AASHTO PAVEMENT ME NATIONAL USERS GROUP MEETINGS

TECHNICAL REPORT: SECOND ANNUAL MEETING—DENVER, CO OCTOBER 11-12, 2017

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providing engineering solutions to improve pavement performance

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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 (PMED)*, was developed and released in 2011. Multiple updates have been made to the software since its initial release, with the latest version (v2.4)[1] and an accompanying *Deflection Data Analysis and Backcalculation Tool* (*BcT*, v1.0), made available in July 2017. Together, the MEPDG and the AASHTOWare software provide an improved process for conducting pavement analysis and for developing designs based on ME 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 state highway agencies (SHAs) 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.

Highway Agency Peer Exchange Meetings

In September 2013, the Wisconsin Department of Transportation (WisDOT) initiated an outreach program to conduct an MEPDG implementation peer exchange meeting with 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.

[1] *PMED* v2.4 is the formal designation given to the software corresponding to the release of *BcT* 1.0. The actual downloadable version from the AASHTOWare website is listed as v2.3.1.

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 continue the sharing of experiences and the dissemination of information related to ME design, and to facilitate the more rapid adoption of the MEPDG and the AASHTOWare *PMED* 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, while the second was held on October 11-12, 2017 in Denver, Colorado.

This report documents the results of the second annual meeting. It includes all pertinent materials and information shared in the meeting and covers the various technical topics presented and discussed by the participants. It also presents key takeaways 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 71 attendees participated in the second annual Pavement ME Users Group meeting, including representatives from 26 states, three Canadian provinces, six consulting firms, seven universities, three industry groups, and FHWA. The meeting was facilitated by Dr. Linda Pierce (NCE) and Mr. Kelly Smith (Applied Pavement Technology, Inc. [APTech]). A complete list of the meeting participants and their contact information is provided 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, Chair of AASHTOWare PMED Task Force and Member of AASHTO Committee on Materials and Pavements [COMP]) and Ms. Marta Juhasz (Alberta Transportation, presenting on behalf of Mr. Felix Doucet [Quebec Ministry of Transportation, Canadian Liaison to the PMED Task Force]), the meeting featured presentations from 14 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 21 agencies (19 SHAs, 2 PHAs), and a summary of the results are presented in tables 1 through 14 and in figures 1 through 4. (Note: The implementation maps in figures 3 and 4 include the pre-meeting survey results, supplemented by results from last year's pre-meeting survey and two previous polls [shown in hatching]—the 2015 ME Peer Exchange survey [Pierce and Smith 2015] and a Transportation Association of Canada [TAC] ME User Group scan). Although the number of respondents in the pre-meeting survey represent slightly less than half of the U.S. states, it is clear that several agencies have already implemented *PMED* or are getting close to doing so.

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?	21	9	12
1b. If No, does your agency intend to implement it and if so, by what year?	12	3 (2018) 3 (2019) 2 (2020) 1 (2021) 2 (no set target)	1
2a. Has your agency implemented Pavement ME Design for the design of concrete pavements and overlays?	21	7	14
2b. If No, does your agency intend to implement it and if so, by what year?	14	3 (2018) 2 (2019) 2 (2020) 1 (2021) 2 (no set target)	4

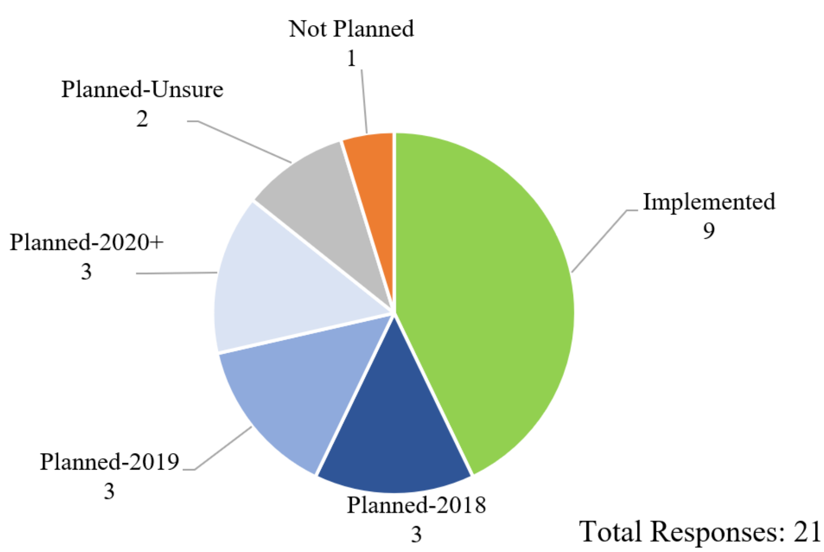


Figure 1. Implementation status for asphalt pavements and overlays.

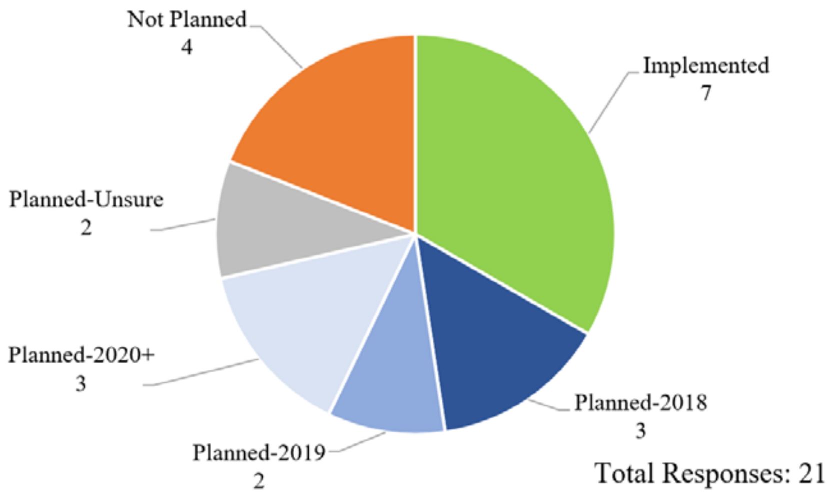


Figure 2. Implementation status for concrete pavements and overlays.

Table 2a. Implementation status by asphalt pavement type.

3. For which types of asphalt pavements has your agency implemented or plan to implement Pavement ME Design?	**Total Responses**	**Implemented**	**Planning to Implement**
New Conventional (Thin or Nominal HMA on unbound base)	17	8	9
New Deep-Strength (Thick HMA on unbound aggregate base)	19	9	10
New Full-Depth (HMA on stabilized or unstabilized subgrade)	16	7	9
New Semi-Rigid (HMA on stabilized base/subbase)	17	5	12
HMA Overlay on Existing Asphalt Pavement	16	4	12
HMA Overlay on Existing Intact or Fractured Concrete Pavement	16	3	13

Table 2b. Implementation status by concrete pavement type.

4. For which types of concrete pavements has your agency implemented or plan to implement Pavement ME Design?	**Total Responses**	**Implemented**	**Planning to Implement**
New Jointed Plain Concrete (JPC)	17	8	9
New Continuously Reinforced Concrete (CRC)	6	1	5
JPCP Overlay on Existing Pavement	11	3	8
CRCP Overlay on Existing Pavement	4	2	2

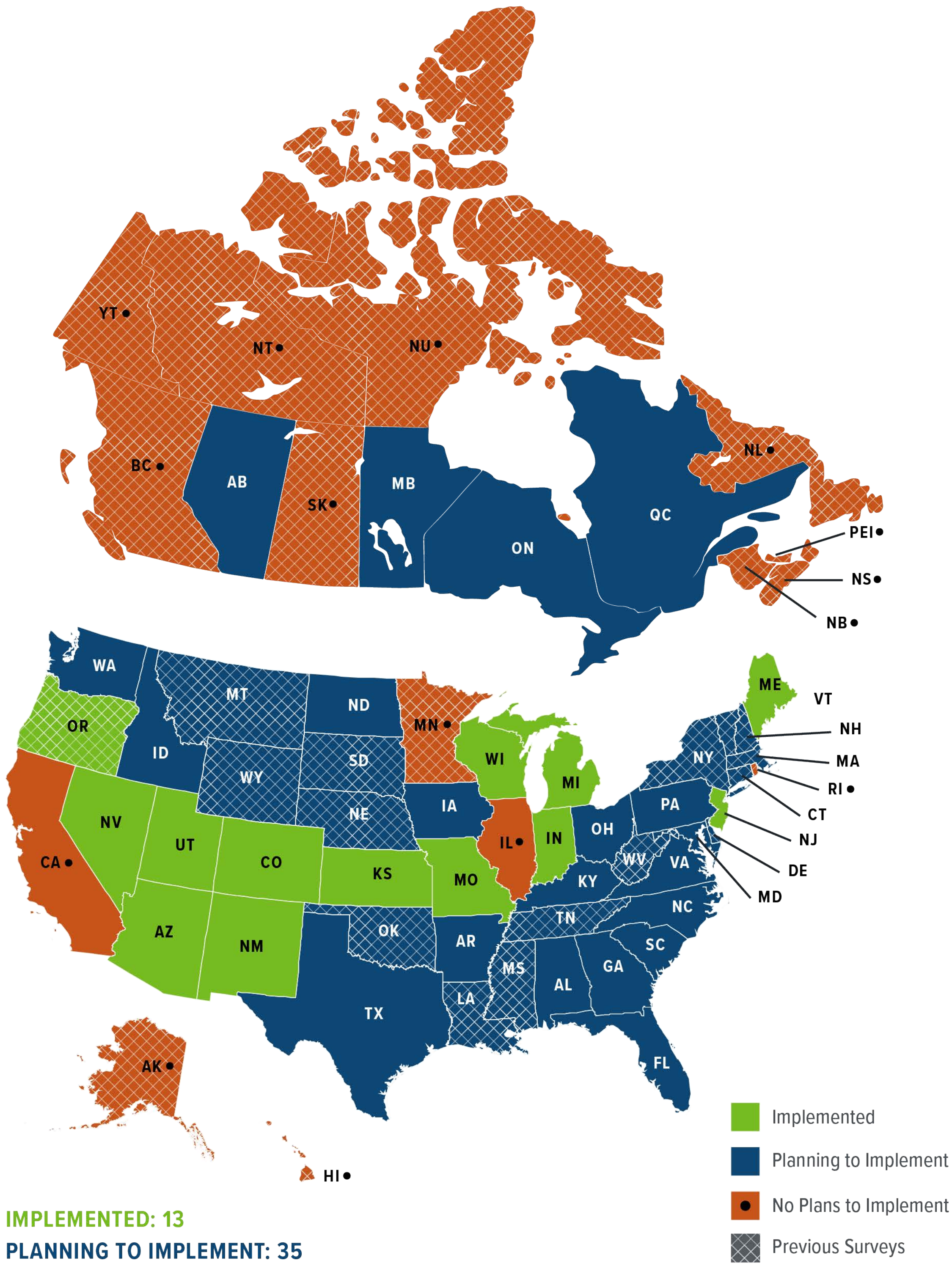


Figure 3. Implementation status by state—asphalt pavements and/or overlays.

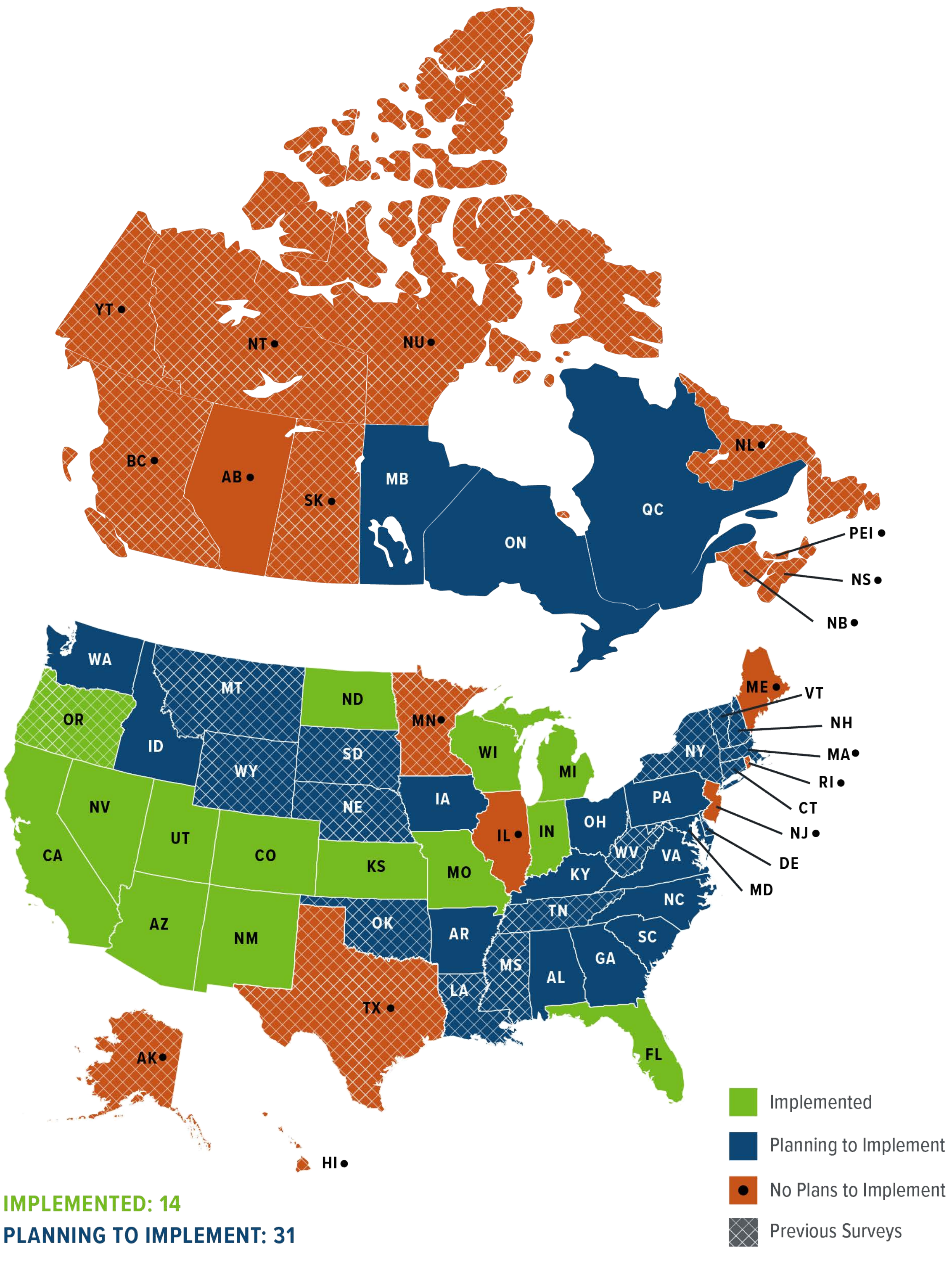


Figure 4. Implementation status by state—concrete pavements and/or overlays.

Table 3. Implementation challenges.

5. What has been the most difficult or challenging technical aspect of implementation (select top two)?	Total Responses
Compatibility of performance measures and threshold criteria	2
Designing pavement structures with features that are not included in Pavement ME or that have not been calibrated (e.g., thin PCC overlays, permeable asphalt- or cement-treated bases, geogrids and other reinforcing materials)	5
Availability of data to adequately characterize inputs	2
Characterization of traffic	2
Characterization of climate	0
Characterization of subgrade, subbase, and/or base material properties	1
Characterization of HMA material properties	4
Characterization of PCC material properties	2
Backcalculation analysis for characterizing existing pavement and subgrade properties	2
Sensitivity testing of key design inputs	0
Availability of performance data to adequately perform local calibration and verification	4
Local calibration and verification of performance model coefficients	10
Other: ➢ Insensitivity to unbound material layer thicknesses and stiffness. ➢ Need new pavement distress models to fit the local conditions. ➢ We have got software recently. Now, we have to provide training to our new engineers. ➢ Keeping up with version changes and the requirements to move to a newer version.	4

Table 4. Hierarchical input levels.

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)	Total Responses	Level 1	Level 2	Level 3
Truck Volume Distribution	19	7	10	2
Lane and Directional Distributions	19	4	10	5
Axle Load Distributions (single, tandem, tridem)	19	3	11	5
Subgrade Resilient Modulus	19	8	5	6
Unbound Base/Subbase Modulus	19	3	11	5
Chemically Stabilized Layer Modulus	18	2	5	11
HMA Dynamic Modulus	19	4	9	6
HMA Creep Compliance and Indirect Tensile Strength	19	3	7	9
HMA Volumetric Properties	19	4	10	5
PCC Elastic Modulus	19	2	7	10
PCC Flexural Strength	19	1	7	11
PCC Coefficient of Thermal Expansion	19	2	10	7
Existing Pavement Moduli	16	3	7	6

Table 5a. Condition threshold levels, Pavement ME Design vs. agency 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?	Total Responses	Default Thresholds	Agency Thresholds/Values
Pavement ME Design default values or agency-selected values	19	6	13

Table 5b. Condition threshold levels, agency values.

7b. If agency-selected values, what are the values used for high-type Interstate/Freeway facilities?	Total Responses	Agency Thresholds/Values
HMA smoothness (IRI), in/mi	13	≤50 (0) 51-75 (0) 76-100 (0) 101-125 (1) 126-150 (2) 151-175 (7) 176-200 (1) TBD or Varies (1) Not applicable (1)
HMA alligator (bottom-up) cracking, % lane area	13	0-5 (1) 6-10 (8) 11-15 (1) 16-20 (2) TBD or Varies (1)
HMA total rut depth, in	13	0.00-0.125 (0) 0.126-0.25 (0) 0.26-0.375 (2) 0.378-0.50 (7) 0.51-0.625 (0) 0.626-0.75 (3) TBD or Varies (1)
HMA transverse thermal cracking, ft/mi	13	≤500 (1) 501-1000 (7) 1001-1500 (2) N/A (1) TBD or Varies (1) Not applicable (1)
JPC / CRC smoothness (IRI), in/mi	13	50-75 (0) 76-100 (0) 101-125 (0) 126-150 (2) 151-175 (7) 176-200 (2) TBD or Varies (1) Not applicable (1)
JPC mean joint faulting, in	13	0.00-0.125 (10) 0.126-0.25 (2) TBD or Varies (1)
JPC transverse slab cracking, %	13	1-5 (1) 6-10 (8) 11-15 (3) 16-20 (0) TBD or Varies (1)

Table 6a. Local calibration.

8a. Has your agency conducted a local calibration?	Total Responses	No	Yes
Local Calibration	21	7	14

Table 6b. Local calibration software.

8b. For which software versions has your agency performed a local calibration?	Total Responses
Pre-DARWin-ME	1
DARWin-ME	1
v0.6-rigid	1
v1.0-flex	1
v1.2	1
v1.3	1
v2.0	1
v2.1	3
v2.x	1
v2.2	2
v2.3	2
v2.3.1	1
Unspecified	2

Table 6c. Use of locally or nationally calibrated models.

8c. Which performance prediction models were analyzed and which type of calibration values (National/Default or Local) are currently being used?	Total Responses	Included in Local Calibration Analysis	National	Local	Not Applicable
HMA smoothness (IRI)	0	0	0	0	0
HMA longitudinal (top-down) cracking	13	8	7	3	1
HMA alligator (bottom-up) cracking	13	12	5	6	0
HMA transverse thermal cracking	14	11	6	5	1
HMA reflective cracking	13	6	7	2	2
HMA rutting (asphalt layer only)	14	14	1	11	0
HMA rutting (total)	13	13	1	11	0
JPC smoothness (IRI)	14	9	7	5	0
JPC transverse slab cracking	14	8	7	5	0
JPC mean joint faulting	14	9	6	6	0
CRC smoothness (IRI)	11	3	5	0	5
CRC punchouts	10	3	2	1	5

Table 7. Incorporation of Modern-Era Retrospective Analysis for Research and Applications (MERRA).

Question	Total Responses	Yes	No
9a. Has your agency incorporated MERRA weather data into Pavement ME Design?	21	1	20
9b. If Yes, has your agency evaluated or sensitivity-tested the effect of using MERRA data versus ground-based weather data on ME performance predictions?	1	0	1

Table 8a. Traffic database, development.

10a. Has your agency developed a comprehensive traffic database for use in Pavement ME Design?	Total Responses	Yes	No
Comprehensive Traffic Database	21	11	10

Table 8b. Traffic database, traffic input hierarchical levels.

10b. 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)?	Total Responses
Level 1 project-specific vehicle class distribution	5
Level 2 vehicle class distribution factors for truck traffic clusters	9

Table 9a. Use of falling weight deflectometer (FWD) backcalculation.

11a. Does your agency use backcalculation of FWD data to characterize the existing pavement and subgrade for rehabilitation design?	Total Responses	Yes	No
FWD Backcalculation Used	20	9[a]	11

[a] Two respondents did not specify which programs/methods they use.

Table 9b. Use of FWD backcalculation, flexible pavement programs/methods.

11b. If Yes, what flexible pavement backcalculation programs/methods are used to establish the necessary Pavement ME Design inputs?	Total Responses
BOUSDEF	0
ELMOD	3
ELSDEF	0
EVERCALC	2
MODULUS	4
WESDEF	0
MODCOMP	0

Table 9c. Use of FWD backcalculation, rigid pavement programs/methods.

11c. If Yes, what <u>rigid pavement</u> backcalculation programs/methods are used to establish the necessary Pavement ME Design inputs?	**Total Responses**
AREA method	1
Best-Fit method	0

Table 9d. Use of FWD backcalculation, composite pavement programs/methods.

11d. If Yes, what <u>composite pavement</u> backcalculation programs/methods are used to establish the necessary Pavement ME Design inputs?	**Total Responses**
Outer AREA method	1
Best-Fit method	0

Table 9e. Use of Pavement ME Backcalculation Tool (EVERCALC).

11e. If Yes, is the Pavement ME Backcalculation Tool (using EVERCALC) being used?	**Yes**	**No**
EVERCALC Used	3	0

Table 10. Materials database/library status.

12. Has your agency developed a materials database or library for quick and reliable establishment of Pavement ME Design inputs?	**Total Responses**	**Yes**	**No**
Subgrade (including chemically stabilized)	18	10	8
Untreated Base/Subbase	18	14	4
Treated Base/Subbase	18	7	11
HMA	20	17	3
PCC	20	12	8

Table 11. Evaluation of unbound materials and subgrade.

13. Has your agency evaluated or sensitivity-tested the impacts of subgrade, subbase, and base layer resilient moduli on the resulting layer thicknesses?	**Total Responses**	**Yes**	**No**
Subgrade (including chemically stabilized)	20	9	11
Untreated Base/Subbase	20	11	9
Treated Base/Subbase	20	7	13

Table 12. HMA material characterization.

14. Which of the following types of asphalt mixes has your agency developed Level 1 or Level 2 inputs for use in Pavement ME Design?	**Total Responses**
Warm-Mix Asphalt (WMA)	6
HMA with Rubber-Modified Binder	1
HMA with Reclaimed Asphalt Pavement (RAP)	13
HMA with Recycled Asphalt Shingles (RAS)	2

Table 13. PCC design features.

15. Which of the following JPC design inputs has your agency evaluated or sensitivity-tested to determine the impacts on PCC thickness?	Total Responses
Transverse Joint Spacing	8
Fixed versus Random Transverse Joint Spacing	2
Dowel Bar Size	8
Dowel Bar Spacing / Placement Configuration	3
Dowel Bar Shape	1
Tied versus Untied Shoulders	6
Slab Width	5

Table 14a. Participant suggestions, software improvements.

16. Do you have any suggestions for software improvements?
Make sure models are coded correctly.
Sensitivity to unbound layer stiffness/thickness and subgrade stiffness.
Swell and frost issues.
Improve the top-down cracking (longitudinal) and alligator cracking models for flexible pavement.
Develop longitudinal cracking model and corner cracking model for JPCP.
Add a calibration tool or application that streamlines the calibration process to quickly recalibrate when new versions of ME are introduced.
The faulting model for PCC needs to be calibrated at the National level.
The widened slab provides too much benefit to PCC and needs to be recalibrated.
It will be very helpful if you release a very detailed manual like the NCHRP 1-37 MEPDG manual when you release a new feature or version (i.e., reflective cracking model, interlayer, semi-ridged, etc.). Most users use the software without full understanding the new features because of lack of information.
Ability to model a stone matrix asphalt (SMA), Bonded Wearing Course (Novachip) and Open Graded Seal Coat (OGSC).
Module for stabilized full-depth recycling process.
When new models are introduced into the software, the older models should remain as an option for a period of time. The local calibration effort is much too expensive and time consuming to just eliminate models. It should be a relatively simple thing to include a toggle within the software to allow the user to select which model to use. Progress is important, but so are the limited resources a state has to perform a calibration.
We would like to see a more user-friendly interface. Occasionally, it is hard to see and navigate the input screens.
Ability to customize the report to reflect only distresses considered by agency.
I would suggest probably reduce the frequency of software versions release unless it is critical. This will require additional resources and efforts from state agencies to decide whether to adopt the new version or not.
Ability to set some threshold values or input parameters as default by an agency. For example, traffic growth rate...user will be required to change for each traffic class manually... instead if there is option to choose to make default would save considerable amount of time.

Table 14b. Participant suggestions, research needs.

17. Do you have any research needs requests?
Consideration of frost issues in performance prediction.
Consideration of swelling issue in performance prediction.
A comprehensive report that shows in a simplified way the impacts of design inputs vs other design inputs.
An interactive application or added function to Pavement ME to show significance of inputs could be a helpful result.
Faulting model for PCC.
Widened slab model for PCC.
CTE and how it affects faulting in PCC.
Close to 50% of asphalt pavements are surface treatment (chip seal over flexible base). This is a major hurdle for Texas to implement Pavement ME as the official design method.
Development of a very detailed manual for updates done after NCHRP 1-37.
No. Consultants and academics provide research for us from time to time.
Any calibration information and clarified sequence of steps required.
Characterization of Cold In-place Recycling (CIR), Cold Central-Plant Recycling (CCPR), and FDR for Pavement ME. The biggest issue modeling of such materials in Pavement ME is their volumetric property (binder and air void). These materials have 10-14% air void and Pavement ME predicts higher fatigue cracking.
Characterization of Stone Mastic Asphalt (SMA) in pavement ME. Since Pavement ME is stiffness based software, we don't see the benefit of SMA compared to Dense graded mixes interims of rutting in Pavement ME.
Overall, the semi-rigid model does require extensive review and recalibration effort.

Table 14c. Participant suggestions, training needs.

18. Do you have any specific training needs?
How to quality and quantify existing pavement characteristics for ME design.
In-depth training by actual developers.
No. Our training is provided by ARA.
For state DOTs who are implementing Pavement ME, it would be beneficial to have fundamental training in modeling, calibration process, and material characterization.
We need to learn more about the rehabilitation design modules. But that's probably more on our end since we haven't really used it yet.

3. INTRODUCTORY SESSION

Mr. Wagner opened the second annual ME Users Group meeting by welcoming both new and returning participants, recognizing their valued efforts in implementing ME design principles, and discussing the fundamental importance of the meeting. He briefly described the meaning of "implementation" as agencies using the *PMED* for routine designs and noted the progress made in recent years by both state and provincial highway agencies. 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 a brief update on the *PMED* software, the newly formed AASHTO COMP, and a key working group within the COMP—Technical Section 5d, *Pavement Design* (see presentation 1, appendix C). He informed the group of the July 2017 rollouts of the v2.4 software and the new *BcT* tool, and he touched upon key upgrades (e.g., integration of the *MEPDG Manual of Practice*, incorporation of the globally recalibrated flexible and semi-rigid performance models) for v2.5 scheduled for release in 2018, as well as planned enhancements for the 2019 software (e.g., incorporation of the NCHRP 1-52 HMA top-down cracking model and automated local calibration). He described the composition of the AASHTO COMP (pavement design engineer representatives from each state) and talked about the immediate focus of Technical Section 5d, which is the development of an updated *Manual of Practice*, *Local Calibration Guide*, and *Pavement Handbook*.

Lastly, Ms. Juhasz provided the audience with an overview of the Transportation Association of Canada (TAC) Pavement ME Design User Group (which comprises approximately 40 members representing highway agencies, academia, consultants, and industry) and a description of Canadian efforts to implement the MEPDG and the *PMED* software (see presentation 2, appendix C). She reported on the User Group's mandates, including collaboration with the AASHTOWare PMED Task Force and finalizing the first version of the User Guide (*Canadian Guide: Default Parameters for AASHTOWare Pavement ME Design* [TAC 2014]). She also reported on the Canadian User Group trials, which began in 2010 with a basic calibration exercise and have since expanded into other trials, including sensitivity analysis of HMA content and air voids on cracking, rutting, and IRI. In one of the recent trials, the User Group found notable differences in the levels of predicted distress between historical Canadian climate data, North American Regional Reanalysis (NARR) data, and MERRA data. In closing, Ms. Juhasz indicated that Manitoba, Quebec, and Ontario are the farthest along with respect to implementation among the Canadian agencies.

4. AGENCY IMPLEMENTATION STATUS

Session 2 of the meeting focused on agency reporting of MEPDG implementation status. Dr. Pierce began the session by presenting HMA and PCC implementation maps developed after the 2016 Users Group meeting, as well as a series of graphics covering the pre-meeting survey results (see presentation 3, appendix C).

Following Dr. Pierce's presentation, meeting participants were asked to provide a brief update on their agency's implementation status. A summary of the implementation efforts and progress reported in the first Users Group meeting was provided as a handout, and participants were instructed to use their respective summary as a guide for their update. In addition, participants were asked to touch upon specific implementation challenges and solutions, and whether local calibrations have been performed and if calibrated models are currently being used.

Table 15 summarizes the information reported 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. • Completed material characterization of subgrade soils. • Participating in NCAT Asphalt Mixture Performance Tester pooled fund study. • Semi-implemented training course for consultants. • Still in process of implementation with new software version. • Sensitivity analysis of subgrade soils and models.
Alberta MOT	• Local calibration has not been conducted. • Traffic data from six WIM sites. • Some materials characterization; biggest hurdle is unbound base. • Conducting *PMED* since April 2016. The designs are outsourced; they require consultants to do one ME design as a design check, and have done about 120 designs so far. • They are questioning the accuracy of both ME design and AASHTO 1993.
Arizona DOT	• Local calibration conducted by ARA (2010-2012). • User guide has been prepared, and is available upon request. • Traffic study completed. Identified three traffic clusters and eight truck traffic distributions. Installed 10 additional WIM sites. • Materials characterization around 2000. • AASHTO 1993 and *PMED* parallel designs for new pavement (2012-present). • Plan on recalibrating once reflection cracking model is included in software. • Implemented *PMED*. Using v2.1 until next software release and calibration are complete. • Design manual does not say to use ME. They are still uncertain about going with full implementation. • Fugro has started collecting automated distress data; will need to evaluate the effects of those data. • Confident with new asphalt pavement designs, uncertain with asphalt overlay designs, primarily with characterizing existing pavement.
California DOT	• Implementation of concrete pavement design procedure only. Asphalt pavements are designed using Cal-ME. • Use a simplified approach whereby default values are used, except for key inputs. • Conducted sensitivity study in 2006. • Waiting for NCHRP 1-51 and 1-53 to be completed before doing a local calibration. University of California is preparing the data for the calibration. • Need to identify methods/process for modeling rapid strength concrete materials and precast concrete pavements.

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

Agency	Status/Update
Colorado DOT	• Conducted local calibration in 2010-2011. • Performed AASHTO 1993 and *PMED* parallel designs 2012-2014. • Full implementation on July 1, 2014. • Added 24 climate stations. Currently using their own climate stations, not NARR/MERRA. • Individual rutting models for HMA mixes with different binders (Marshall, Superpave, and polymer-modified). • Completed cold in-place recycling (CIPR) site sampling. • Sensitivity study for SMA is ongoing. • Plan on model recalibration within the next year. • Completed database, dynamic modulus sensitivity testing on 105 asphalt mixes (by contractor, region). • Currently not using BCOA; they have their own spreadsheet tool for this. • Currently using version 2.2, waiting for release of version 2.5 (recalibrated models and MERRA data). • CDOT *Pavement Design Manual* (https://www.codot.gov/business/designsupport/materials-and-geotechnical/manuals/pdm) has ME design procedures for HMA, PCC, and overlays.
FHWA Federal Lands	• Most roads are low volume. • Currently using AASHTO 1993. However, ad hoc use of *PMED* with agency designs. • Not planning a robust calibration effort at this time. • Focusing on getting better traffic data.
Florida DOT	• Implementation of PCC design procedure completed, but PCC represents a small portion of Florida roads. • HMA design procedure not implemented; waiting for the release of the top-down cracking model. • Conducting a third local calibration effort. Industry disputed results of second calibration, thus they are currently using the results of the first calibration. • 9 software licenses. • Design manual (including populating the PCC pavement design tables) will be available November 1, 2017.
Georgia DOT	• Conducted some CTE testing. • University of Georgia study for training and software. • Some HMA testing; research on polymer-modified asphalt and SMA mixtures. • Assessment of LTPP distress types, modified to Georgia DOT. • Working to utilize level 2 inputs as much as possible. • Plan to calibrate after the release of version 2.5. • Number of IT issues need to be resolved. With big changeover in staff, stopped doing parallel designs.
Idaho TD	• Completed traffic and asphalt pavement material database (2009-2011). • Developed initial implementation roadmap and User Guide (2013-2014). • U of I research on asphalt model calibration (2015-2018), unbound materials database (2017-2018), PCC materials database (2016-2017), and PCC model calibration (2017-2019).
Illinois DOT	• IDOT developed their own ME design procedure in the 1980's and updated it in the early 2000's. • No plans to implement Pavement ME in the next 5 years.
Indiana DOT	• Primarily an asphalt state (90% HMA) and responsible for approximately 10,000 miles of road. • Full implementation in 2009 (first section designed and built that year). • Currently perform ME pavement designs on approximately 500 miles of pavement/year. • ME design procedure is featured in INDOT *Design Manual, Chapter 304, Comprehensive Pavement Analyses* (https://www.in.gov/indot/design_manual/files/Ch304_2013.pdf) • Currently using v2.3 of *PMED*. • Developed materials database in 2000. • Developed traffic database in 2004. • Conducted sensitivity study in 2004. • Local calibration performed using data from 103 calibration sections. • Currently refining and recalibrating the models based on performance of as-built pavement sections. • Evaluating SMA model and calibration factors.

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

Agency	Status/Update
Kansas DOT	• Conducted local calibration using Level 3 data. • Implemented new asphalt and JPCP designs. • Kansas State University is conducting research on concrete pavements. The pavement management system (PMS) database has no slab cracking information for JPCP, so selected PCC sites must be identified and surveyed for cracking. • Need to conduct improved HMA material characterization; not sure if they have any bottom-up cracking (cores needed to verify). • Need to verify calibration efforts, but have limited staff. • Kansas State University is doing a research project on subgrade resilient modulus. • AASHTO 1993 and *PMED* parallel designs for new full-depth asphalt and PCC. • Evaluating where to put research efforts and the level of effort needed (lab testing and field studies).
Kentucky Transportation Cabinet	• Currently in process of replacing current design procedure with *PMED*. • ME design catalog being developed by University of Kentucky. • Concrete models not yet calibrated due to lack of sufficient pavement sections (currently only 20 sites). • Conducted limited dynamic modulus testing. • Traffic studies not yet performed.
Maine DOT	• State highway system comprised of only asphalt pavements. • Good progress on climate database and traffic data from WIM sites. • Database for unbound layers, missing subbase information, obtaining samples and testing. • Conducting PG binder testing and asphalt mix characterization. • Conducting data collection for calibration effort. • Focusing on characterization of recycled materials. • Waiting for the release of reflection and top-down cracking models.
Manitoba Infrastructure	• Developed database for pavement materials. • Level 1 inputs for base and subgrade materials and level 3 for subbase. • Traffic data available from 7 WIM sites. Developed Level 1 traffic inputs. • Level 1 asphalt binder and mix characterization completed (for penetration-grade binder). • Local calibration was performed for HMA but was unsuccessful (results were all over the place). Will develop a new dataset for calibration. • Currently conducting parallel designs with AASHTO 1993. • PCC design is all level 3, however no design met the criteria (high plastic clay subgrade issues). • Currently going slow—waiting on NCHRP 1-51, 1-52, and 1-53 (Manitoba observed low sensitivity to unbound martials inputs and high top-down cracking prediction), test data on new asphalt binder, asphalt mix and granular base materials (they are moving from pen-grade to SuperPave binders, Marshall to SuperPave mixes, and poorly drainable to drainable stable granular bases), and characterization of subbase materials.
Maryland SHA	• Completed materials characterization and traffic study. • Local calibration on AC pavements (for now) is in progress. • Need more WIM sites for better traffic characterization. • University of Maryland conducted AC/unbound base sensitivity analysis (E* not changing significantly with time) and study on comparing AASHTO 1993 designs and ME designs). • Design parameters are available in the MDSHA *Pavement Design Guide* (http://www.sha.maryland.gov/OMT/ pdguide0616.pdf). • AASHTO 1993 is primary method, and can be supplemented by *PMED,* but not required.
Michigan DOT	• Fully implemented for new HMA and new PCC design since 2014. • Currently, they are on a hiatus until a new local calibration is performed. Previous calibration, version 2.0, resulted in a significant increase in JPC design thickness (over-prediction). • Traffic characterization and climate characterization projects complete. • HMA characterization database completed for Level 1 inputs. • MDOT *User Guide for Mechanistic-Empirical Pavement Design* prepared and available (https://www.michigan.gov/documents/mdot/MDOT_Mechanistic _Empirical_Pavement_Design_User_Guide_483676_7.pdf). • Conducting JPCP, HMA full-depth, and recycled material designs, with AASHTO 1993 as initial and *PMED* as final (results are within 1 in of the AASHTO 1993 design).

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

Agency	Status/Update
Michigan DOT (cont)	• Working on efforts to include rehabilitation designs. • Evaluating changes in software. They find it difficult to keep up with what has changed. Calibration is costly, especially when having to do it multiple times. Looking forward to automated calibration. • Not confident with the thermal cracking model, research is almost complete. • Additional analysis is needed on JPCP. • Use WIM and Level 2 cluster data based on WIM for traffic. Next research coming out in 2018 to update clustering.
Missouri DOT	• Implementation in 2004 (national models). • Local calibration in 2009. • Completed second local calibration; moving to level 1 inputs. • Conducting recycled HMA characterization. • Currently focusing on AC/AC overlays (complete evaluation early 2018). • Evaluating what threshold criteria to use; trying to strike balance between threshold and thickness. • Concerned with the quality of condition data.
Nevada DOT	• Challenges with traffic characterization (nine WIM sites with plans to add an additional three sites) and climate stations. • Full implementation (July 2015); using version 2.3.1. • AASHTO 1993 and *PMED* parallel designs; not yet confident with Pavement ME results. • Completed local calibration for some models (e.g., rutting and bottom-up fatigue cracking) but not for others (longitudinal top-down cracking, reflection cracking, and thermal cracking). Default calibration factors are used for IRI. • Question the need to use ME for low-volume roads. • Adopted national calibration values for JPC. • CTE testing on four aggregate sources. • 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. • Materials characterization completed for Level 1 inputs. • Traffic user's manual development completed. • *PMED* used for new and reconstructed HMA pavements (very little or no PCC in state). • Training for designers is on-going.
New Mexico DOT	• Predominantly asphalt state. • Concrete Section starting to look at JPC and CRC design. • Conducted local calibration for asphalt designs (University New Mexico study). No PCC calibration. • Materials database significant for HMA, but they don't have good subgrade data. • Need study for incorporating recycled materials. They are big into recycling, but not sure how to model these materials in ME. • Conducting CTE testing. • Need additional WIM sites, but costly. • Conducting AASHTO 1993 and *PMED* parallel designs.
North Carolina DOT	• Implemented *PMED* for new HMA designs on major projects (2011-2015). • 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. • 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. • Project to characterize JPC and CRC materials is almost complete.
North Dakota DOT	• Local calibration performed for concrete pavements in 2013-2014. • *PMED* implemented for concrete pavement design (primarily using national default values). • Using North Dakota DOT-determined values for CTE. • Conducting parallel designs with AASHTO 1993 and *PMED* (v2.3, level 2 inputs, except traffic, which are based on level 3 inputs).

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

Agency	Status/Update
North Dakota DOT (cont)	• E* appears to have a minimum effect on calibration factors (by aggregate and binder type). Moving to new PG binder specification, which does not match *PMED* asphalt mix characterization. • Literature review on dynamic modulus on-going. They hope to develop different calibration factors for different mixes. • Recalibration for flexible pavements when v2.5 comes out.
Ontario MOT	• Implementation has not yet occurred. *PMED* was used by a consultant for a high-profile project in Summer 2016. • Completed HMA model local calibration. • Need to verify PCC model predictions with actual projects. • Web-based traffic information system good source for traffic characterization; updated database in 2017. • Climate characterization based on 34 weather stations; completed comparison with NARR and MERRA. • Level 3 materials inputs based on contract specifications. Resilient modulus testing has been completed on some soils; but need to include more soil types. • Conducting parallel designs with AASHTO 1993 and *PMED*.
Pennsylvania DOT	• 12 WIM sites for traffic data. • Collecting samples for materials characterization of SMA and 9.5-mm, PG 76-22. • LTPP 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. • Evaluating long-life concrete design (mix optimization). • Using LTPP and Superpave In-Situ Stress/Strain Investigation (SISSI) sites for local calibration. • Received ARA training in ME theory and *PMED* applications. • Use AASHTO 1993 and *PMED* parallel designs for truck traffic > 500 trucks/day.
South Carolina DOT	• Dynamic modulus, sensitivity testing, and CTE studies completed. • University of South Carolina conducting subgrade characterization and design catalog work. • Collecting WIM data. • Lack of PCC sites; considering regional calibration effort with Virginia and North Carolina DOTs. • Limited use of pavement management data. • AASHTO 1972 is official design procedure in use. They do use the ME PCC module for evaluation of joint spacing and dowel bar issues.
Texas DOT	• Two traffic projects on-going, including traffic spectra for different districts. • Considering use of *PMED* for flexible pavements only. • Completed HMA mix characterization as part of TxDOT ME effort. • 120 sites for calibration effort. • Will develop an implementation plan soon.
Utah DOT	• Began conducting pavement designs using the MEPDG in 2004. • Level 1 traffic inputs. • Completed resilient modulus testing of soils and unbound aggregate materials. • Completed CTE testing. • Calibration and validation using both LTPP and state highway pavement sections. • Parallel designs with AASHTO 1993 since 2010. • Pavement designs conducted using Pavement ME since 2011; required all Federal Aid – Local pavement designs to use Pavement ME in 2015. • Challenges modeling pavement structures outside the norm. • Problems with modeling SMA correctly.
Virginia DOT	• HMA characterization completed to Level 1 for just one surface, one intermediate, and one base mix. Looking at trying to get specific mixes modeled. • Initial local calibration for HMA and CRCP in 2015. • Mix selection guidelines developed. • Need training on basics of *PMED*. • Desire a more formal update from AASHTO/FHWA on software developments, research studies, etc. • Interest in addressing national industry concerns, rather than individual state industry concerns. • Plan to fully implement *PMED* (v2.2.6) on January 1, 2018. • Rehabilitation design work to begin in 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). • Original calibration effort in 2002. • Traffic data (Level 1) study completed in 2007. • Developed 2013 design catalog based on *PMED* and AASHTO 1993. • 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, use site specific data. • Materials characterization (primarily for Level 3 inputs) based on LTPP sites and research studies. Completed HMA materials characterization. Local calibration completed in 2010. • Full implementation in 2014 for new and reconstruction design of asphalt and concrete pavements. • Currently using v2.1 of *PMED*. Planning on recalibrating with version 2.5. • Not currently conducting rehabilitation designs, possible will include after version 2.5 calibration, potentially in 2019. • 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	—	—	—
Arizona DOT	Completed	Completed	Completed	2010-2012	2012-current	Yes, in general	Yes
California DOT	N/A	—	—	PCC national calibration values (v0.8)	—	PCC only	Included in Design Manual
Colorado DOT	Yes	—	—	2010-2011	2012-2014	2014	Yes
FHWA Federal Lands	—	—	—	—	Yes	—	—
Florida DOT	N/A	—	—	On 3rd Round	—	PCC only	Anticipated Nov. 2017
Georgia DOT	Some HMA	Some CTE	—	Planned with version 2.5	—	HMA and JPCP only	—
Idaho TD	—	—	—	—	Yes	—	—
Illinois DOT	—	—	—	—	—	—	—
Indiana DOT	Completed	Completed	Completed	2009	—	2009	Yes
Kansas DOT	—	—	—	Level 3	full-depth asphalt only	Yes, in general	—
Kentucky Transportation Cabinet	Limited dynamic modulus testing	—	—	HMA only (synthesized factors)	—	Design catalogs	In progress
Maine DOT	Yes	—	Yes, working on subbase data	—	—	New and major rehabilitation (HMA)	—
Manitoba Infrastructure	Completed	—	—	Yes	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
Maryland SHA	Completed	—	Completed	In progress	Yes	Asphalt pavements only	Yes
Michigan DOT	Level 1	—	—	V2.0 and v2.3	—	2014 (JPCP, HMA, and recycled mtls)	Yes
Missouri DOT	—	—	—	2009	—	2004	—
Nevada DOT	Yes	CTE testing on four aggregate sources	On-going	HMA only; national calibration values for PCC	Yes	2015 (v2.3.1)	Draft guide for HMA pavement
New Jersey DOT	Level 1	—	—	—	—	Yes (begin use in 2017)	Traffic user guide
New Mexico DOT	Yes	CTE study	—	HMA only	Yes	—	—
North Carolina DOT	Yes	Almost completed	Yes	Yes, but need to recalibrate	Yes; use AASHTO 1993 since 2015	2011-2015 (currently using AASHTO 1993; will re-implement in future)	—
North Dakota DOT	—	CTE testing completed	—	Recalibrate with v2.5	Yes	PCC (primarily default values)	—
Ontario MOT	Level 3	Level 3	Level 3; some subgrade characterization	HMA models; verifying PCC models	Yes	High-profile project only	Yes
Pennsylvania DOT	Yes; includes WMA, SMA, and RAP	Yes	Yes	—	Yes, for truck traffic > 500 veh/day	—	—
South Carolina DOT	Dynamic modulus testing completed	CTE study completed	—	Considering regional calibration of PCC models with VA and NC DOTs	—	—	—
Texas DOT	Completed	—	—	—	—	Considering HMA models only	—
Utah DOT	—	CTE testing completed	Resilient modulus testing completed	Yes	Yes	All designs since 2011	Yes
Virginia DOT	Level 1	—	—	2015	—	Expected 2018	Yes
Washington State DOT	—	—	—	2002	—	Design catalog 2013	—
Wisconsin DOT	Update HMA materials	Level 3	Level 3	2010 (v2.1); plan to recalibrate with v2.5	—	Yes, new and reconst. 2014; rehab potentially in 2019	Yes (updating)

5. AASHTOWARE PMED SOFTWARE UPDATE

Session 3 of the meeting consisted of a briefing on purchasing and licensing of the AASHTO *PMED* software, followed by a presentation from the software developer (ARA) on the latest software enhancements and the new *BcT* program. Summaries of the information presented and surrounding discussions are provided below. Copies of the presentations are featured as presentations 4 through 6 in appendix C.

1. ***Software Announcements and News* (Mr. John Donahue, Missouri DOT)**—This presentation centered on key pages of the AASHTOWare *PMED* website (http://www.aashtoware.org/Pavement/), including the following:

    - User Support Help Desk for downloading software and climatic data and for reporting software bugs. Mr. Donahue pointed out that the MANTIS Bug Reporting System will soon be replaced with the Visual Studio Team Services (VSTS) setup.
    - Documents link for downloading PDF files of software version Release Notes, the *MEPDG Manual of Practice*, the *BcT* Release Notes, and the *BcT* User Manual.
    - Tools link for accessing or downloading beneficial tools, such as the XML Validator, *Drainage Requirements In Pavements* (DRIP), MapME, and Application Programmable Interfaces (APIs) for the JULEA backcalculation program and the Integrated Climatic Model (ICM).
    - Licensing link for purchasing or securing software licenses and activating them for use.

    Mr. Donahue gave a quick breakdown of the current (September 2017) number of SHA (40) and PHA (3) license-holders, as well as the types of licenses held by other organizations (39 no-cost educational, 67 private sector companies, and 9 universities). Among SHAs and PHAs, the numbers of licenses are comparable to 2016; however, for other organizations, the numbers have decreased slightly since 2016.

    The presentation concluded with a look at the near future of the *PMED* software. As Mr. Donahue noted previously, v2.5 is scheduled for release on January 1, 2018 and will include major enhancements, such as integration of the *MEPDG Manual of Practice* and incorporation of the globally recalibrated flexible and semi-rigid performance models. Another tool that will be transitioned for application with the design program is the *rePave* scoping tool developed under SHRP 2 Project R23. This interactive web-based tool enables designers to evaluate if rehabilitation is viable for a particular project.

2. ***AASHTOWare PMED: Enhancements and Future Outlook* (Mr. Chad Becker, ARA)**—The focus of this presentation was on the enhancements and updates planned for the *PMED* software in the coming years. The currently available software version is v2.3, with *BcT* v1.0 recently released in July 2017 (Note: *BcT* may be licensed both with and separately from *PMED*). Key enhancements and new features of each software version are summarized below.

    <u>*Next Version of BcT*</u>
    - Condensing of the segmentation screens into a single feature screen.
    - Additional reporting capabilities.

PMED v2.5 (January 2018)

- Integration of the AASHTO *MEPDG Manual of Practice*. The software will include a link to a PDF of the manual.
- API for HMA layer modulus, which will be particularly helpful for materials/laboratory personnel.
- File API for master transverse cracking model, which will be useful for local calibration activities.
- Globally recalibrated flexible and semi-rigid performance models for both new and rehabilitated pavements using MERRA climatic data.

PMED v2.6 (July 2018)

- Customization of reports to allow selection of specific performance criteria.
- Maintenance strategy module that allows the user to reset performance parameters to reflect the changes in conditions associated with limited planned non-structural preservation treatments (e.g., cold milling, microsurfacing, thin HMA overlays, diamond grinding).
- Level 1 and 2 tensile strength input capabilities.

PMED v3.0 Demo: Minimally Viable Product (~3 years out)

- Evolution of v2.6 into a Web Technology Application that can access various information management systems (e.g., traffic, materials, pavement management).
- Inclusion of new pavement design strategies, such as new composite pavements and pavements designed with geosynthetics.
- Other features to be considered include specialized traffic, top-down cracking in asphalt, slab/underlying layer interaction/bond degradation, durability and mixture disintegration, and short-jointed concrete pavement performance models.

Mr. Harold Von Quintus (ARA) pointed out that there are periodic addendums issued regarding the software. These can be accessed at the AASHTOWare PMED website (http://me-design.com/MEDesign/). In addition, Mr. Becker informed the group that a pavement community forum was created that allows for questions and community expert answers regarding pavement engineering and design. The Pavement Engineering Community link can be accessed at the AASHTOWare *PMED* website (http://me-design.com/MEDesign/, at bottom under "Questions on Pavement ME Design") or directly at the following AllAnswered webpage: https://www.allanswered.com/community/s/pavement-engineering/.

Mr. Scott Weinland (Arizona DOT) inquired if there has been a discussion about giving *PMED* users the option of using different performance model versions. Mr. Becker stated there has been no such discussion, but added that AASHTO supports older software versions (back to v2.1) that use older models.

3. ***Deflection Data Analysis and Backcalculation Tool (BcT)* (Mr. Harold Von Quintus, ARA)**—This presentation consisted of a brief overview of the *BcT* tool. Since Mr. Von Quintus demonstrated the tool as part of an AASHTOWare webinar on August 15, 2017 and planned to give another demonstration on Day 2 of the Users Group meeting, he shortened this presentation to the first few slides. Key items discussed included the website location (http://www.me-design.com/) for the August webinar and corresponding questions and answers from the webinar, the background behind the selection of

EVERCALC as the backcalculation program for *PMED*, and the following 3-phase process for running *BcT* independently to generate inputs for PMED:

1. Pre-processing—Allows the user to (a) import and pre-process raw deflection data file formats from three FWD testing devices: Dynatest, JILS and KUAB; (b) segment projects, compare project segments, and merge statistically similar segments; and (c) select project segments for backcalculation.
2. Backcalculation—Allows the user to (a) define pavement layer structure and other backcalculation inputs; and (b) backcalculate elastic layer moduli for every segment with the pavement layer structure.
3. Post-processing—Allows the user to export backcalculation results to a *PME*D rehabilitation design file.

Dr. Fuoad Bayomy (University of Idaho) inquired about the use of the JULEA program as a separate tool. Mr. Von Quintus stated there is no plan to have a stand-alone JULEA tool, but indicated that there is a JULEA API that allows for integration of JULEA analyses.

6. AGENCY IMPLEMENTATION EXPERIENCES

Session 4 of the meeting featured three presentations on agency implementation experiences and one university presentation on the *PrepME* database and software tool. Summaries of the information presented and subsequent discussions are provided below. Copies of the presentations are featured as presentations 7 through 10 in appendix C.

1. ***PennDOT's MEPDG Implementation Plan* (Ms. Lydia Peddicord, Pennsylvania DOT)**—Included in this presentation was a status update on *PMED* implementation in the state of Pennsylvania and a report on the results of a 2017 local calibration study using selected in-service asphalt and concrete pavement sections. The Pennsylvania DOT's pavement design procedures are presented in its *Pavement Policy Manual*. While the Department's procedures are based on the AASHTO 1993 Design Guide and corresponding *DARWin* software, it has been performing parallel pavement designs (*DARWin* and *PMED*) on a limited basis since July 2014. Over the years, the agency has developed material testing and characterization libraries for various asphalt (including warm-mix asphalt) and concrete mixes, the agency's standard aggregate subbase material, and 19 native soils.

   In 2015, the DOT contracted with ARA to perform a local calibration and verification study. A total of 17 asphalt sections and 22 concrete sections located throughout the state were used in the effort, which resulted in various calibration coefficients. Subsequent design analyses of 18 typical asphalt designs and 9 typical concrete designs using *DARWin* and the ME locally calibrated models showed significant differences in thickness between the two design models. On average, 20-year *DARWin* asphalt designs were 4.5 inches thicker than designs generated using the 15-year ME locally calibrated models and 20-year *DARWin* designs were 2.4 inches thicker, on average, than the designs from the 20-year ME locally calibrated models. Similarly, on average, 20-year *DARWin* concrete designs were 3.1 inches thicker than those generated using the ME locally calibrated models.

   Ms. Peddicord showed the *PMED* outputs for a few long-life designs and pointed out how modest increases in concrete thickness can result in substantial increases in predicted life. She discussed performance model issues related to the PCC coefficient of thermal expansion (CTE) and the use of a widened slab, and indicated that the Department is seeking solutions to these matters (as well more appropriate CTE values) that will help them update their *Pavement Policy Manual*.

2. ***Kentucky's Updated Pavement Design Process* (Mr. Joe Tucker, Kentucky Transportation Cabinet)**—The focus of this presentation was on the development and implementation of the Kentucky Transportation Cabinet's pavement design catalog (replete with new pavement performance curves based on thousands of *PMED* design runs), updated pavement policies associated with the performance curves, and a new web-based program for storage and easy approval of pavement designs. The agency has long used a design catalog in part because of its simplicity of use by pavement engineers. In transitioning to the MEPDG methodology so as to get away from the very conservative designs obtained with the old methodology (a combination of the AASHTO *Guide for*

Design of Pavement Structures and Kentucky ME procedures), the Kentucky Transportation Cabinet has decided to retain the design catalog approach.

Over the last several years, the agency developed comprehensive materials and traffic libraries and created a Kentucky-specific User Input Guide for *PMED*. New ME-based pavement performance curves were developed for a variety of asphalt and concrete pavement structures using input values from the User Guide, selected distress and IRI threshold criteria, and performance model calibration coefficients established from a synthesis of surrounding states. Verification of the performance curves, based on performance data from 45 sections at 15 sites throughout the state, has been initiated and will continue, with the calibration coefficients refined as appropriate. Figure 5 provides an example comparison of the asphalt pavement thickness requirements using the old and new performance curves. As can be seen, for AADTT levels above 250 trucks/day, the ME design is at least 2 in thinner than the value obtained using the old design procedure.

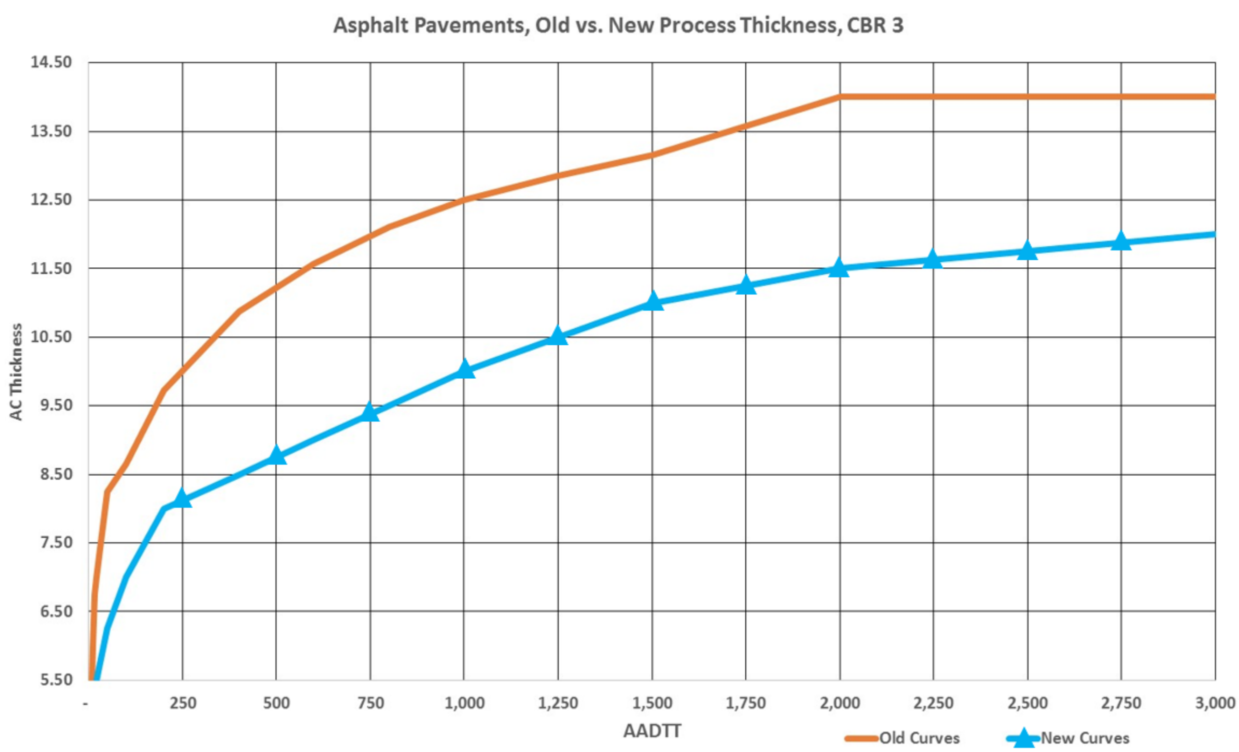


Figure 5. Comparison of asphalt pavement thicknesses obtained using Kentucky's old and new performance curves.

The Kentucky Transportation Cabinet has made significant progress in updating their pavement policies. The Agency has updated the pavement chapter of their Highway Design Manual, developed a traffic request form for pavement design, and updated warrants for selecting asphalt mixes and compaction options. Remaining work includes updating their Pavement Design Guide and pertinent sections of the Kentucky Standard Specifications.

As illustrated and described by Mr. Tucker, the web-based pavement design program consists of eight modules. Modules 1 through 4 are input screens for project information, subgrade, asphalt design, and concrete design, respectively. A life-cycle cost analysis template is provided in Module 5. Module 6 is for attaching supplemental design files, while Module 7 is for indicating the selected pavement design and selecting pertinent design notes. Design approval is carried out in Module 8. Mr. Tucker noted that the program is accessible to all, but requires user registration. He also indicated that initial deployment of both the spreadsheet-based design catalog and the web-based design program is scheduled for January 2018.

3. ***Modeling of Stabilized Materials in Pavement ME* (Mr. Affan Habib, Virginia DOT)**—This presentation reported on the types of stabilized materials used by the Virginia DOT, its efforts and challenges in characterizing these materials, and its interim strategy in modeling them in *PMED*. The DOT's most commonly used chemically stabilized materials are cement-treated aggregate (CTA) base (typically 6 inches thick), cement-treated full-depth reclamation (FDR) (typically 10 to 12 inches thick), and soil cement. Asphalt-treated permeable base (ATPB) is also frequently used.

   Since the release of *PMED* v2.2, designs incorporating chemically stabilized materials have required modeling them as part of a semi-rigid pavement system. This has created challenges for the Department, since the semi-rigid model is not calibrated and is known to have some issues. Design analysis of CTA using the semi-rigid model showed that this material greatly reduces predicted bottom-up cracking in asphalt (compared to an unstabilized base), which in turn results in rutting often governing the HMA design thickness. For high truck traffic levels, the benefit of a stabilized base compared to an unstabilized base may be negligible due to the predicted rutting (see figure 6). Additional analysis revealed that the HMA design is not very sensitive to CTA thickness, elastic modulus, or modulus of rupture.

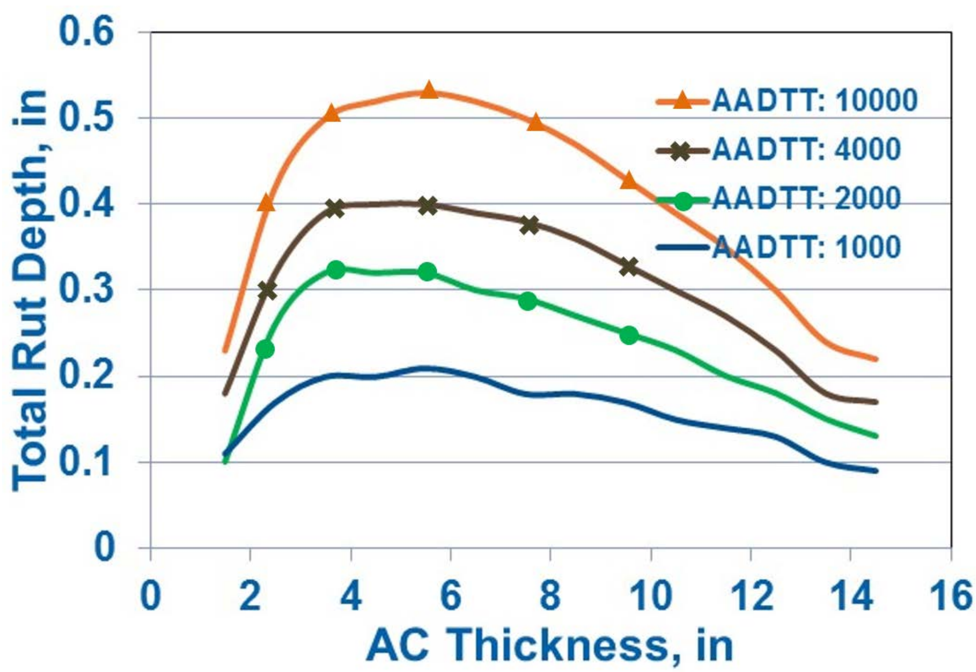


Figure 6. Predicted rutting for HMA pavements on CTA base using the *PMED* semi-rigid model.

Given the above observations, the DOT's interim strategy for modeling CTA and cement-treated FDR is to not use the semi-rigid option in *PMED*, but rather model the materials as a non-stabilized base with a resilient modulus of 80,000 lb/in^2. Similarly, soil-cement is to be modeled as a subgrade soil with a resilient modulus of 40,000 lb/in^2. For CTA use in rigid pavement, the material is to be modeled as a chemically stabilized layer with properties established per the *MEPDG Manual of Practice*. Although the DOT generally includes an asphalt- or cement-treated open-graded drainage layer (OGDL) (minimum permeability of 1,000 ft/day) between the PCC layer and the CTA base, pavement performance with this structure arrangement has not been particularly good and questions have been raised about whether to include the OGDL.

Mr. Habib concluded the presentation by pointing out that the release of *PMED* v2.4 will compel the DOT to re-investigate the best way to model chemically stabilized materials. He also noted that the agency's focus to date for PMED implementation has been with new design, and that they expect to start the implementation process for rehabilitation design in 2019.

4. ***Multi-Agency Effort to Prepare Data for PMED*** **(Dr. Joshua Li, Oklahoma State University)**—*Prep-ME* is a software program that was developed to assist DOTs with data preparation for implementation and local calibration and to improve the management and workflow of input data for *PMED* in a production environment. Developed in large part through the Transportation Pooled Fund (TPF)-5(242) project, this database tool can pre-process, import, and check the quality of traffic data, as well as generate the required traffic inputs for *PMED* in the required file format. In addition, the program can import raw climatic data and export the required climate files for *PMED*, populate and export key pavement and soil material inputs, and import raw FWD files and prepare the required files for *PMED*.

   This presentation described the challenges of both data availability and quality, and the process of compiling the extensive amounts of data needed as inputs for pavement *PMED*. Dr. Li provided an overview of each of the four modules (Traffic, Climate, Materials, and Tools) that comprise the current version of *Prep-ME* (3.17) and discussed future software development efforts.

   The foremost feature of the *Prep-ME* program is the Traffic module. In this module, raw weigh-in-motion (WIM) data are imported according to the file format given in the FHWA *Traffic Monitoring Guide*, and the weight and classification data undergo quality control (QC) checks. Interfaces in the program allow the user to review daily, weekly, and monthly data for a site, make various comparisons, replace data as appropriate, and manually accept or reject data (see figure 7). Using accepted traffic data, *Prep-ME* can develop and export load spectra data using any of the three hierarchy input levels—level 1 site specific (level 1), level 2 clustering average, and level 3 state or LTPP defaults.

   The Climate module allows a user to import climate data (in the *PMED* hourly climate data [HCD] format), perform data checks, and export the XML climate files. In the Materials module, material properties such as the HMA dynamic modulus (E*) and the PCC CTE can be retrieved from an agency's materials library, reviewed, and then exported for use in *PMED*. The module also allows a user to obtain important subgrade

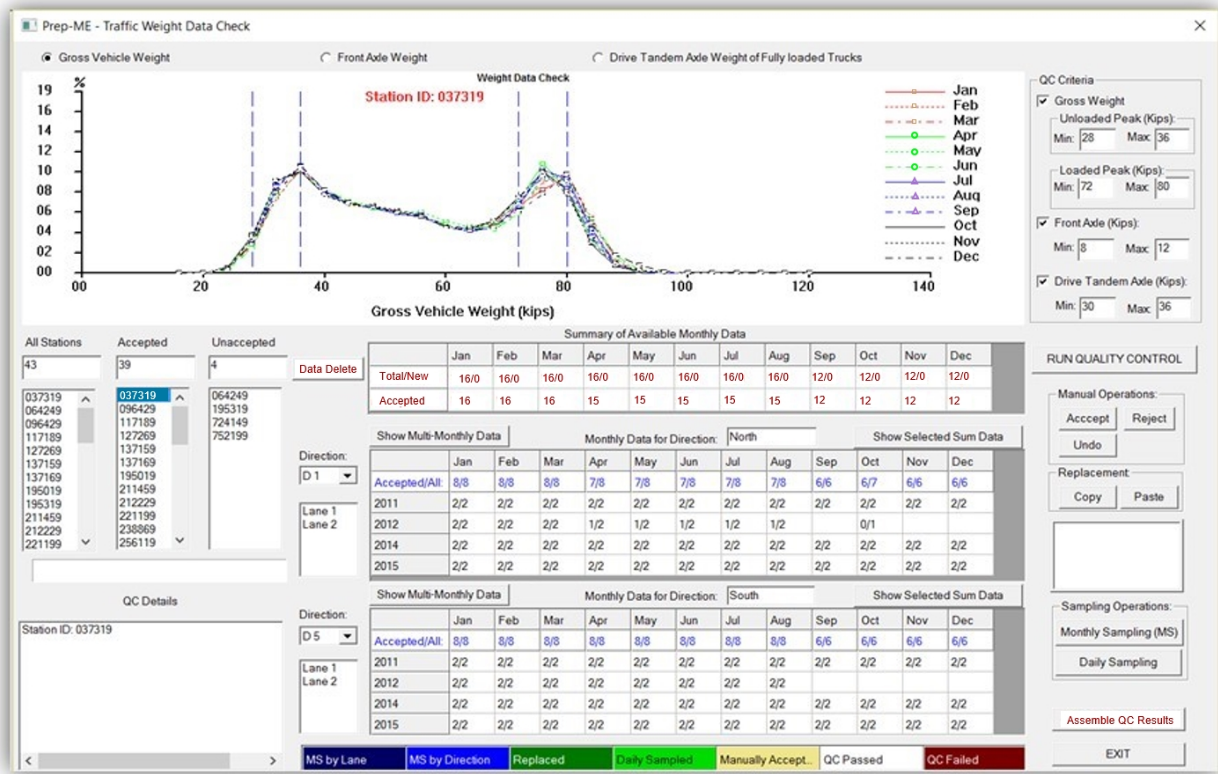


Figure 7. Traffic data checks and comparisons in *Prep-ME*.

soil information, such as soil type and resilient modulus (M_r), using soil maps programmed in the software. Lastly, raw FWD data (Dynatest .F25 files only) that are imported into *Prep-ME* can be combined with manually entered pavement structure data and backcalculated modulus data to generate an FWD XML file for *PMED*.

Dr. Li briefly described the Tools module, noting in particular that the Google Map v3.22 utility powers all the mapping and geo-referencing applications. He noted that there are a few interface problems that are still being worked out for the Materials module. One in particular is the subgrade soil maps developed under NCHRP Project 9-23A (Zapata 2011). The website for accessing those maps is not currently working, and thus they can only be accessed via the CD that is included with the NCHRP 9-23A report. Regarding the FWD data, Mr. Becker (ARA) pointed out that the new *BcT* program can perform conversions between Dynatest, KUAB, and JILS deflection data.

In concluding his presentation, Dr. Li talked about future development of the software, dwelling mostly on the planned module for automated local calibration. He described how functions would have to be developed to import the required performance data from an agency's PMS database and/or the LTPP database, and noted that several of the 11 steps in the local calibration process could be automated. The first performance model targeted in the effort would be HMA rutting, followed by fatigue cracking.

7. REHABILITATION DESIGN

Session 5 of the meeting featured presentations on efforts to improve *PMED* rehabilitation design using data from actual rehabilitation projects. 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. ***Concrete Overlay Design and Performance Evaluations Using AASHTOWare Pavement ME Design*** **(Dr. Halil Ceylan, Iowa State University)**—The State of Iowa is a high PCC use state, and many of the PCC pavements that have been constructed since the 1970s have been in the form of concrete overlays. Detailed evaluations of over 500 overlays (with a range of thicknesses and joint spacings and placed on both asphalt and concrete pavements) have shown good performance. These overlay projects provided the opportunity to compare actual overlay performance with *PMED* predicted performance and to investigate the effect of structural design options on Iowa PCC overlay performance, and this presentation reported on the results of the research efforts. Dr. Ceylan acknowledged that most of the overlays included in the study were located on low-volume county roads, with only about 6 percent of the projects subjected to ADTs greater than 4,000 vehicles/day. However, he pointed out that many of the roads carry considerable amounts of farm machinery with high concentrated loads. Hence, while the ADTs are low, the equivalent single axle loads (ESALs) per vehicle are quite high.

   PCC overlay design options in *PMED* include bonded overlays on concrete pavement (BCOC), unbonded overlays on concrete pavement (UBCOC), bonded overlays on asphalt pavement (BCOA), and unbonded overlays on asphalt pavement (UBCOA). Cracking, faulting, and IRI performance predictions for each overlay project were developed using project details, selected threshold criteria, and the appropriate overlay type. Because measured performance data were only available in terms of IRI and pavement condition index (PCI), comparisons of actual versus predicted performance could only be made in terms of IRI. An example of one of the comparisons is illustrated in figure 8. In this figure, the predicted IRI trends are based on four different truck percentages (2.5, 5.0, 7.5, and 10.0) and two different reliability levels (50 and 90 percent). The actual IRI values are based on measurements taken between 18 and 30 years of age.

   For the investigation on the effect of structural design options on performance, the predicted IRI trends corresponding to three different joint spacings (12, 15, and 20 ft), as well as different overlay and existing pavement thicknesses, were calculated using *PMED*. Evaluation of the many performance prediction curves developed for UBCOC, UBCOA, and BCOA indicated that 20-ft joint spacing results in a considerably shorter service life compared to 12- and 15-ft joint spacings. In addition, increased service life can be achieved through both thicker overlays and thicker existing pavements. Dr. Ceylan commented that the pavement ME performance predictions generated for concrete overlays seemed reasonable, despite the fact that level 2 and 3 data and an uncalibrated version of the software were used.

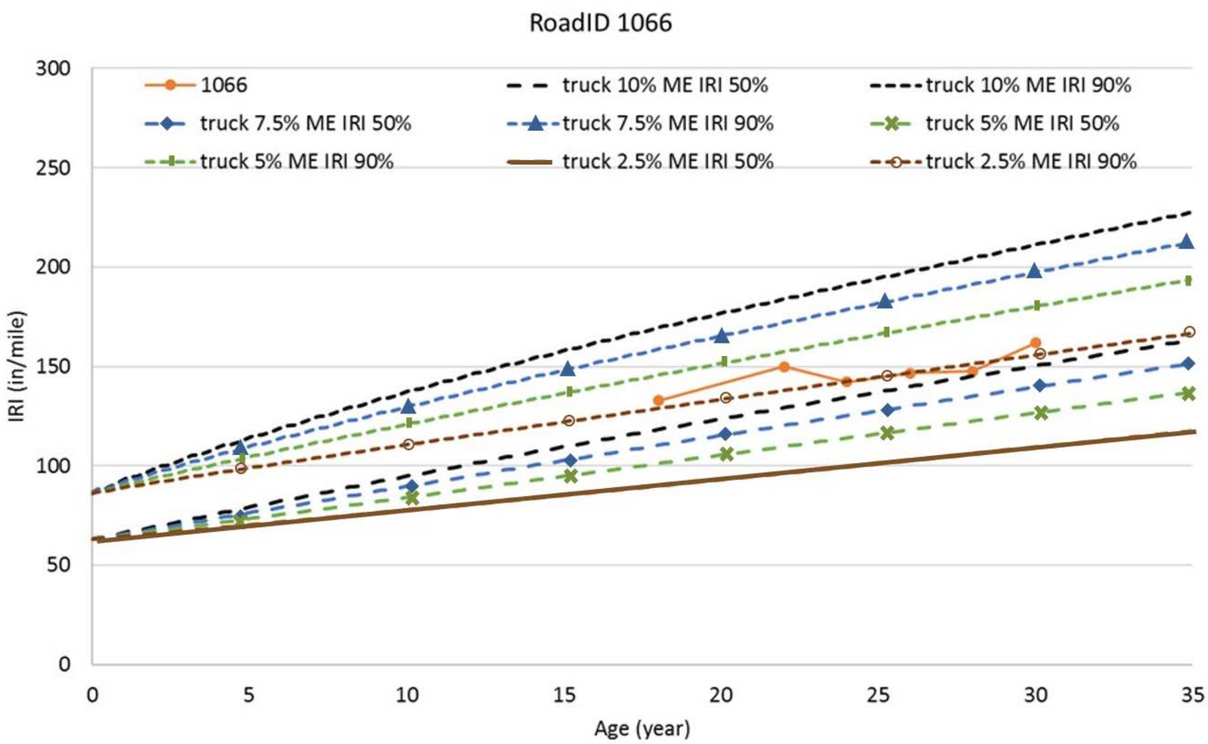


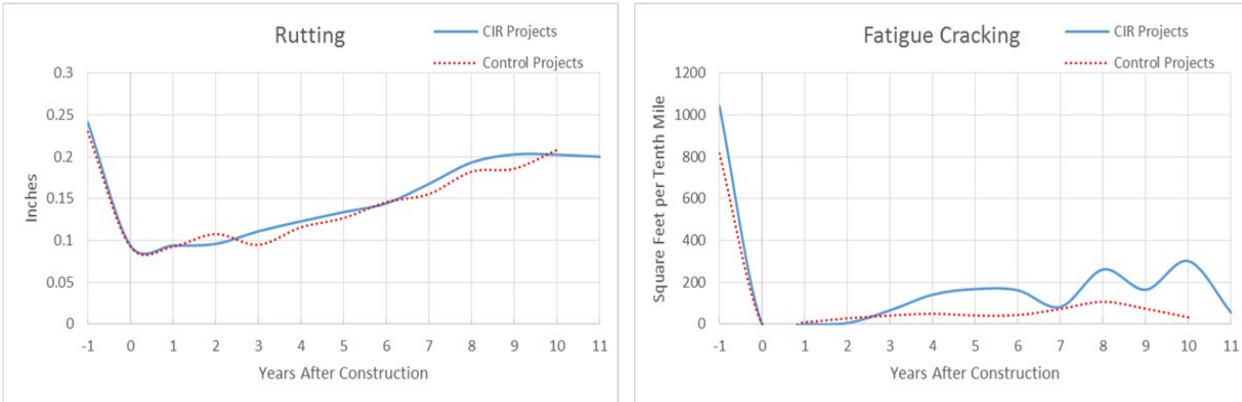
Figure 8. Predicted IRI for a BCOA project—County Road X37 in Louisa County.

2. ***CDOT's Dynamic Modulus Research on Cold In-Place Recycling*** **(Mr. Jay Goldbaum, Colorado DOT)**—Cold-in-place recycling (CIR) is a frequently used pavement rehabilitation technique for the Colorado DOT. Since 2000, the Department has implemented 37 recycling projects comprising nearly 8 million square yards of pavement. CIR materials normally include 1.5 percent lime and contain no foam in the emulsion mix.

   This presentation described the research efforts undertaken to characterize CIR material for application in *PMED*. Specific objectives included:

   - Investigate the dynamic modulus properties of CIR pavements.
   - Establish a range of reliable dynamic modulus values for CIR materials to be used as input to the PMED program.
   - Examine the appropriateness of the PMED predictive equations for CDOT's CIR material, if possible.

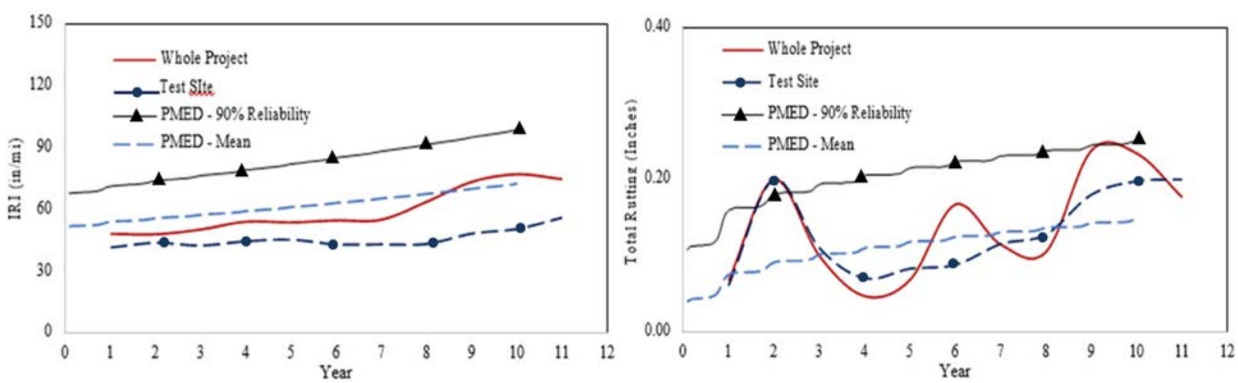
   The research was carried out using performance data (IRI, fatigue cracking, rutting, transverse cracking) from 10 CIR sites, as well as laboratory test data on cores extracted from those sites. Performance data from 10 corresponding control sites were used as a basis for comparing pavements with CIR base versus pavements with conventional base. Collectively, the CIR pavements have shown comparable performance to the control pavements after 11 years. Figure 9 illustrates the measured averages of two (rutting and fatigue cracking) of the five performance indicators used in the evaluation.



(a) (b)

Figure 9. Performance of CIR and control pavements in terms of (a) rutting and (b) fatigue cracking.

Testing of intact CIR cores (typically containing 9 to 10 percent air voids) resulted in dynamic modulus curves comparable to those developed in NCHRP Project 9-51 (Schwartz, Diefenderfer, and Bowers 2017). Application of the calibrated dynamic modulus model in *PMED* largely resulted in predicted performance trends similar to actual trends, as illustrated in figure 10 for one CIR project. Mr. Goldbaum noted that, although the design runs included bottom-up fatigue cracking, comparisons to actual bottom-up cracking trends could not be made since the DOT's PMS does not distinguish between bottom-up and top-down cracking.



(a) (b)

Figure 10. Actual versus predicted (a) IRI and (b) rutting for I-70 CIR pavement.

8. ME RESEARCH

Session 6 of the meeting consisted of brief updates on current FHWA and NCHRP ME research activities, followed by summary presentations on two NCHRP projects (1-52 and 1-53) expected to have significant impacts on *PMED*. Summaries of the information presented and subsequent discussions are provided below. Copies of the presentations are featured as presentations 13 through 15 in appendix C.

1. ***FHWA Research Summary* (Mr. Tom Yu, FHWA)**—Mr. Yu provided a brief discussion on three FHWA projects. He noted that the ME Clearinghouse study contains the latest summary on MEPDG-related research information and informed participants that a hardcopy of the summary was provided in their packets. He also described the ME Design Catalog project and the Benefits of Foundation Design projects. Mr. Yu discussed the need to develop an agency forum for discussing how to develop *PMED* performance criteria.

2. ***NCHRP Research Summary* (Dr. Linda Pierce, NCE)**—Dr. Pierce provided a brief overview of past, current, and future NCHRP research efforts pertaining to the MEPDG and *PMED* software. Table 17 lists the relevant NCHRP projects and their timeline.

Table 17. Timeline of NCHRP research projects related to MEPDG and the *PMED* software.

NCHRP Project	Title	Year Completed	Included in *PMED*
1-37A	Development of the 2002 Guide for the Design of New and Rehabilitated Pavement Structures: Phase II	2004	–
9-30	Experimental Plan for Calibration and Validation of HMA Performance Models for Mix and Structural Design	2004	No
1-39	Traffic Data Collection, Analysis, and Forecasting for Mechanistic Pavement Design	2004	Indirectly
1-40	Facilitating the Implementation of the Guide for the Design of New and Rehabilitated Pavement Structures	2006	No
1-40A	Independent Review of the Recommended Mechanistic-Empirical Design Guide and Software	2006	–
9-23A	Implementing a National Catalog of Subgrade Soil-Water Characteristic Curve (SWCC) Default Inputs for Use with the MEPDG	2007	No
1-42A	Models for Predicting Top-Down Cracking of Hot-Mix Asphalt Layers	2009	No (see 1-52)
1-40B	User Manual and Local Calibration Guide for the Mechanistic-Empirical Pavement Design Guide and Software	2009	–
1-40D(01)	Technical Assistance to NCHRP and NCHRP Project 1-40A: Versions 0.9 and 1.0 of the M-E Pavement Design Software	2009	–

Table 17. Timeline of NCHRP research projects related to MEPDG and the PMED software (continued).

NCHRP Project	Title	Year Completed	Included in *PMED*
1-41	Models for Predicting Reflection Cracking of Hot-Mix Asphalt Overlays	2010	Yes
1-40D(02)	Technical Assistance to NCHRP and NCHRP Project 1-40A: Versions 0.9 and 1.0 of the M-E Pavement Design Software	2011	–
1-47	Sensitivity Evaluation of MEPDG Performance Prediction	2011	No
9-23B	Integrating the National Database of Subgrade Soil-Water Characteristic Curves and Soil Index Properties With the MEPDG	2012	No
9-30A	Calibration of Rutting Models for HMA Structural and Mix Design	2012	Yes
4-36	Characterization of Cementitiously Stabilized Layers for Use in Pavement Design and Analysis	2013	FY 2017
1-48	Incorporating Pavement Preservation into the MEPDG	2013	FY 2018[1]
20-05, Topic 44-06	Implementation of the AASHTO Mechanistic-Empirical Pavement Design Guide and Software	2014	No
1-51	A Model for Incorporating Slab/Underlying Layer Interaction into the MEPDG Concrete Pavement Analysis Procedures	2016	FY 2018[2]
1-52	Top-Down Cracking Model for Asphalt Pavements	2017	FY 2018[2]
9-51	Material Properties of Cold In-Place Recycled and Full-Depth Reclamation Asphalt Concrete for Pavement Design	2017	Software addendum to be added
1-50	Quantifying the Influence of Geosynthetics on Pavement Performance	2017	FY 2018[2]
1-53	Improved Consideration of the Influence of Subgrade and Unbound Layers on Pavement Performance	2018	FY 2020 (plan)
1-59	Including the Effects of Shrink/Swell and Frost Heave in ME Pavement Design	TBD	TBD

[1] Limited treatment types.

[2] Final decision to be made spring 2018.

3. ***NCHRP 1-52, Top-Down Cracking Model for Asphalt Pavements* (Dr. Linda Pierce, NCE)**—Dr. Pierce provided a presentation summarizing a presentation previously provided to the AASHTOWare *PMED* Task Force by Dr. Bob Lytton. The objective of NCHRP Project 1-52 is to develop a calibrated ME model for predicting load-related top-down cracking that is compatible with the AASHTOWare *PMED*. Dr. Lytton's approach includes determining crack depth using Paris' Law to determine crack width and crack severity. Model calibration and validation has been carried out using the results from the LTPP database. Efforts are currently being conducted to complete the software user interface and complete the final report. Project completion is anticipated for October 2017.

4. ***NCHRP 1-53, Improved Consideration of the Influence of Subgrade and Unbound Layers on Pavement Performance*** **(Dr. Linda Pierce, NCE)**—Dr. Pierce provided a presentation summarizing a presentation previously provided to the AASHTOWare *PMED* Task Force by Dr. Bob Lytton. The objective of NCHRP Project 1-53 is to propose enhancements to better reflect the influence of subgrade/unbound layers (properties and thickness). Models characterizing the influence of the subgrade and unbound layers are being evaluated and include models for layer modulus, permanent deformation, shear strength, erosion, foundation, and thickness sensitive (incorporated into above models). Project completion is anticipated for June 2018.

9. PERFORMANCE CRITERIA

Day 2 of the Users Group meeting resumed with Session 7 covering *PMED* performance criteria. The session began with a presentation on performance criteria thresholds and followed with a panel discussion on the topic involving representatives from five selected SHAs. Summaries of the information presented and subsequent discussions are provided below. A copy of the session presentation is featured as presentation 16 in appendix C.

1. ***Performance Criteria Thresholds for ME Design* (Mr. Tom Yu, FHWA)**—Mr. Yu provided a thought-provoking presentation on the determination of performance criteria thresholds. He presented pavement design objectives, how to achieve well-performing pavements, and concluded with changing the mindset of thickness design to one that considers minimizing the risk of poor pavement performance, rather than designing with a specific level of distress in mind. Since any pavement that is built must be maintained in perpetuity, designing for long-life is the more effective strategy than designing to a specified level of distress.

   Figure 11 provides an example of predicted transverse cracking versus slab thickness for PCC pavements. Mr. Yu suggested that agencies should be mindful of the inflection point location (which for this example is 9- to 9.5-inch-thick slabs), designing pavements slightly greater than the inflection point may result in longer pavement life without resulting in significantly higher costs.

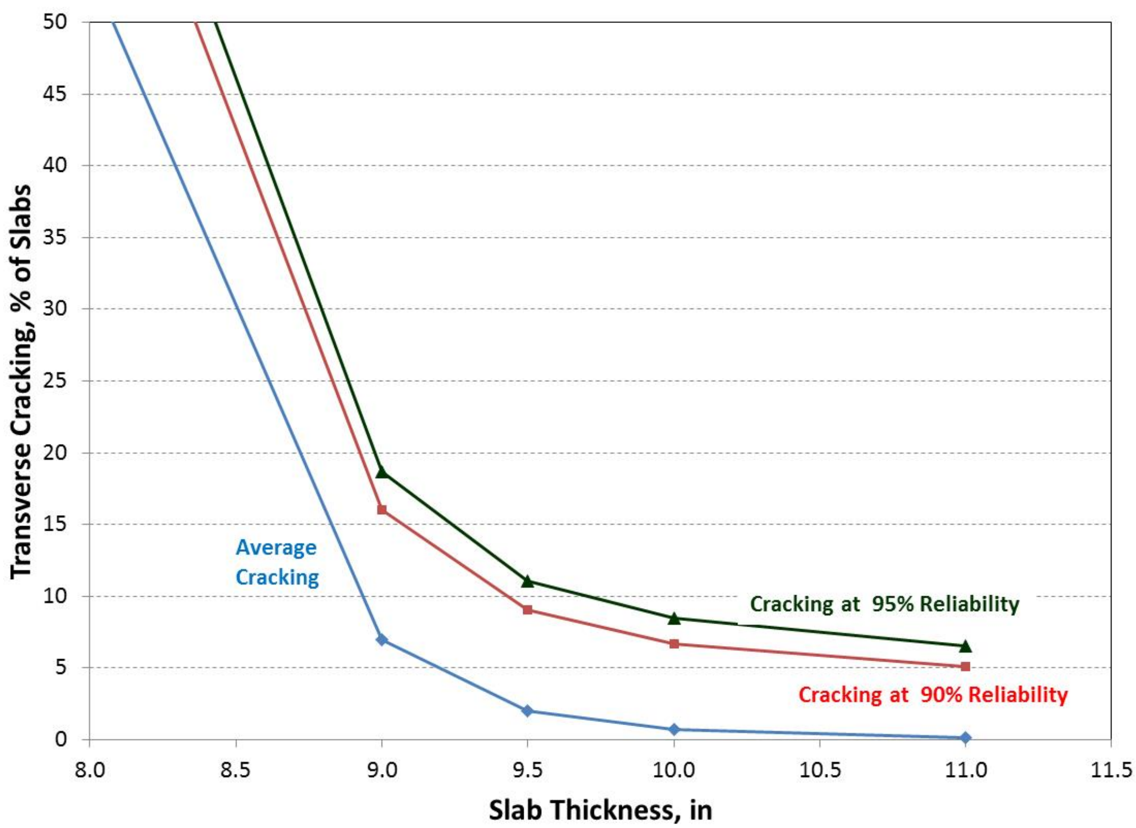


Figure 11. Performance criteria thresholds.

2. ***State Perspectives on Selection of Thresholds*** **(State Agency Panel Discussion)**—As part of the pre-meeting survey, SHA participants were asked if they would be willing to be a part of the convened panel. Although several individuals expressed an interest in participating, five were ultimately selected to meet the time constraints of session 7. A summary of each selected individual's description of their agency's performance thresholds is provided below.

    - Mr. Affan Habib (Virginia DOT): Asphalt pavement thresholds in Virginia are based on local calibration and pavement management data. The DOT assessed the standard error of rutting and incorporated it into the performance criterion of 0.26 inches. Fatigue cracking is based on limiting distress (6 percent with 90 percent reliability). For concrete pavements, there was no local calibration for JPCP; therefore, the DOT is using the global/default calibration values for faulting (0.12 inches) and slab cracking (10 percent). IRI was not evaluated and is not used at this time. For CRCP, the local calibration included minimal sites. Analysis suggested 50 punchouts/mi, which was considered unrealistic. Hence, the Department selected a value (6 punchouts/mi) that would reflect the pavement dropping into the major rehabilitation/reconstruction category.
    - Mr. David Holmgren (Utah DOT): The DOT reviewed the default criteria, determined what values they felt comfortable with, and reviewed the associated reliability values. As an example, a rutting value of 0.75 inches was selected as a value they could live with.
    - Mr. Yathi Yatheepan (Nevada DOT): The initial IRI value in Nevada is based on construction experience (60 in/mi for HMA, 80 in/mi for PCC). The terminal IRI of 170 in/mi is based on FHWA guidance for rough pavement. The HMA rutting criteria is 0.15 inches, while the total rutting criteria is 0.5 inches. The HMA bottom-up fatigue cracking threshold is 15 percent. Other performance parameters are not used for the flexible pavement design at this time.
    - Mr. Bob Shugart (Alabama DOT): Distress criteria in Alabama are based on the LTPP *Distress Identification Manual*, modified to Alabama condition. The threshold criteria are based on the assumption that new HMA pavement is resurfaced after 12 years and HMA overlays are applied on an 8-year cycle.
    - Mr. Justin Schenkel (Michigan DOT): The Michigan life cycle-cost law requires the DOT to establish equivalences between asphalt and concrete pavements. However, currently, the DOT performance criteria and reliability thresholds are per reconstruction designs. For initial pavement smoothness, IRI values include 72 in/mi for concrete pavement and 67 in/mi for asphalt pavement. For terminal IRI, a value of 172 in/mi is used for both pavement types. For full-depth asphalt pavement, the criteria used for total pavement rutting, thermal cracking, and bottom-up fatigue cracking are 0.5 inches, 1,000 ft/mi, and 20 percent, respectively. Per the DOT's calibration effort, top-down fatigue cracking and asphalt-only rutting are not used. For JPC pavement, the criteria used for joint faulting and transverse cracking are 0.125 inches and 15 percent slabs, respectively.

    Although this effort only captured the efforts of five agencies, it demonstrates the various approaches agencies have used to establish the threshold criteria values.

10. LOCAL CALIBRATION EXPERIENCES

Session 8 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 17 through 19 in appendix C.

1. ***Implementation and Calibration of AASHTOWare Pavement ME Design for Idaho* (Dr. Fouad Bayomy, University of Idaho)**—This presentation provided an overview of the Idaho Transportation Department's efforts to implement the MEPDG and PMED software program. The process includes five phases as shown in figure 12, with the first phase begun in 2009 and the last phase just underway with expected completion in December 2019.

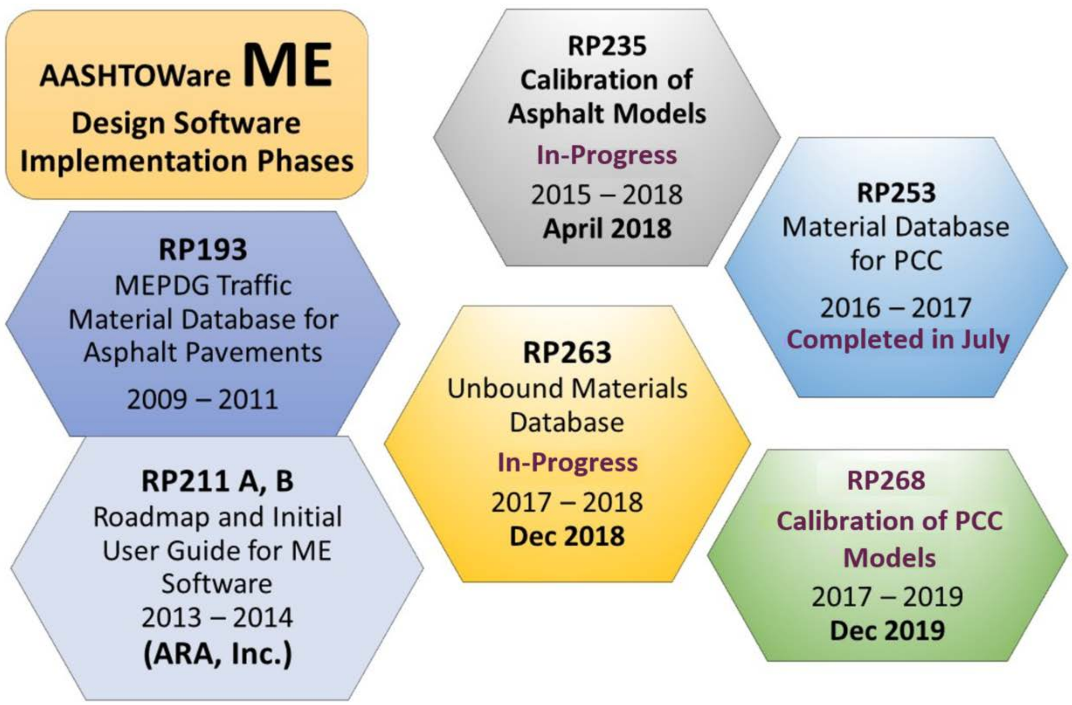
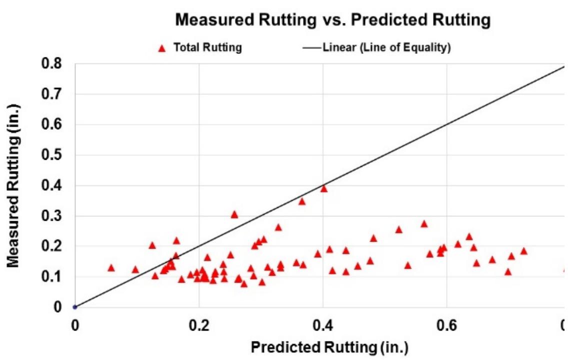


Figure 12. Pavement ME design implementation schedule for Idaho.

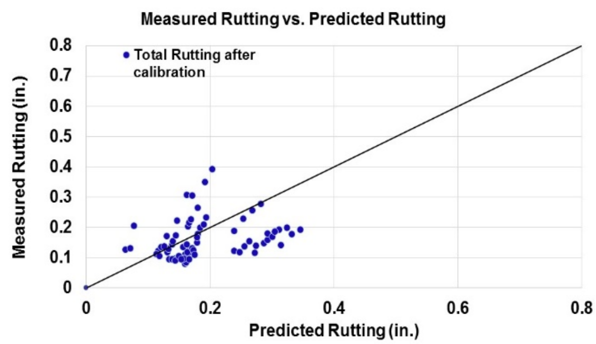
Phase 1 activities focused on establishing a comprehensive materials, traffic, and climatic database. Version 1.100 of this Microsoft Excel-based database included level 1 through 3 input information for HMA binder and mix properties (G*, δ, volumetric properties, E* models), level 2 and 3 input information for unbound base/subbase materials and subgrade soils (typical soil property values and ranges, R-value model, subgrade M_r/R-value model), and level 1 and 2 traffic data (volume, axle load spectra [ALS], traffic adjustment factors). Dr. Bayomy noted that the M_r/R-value model is different than the one presented in the *MEPDG Manual of Practice*.

Under Phase 2, a pavement ME design workshop was conducted and a *PMED* v1.1 User's Guide was developed, along with a *PMED* software implementation road map.

Local calibration of the flexible pavement performance models under Phase 3 is on-going and uses data from 32 road sections located throughout the state. Calibration of the rutting model using *PMED* v2.3.1 was recently completed and new calibration coefficients for β_{r1}, β_{r3}, β_{s1_coarse}, and β_{s1_fine} (see figure 13). Calibration of the fatigue cracking and thermal cracking models is underway, and calibration of the IRI model will begin soon. Dr. Bayomy explained that fatigue cracking and thermal cracking data for the sites were not readily available and that the data were having to be generated from automated survey images. He indicated that the flexible pavement calibrations will be completed by April 2018.



(a)



(b)

Figure 13. Actual versus predicted rutting (a) before calibration and (b) after calibration.

Development of the PCC materials database as part of Phase 4 is ongoing, along with further development of the unbound materials and subgrade soils database. December 2018 is the expected completion date for the latter.

Finally, local calibration of the rigid pavement performance models under Phase 5 is expected to start soon and will be completed by July 2019.

2. ***MEPDG Design Parameters for Ontario and Canada* (Mr. Warren Lee and Ms. Susanne Chan, Ontario Ministry of Transportation)**—The focus of this presentation was on the development of two guides containing default design parameters for use in pavement ME design. The first guide, titled "Ontario's Default Parameters for AASHTOWare Pavement ME Design," was initially developed by the Ministry of Transportation in 2012 and has since undergone two revisions. The second guide, titled "Canadian Guide: Default Parameters for AASHTOWare Pavement ME Design," is currently under development (current working version is 2016) by the TAC PMED User Group and is primarily based on the Ontario Guide.

   The purposes of the guides are to facilitate the design process for pavement engineers, provide consistent design input values for practitioners, specify design parameters that are customized to agency conditions, and update inputs based on new specifications, data, models, and/or software. The default parameters in the guide documents are mostly for Level 3 design.

Key revisions to the Ontario Guide include new source references and design inputs. Examples include:

- Ontario's asset management system contains IRI trends for various highway sections, and these trends have provided the basis for recommendations for initial and terminal IRI in ME pavement design.
- Ontario's web-based data visualization and information sharing tool, *iCorridor* (http://www.maps.mto.gov.on.ca/icorridor/), can be used to obtain traffic inputs (e.g., truck volume, axle loads, and configuration) for a roadway section and download the data into .xml and .alf files for direct entry into *PMED* (see figure 14).
- Ontario's source for climate data has changed from ground-based weather stations (34 throughout Ontario) to NARR grid points.

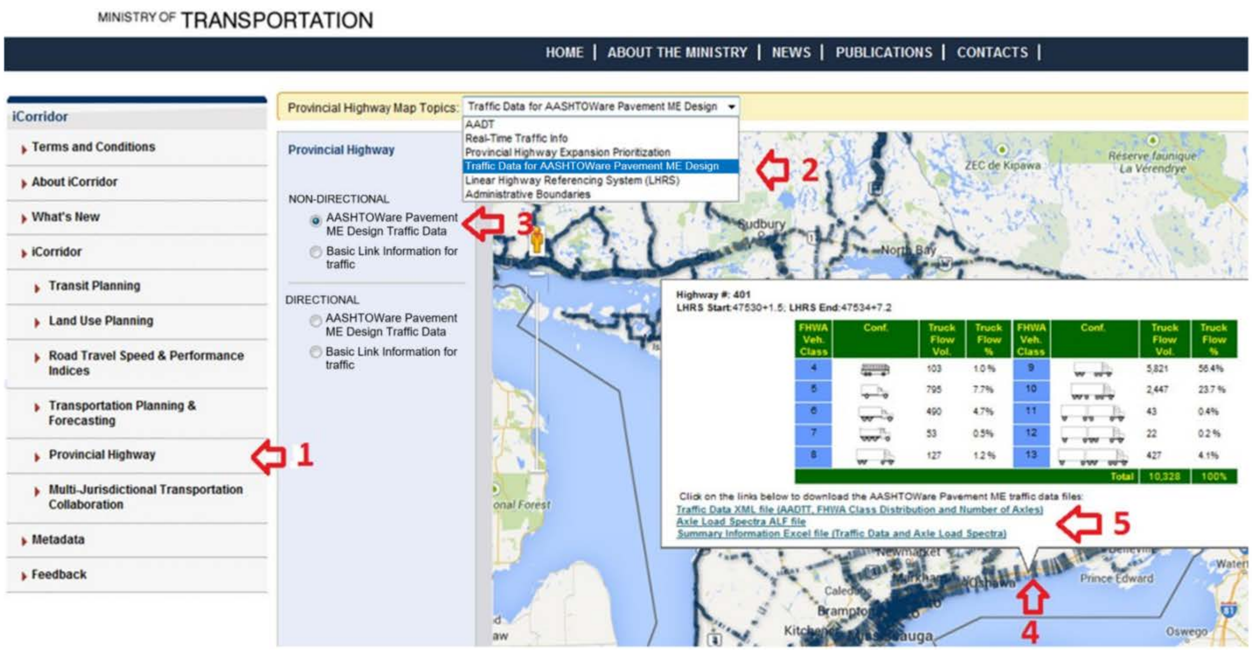


Figure 14. Obtaining traffic data for *PMED* using Ontario's *iCorridor* web-based program.

In addition to these and other input parameters, the Ontario Guide includes the results of a local calibration performed on the HMA rutting model. Mr. Lee reported that a total of 84 pavement sections were used in the study and that new coefficients were identified for β_T, β_N, β_{AC}, β_{GB}, and β_{SG}.

The Canadian Guide provides a cross reference of design parameters used by agencies in Canada. It contains customized default inputs, based on information contributed by the Provinces of Alberta, Manitoba, Ontario, and Quebec, and the City of Edmonton. According to Ms. Chan, the TAC ME Design User Group is hoping to get information from several other provinces in the future.

In addition to recommended design reliability levels and performance criteria for different highway functional classes, the Guide includes access to climate data from 223 ground-based weather stations throughout Canada, as well as material properties for the HMA, PCC, granular, and subgrade soils used by different agencies.

At the conclusion of the presentation, the issue of changing performance criteria versus changing the design reliability level was raised. Mr. Lee indicated that the two go hand-in-hand and that the Ministry has been dealing with this issue for a while.

3. ***Mechanistic-Empirical Pavement Design Software Automation* (Mr. John Donahue, Missouri Department of Transportation)**—Mr. Donahue delivered a shortened version of a presentation on automated calibration given by Dr. David Timm (Auburn University) at the September 2017 Pavement ME Task Force meeting. The presentation consisted of an overview of the local calibration process, a discussion of the need for automation and the selection of an automated software program, and a description of the automation process within the tool.

   The 11-step procedure for conducting a local calibration is given in the AASHTO *Local Calibration Guide* (2010) and consists of the following:

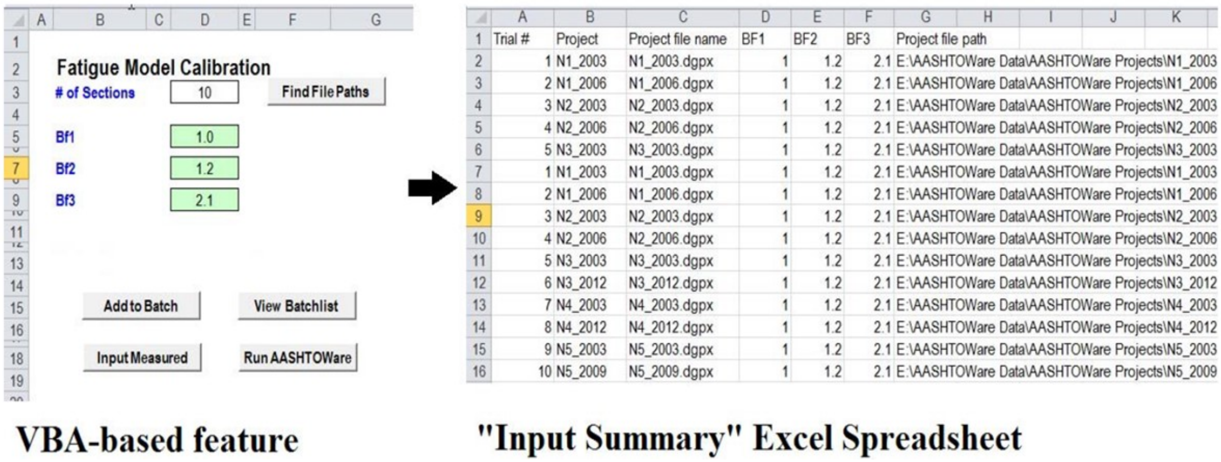
   1. Select hierarchical input level for each input parameter.
   2. Develop local experimental plan and sampling template.
   3. Estimate sample size for specific distress prediction models.
   4. Select roadway segments.
   5. Extract and evaluate distress and project data.
   6. Conduct field and forensic investigations.
   7. Assess local bias: validation of global calibration values to local conditions, policies, and manuals.
   8. Eliminate local bias of distress and IRI prediction models.
   9. Assess the standard error of the estimate.
   10. Reduce standard error of the estimate.
   11. Interpretation of the results, deciding on adequacy of calibration parameters.

   Steps 7 through 11 are often the most challenging and time-consuming steps. They represent the evaluation, calibration, and verification portions of the process, which require advanced statistical analyses and many repeated runs of the *PMED* software to complete. The assembly of pavement section data and preparation of design files can also be time-consuming, as more and better data continually become available for the calibration sections.

   With many agencies working toward implementation and having to deal with several other obstacles (e.g., new global models, updated versions of *PMED*), the need for automation in the local calibration process is great. To fill this need, the robotic process automation (RPA) software program, *Automation Anywhere*, was selected by Dr. Timm using the following criteria:

   - Capable of recording mouse movements and keyboard operations.
   - Capable of creating self-contained executable for others to use.
   - Capable of recording absolute and relative mouse coordinates.

   Automation Anywhere features tools for creating digital robots that can perform a variety of assigned and controlled tasks, such as those listed above. The program can interact with many different systems or applications, including Microsoft Excel VBA, which was used by Dr. Timm in developing a fatigue model calibration tool (see figure 15).



Trial #	Project	Project file name	BF1	BF2	BF3	Project file path
1	N1_2003	N1_2003.dgpx	1	1.2	2.1	E:\AASHTOWare Data\AASHTOWare Projects\N1_2003
2	N1_2006	N1_2006.dgpx	1	1.2	2.1	E:\AASHTOWare Data\AASHTOWare Projects\N1_2006
3	N2_2003	N2_2003.dgpx	1	1.2	2.1	E:\AASHTOWare Data\AASHTOWare Projects\N2_2003
4	N2_2006	N2_2006.dgpx	1	1.2	2.1	E:\AASHTOWare Data\AASHTOWare Projects\N2_2006
5	N3_2003	N3_2003.dgpx	1	1.2	2.1	E:\AASHTOWare Data\AASHTOWare Projects\N3_2003
1	N1_2003	N1_2003.dgpx	1	1.2	2.1	E:\AASHTOWare Data\AASHTOWare Projects\N1_2003
2	N1_2006	N1_2006.dgpx	1	1.2	2.1	E:\AASHTOWare Data\AASHTOWare Projects\N1_2006
3	N2_2003	N2_2003.dgpx	1	1.2	2.1	E:\AASHTOWare Data\AASHTOWare Projects\N2_2003
4	N2_2006	N2_2006.dgpx	1	1.2	2.1	E:\AASHTOWare Data\AASHTOWare Projects\N2_2006
5	N3_2003	N3_2003.dgpx	1	1.2	2.1	E:\AASHTOWare Data\AASHTOWare Projects\N3_2003
6	N3_2012	N3_2012.dgpx	1	1.2	2.1	E:\AASHTOWare Data\AASHTOWare Projects\N3_2012
7	N4_2003	N4_2003.dgpx	1	1.2	2.1	E:\AASHTOWare Data\AASHTOWare Projects\N4_2003
8	N4_2012	N4_2012.dgpx	1	1.2	2.1	E:\AASHTOWare Data\AASHTOWare Projects\N4_2012
9	N5_2003	N5_2003.dgpx	1	1.2	2.1	E:\AASHTOWare Data\AASHTOWare Projects\N5_2003
10	N5_2009	N5_2009.dgpx	1	1.2	2.1	E:\AASHTOWare Data\AASHTOWare Projects\N5_2009

Figure 15. Auburn University's Microsoft Excel VBA tool for fatigue model calibration.

An evaluation of the time requirements associated with manual and automated calibration of the fatigue cracking model calibration using National Center for Asphalt Technology (NCAT) pavement section data showed 44 percent time savings with the automated method. The actions with the greatest time reductions included the extraction and tabulation of outputs and the computation of statistics. Mr. Donahue noted that an 86 percent time savings was observed when considering only the human interaction processes.

At the conclusion of the presentation, Ms. Juhasz suggested that the expectations of what the tool can do should be tempered. She emphasized that there is still a significant amount of engineering that needs to be part of the calibration process.

11. SOFTWARE TRAINING

Session 9 of the meeting featured demonstration-based training by Mr. Von Quintus (ARA) on the use of the *PMED* and *BcT* software programs. The training included live use of the programs, supplemented with various output screen shots and Microsoft PowerPoint slides. Topics included in the training were: (1) simulating stabilized bases, (2) characterization of existing flexible pavements, (3) rehabilitation design example using I-84 in Boise, Idaho, and (4) calibration process example. A summary of each block of the training is provided below, along with key discussions generated by the presentations. A copy of the software training presentation is featured as presentation 20 in appendix C.

1. ***Simulating Stabilized Bases***—The first training block covered the simulation of stabilized bases in the design of new pavements. Mr. Von Quintus stated that simulation in ME design depends on the nature of the material and the type of pavement in which it is used. He offered the following general guidance:

   - Asphalt Stabilized Base in New Flexible Pavement
     - Plant-mixed material → dense-graded AC layer.
     - In-place mixed material → dense-graded AC layer.
     - Cold recycled asphalt (i.e., RAP from stockpile with no additive) → aggregate base layer with E=30,000 lb/in^2.
     - Permeable asphalt-treated base (PATB) → aggregate base layer with high constant modulus.
   - Chemically Stabilized Base in New Semi-Rigid Pavement
     - Cement-treated base (CTB) (or other chemical stabilizers, such as lime and lime-flyash) → aggregate with high constant modulus <u>or</u> stabilized layer with constant or decreasing modulus.

   Chemically stabilized base can be grouped into three categories:

   - High-strength CTB, in which intact, testable cores are recovered.
   - Moderate-strength CTB, in which untestable cores are recovered.
   - Low-strength CTB, in which cores are not be recovered due to disintegration.

   Examples of strength and modulus simulation values for each category, based on information from Georgia, Mississippi, and Montana, are shown in table 18.

   Mr. Von Quintus used the *PMED* software to demonstrate the modeling of chemically stabilized base in a new semi-rigid pavement. This demonstration focused on the selection of inputs for the stabilized material, when simulated as a stabilized layer with constant moderate or high strength. Key points made during the presentation included the following:

   - Modeling is only needed for applications in flexible design; rigid design requires less characterization of material properties.
   - An addendum for incorporating chemically stabilized layers into the *PMED* will be issued after the release of the NCHRP 9-51 report.
   - A sandwich layer must be specified in the case where a granular layer is placed on the chemically stabilized layer (and beneath the HMA surface).

Table 18. CTB simulation options and example input values for strength and modulus.

Description of CTB Layer	28-Day Compressive Strength, psi	28-Day Elastic Modulus, psi	Modulus of Rupture, psi
High Strength CTB (intact, testable cores recovered)	1,400	2,250,000	350
Moderate Strength CTB (untestable cores recovered)	500	1,000,000	200
Low Strength CTB (cores not recovered)	*	*	*

*Semi-Rigid Pavement Simulation not applicable; assume conventional flexible pavement with high stiffness GAB layer.

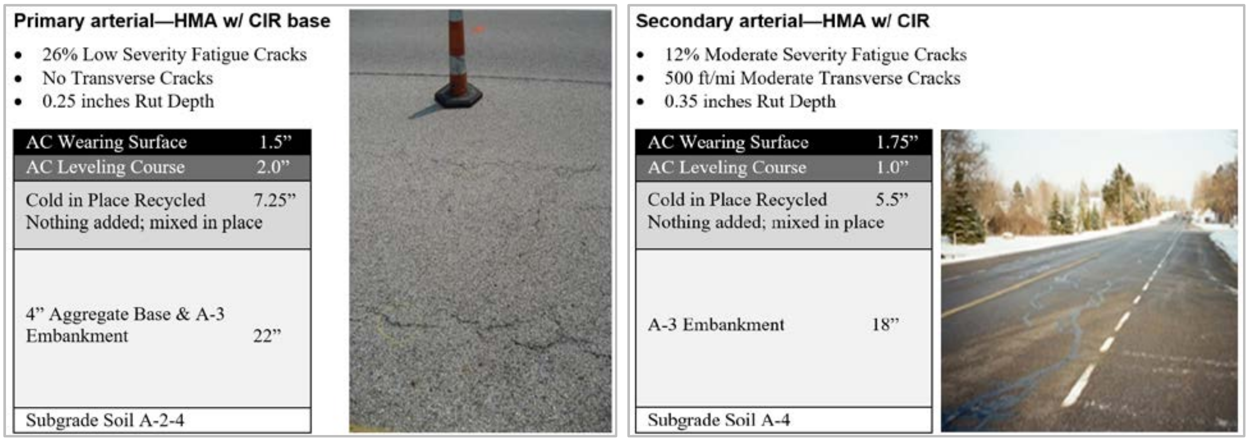
In addressing questions at the end of the training block, Mr. Von Quintus pointed out the following:

- ME design allows for only one chemically stabilized layer in the pavement cross-section. If two or more such layers are planned, an engineering decision must be made on how best to model the combination. One criterion for this is to determine which material will have greater control on stresses.
- *PMED* will not run unless there is an aggregate base under the stabilized layer.
- Load-transfer efficiency in chemically stabilized layers were measured in the LTPP program. There is a built-in assumption that transverse cracks are reflection shrinkage cracks.
- If it is likely that a chemically stabilized layer will develop micro-cracking at the time of construction, then it is best to treat the layer in ME design as a granular layer.

2. ***Characterization of Existing Flexible Pavements***—The second training block focused on describing and demonstrating the differences between input levels 1 (FWD backcalculation results) and 2 (distress survey results) in characterizing existing flexible pavement as part of a rehabilitation design. Two highway projects located in colder climates were used as examples, the structure and condition details of which are shown in figure 16.

   Key descriptions and guidance shared by Mr. Von Quintus as part of the Project 1 demonstration included the following:

   - Per the *MEPDG Manual of Practice*, the total rut depth of 0.25 inches is distributed 70 percent to the HMA layer and 15 percent each to the base layer and the subgrade.
   - For existing layer material properties:
     - PG grade and volumetric properties must be entered. The volumetric properties of the lower HMA layer should be used, since that is where fatigue cracking will initiate.
     - Dynamic modulus from backcalculation must be entered.
   - The BELLS curve process can be used to obtain 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.



(a) Project 1 (b) Project 2

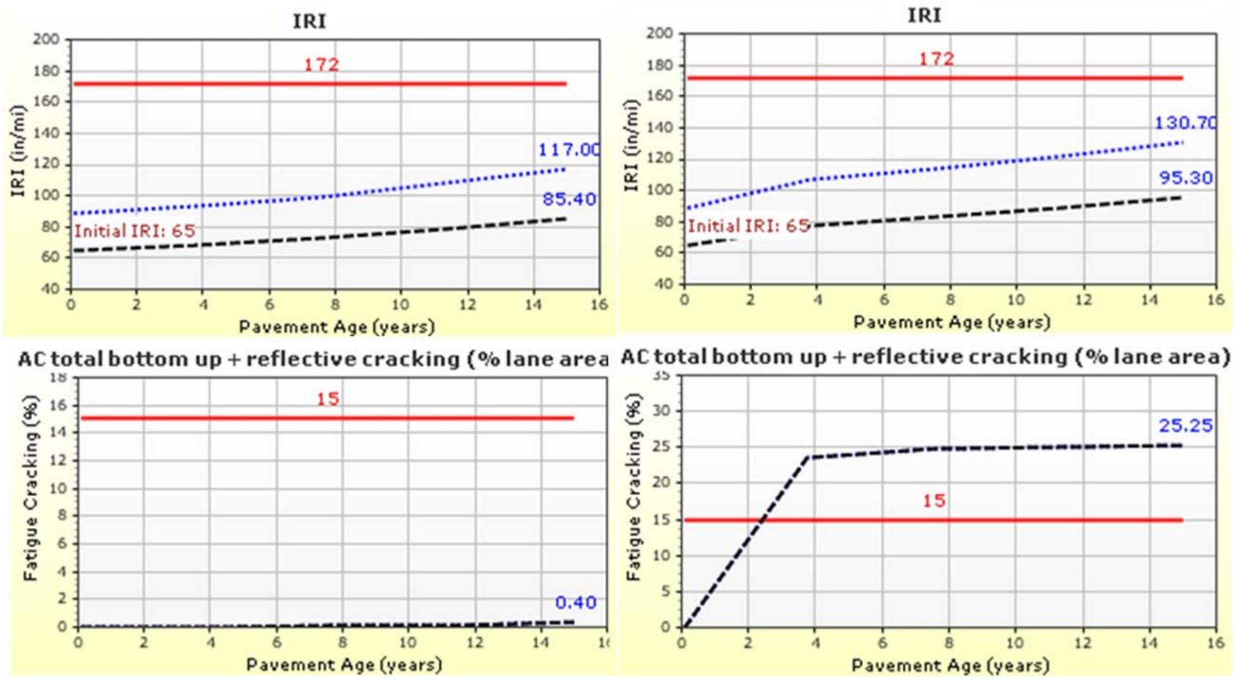
Figure 16. Example projects used to demonstrate characterization of existing flexible pavement.

- For the in-place CIR layer:
  - The backcalculated modulus ranged from 100,000 lb/in^2 (afternoon) to 150,000 lb/in^2 (morning). A value of 100,000 lb/in^2 was selected as the input.
  - No correction of the CIR modulus was required because it is a bound layer with no stress sensitivity (1.0 conversion factor).
- Per the *MEPDG Manual of Practice*, a conversion factor of 0.35 was used for the backcalculated subgrade resilient modulus.
- Level 1 NDT data are so important because the data gives the best characterization of the existing pavement. That said, there are some times when engineering judgment needs to be used to help characterize or model the inputs.

As illustrated in figure 17, the use of level 1 and 2 inputs for existing pavement characterization resulted in substantial differences in overlay design performance for Project 1. Because core photos that showed cracking confined to the top inch of the surface course were more consistent with the Level 1 performance predictions, the value of using Level 1 was apparent and an appropriate treatment in the form of a mill-and-overlay was identified.

Key narratives and guidance given by Mr. Von Quintus as part of the Project 2 demonstration included the following:

- Distress severity level does not go into the prediction of reflective cracking, only the amount.
- The C-factor is used for converting the backcalculated modulus of base, subbase, and subgrade materials to a laboratory-determined modulus. It represents an adjustment to account for confinement. Its use is recommended in the *MEPDG Manual of Practice*, along with specified values for different materials; however, some pavement experts have advised against its use. The important thing regarding the use of the C-factor is to apply it consistently for rehabilitation design and new design. If the C-factor is applied in rehabilitation design, it should be reverse-applied for new design.



(a) Level 1 inputs (b) Level 2 inputs

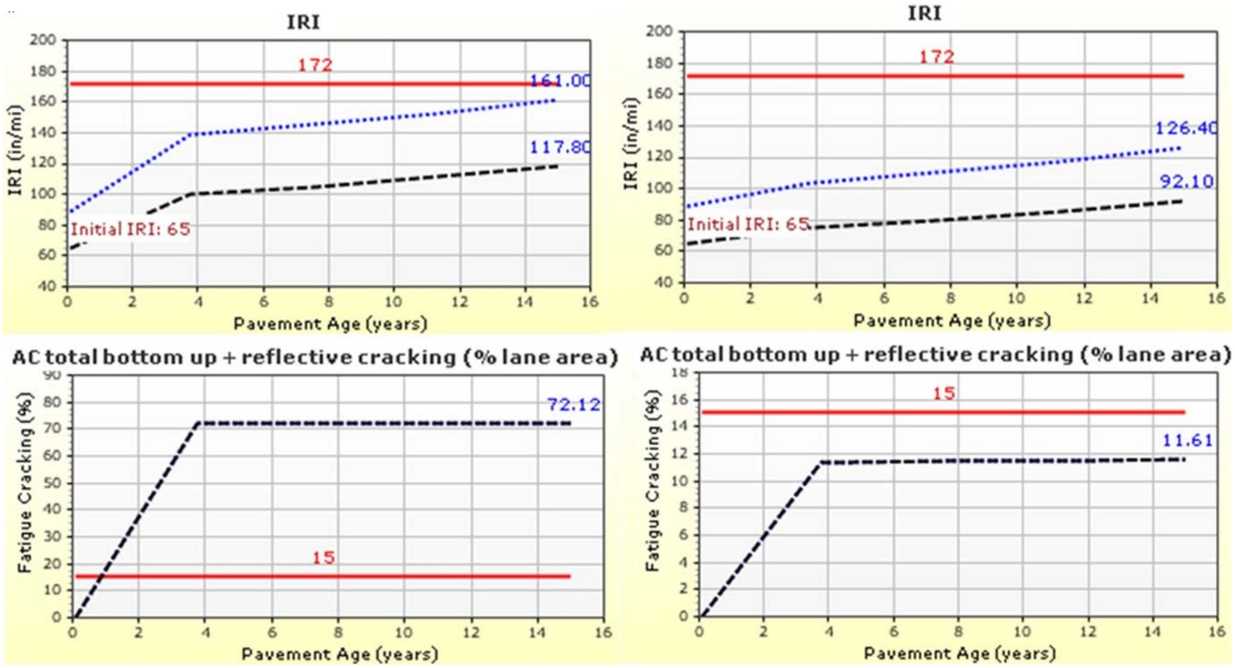
Figure 17. Predicted overlay performance for Project 1 using different input levels for existing pavement characterization.

- Sometimes backcalculation results in modulus values that are higher for the subgrade than the base. Application of the C-factor may cause the moduli for the layers to be more as expected.
- Level 2 input analysis requires laboratory values and distress information (no C-factors are needed). Damage to the existing pavement is defined by cracking in the in-place surface. Level 1 input analysis requires NDT data to define existing pavement damage.

As shown in figure 18, the use of Level 1 and 2 inputs for existing pavement characterization resulted in substantial differences in overlay design performance for Project 2. Core photos showed that cracking extends through all layers and that the CIR layer is disintegrating, again showed greater consistency with the Level 1 predicted performance than Level 2. As a result, an appropriate treatment in the form of reconstruction was identified.

In addressing questions at the conclusion of the second training block, Mr. Von Quintus noted the following:

- Characterization of the existing pavement using Level 2 inputs should continue to be an option in the PMED program. Although clearly not as discerning as Level 1 inputs, many agencies do not perform FWD testing and thus do not have the option of a Level 1 analysis. In addition, a Level 2 analysis is far better than a Level 3 analysis (condition categories).



(a) Level 1 inputs (b) Level 2 inputs

Figure 18. Predicted overlay performance for Project 2 using different input levels for existing pavement characterization.

- Backcalculation and moisture content have to be used together. One can either measure the moisture content at the time of FWD testing or develop an estimate of the moisture content based on the time of year that the FWD testing was performed.
- The NCHRP *Guide for Conducting Forensic Investigations of Highway Pavements* (Rada et al. 2013) has good information on procedures and what to look out for when performing FWD testing and coring.

3. ***Rehabilitation Design Example: I-84 in Boise, Idaho***—The third training block demonstrated how the *BcT* program was used to analyze an existing flexible pavement as part of a rehabilitation design. The project used in the example was located on I-84 near Boise, Idaho. To begin the presentation, Mr. Von Quintus described and illustrated both the pavement conditions (severe transverse and longitudinal cracking and moderate fatigue cracking) and extracted core conditions (intact and good condition for one segment of road, broke apart and poor condition for the other). He then proceeded to demonstrate how FWD deflection data were processed and analyzed using *BcT*, and how the outputs from *BcT* were uploaded into the *PMED* software.

   Key points and guidance made during the presentation included the following.

   - The *BcT* program includes a Guided Process box in the bottom left corner (see figure 19), which shows where the user is at in the process and describes what needs to be done on each screen.

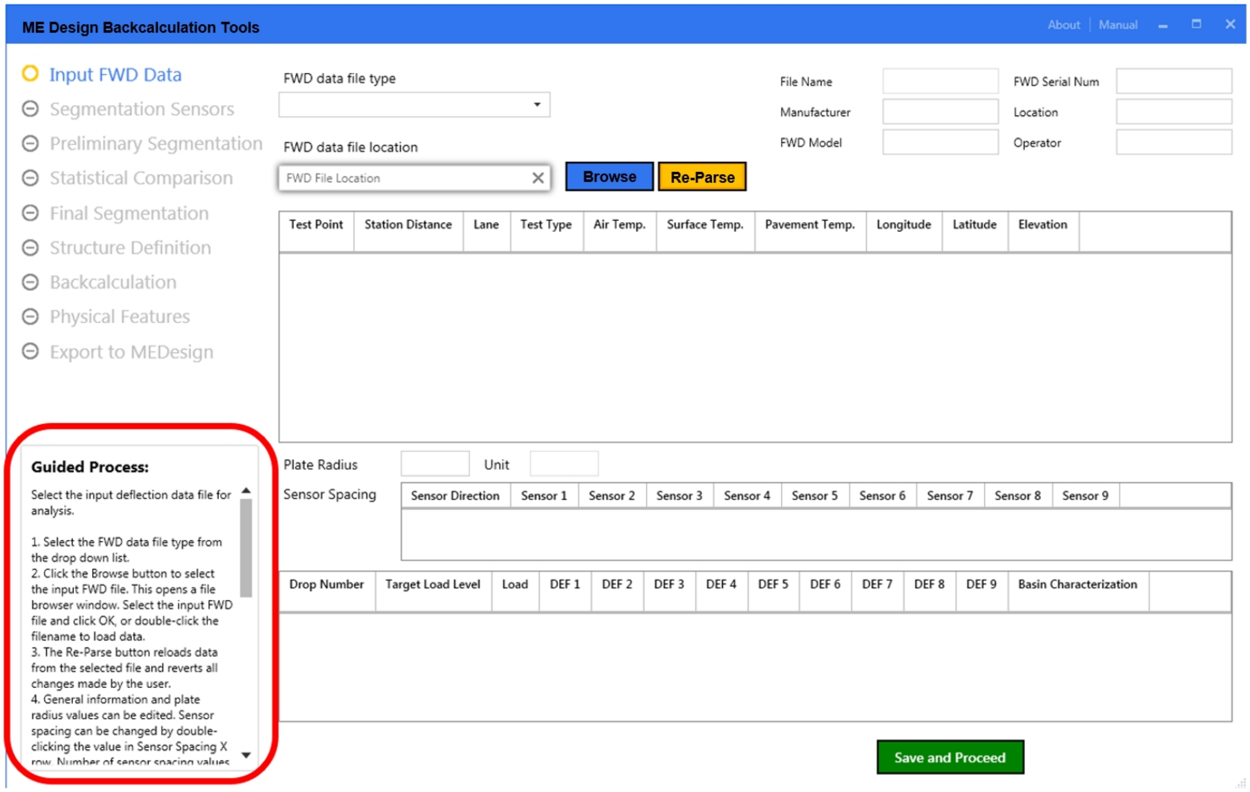


Figure 19. Guided Process informational box in *BcT*.

- A variety of FWD datasets (e.g., JILS .dat, Kuab .fwd, Dynatest .f25) can be uploaded. Once uploaded, the program brings up the test locations, for which the deflection profiles for different load levels can be displayed.
- For segmentation of the data, the user must specify a single load level.
- Segmentation can be based on known differences in pavement structure. However, for the first run, it is probably best just to specify one structure.
- *BcT* includes three sequences of segmentation:
  - Preliminary: Uses the maximum deflection parameter.
  - Statistical: Uses the AREA parameter.
  - Final: Uses a combination of maximum deflection and AREA.
- The "Fix" option constrains a particular layer to one modulus value.
- In conducting a backcalculation, the root-mean-square error (RMSE) should be kept as low as possible. As a general rule, RMSE≤3 percent is a good target, while RMSE>5 percent is unacceptable.
- There will be cases where individual RMSE values are very high (say, >10 percent). These should not be used in the analysis. Dr. Pierce (NCE) pointed out the importance of keeping backcalculation separate from ME design. She noted that doing so forces the user to review the validity of the backcalculated values before automatically transferring them into *PMED*.
- Although the LTE and voids graphs are primarily for assessing PCC pavement, they can be useful to HMA pavement analysis too.

- The *BcT* output file can be easily uploaded into the *PMED* software. The pavement layers are automatically established within *PMED*, based on the contents of the output file. The backcalculated layer moduli are also contained in the *BcT* output file.
- *PMED* creates multiple files based on the segments that were established in *BcT*.

Mr. Von Quintus illustrated the results of different rehabilitation design options for the I-84 project, based on Level 1 (FWD backcalculation results) and Level 2 inputs (distress survey results). A deep mill and thick overlay treatment was shown to be the best option, and the advantages of using Level 1 inputs were again demonstrated.

Calibration Process Example—In the final training block, which was shortened due to time constraints, Mr. Von Quintus examined the concerns and issues identified with calibration coefficients as related to material characterization. As a backdrop for the discussion, he showed a comparison of the global and local calibration coefficients that have been developed for the HMA rutting (see table 19), bottom-up fatigue cracking, and transverse cracking models. Each comparison showed a wide range in the values for some of the coefficients. (As noted by Mr. Von Quintus, K-value coefficients are defined through laboratory testing, while β-value coefficients are defined by field measurements).

Table 19. Comparison of HMA rutting model calibration coefficients.

Layer or Material	Coefficient	Global Values	Local Value Material Specific	Local Value Range of Values
AC	Kr1	-3.35412	√	-2.45 to -3.354
AC	Br1	1.0	√	0.51 to 1.48
AC	Kr2	1.5606	√	–
AC	Br2	1.0	–	0.86217 to 1.15
AC	Kr3	0.4791	–	0.28 to 0.4792
AC	Br3	1.0	–	0.90 to 1.35392
Coarse-Grained Material	Ks2	2.03	–	1.673 to 2.03
Coarse-Grained Material	Bs2	1.0	√	0.0 to 1.0
Fine-Grained Soil	Ks1	1.35	–	–
Fine-Grained Soil	Bs1	1.0	√	0.0 to 1.53

Mr. Von Quintus indicated that global calibrations were performed using projects with a wide range of HMA thicknesses, support conditions, structures, mix types (neat, RAP, or other modified mixes), and volumetric properties. He pointed out that none of the global values for rutting take into account the difference between mix types, and that dynamic modulus alone, as measured in the laboratory, is not enough to explain the differences between the mixes in terms of rutting.

12. RESEARCH AND TRAINING NEEDS

Session 10 of the meeting featured a narrated presentation on the future of the MEPDG and *PMED*, software. A summary of the information presented is provided below. A copy of the narrated presentation is featured as presentation 21 in appendix C.

1. ***MEPDG/Pavement-ME: Future Directions*** **(Dr. Kevin Hall, University of Arkansas)**—Dr. Hall provided a recorded presentation intended to provoke discussion on the future direction of pavement design. His specific topic addressed how pavement design is used to address cracking in flexible pavements. Dr. Hall discussed the current status for modeling bottom-up, top-down, transverse (low temperature), and reflection cracking, and subsequently posed three important questions:

    - Is it desired to continue to predict the extent of cracking or attempt to prevent cracking?
    - Is it important and/or desirable to model all forms of load-related cracking using the same general approach and/or mechanistic basis?
    - Is it important and/or desirable to integrate, more fully, asphalt mixture characterization between the processes for asphalt mixture design and flexible pavement structural design?

    Dr. Hall provided discussion related to each of the three questions, and proceeded to an even broader question: What is the next big thing…what does the next generation of Pavement ME look like?

13. PLANS FOR THE THIRD ANNUAL USERS GROUP MEETING

At the conclusion of the meeting, Dr. Pierce informed the group that planning for the 2018 Users Group meeting was underway and that Nashville, Tennessee was selected as the destination for the meeting. She reported that a handful of hotels in the downtown and airport areas had been recently contacted about hosting the 2-day meeting in the fall, and that various hotel and date options were identified based on the hotel responses. The general consensus of the participants was to hold the meeting in the downtown area in mid-October, with preference for a Wednesday-Thursday date combination.

In the weeks following the Denver meeting, Mr. Smith and other APTech staff solicited proposals from additional Nashville hotels and evaluated the details of each offer with Dr. Pierce. Recommendations were submitted to FHWA (Mr. Yu and Mr. Wagner) and a decision was made to hold the third annual Users Group meeting at the Holiday Inn Express in downtown Nashville on November 7-8, 2018.

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