general logistics for the next annual meeting. A total of 31 responses were received representing 24 agencies (21 SHAs, two PHAs, and one FHWA). The results of the survey are summarized in tables 20 through 25. Key takeaways from the meeting included issues with local calibration efforts (e.g., complex process made more difficult by continuous software updates), the varying degrees of implementation among agencies and the unique challenges that agencies face, and the need for improved communication about upcoming changes in MEPDG and *Pavement ME Design*. Notable suggestions for topics at the next meeting included additional updates on the software, agency implementation progress and experiences, simplified methods for performing local calibrations, and additional "live" software training. Feedback on locations and dates for the next annual meeting suggest that it be held in Nashville, Denver, Phoenix, or Kansas City between September 17 and October 21, 2017. A conventional 2-day meeting (Wednesday and Thursday combination) with sequential sessions like the Indianapolis meeting is desired.

Table 19. Best or most beneficial topics of Day 1 of ME Users Group meeting.

| Topic | Total Responses |
|---|---|
| • *Pavement ME Design* software update (Becker / ARA presentation). | 10 |
| • Agency implementation status. | 7 |
| • Agency implementation experiences session. | 5 |
| • Design parameters (Hall / Maryland presentation). | 5 |
| • Design parameters session. | 4 |
| • Determining in-place elastic layer moduli via FWD/backcalculation (Von Quintus / ARA presentation). | 3 |
| • ME process issues (Habib / Virginia presentation). | 2 |
| • Subgrade soils (Perkins / Colorado presentation). | 2 |
| • Climate session | 2 |
| • Local calibration/validation session | 2 |
| • HMA materials session. | 1 |
| • Subgrade and treated and untreated base/subbase materials session. | 1 |
| • MEPDG to AASHTO Pavement ME: 2004 to Present (Denkler / Missouri presentation). | 1 |
| • MERRA climate data tool (Wiser / FHWA presentation). | 1 |
| • Design catalog (Graves & Tucker / Kentucky presentation). | 1 |

Table 20. Survey responses on main takeaways from ME Users Group meeting.

| **2. List up to three main takeaways from this meeting** | |
|---|---|
| • The 'addendum' This is the first time I heard about it<br>• MO has calibrated for concrete pavement (maybe we can borrow theirs and maybe it would be closer than the national because they are our neighbor)<br>• The ongoing calibrations required from each agency seem like a major expense<br>• Understanding that local calibration has an extremely short shelf-life<br>• Recalibration is going to be continuous and problematic until a broader automated solution is derived<br>• Issue with recent updates causes need for Recalibration<br>• Understanding the need of a local calibration database clearing house<br>• We need to be preparing for future calibrations by creating a good database because calibrations will be an ongoing process<br>• Tools to facilitate recalibration are very much needed<br>• Several DOT's performing a second local calibration<br>• The calibration and validation status<br>• Indiana local calibration of rutting for HMA pavements<br>• Local Calibration pitfalls<br>• States bogged down in analysis of local calibration "paralysis by analysis"<br>• The concern about having an effective local calibration and the impact on local calibration from the planned changes<br>• Availability of improved weather data<br>• Availability of MERRA data from LTPP DataPave<br>• I learned about the new Climate Data<br>• Weather file updates<br>• Climate is hugely important in the Concrete models<br>• NARR vs MERRA sensitivity very interesting<br>• LTPP Climate Tool, and its use<br>• Update to weather station data<br>• Many states seem to be thinking or in the process of evaluating *Pavement ME Design*<br>• Agencies are all over the place regarding *Pavement ME Design* utilization<br>• Changes to Pavement ME are coming soon that probably require recalibration<br>• The functionality of the newer versions<br>• Significant impacts with version changes, experienced by other ME users<br>• Use of Pavement ME as a Pavement Management Tool<br>• Pave-ME software advances<br>• Look more at DRIP software for drainage<br>• A few agencies adopted a catalogue approach to ME design | • Amazing participation level by state DOTs<br>• Know what other State DOTs are doing<br>• Personal contact with other agencies<br>• Personal contact with other agencies<br>• Good to understand where other States are in their process<br>• Experience from other agencies and their challenges<br>• Many DOT's are performing parallel designs<br>• Other DOT's experience with local calibration<br>• How many agencies are using the program<br>• Level of efforts states are spending to implement ME Design<br>• Why some State DOTs are not yet implement the Pavement ME<br>• Learning status on Pave-Me implementation of agencies/provinces<br>• Surprised to hear that some States have not moved in the ME direction or are not using currently<br>• Much hesitancy by agencies to implement the Pavement ME Design - always waiting for one more model enhancement or national recalibration or more local calibration performance data or…<br>• Learning experiences from other agencies<br>• I learned how other states have handled local calibration<br>• Other DOT's ME implementation status<br>• How many agencies have tried the program<br>• States are very careful about changing pavement design practices<br>• I was very happy with the attendance numbers<br>• Remaining service life approach to analyze pavement design by Maryland<br>• The implementation status<br>• How are agencies collecting traffic data<br>• Better communication from Task Force is required<br>• Need for formal and transparent communication to the states on the future changes to MEPDG<br>• Everyone seems to be operating in a bit of a silo<br>• What milled thickness actually means<br>• AASHTO Ware with update information<br>• Web *Pavement ME Design* update very useful<br>• Learning Pave-ME software advances<br>• Information about future updates<br>• I learned about the new Concrete Overlay Module<br>• Available training<br>• New updates and other new software as part of AASHTO ME<br>• Good contacts made with other *Pavement ME Design* users<br>• InfoPave site<br>• Expert knowledge required to competently utilize the program |

Table 21. Survey responses on potential topics of interest at next ME Users Group meeting.

**3. List up to three potential topics of interest that you would like to have covered at the next meeting**

- Overlay analysis
- How to analyze rehab on existing HMA over concrete
- Modeling polymer modified asphalt mixtures
- NARR vs MERRA and future climate data plans
- Adjusting weather data
- Selecting resilient modulus for unbound layers
- Long life pavement design
- Full depth reclamation design
- Use of MEPDG in design build
- Gauging interest in web-based ME Design applications
- Asphalt overlay design
- Design parameters: traffic
- How to evaluate daily temp changes on JPCP cracking
- Progress of longitudinal cracking in PCCP analysis research
- Data collection - efficiently select sites & testing
- Longitudinal cracking for concrete pavements
- Reality check - predictions vs. actual pavement performance
- Emphasis on measurement of fatigue cracking and top down cracking data for input into HMA/WMA designs
- Top-down alligator cracking for flexible pavements
- Status of ME design implementation
- Identify potential road blocks and challenges to implementation for agencies
- Agency implementation experiences
- Agency implementation status
- Agencies' Pave-ME implementation activities
- Implementation experience - how are your designs performing relative to the predictions?
- Identify the resource need for ME implementation and discuss if any coordinated help tool can be structured
- Sensitivity of analysis to various inputs-what really has impact
- Emphasis on how data is being collected and input into pavement ME and sensitivity testing
- Discussion of dynamic modulus sensitivity
- Measurement of asphalt stiffness
- Hands-on training on Pave-ME calibration studies
- Training on Pave-ME calibration studies
- How to utilize the database that comes with the software
- More "hands on" workshop training
- Pave-ME software training
- Pave-ME software training
- A demo of MapME
- Need for database (back-end) guide, intermediary file info and definitions, etc.
- The current related NCHRP or FHWA studies
- Funding and potential research study for this group
- Updates in version 2.2 and 2.3, sensitivity analysis
- Upcoming changes to the software
- Updates in version 2.2 and 2.3, what are they
- Updates on version 3.0
- Updates in version 2.2 and 2.3, calibration efforts
- Further updates on current and planned improvements to the program
- Demonstration of back calculation that will be available in the next version of the software
- New findings / challenges of latest software
- Software updates - specific changes and reasons why
- More on rehabilitation modules, examples, things to look out for
- Recalibration - how to automate process
- Emphasis on how other states are handling recalibration efforts each time the software is updated
- Are any states using PrepME with *Pavement ME Design* and if so what parts of PrepME?
- A presentation from consultants and or contractors using software
- Examples where the software is used live, even if it takes a little longer session
- Use of back calculation module
- Use of database for server version of *Pavement ME Design*
- Using ME software for overlay design
- Summary of calibrated factors/coefficients from each agency
- Are other states having difficulties getting all their various divisions on the same page? How many divisions do they have to coordinate?
- State design practices
- A presentation from universities
- A compilation of common take aways from pioneer agencies that can be applicable for all or most users
- Updates on local calibration efforts by states and provinces
- Any updates on states developing design curves
- Status of any new HMA top-down cracking models
- Update on status of NCHRP work related to ME Design
- How to perform local calibrations of each variable so one knows what not to do?
- General local calibration guidelines for State DOT's
- How to setup for local calibration when it will have to be done for every version change
- Local calibration
- Regional calibration versus national calibration
- Rutting and fatigue models local calibration: factors to consider
- Follow up on the resource compilation that FHWA is doing
- Thorough discussion of what goes on behind the scenes
- Wrap up with specific action items

Table 22. Survey responses on potential dates for next ME Users Group meeting.

| Question | Total Responses |
|---|---|
| *4. Indicate all potential 2017 dates that would work for the next Pavement ME Users Group meeting?* | |
| • Week of August 13 | 17 |
| • Week of August 20 | 16 |
| • Week of August 27 | 15 |
| • Week of September 10 | 17 |
| • Week of September 17 | 20 |
| • Week of September 24 | 21 |
| • Week of October 1 | 23 |
| • Week of October 8 | 20 |
| • Week of October 15 | 19 |
| • Week of October 22 | 14 |
| • Week of October 29 (note: Halloween on October 31) | 13 |
| • Week of November 5 (note: Election Day on November 7) | 14 |
| • Week of November 12 | 15 |

Table 23. Survey responses on 2-day meeting day preferences.

| Question | Total Responses |
|---|---|
| *5. Which 2-day meeting day combinations are preferred (select one)?* | |
| • Tuesday/Wednesday | 8 |
| • Wednesday/Thursday | 21 |

Table 24. Survey responses on preferred locations for next ME Users Group meeting.

| Question | Responses | | | |
|---|---|---|---|---|
| | #1 Location | #2 Location | #3 Location | Total |
| *6. Rank your top three preferred locations for the next meeting.* | | | | |
| • Indianapolis, IN | 5 | 2 | 1 | 8 |
| • Kansas City, MO | 2 | 3 | 5 | 10 |
| • St. Louis, MO | 2 | 4 | 3 | 9 |
| • New Orleans, LA | 3 | 0 | 4 | 7 |
| • Phoenix, AZ | 2 | 5 | 4 | 11 |
| • Atlanta, GA | 4 | 4 | 1 | 9 |
| • Denver, CO | 8 | 5 | 0 | 13 |
| • San Antonio, TX | 1 | 1 | 2 | 4 |
| • Austin, TX | 1 | 0 | 4 | 5 |
| • Nashville, TN | 2 | 6 | 6 | 14 |

Table 25. Survey responses on meeting format for next ME Users Group meeting.

| Question | Total Responses |
|---|---|
| *7. What meeting format would you prefer for the next meeting?* | |
| • General Meeting: Conventional 2-day meeting with sequential sessions attended by all participants (e.g., 1st Annual Meeting in Indy). | 24 |
| • General Meeting with Breakout Sessions: Conventional meeting on Day 1, followed by two concurrent breakout sessions on Day 2. | 7 |

# REFERENCES

American Association of State Highway and Transportation Officials (AASHTO). 2008. *Mechanistic-Empirical Pavement Design Guide: A Manual of Practice, Interim Edition*. Publication No. MEPDG-1. AASHTO, Washington, DC.

American Association of State Highway and Transportation Officials (AASHTO). 2010. *Guide for the Local Calibration of the MEPDG*. AASHTO, Washington, DC.

American Association of State Highway and Transportation Officials (AASHTO). 2015. *Mechanistic-Empirical Pavement Design Guide: A Manual of Practice, Second Edition*. Publication No. MEPDG-2. AASHTO, DC.

Pierce, L.M. and G. McGovern. 2014. *Implementation of the AASHTO Mechanistic-Empirical Pavement Design Guide and Software*. NCHRP Synthesis 457. Transportation Research Board, Washington, DC. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_457.pdf.

Pierce, L. and K.D. Smith. 2015. *AASHTO MEPDG Regional Peer Exchange Meetings*. Publication No. FHWA-HIF-15-021. Federal Highway Administration, Washington, DC.

Transportation Association of Canada (TAC). 2014. *Canadian Guide: Default Parameters for AASHTOWare Pavement ME Design, Working Copy*. TAC Pavement ME Design User Group. TAC, Ottawa, ONT, Canada.

Wisconsin Department of Transportation (WisDOT). 2013. *WisDOT MEPDG Implementation Peer Exchange*. WisDOT ID No. 0092-13-17. Wisconsin Department of Transportation, Madison, WI. http://wisdotresearch.wi.gov/wp-content/uploads/WisDOT-0092-13-17-MEPDG-peer-exchange-final-report.pdf.