APPENDIX A. MEETING PARTICIPANTS

TAC and Pooled Fund Member Participants

Name	Agency	TAC Member	Pvt ME Design TF Member	Email Address
Tom Yu Chris Wagner	FHWA	Yes Yes	FHWA Liaison No	tom.yu@dot.gov christopher.wagner@dot.gov
Vicki Schofield Tinika Fowlkes	AASHTO	Yes No	Yes No	vschofield@aashto.org tfowlkes@aashto.org
Robert Shugart Jr. Scott George John Jennings	Alabama DOT	Yes Yes Yes	Yes No No	shugartr@dot.state.al.us georges@dot.state.al.us jenningsj@dot.state.al.us
NourAli Zareh Ashek Rana	Arizona DOT	No Yes	No No	azareh@azdot.gov arana@azdot.gov
Mehdi Parvini Dulce Rufino Feldman	California DOT	Yes Yes	No No	Mehdi_Parvini@dot.ca.gov dulce.rufino@dot.ca.gov
Melody Perkins	Colorado DOT	Yes	No	melody.perkins@state.co.us
Mary Jane Hayden	Florida DOT	Yes	No	MaryJane.Hayden@dot.state.fl.us
Ian Rish Ciprian Donisa Robie Cunningham	Georgia DOT	Yes No No	No No No	irish@dot.ga.gov CDonisa@dot.ga.gov RCunningham@dot.ga.gov
Charles Wienrank John Senger	Illinois DOT	Yes No	No No	charles.wienrank@illinois.gov John.Senger@illinois.gov
Ben Behnami Chris B. Brakke	Iowa DOT	Yes Yes	No No	Ben.Behnami@dot.iowa.gov Chris.Brakke@iowadot.us
Nat Valesquez Jr. Ryan Barrett	Kansas DOT	Yes Yes	No No	nat.velasquez@ks.gov Ryan.Barrett@ks.gov
Sunil Saha Brad Frazier Jonathan Reynolds	Kentucky TC	Yes No No	No No No	sunil.saha@ky.gov Brad.Frazier@ky.gov Jonathan.Reynolds@ky.gov
M. Alauddin Ahammed Yasir Shah Tara Liske	Manitoba Transportation	Yes No No	No No TAC Liaison	alauddin.ahammed@gov.mb.ca Yasir.Shah@gov.mb.ca Tara.Liske@gov.mb.ca
Praveen Desaraju Geoffrey Hall	Maryland SHA	Yes Yes	No No	PDesaraju@mdot.state.md.us GHall1@sha.state.md.us
Justin Schenkel Jami Trudelle	Michigan DOT	Yes No	No No	schenkelj@michigan.gov TrudelleJ1@michigan.gov
W. Griffin Sullivan Bill Barstis	Mississippi DOT	No No	No No	wsullivan@mdot.ms.gov wbarstis@mdot.ms.gov
John Donahue Jason Blomberg Jeff Kroner	Missouri DOT	Yes Yes No	Yes No No	john.donahue@modot.mo.gov Jason.Blomberg@modot.mo.gov jeffery.kroner@modot.mo.gov
Christine Chia Kelgard	Nevada DOT	No	No	CChia@dot.nv.gov
Clark Morrison Shihai Zhang	North Carolina DOT	Yes Yes	Yes No	cmorrison@ncdot.gov szhang2@ncdot.gov
TJ Murphy Aaron Perez	North Dakota DOT	No Yes	No No	tjmurphy@nd.gov asperez@nd.gov
Josh Freeman Lydia Peddicord	Pennsylvania DOT	Yes Yes	No No	josfreeman@pa.gov lpeddicord@pa.gov
Dahae Kim	South Carolina DOT	No	No	kimd@scdot.org
Hari Nair Girum Merine	Virginia DOT	Yes No	No No	harikrishnan.nair@vdot.virginia.gov girum.merine@vdot.virginia.gov
Tirupan Mandal	Wisconsin DOT	Yes	No	Tirupan.Mandal@dot.wi.gov

Non-TAC / Non-Pooled Fund Member Participation

Name	Agency	Pvt ME Design TF Member	Email Address
Kelly Smith	APTech	No	klsmith@appliedpavement.com
Chadwick Becker Harold Von Quintus Wouter Brink	ARA	No No No	cbecker@ara.com hvonquintus@ara.com wbrink@ara.com
Richard B. Duval LaToya Johnson Scott Nelson	FHWA	No No No	Richard.Duval@dot.gov Latoya.Johnson@dot.gov Scott.Nelson@dot.gov
Jennifer Albert	FHWA Resource Center	No	jennifer.albert@dot.gov
Kumar Dave	Indiana DOT	No	KDAVE@indot.IN.gov
Xingwei Chen James Ball Jeffrey Lambert Mark Ordogne	Louisiana DOTD	No No No No	xingwei.chen@la.gov James.ball@la.gov jeff.lambert@la.gov mark.ordogne@la.gov
Casey Nash	Maine DOT	No	casey.b.nash@maine.gov
Nusrat Morshed Sudeh Sadeqlu	New Jersey DOT	No No	Nusrat.Morshed@dot.nj.gov sudeh.sadeqlu@dot.nj.gov
William Feehan	Ohio DOT	No	william.feehan@dot.ohio.gov
Felix Doucet	Quebec	Yes	Felix.Doucet@transports.gouv.qc.ca
David Holmgren	Utah DOT	Yes	dholmgren@utah.gov
Ryan Steinbrenner	Wyoming DOT	No	ryan.steinbrenner@wyo.gov

Academia/Consultant/Industry Representative Participation

Name	Agency	Pvt ME Design TF Member	Email Address
Eric Ferrebee	ACPA	No	eferrebee@acpa.org
L. Allen Cooley, Jr.	Burns Cooley Dennis, Inc.	No	acooley@bcdgeo.com
Tyler Speakmon	CEMEX	No	michaelt.speakmon@cemex.com
Robert Kluttz	Kraton Polymers US LLC	No	bob.kluttz@kraton.com
Timin Punnackal	NCE	No	tpunnackal@ncenet.com
Bruce Dietrich Wiley Cunagin	Pavement Analytics, LLC	No No	bdietrich@pavementanalytics.com wcunagin@gmail.com
Mohammadreza Mirzahosseini	Purdue University	No	mhoseini@purdue.edu
Hao Wang	Rutgers University	No	hwang.cee@rutgers.edu, hw261@soe.rutgers.edu
Vladimir Mitchev	S&ME	No	vmitchev@smeinc.com
Prajwol Tamrakar Garrett Fountain	Tensar Corp	No	PTamrakar@tensarcorp.com GFountain@tensarcorp.com
Sonny Kim Stephen A. Durham Hampton Mark Worthey	University of Georgia	No No No	kims@uga.edu sdurham@uga.edu hampton.worthey25@uga.edu
Clark Graves	University of Kentucky	No	clark.graves@uky.edu
Sarah Gassman Pierce	University of South Carolina	No	gassman@cec.sc.edu

APPENDIX B. MEETING AGENDA

Wednesday, November 6

Time	Topic
8:00–8:45 AM	WELCOME AND INTRODUCTIONS Welcome | Chris Wagner (FHWA). Introduction and Remarks | John Donahue (Missouri DOT, AASHTO Committee on Materials and Pavements, and Chair, AASHTOWare Pavement ME Design Taskforce). Canadian Users Group Update | Tara Liske (Manitoba Infrastructure) Review of agenda and meeting goals | Kelly Smith (APTech)
8:45–10:15 AM	AGENCY IMPLEMENTATION STATUS Implementation map updates | Kelly Smith (APTech) Agency briefings on implementation plans, timelines, and progress | All
10:15-10:30 AM	BREAK
10:30-11:30 AM	AASHTOWARE PAVEMENT ME DESIGN SOFTWARE UPDATE AASHTO Briefing (announcements/news, customer relations) | Vicki Schofield and Tinika Fowlkes (AASHTO) Software enhancements/updates (incl. new features/capabilities) | Chad Becker (ARA) Engineering Stack Exchange | Chad Becker (ARA)
11:30 AM-NOON	ME RESEARCH SUMMARIES NCHRP Research Update (incl. preview of NCHRP 1-61) | Kelly Smith (APTech) FHWA Research Update (incl. preview of Design Catalog) | Tom Yu (FHWA)
NOON-1:15 PM	LUNCH (ON YOUR OWN)
1:15-2:45 PM	ME RESEARCH INTO PRACTICE MEPDG Manual of Practice (MOP) Edits | Harold Von Quintus (ARA) NCHRP 1-52 Top-Down Cracking Model | Harold Von Quintus (ARA) “Calibrator” Automated Calibration Tool Demo | Wouter Brink (ARA)
2:45-3:00 PM	BREAK
3:00-4:00 PM	AGENCY IMPLEMENTATION EXPERIENCES Old Implementer Updates: Effects of Utah DOT’s Recalibration Effort on HMA Pavement Design and Changes to the Agency’s Pavement Manual of Instruction | David Holmgren (Utah DOT) Implementer Backtracking: New Jersey Implementation Experiences | Nusrat Morshed (New Jersey DOT)
4:00-5:00 PM	INNOVATIONS/IMPROVEMENTS IN TRAFFIC AND CLIMATE FORECASTING Updated Traffic Data Cluster Methodology for Locations where WIM Station is not Present | Justin Schenkel (Michigan DOT) Impact of Warming Temperature on Pavement ME Outputs Considering Climate Change Effect | Dr. Hao Wang (Rutgers University)

Thursday, November 7

Time	Topic
8:00-9:00 AM	PAVEMENT ME Q&A FORUM AASHTOWare Survey and Pavement ME Design Task Force Discussions | Bob Shugart (Alabama DOT) and other Task Force members
9:00-10:00 AM	DESIGN ISSUES AND APPLICATIONS Practitioner's Guide for Mechanistic-Empirical Design of Pavements with R^2AMs | Harold Von Quintus (ARA) Characterization of Base, Intermediate, SMA, and Polymer-Modified Dense-Graded Asphalt Mixtures for Pavement ME | Hari Nair (Virginia DOT)
10:00-10:15 AM	BREAK
10:15-11:10 AM	DESIGN ISSUES AND APPLICATIONS (Continued) Sensitivity of Pavement ME Fatigue Cracking Predictions on Effective Binder Contents | Mohammadreza Mirzahosseini (Purdue University) Advanced Use of Pavement ME v2.3 for Major Project Full-Depth Pavement Design with High-Performance Materials using Material Property Global Recalibration | Bob Klutz (Kraton Polymers)
11:10 AM-NOON	LOCAL CALIBRATION EXPERIENCES Field and Laboratory Work to Locally Calibrate the New Pavement Design Guide for Mississippi DOT | Dr. Allen Cooley (Burns Cooley Dennis) Maine DOT's Experience with First Local Calibration using Beta Version of Calibrator | Casey Nash (Maine DOT)
NOON–1:15 PM	LUNCH (ON YOUR OWN)
1:15–3:15 PM	SOFTWARE TRAINING Live demonstration-based training on new software features and example applications (e.g., AC overlay with interlayer, inverted pavement) | Harold Von Quintus (ARA) Innovative and Effective Training Modules and Methods for Pavement Designers for Rapid Deployment and Continuous Operation of MEPDG | Stephan Durham, Dr. Sung-Hee Kim, and Hampton Worthey (University of Georgia)
3:15–3:30 PM	BREAK
3:30-4:00 PM	ALTERNATIVE ME ANALYSIS TOOLS FlexPave | Richard Duval (FHWA)
4:00–4:30 PM	MEETING WRAP UP Discuss key takeaways of Users Group meeting | All Future of the National ME Users Group | Chris Wagner (FHWA) Concluding remarks | Kelly Smith (APTech)

APPENDIX C. MEETING PRESENTATIONS

Presentation 1—Tara Liske, Manitoba Infrastructure

TRANSPORTATION ASSOCIATION OF CANADA (TAC)
ASSOCIATION DES TRANSPORTS DU CANADA (L'ATC)

ME Pavement Design Subcommittee Update

Tara Liske, TAC Liaison
New Orleans, LA
November 6th, 2019

We are changing!

- Felix Doucet (Ministere des Transports du Quebec), past TAC Liasion, is now the Canadian Task Force Member
- Tara Liske (Manitoba Infrastructure), new TAC Liaison

Subcommittee History

- User Group since 2008 (10 years)
- Subcommittee of the Pavement Standing Committee in Fall 2018
- 2 in-person meetings, 2 conference calls
- 25 active members
  - Agencies, Consultants, Industry, Associations, Academics

Terms of Reference (Mandate)

- Promote collaboration with other ME Pavement Design Users
- Identify and promote research needs regarding pavement design technologies and software
- Conduct AASHTO PavementME software evaluations through coordinated trials
- Liaise with AASHTO PavementME Task Force

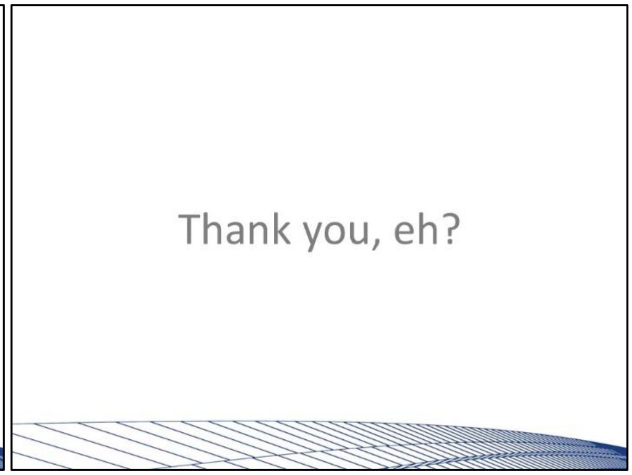
Upcoming TAC Conference

- September 2020 in Vancouver, British Columbia
- Hosting a panel discussion on *case studies and practical application of ME designs for pavement rehabilitation*

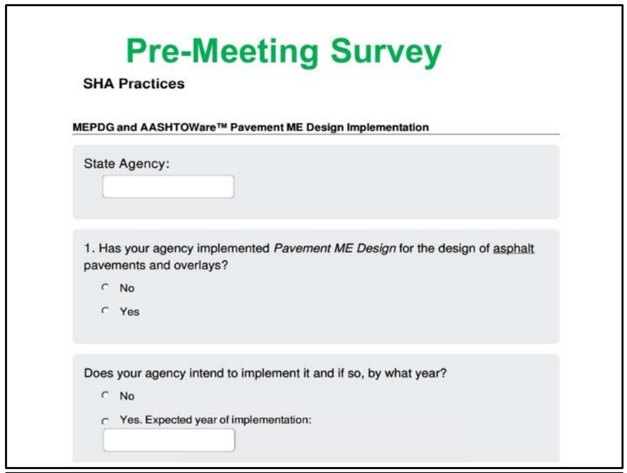
Recent Work

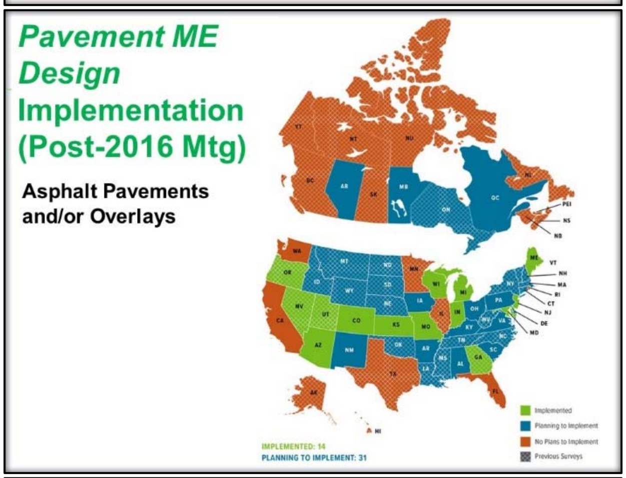
- Conducting trials
  - JPCP (dowels, no dowels, size of dowels, thickness of pavement)
- Continually updating the *Canadian User Guide: Default Parameters for AASHTOWare Pavement ME Design*
  - September 2019 latest edition

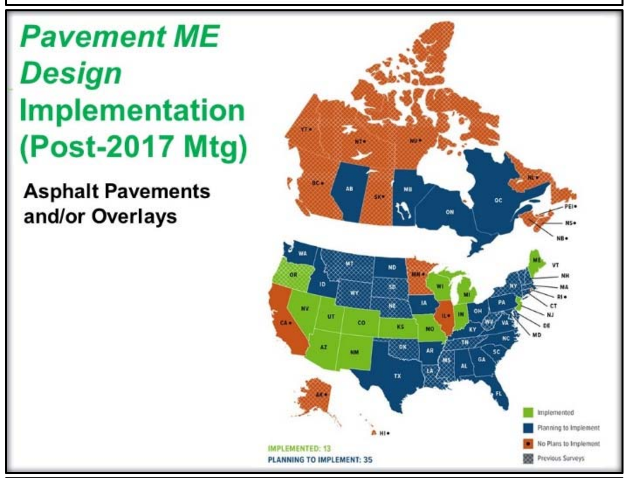

Future Work
• Presentation of the Calibration Tool at the 2020 Spring meeting
• Top-down cracking model trials
• Continue to update the Canadian User Guide

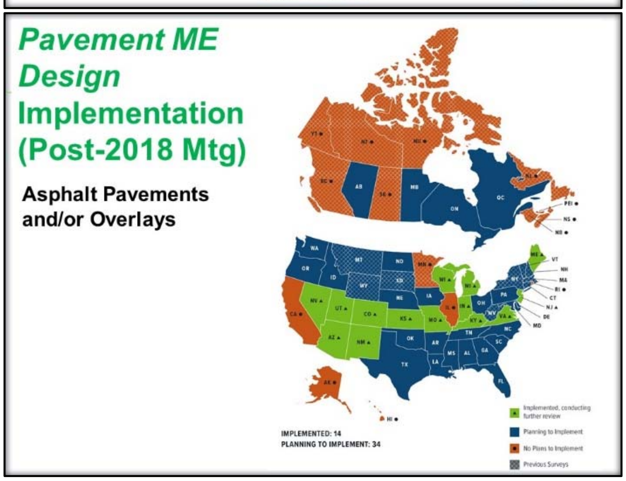

Thank you, eh?

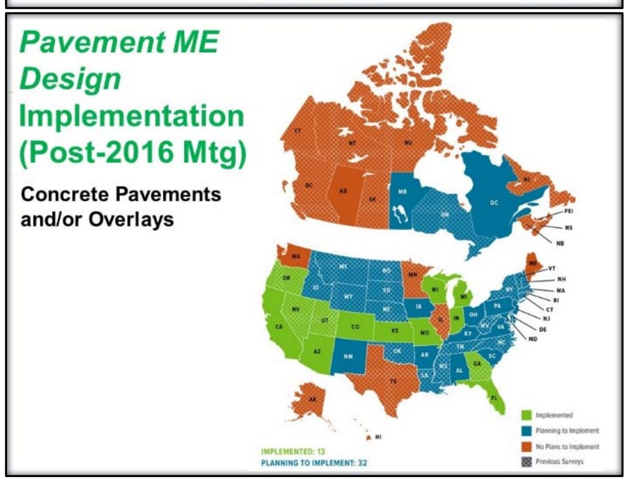
Presentation 2—Kelly Smith, Applied Pavement Technology (APTech)

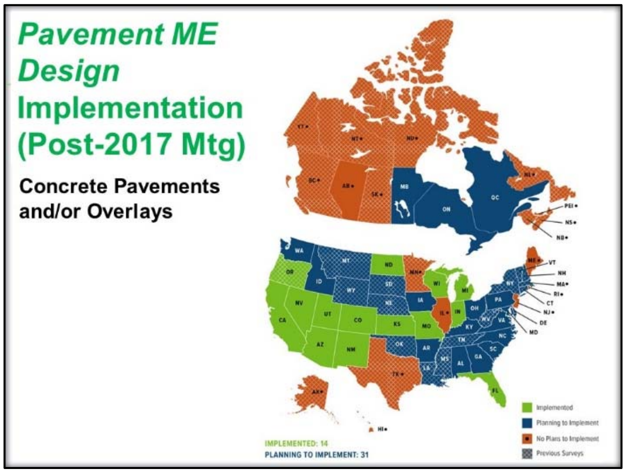


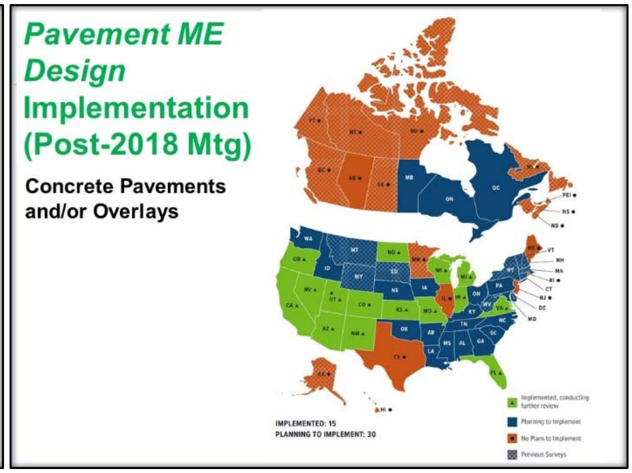









Pavement ME Design Implementation (Post-2017 Mtg)
Concrete Pavements and/or Overlays
IMPLEMENTED: 14
PLANNING TO IMPLEMENT: 31
Implemented
Planning to Implement
No Plans to Implement
Previous Surveys


Pavement ME Design Implementation (Post-2018 Mtg)
Concrete Pavements and/or Overlays
IMPLEMENTED: 15
PLANNING TO IMPLEMENT: 30
Implemented, conducting further review
Planning to Implement
No Plans to Implement
Previous Surveys

Presentation 3—Vicki Schofield, AASHTO

AASHTOWare Pavement ME Design AASHTO

User Group Meeting 2019

Where Can I get Information about Pavement ME Design?

- AASHTOWare's web site at www.aashtoware.org/pavement/
- ARA's Support Site at www.me-design.com

AASHTOWare's Site provides information on

- ✓ licensing
- ✓ ordering
- ✓ technical matters
- ✓ user support
- ✓ training

www.aashtoware.org/pavement/

ARA's Pavement ME Design web site at www.me-design.com provides

- ✓ software download information
- ✓ release notes
- ✓ access to technical help
- ✓ access to the tools
- ✓ climatic data
- ✓ Webinars
  - Training
  - Enhancements

Tools included in the software:

Pavement ME Design includes several tools to assist the pavement engineer:

1. **DRIP** performs hydraulic design computations for the subsurface drainage analysis of pavements;
2. **XML** Validator checks for most of the errors present in the xml files. It can also check for recommended ranges for data values;
3. **MapME** creates ME Design project files (DGPX) seeded with geospatially-referenced information relevant to the analysis and design of your pavement;
4. **File and analysis APIs Tools** include JULEA and ICM;
5. **Calibration Assistance** helps with local calibration efforts so the user can determine whether there is any bias in the predictions; establish the cause of any bias if found through the calibration process; and optimize the calibration coefficient of the transfer function(s) for each distress to eliminate bias and minimize the standard error of the estimate;
6. **rePave Scoping Tool** provides guidance for deciding where and under what conditions to use existing pavement as part of roadway renewal projects. This tool is available at no cost to non-licensees, too.
7. **Backcalculation Tool** is a standalone software program that can be used to generate backcalculation inputs from Falling Weight Deflectometer (FWD) files to the AASHTO Pavement ME Design software for rehabilitation design. The tool is capable of analyzing raw deflection data files from three FWD testing devices: Dynatest®, JILS and KUAB. The tool provides three major functions: pre-processing deflection data (including project segmentation), backcalculation, and post-processing of results to generate inputs for Pavement ME rehabilitation design. This tool uses the EVERCALC® algorithm for the iterative backcalculation process. This tool can also be licensed separately.

Enhancements Planned

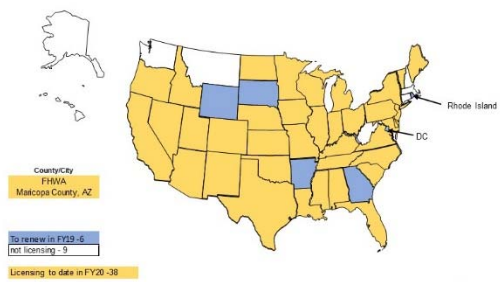
- Top-down cracking model from NCHRP 1-52 – planning release in February 2020

Training Webinars on FY19 Enhancements

The two webinars to explain and demonstrate the Calibration Tool and database were held October 10 and 22.

Copies of the presentation are available at https://me-design.com/MEDesign/Webinars.html

AASHTOWare Pavement ME Design Licensee Map – FY20



AASHTOWare Pavement ME Design Licensee Map

Additional License Types

	2019 (as of 10/17)
No Cost Educational	56
Private Sector and Universities	117

International

2019 – (16) Canada, Japan, Hong Kong SAR, UAE, Guatemala, C.A., Spain, Brazil, China, Egypt, Peru, South Korea, St Lucia, Lebanon, Mexico, South Korea, Trinidad

Licensing in FY 2020

Single user	$ 6,400
Site License – up to 9 concurrent users	$25,400
Site License – up to 14 concurrent users	$38,200
Site License – up to 20 concurrent users	$50,800
Backcalculation Tool	$ 1,250
Service Units (about 65 hours)	$13,500

- ARA manages international licenses

Web Technology

- Move from a single user desktop application to a web technology based software application.
- Period of Performance – FY19 – FY22
  - FY19:
    - Formal inventory requirements and backlog report
    - Budget/Schedule re-evaluation
    - Analysis library domain enrichment
  - FY20
    - Data and behavior refactoring
    - Adapt and develop a modular reporting subsystem
  - FY21
    - Design and develop a uniform data persistence module
    - Core platform integration
    - Adapt and transition the existing WinForms and MVP user interfaces (split between FY 21 &22)

- FY22
  - Adapt and transition the existing WinForms and MVP user interfaces – (split between FY 21&22)
  - Perform system alpha testing
  - Perform system beta testing
  - Deploy web technology application

AASHTOWare Pavement ME Design Product Task Force

John Donahue - Missouri DOT - Chair
Clark Morrison – North Carolina DOT – Vice Chair
Patrick Bierl, Ohio DOT
Felix Doucet, Ministère des Transports du Québec
David Holmgren, Utah DOT
Bob Shugart – Alabama DOT
Vacancy

Liaisons:
Tom Yu, FHWA
Tara Liske, Manitoba Infrastructure - TAC
Jeff Dean, Kansas DOT - SCOA
Travis Tackett, Florida DOT - TAA

For Additional Information:

Vicki Schofield
AASHTO Project Manager
vschofield@aashto.org
(202) 624-3640

Presentation 4—Chad Becker, Applied Research Associates Inc. (ARA)

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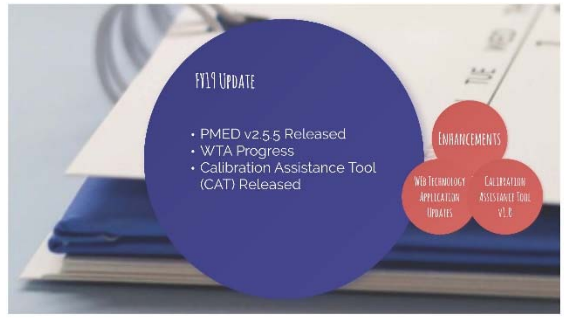

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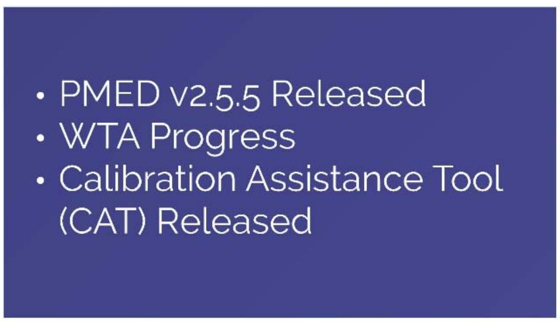

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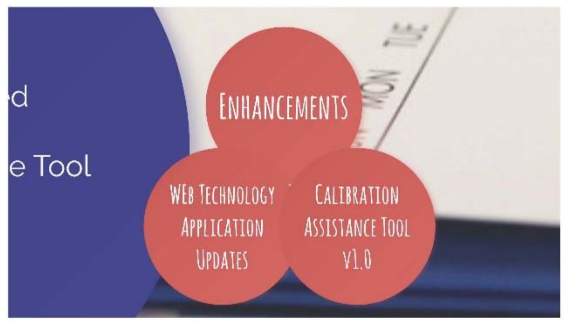

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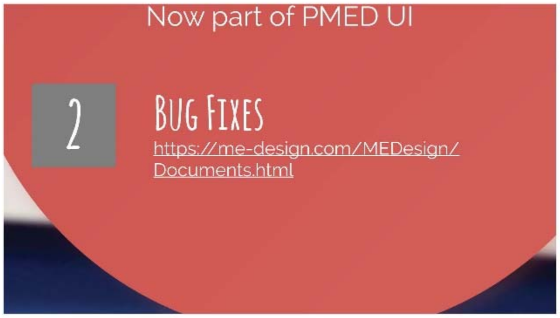
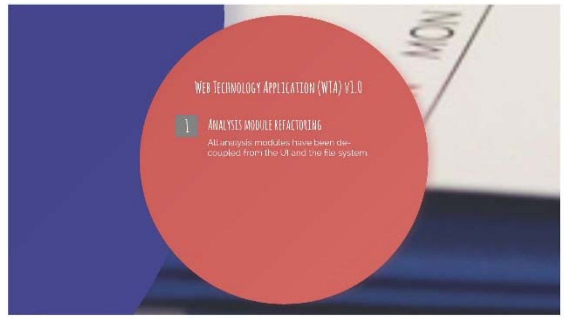
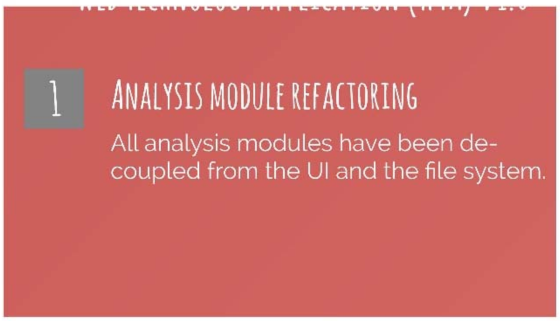

Now part of PMED UI
2
Bug Fixes
https://me-design.com/MEDesign/Documents.html

8.


Web Technology Application (WTA) v1.0
1
Analysis module refactoring
All analysis modules have been de-coupled from the UI and the file system.

9.


1
Analysis module refactoring
All analysis modules have been de-coupled from the UI and the file system.

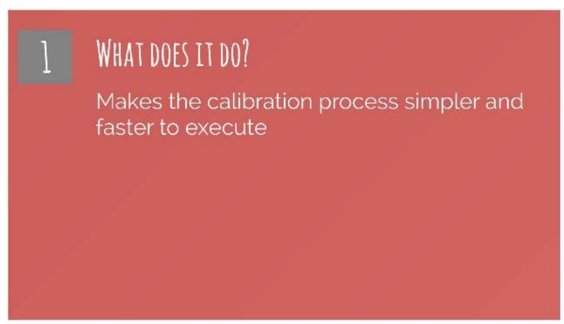
10.


2
Benefits to the CAT
Optimization caching

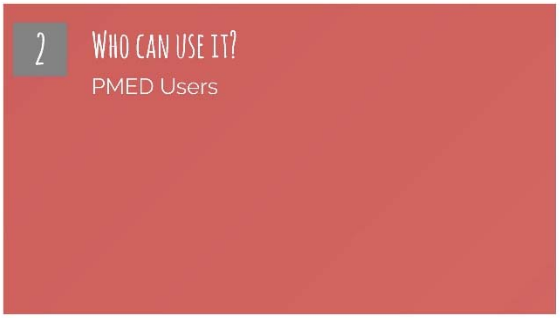
12.


Calibration Assistance Tool (CAT)
1
What does it do?

13.


1
What does it do?
Makes the calibration process simpler and faster to execute

14.



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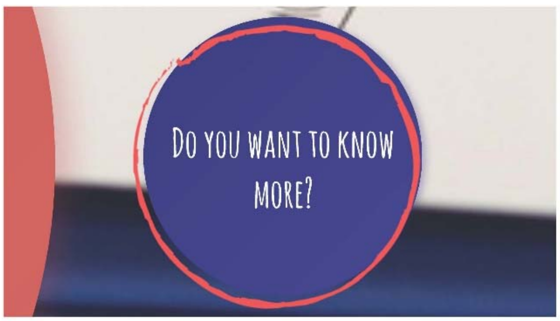

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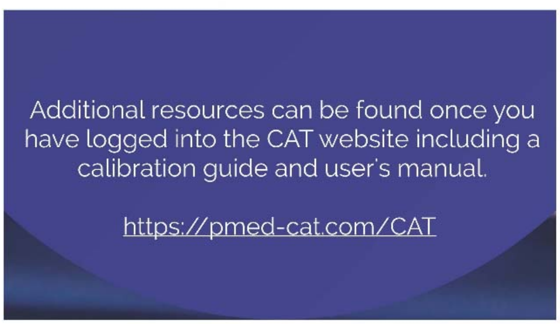

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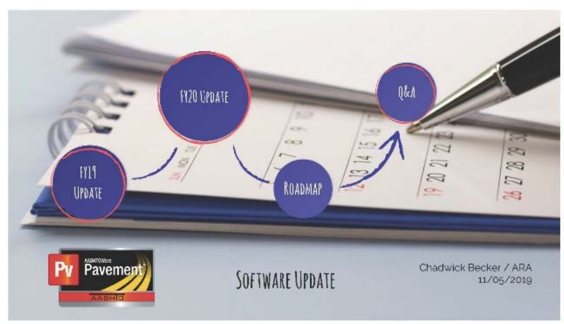

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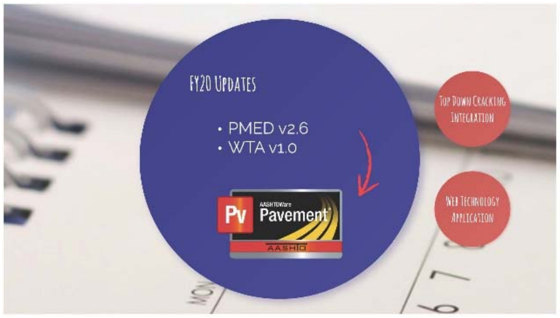

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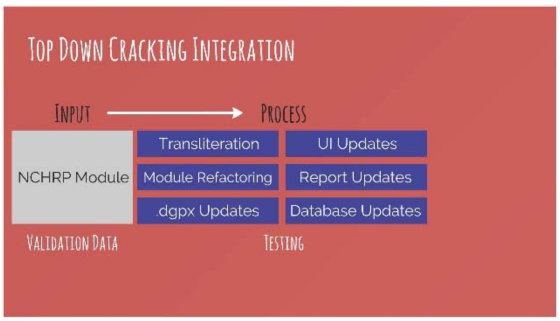

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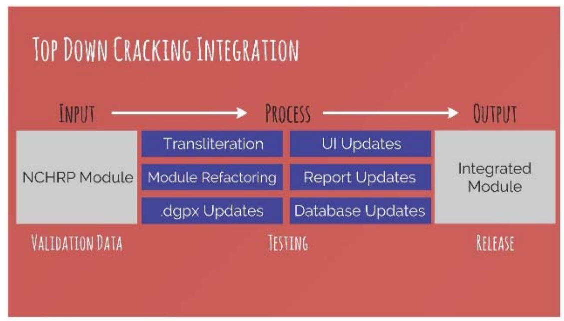

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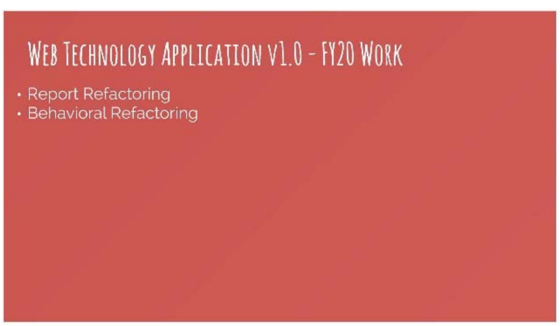

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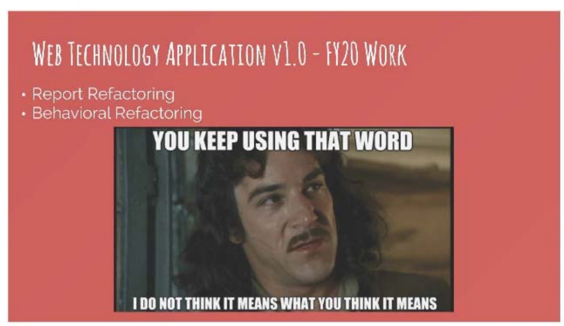

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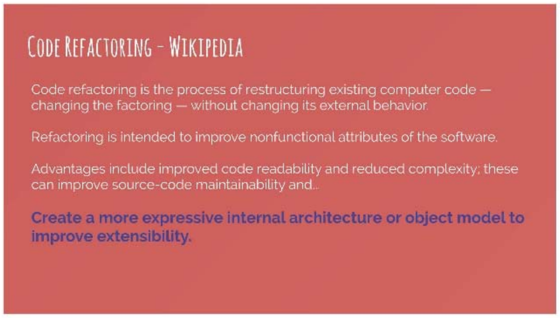

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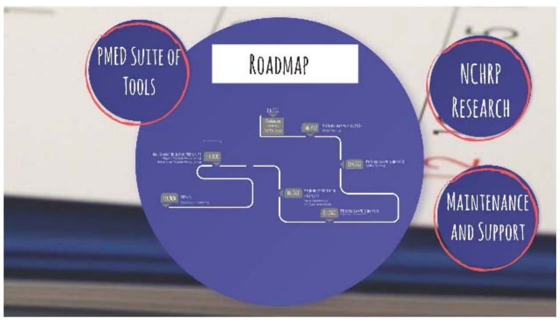

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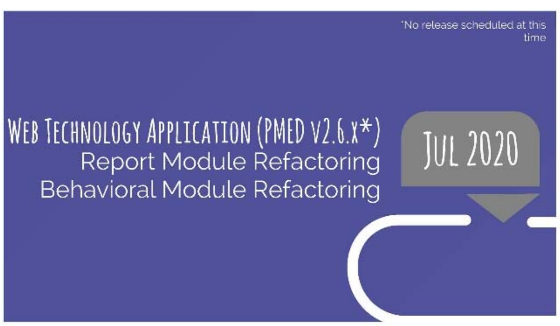

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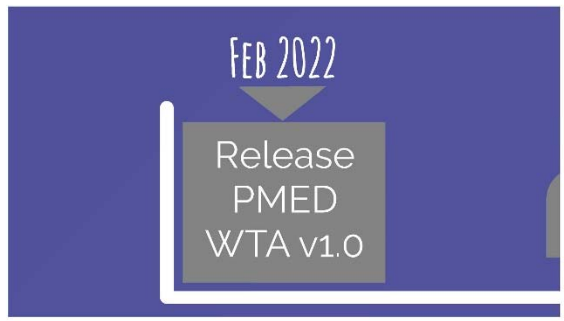

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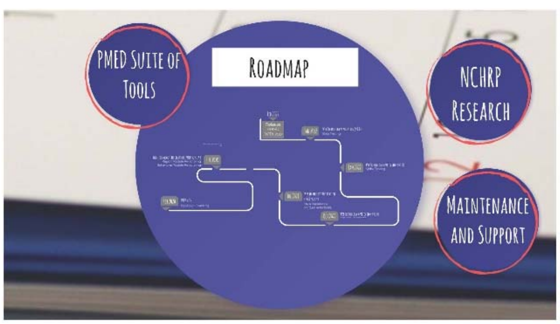

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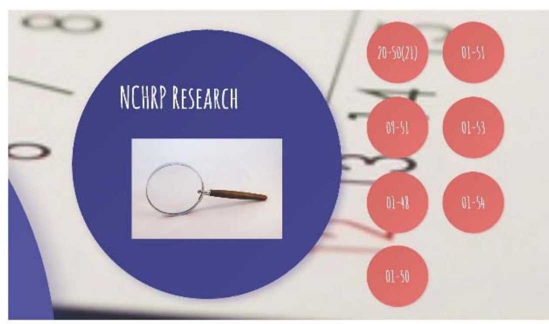
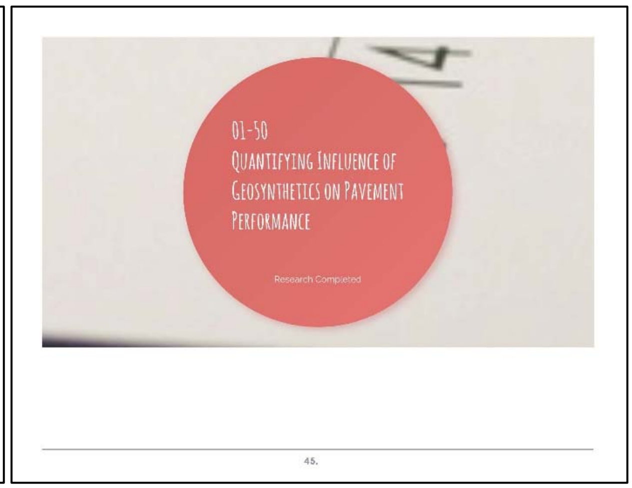


41.


20-50(21)
Enhancements of Climatic Inputs and Related Models for Pavement ME Using LTPP Climate Tool (MERRA-2)
Research Underway
42.

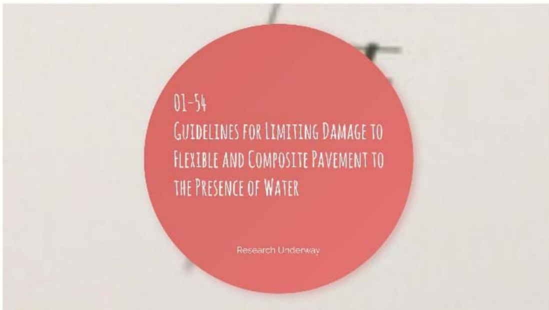

09-51
Material Properties of Cold In Place Recycled and Full Depth Reclamation Asphalt Concrete for Pavement Design
Research Complete
43.


01-48
Incorporating Pavement Preservation into the MEPDG
Research Completed
44.


01-50
Quantifying Influence of Geosynthetics on Pavement Performance
Research Completed
45.


01-51
Slab/Underlying Layer Interaction in Concrete Pavement Design
Research Complete
46.


01-53
Proposed Enhancements to Pavement ME: Improved Consideration of the Influence of Subgrade and Unbound Layers on Pavement Performance
Research Underway
47.



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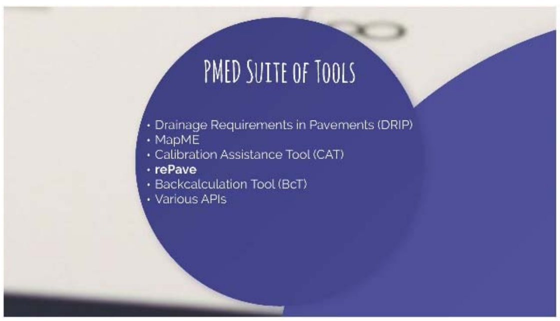

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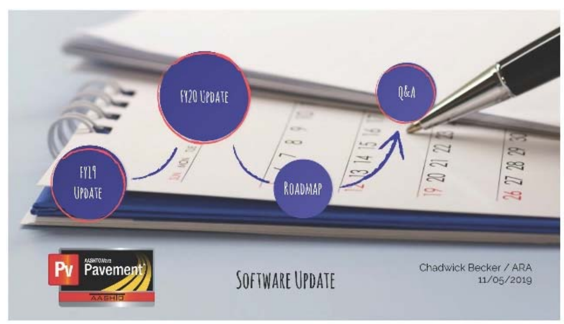

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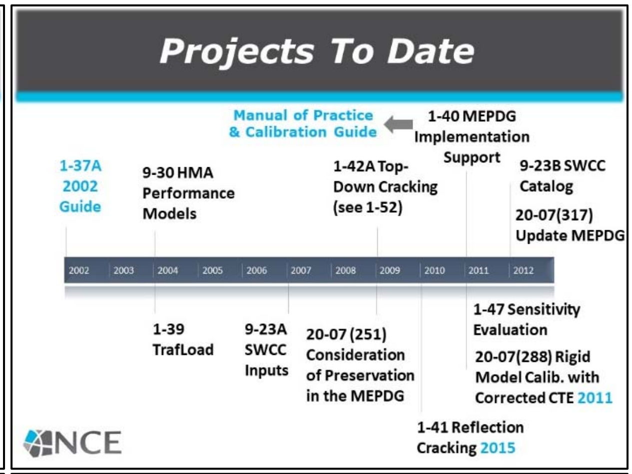
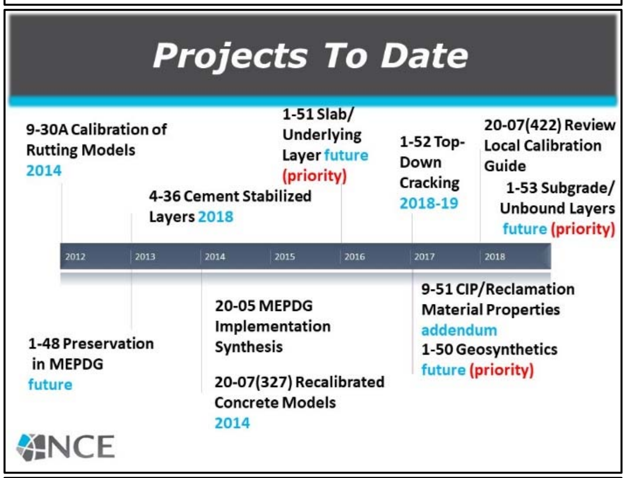
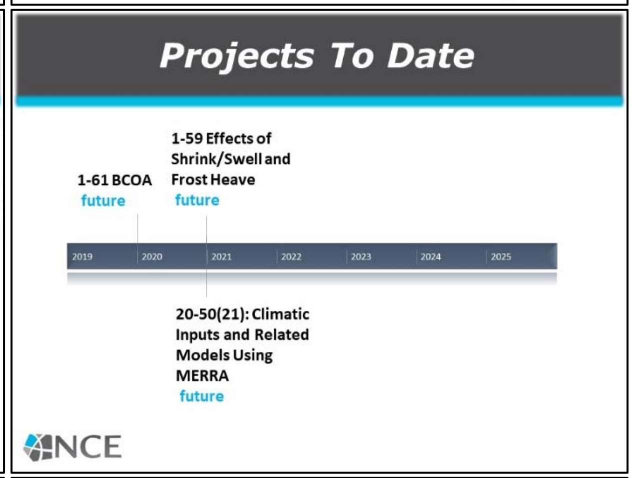
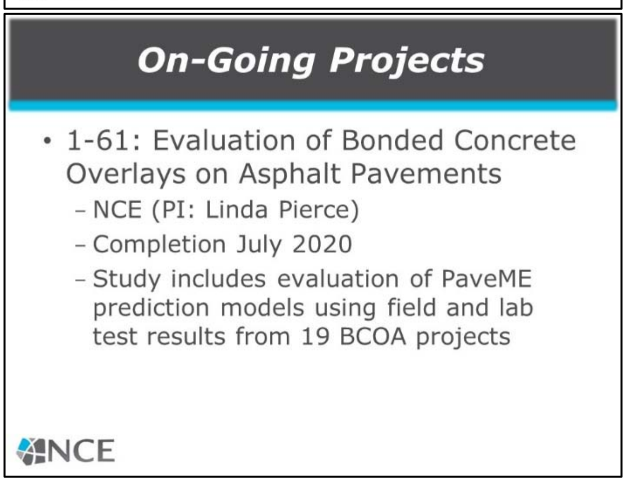
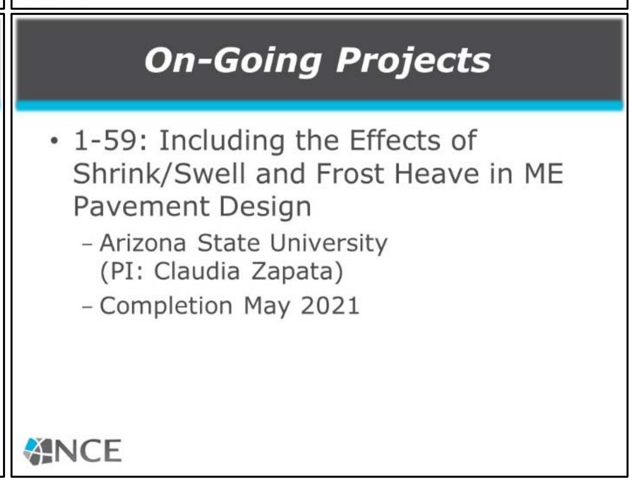
Presentation 5—Kelly Smith, APTech











On-Going Projects (continued)

- 20-50(21): Enhancements of Climatic Inputs and Related Models for Pavement ME Using LTPP Climate Tool (MERRA-2)
  - ARA (PI: Wouter Brink)
  - Completion February 2021

NCE

New Projects

- No upcoming projects planned FY 2020

NCE

Project Summary

MEPDG
- Software
- Manual of Practice & update
- Calibration Guide
- Sensitivity Evaluation

Traffic/Climate
- TrafLoad
- MERRA/MERRA-2

Subgrade/Base
- SWCC
- Cementitious-Stabilized
- Geosynthetics
- CIR/Reclamation
- Subgrade/Unbound Layers
- Shrink/Swell/Frost Heave

Pres/Rehab
- Considering preservation
- Incorporating preservation

Concrete
- Modeling Slab/Underlying Layer
- BCOA

Asphalt
- Top-Down Cracking Model
- Reflection Cracking Model
- Rutting Model

NCE

Presentation 6—Harold Von Quintus, ARA

expanding the realm of POSSIBILITY®

MEPDG Manual of Practice; Third Edition

AASHTOWare Pavement ME Design
MEPDG User Group Meeting
New Orleans, LA
November 6, 2019

Harold L. Von Quintus, P.E., ARA

ARA

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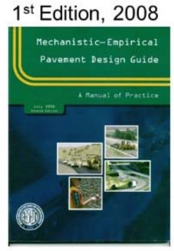
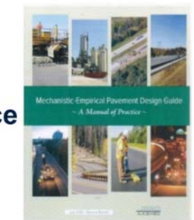
expanding the realm of POSSIBILITY®

1st Edition, 2008



2nd Edition, 2015



MEPDG Manual of Practice 3rd Edition

Many enhancements added after publication of the 2nd Edition.

AASHTOWare Pavement ME Design AASHTO

MEPDG Manual of Practice, 3rd Edition

1. Errors and comments submitted just prior to publication of the MEPDG MOP 2nd Edition, 2015.
2. Technical audit executed in FY 2016.
3. Enhancements of the software; FY 2015 to current version.

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MEPDG Manual of Practice, 3rd Edition

Enhancements of the software; FY 2015 to current version.

1. Asphalt layer dependent plastic strain model coefficients.
2. Four default normalized axle load spectra added.
3. Rigid pavement calibration coefficients updated for CTE.
4. Integration of reflection cracking model from NCHRP 1-51.
5. SJPCP bonded overlay of flexible pavements.

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MEPDG Manual of Practice, 3rd Edition

Enhancements of the software; FY 2015 to current version.

6. Updated model/calibration coefficients for flexible and semi-rigid pavements.
7. Added new climate datasets/weather data:
   - North American Regional Reanalysis (NARR) for rigid pavements.
   - MERRA for flexible pavements.
8. Resetting selected distress/performance measures for preventive maintenance treatments.
9. Input level 1, indirect tensile strength as a function of temperature.

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MEPDG Manual of Practice, 3rd Edition

Enhancements of the software; FY 2015 to current version.

- Addendum prepared for all enhancements in support of the MOP.
- Addendum posted on the Pavement ME Design website for users to review and use.

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MEPDG Manual of Practice, 3rd Edition

1. 3rd Edition balloted and affirmed.
2. Under publication by AASHTO.
   - Figures being redone to fit enhancements completed in the previous 5 years.
3. Will be available in next release of software; January/February 2020.

Does not include top-down cracking enhancement.

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Presentation 7—Harold Von Quintus, ARA

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NCHRP 1-52 Top-Down Cracking Model Integration

AASHTOWare Pavement ME Design
MEPDG User Group Meeting
New Orleans, LA
November 6, 2019

Harold L. Von Quintus, P.E., ARA

Outline

1. **Overview of NCHRP 1-52 TDC Prediction Model**
2. **Inputs Required for TDC**
3. **Issue and Example Results**
4. **Outcome from TDC Predictions**

 2

NCHRP 1-52 Top-Down Cracking (TDC) Model

- Title: **A Mechanistic-Empirical Model for Top-Down Cracking of Asphalt Pavement Layers**
- Agency: Texas A&M Transportation Institute; The Texas A&M University System
- Authors:
  - Robert L. Lytton, P.I.
  - Xue Luo
  - Meng Ling
  - Yu Chen
  - Sheng Hu
  - Fan GU

 3

NCHRP 1-52 TDC Model Integration

- As a reminder, current model in PMED:
  - Fatigue strength, bending beam based, like the bottom-up alligator fatigue cracking model.
- NCHRP 1-52 model integrated in PMED:
  - Fracture mechanics based, similar to the transverse cracking model.

 4

NCHRP 1-52 TDC Model Integration

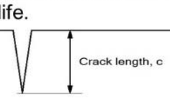
- Staff: Engineers: Dinesh Ayalla, Wouter Brink
  Software: Brendan Neunaber, Yanbin Zhang.
  SME: Robert Lytton, P.E.
- Status: 1. Work completed for the integration; finalizing the alpha testing.
  2. Beta Testing to be initiated this month.
  3. Software to be released in version 2.6, Feb. 2020.
  4. *Predicted distress to be finalized this month based on results of calibration.*
- Training: Webinar to be scheduled around the release of version 2.6; January-February 2020.

 5

NCHRP 1-52 TDC Model Integration

- Fracture mechanics based model to calculate incremental crack length due to repetitive traffic loads using Paris' law.
- Inputs similar to PMED: traffic, climate, structure and material properties.
- Calculate stress intensity factors due to single and dual tire loads and growth of crack length for each month in pavement design life.

Crack geometry is important.



Terminology: Crack length vs. Crack depth

 6

Outline

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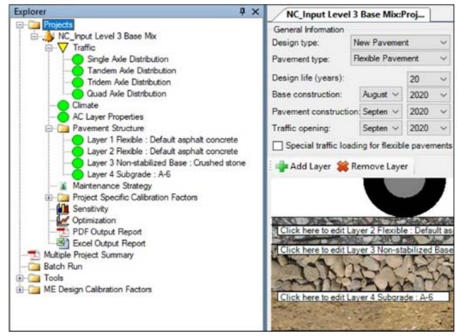
 7

NCHRP 1-52 TDC Model Integration – Inputs

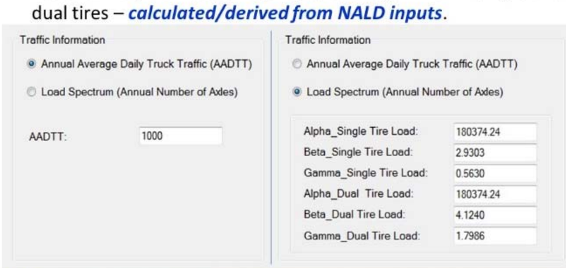


1. Traffic
2. Climate
3. Structure
4. Layer Properties

 8

TDC Model Inputs – *Traffic*

- $AADTT_0$ (initial).
- Cumulative axle load distribution (CALD) parameters; Fitted curve parameters – alpha, beta and gamma for single and dual tires – ***calculated/derived from NALD inputs***.



 9

TDC Model Inputs – *Traffic*

Cumulative axle load distribution curve function

$$P(L) = \alpha e^{-e^{\beta - \gamma L}}$$

L is length of rectangular contact area, calculated as a function of tire inflation pressure, tire load and tire width

PMED traffic inputs used to calculate CALD parameters:

- Normalized axle load spectrum
- Truck class distribution
- Average no. of axles per truck
- Tire pressure

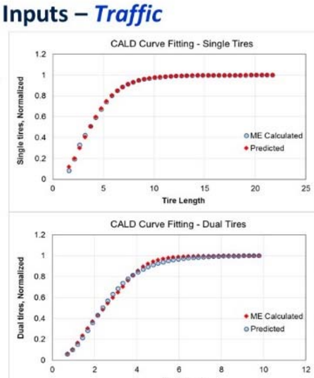
For axles with both single and dual tires.

 10

TDC Model Inputs – *Traffic*

Sample fitted curves for axle loads with single and dual tires.

No changes to traffic inputs; program assumes axles that have single tires and dual tires (via truck classification).



 11

TDC Model Inputs – *Climate*

- Hourly climatic data (HCD)
- Climatic zone (DF, DNF, WF, WNF)
- Number of days above 32°C and below 0°C

No changes required to climate inputs. Program calculates parameters needed from EICM outcome.

Climatic zone

- Existing procedure in PMED for CRCP design.
- Uses EICM data to determine climatic zone for project location.

Number of days above 32°C and below 0°C

- Calculated as average number of days with temperature above 32°C and below 0°C from hourly climatic data

 12

TDC Model Inputs – *Structure*

Pavement layer structure consists of only three layers:

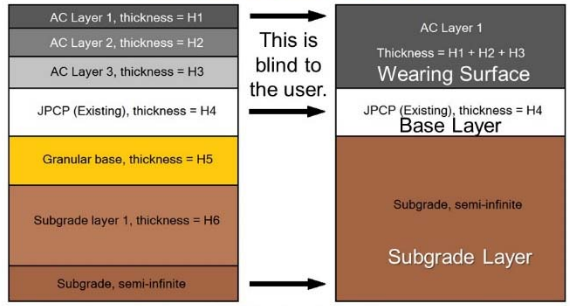
1. Asphalt wearing surface layer
2. Base course layer
3. Subgrade

All pavements with an asphalt surface in PMED are converted to an equivalent three-layered structure:

- Equivalent layer thickness
- Properties for wearing surface (for multiple asphalt layers)
- Base layer modulus and thickness
- Subgrade modulus

 13

TDC Model Inputs – *Structure*



No changes required to structure. Program combines layers and calculates modulus values needed.

 14

TDC Model Inputs – *Asphalt Layer Inputs*

Asphalt layer inputs required for TDC model:

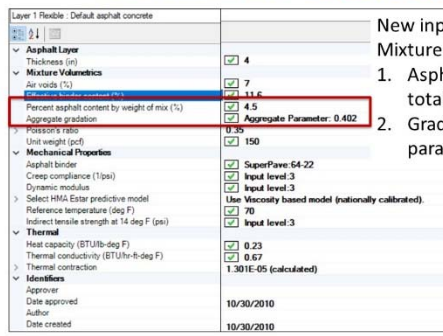
- Percent asphalt content by weight of mix, P_b.
- Gradation parameter *y* from gradation Power law curve.
- Representative modulus of asphalt concrete, E_R calculated at each monthly interval.

Changes to PMED user inputs:

- P_b is added as a new mixture volumetric input for surface layer.
- *y* is calculated from aggregate gradation inputs (or can be entered by user if calculated separately).
- Asphalt dynamic modulus Level 1 analysis now requires gradation.
- E_R is calculated internally by PMED (no user input required).

 15

TDC Model Inputs – *Layer Properties*



New inputs under Mixture Volumetric:

1. Asphalt content by total weight of mix.
2. Gradation parameter.

 16

TDC Model Inputs – *Layer Properties*

New inputs under Mixture Volumetric:

1. Asphalt content by total weight of mix.
2. Gradation parameter.

 17

TDC Model Inputs – *Layer Properties*

Asphalt content by total weight of mix.

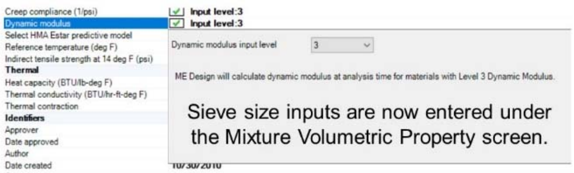
Included in the documentation to ensure input compatibility:

- VMA = V_{be} + V_a
- Combined aggregate specific gravity.
- Asphalt specific gravity.

 18

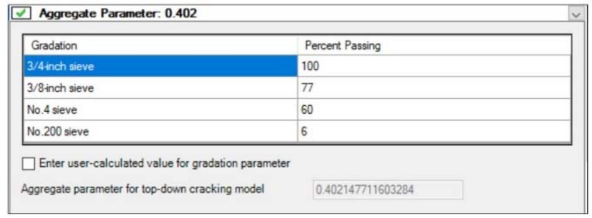
Gradation Parameter

- Gradation parameter is calculated from the gradation of dense-graded asphalt mixtures.
- Gradation/sieve sizes were entered in the dynamic modulus screen.



 19

Gradation Parameter


Aggregate Parameter: 0.402

Gradation	Percent Passing
3/4-inch sieve	100
3/8-inch sieve	77
No.4 sieve	60
No.200 sieve	6

Enter user-calculated value for gradation parameter

Aggregate parameter for top-down cracking model: 0.402147711603284

No additional inputs are needed; the gradation parameter is calculated from the current sieve sizes.

 20

Outline

1. **Overview of NCHRP 1-52 TDC Prediction Model**
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 21

TDC Model Integration

- All longitudinal cracks assumed to start at the surface; TDC(?).
- All alligator cracks (BUC) assumed to start at the bottom of the asphalt layer(?).

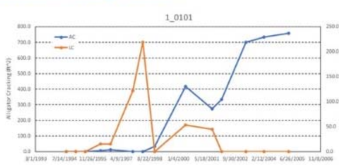
 22

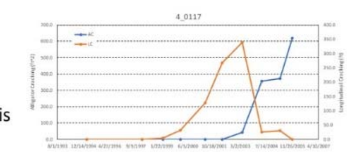
TDC Model Integration

Is this TDC or BUC?

- Longitudinal cracks increase and then decrease.
- Length of wheel path area or just length of wheel path with longitudinal cracks?

Remember; TDC or longitudinal cracks are converted to an area basis for the IRI regression equation.





 23

Top-Down Cracking Model Integration

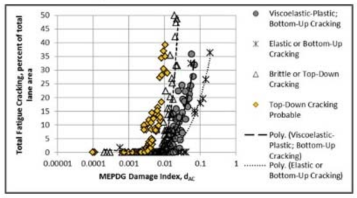
Construction defects versus load related TDC without construction defects.

 24

TDC Model Integration

Separated TDC from bottom-up cracking and TDC caused by construction defects - segregation.

Group all LTPP sites into TDC and Bottom-Up Cracks.



$DI_{E\text{-}Ratio}$	Fatigue Cracking (Percent Total Lane Area) 0	0–2	2–10	10–20	20–35	35–50	> 50
Negative				Area with higher probability of TDC, debonding near the surface, or some other near surface defect.			
0–0.25							
0.25–0.5							
0.50–0.75	Area with higher probability of bottom-up cracking. All cracks have yet to reach the surface, or there is moisture damage, debonding, or other lower AC layer defects.						
> 0.75							

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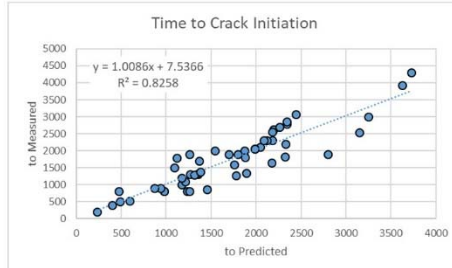
TDC Model Integration

Crack initiation time was determined from LTPP sites for longitudinal cracks – assumed to initiate at the surface.



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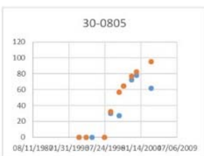
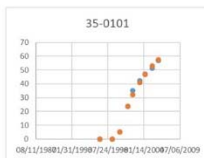
26

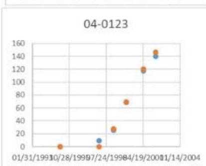
TDC Model Integration

Example results for predicting TDC using NCHRP 1-52 models.

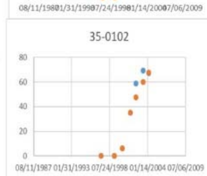


Using revised software, predicted to measured crack length looks excellent.





Outcome: Overall model is believed to be good and captures crack initiation & growth.



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27

Outline

1. **Overview of NCHRP 1-52 TDC Prediction Model**
2. **Inputs Required for TDC**
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4. **Outcome from TDC Predictions**

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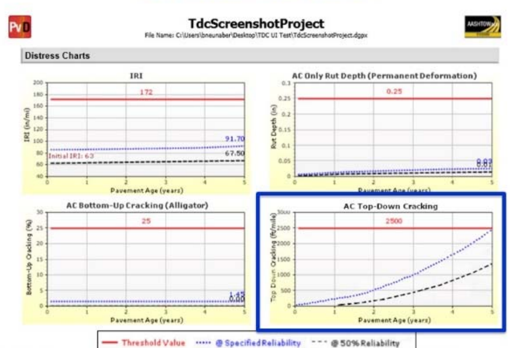
28

TDC Model Integration



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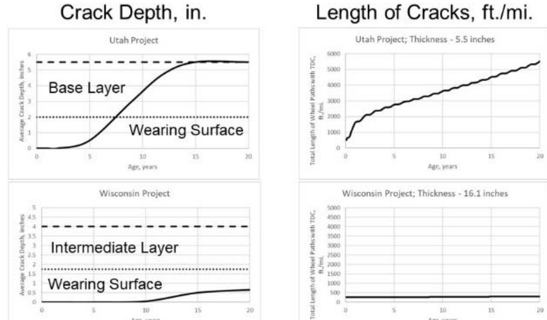
29

TDC Model Integration

Crack Depth, in.

Length of Cracks, ft./mi.



50% Reliability

90% Reliability

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QUESTIONS?
Comments & suggestions;
Send an email to
pavementmedesign@ara.com.
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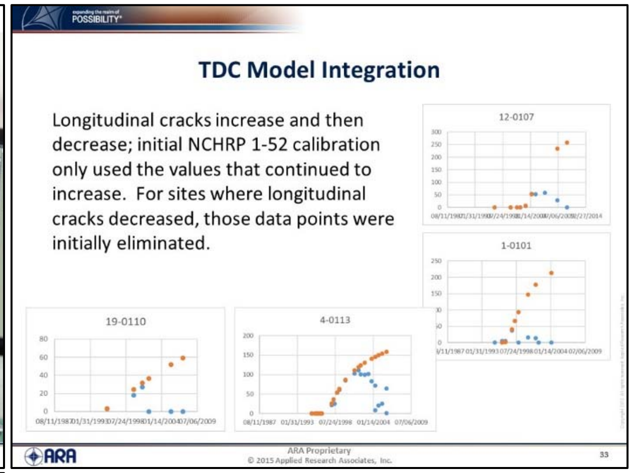
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TDC Model Integration
Longitudinal cracks increase and then decrease; initial NCHRP 1-52 calibration only used the values that continued to increase. For sites where longitudinal cracks decreased, those data points were initially eliminated.
12-0107
1-0101
19-0110
4-0113
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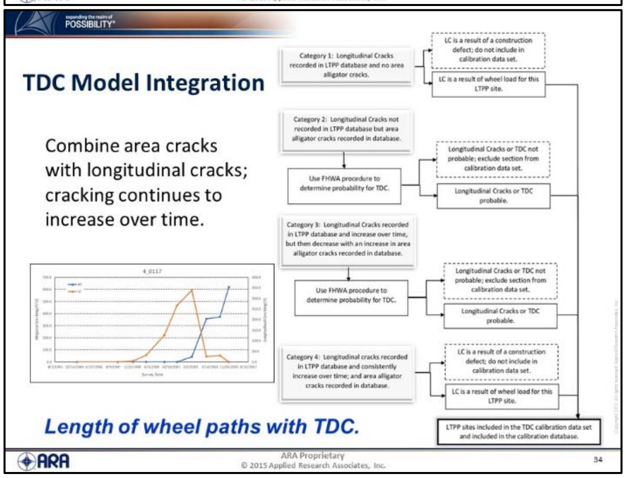
33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POSSIBILITY
TDC Model Integration
Combine area cracks with longitudinal cracks; cracking continues to increase over time.
4_0117
Length of wheel paths with TDC.
Category 1: Longitudinal Cracks recorded in LTPP database and no area alligator cracks.
LC is a result of a construction defect; do not include in calibration data set.
LC is a result of wheel load for this LTPP site.
Category 2: Longitudinal Cracks not recorded in LTPP database but area alligator cracks recorded in database.
Use FHWA procedure to determine probability for TDC.
Longitudinal Cracks or TDC not probable; exclude section from calibration data set.
Longitudinal Cracks or TDC probable.
Category 3: Longitudinal Cracks recorded in LTPP database and increase over time, but then decrease with an increase in area alligator cracks recorded in database.
Use FHWA procedure to determine probability for TDC.
Longitudinal Cracks or TDC not probable; exclude section from calibration data set.
Longitudinal Cracks or TDC probable.
Category 4: Longitudinal cracks recorded in LTPP database and consistently increase over time; and area alligator cracks recorded in database.
LC is a result of a construction defect; do not include in calibration data set.
LC is a result of wheel load for this LTPP site.
LTPP sites included in the TDC calibration data set and included in the calibration database.
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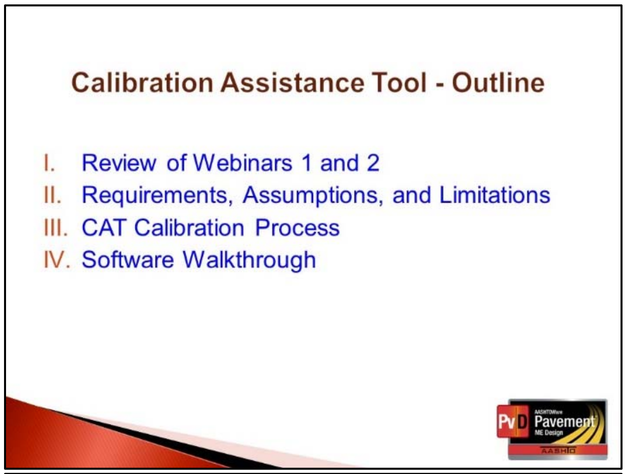
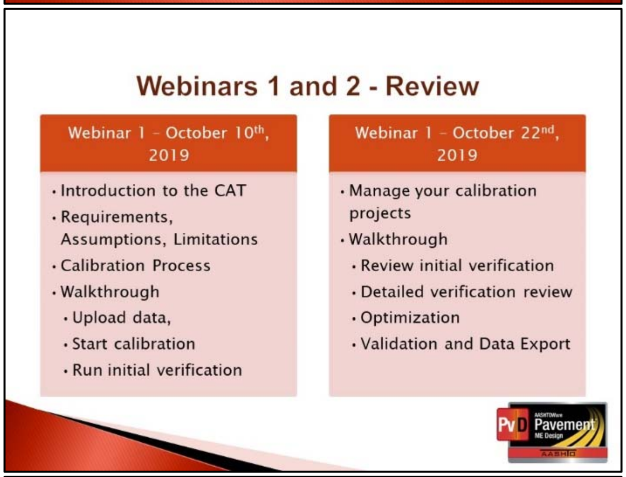
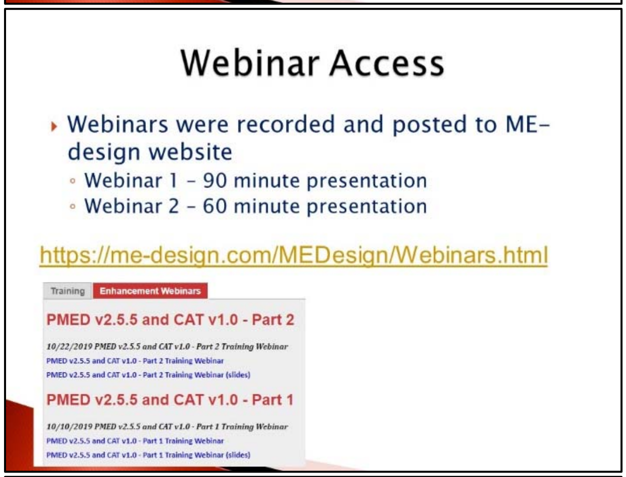
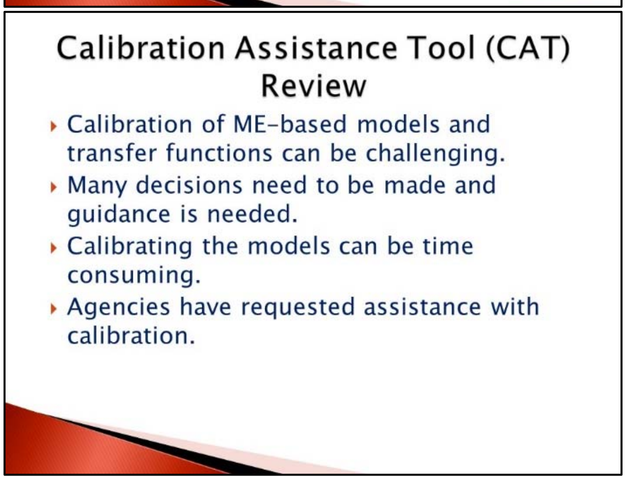
34

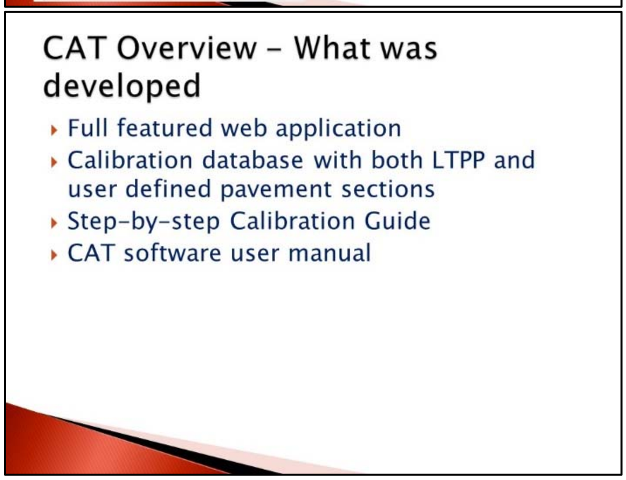
Presentation 8—Wouter Brink, ARA

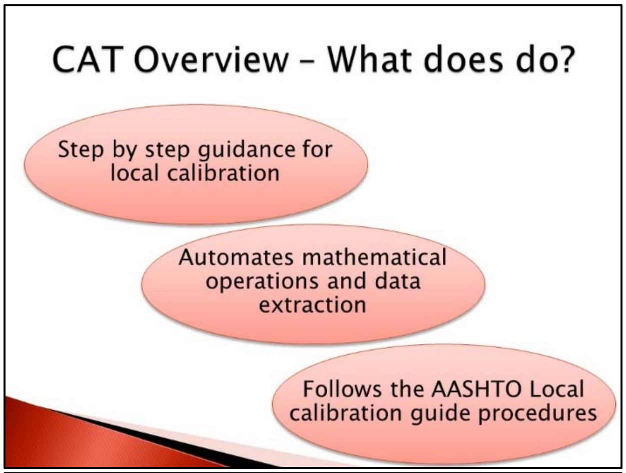


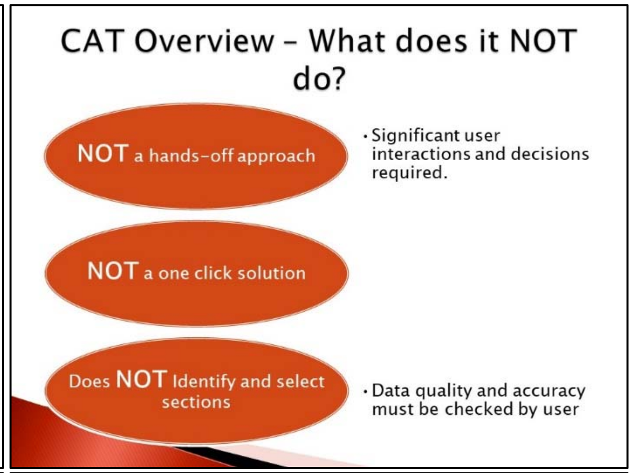


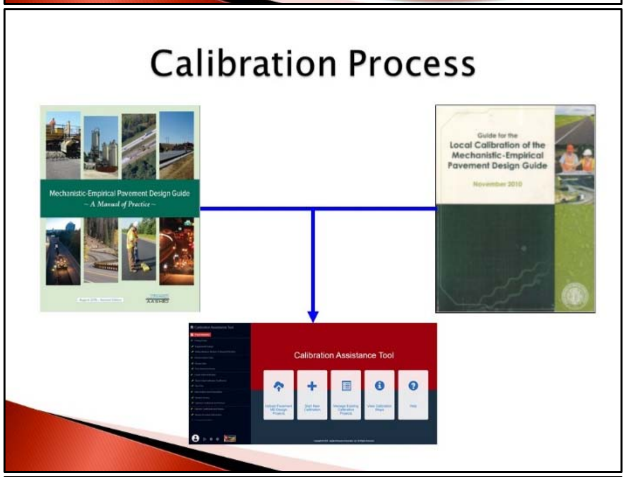


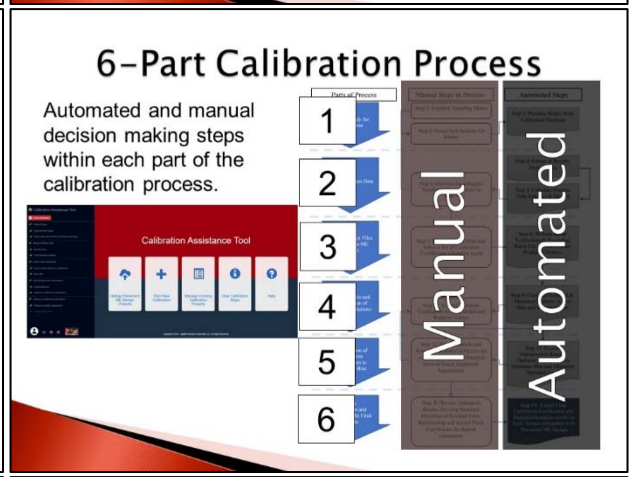


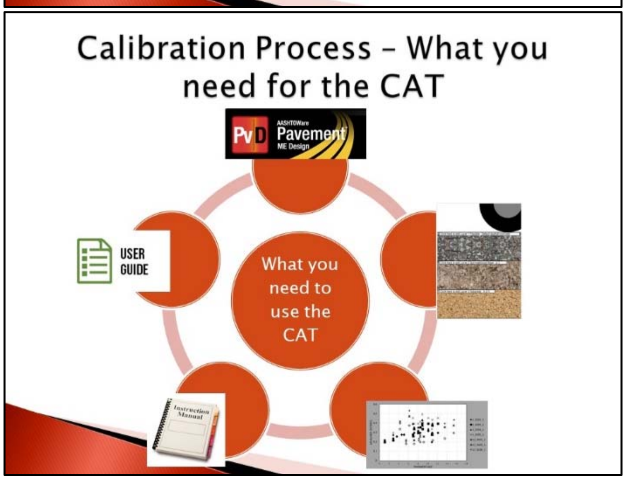


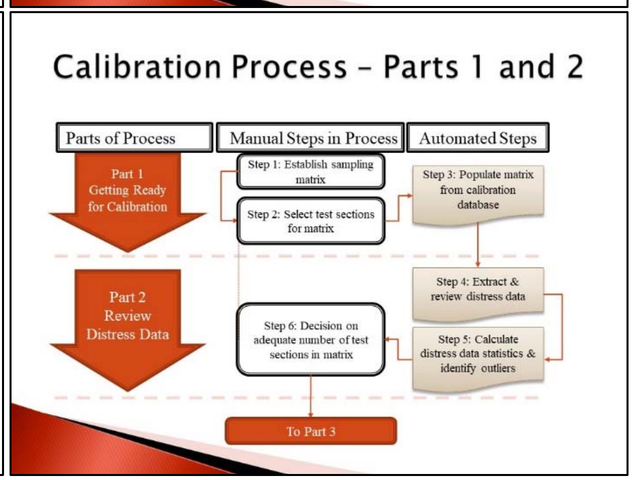

CAT Overview – What does do?
Step by step guidance for local calibration
Automates mathematical operations and data extraction
Follows the AASHTO Local calibration guide procedures


CAT Overview – What does it NOT do?
NOT a hands-off approach
• Significant user interactions and decisions required.
NOT a one click solution
Does NOT Identify and select sections
• Data quality and accuracy must be checked by user

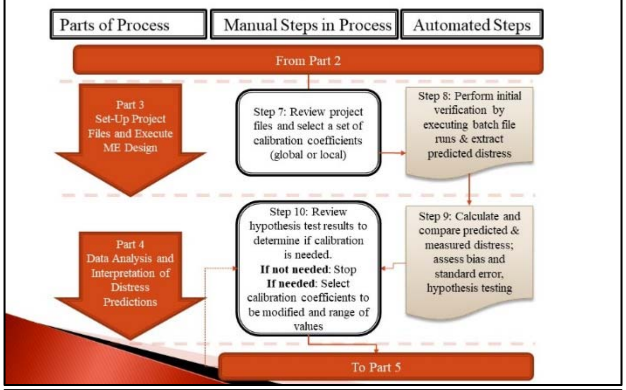

Calibration Process
Mechanistic-Empirical Pavement Design Guide
– A Manual of Practice –
Guide for the Local Calibration of the Mechanistic-Empirical Pavement Design Guide
November 2010
Calibration Assistance Tool


6-Part Calibration Process
Automated and manual decision making steps within each part of the calibration process.
Calibration Assistance Tool
1
2
3
4
5
6
Manual
Automated

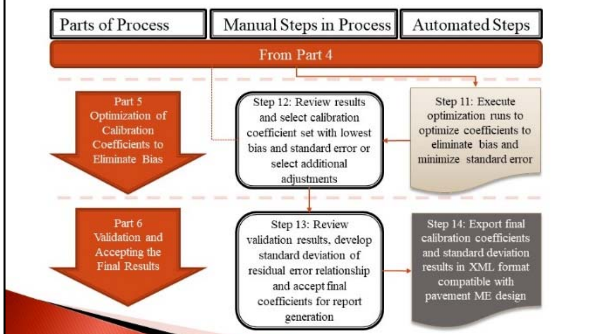

Calibration Process – What you need for the CAT
PvD
Pavement
ME Design
USER GUIDE
What you need to use the CAT


Calibration Process – Parts 1 and 2
Parts of Process
Manual Steps in Process
Automated Steps
Part 1 Getting Ready for Calibration
Step 1: Establish sampling matrix
Step 2: Select test sections for matrix
Step 3: Populate matrix from calibration database
Part 2 Review Distress Data
Step 4: Extract & review distress data
Step 5: Calculate distress data statistics & identify outliers
Step 6: Decision on adequate number of test sections in matrix
To Part 3

Calibration Process – Parts 3 and 4



Calibration Process – Parts 5 and 6



CAT Overview – Assumptions and Requirements

Assumptions

- Selected pavement sections are representative of local design practices.
- User has verified accuracy of inputs, pavement structure, and measured performance.
- User has an understanding of the performance prediction models and impact of calibration coefficients.
- DGPX files are free of any errors and successfully executes to completion in the current PMED version.
- User is familiar with specific materials inputs used in their uploaded sections.

CAT Overview – Assumptions and Requirements

Requirements

- Pavement ME Design License and Customer ID
- PMED .dgpx file
- Measured Distress Data

CAT Overview – Limitations

Server and Usage Limitations

- Everyone shares the same server
- Verification and Optimization queues have been set up
- First come first serve
- Maximum limit – 60 hours of runs

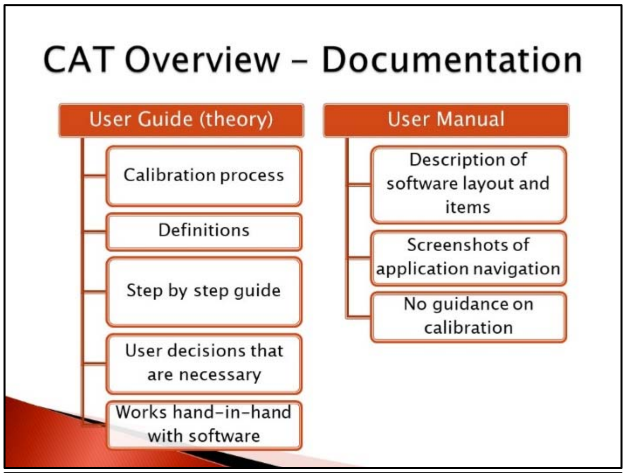
Coefficient Limitations

- Everything runs sequentially
- Large number of coefficients and increments will SIGNIFICANTLY increase runtime

Calibrator Overview – Limitations

Coefficients	Coef. Increments	Coef. Combinations	Estimated Run Time	
			1 project	100 projects
5 (br1, br2, br3, bs1, bsg1)	5	3125	26 hr	108 days
5 (br1, br2, br3, bs1, bsg1)	2	32	0.35 hr	1.5 days
3 (br1, br2, br3)	5	125	1.15 hr	4.7 days
1 (br1)	100	100	0.9 hr	3.8 days

$$RT = 5\min + 0.5\min \times (n-1)$$


CAT Overview – Documentation
User Guide (theory)
Calibration process
Definitions
Step by step guide
User decisions that are necessary
Works hand-in-hand with software
User Manual
Description of software layout and items
Screenshots of application navigation
No guidance on calibration


Calibration Assistance Tool – Walkthrough


Walkthrough Items
Login Screen
Home Screen
Navigation Pane
Upload Required Data
Start New Calibration
Parts 1 through 3
Manage Existing Calibration Projects
Initial Verification Review – from Part 1
Detailed Verification Review – Filters and Data Review
Optimization
Validation and Data Export


Demonstration
https://pmed-cat.com/cat/

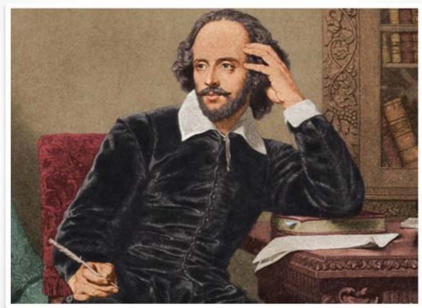
Presentation 9—David Holmgren, Utah DOT

AASHTO Pavment ME Users Meeting

November 2019
New Orleans, Louisiana

Effects of Utah DOT's Recalibration Effort on HMA Pavement Design and Changes to the Agency's Pavement Manual of Instruction

To recalibrate or not to recalibrate



That is the question

Why recalibrate?

- Flexible pavements globally calibrated in FY2002, so an additional 15+ years of data in LTPP.
- Verify impact of added data used in recalibration.
- Bottom-up fatigue cracks are much greater.

ARA

Data collection for flexible pavments

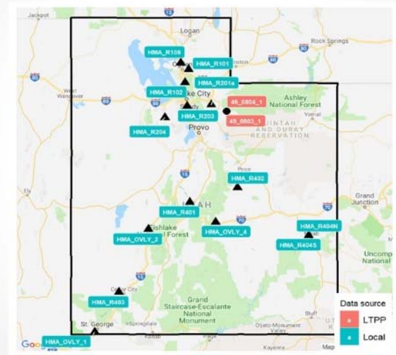
- **2009 Data Collection:** Major effort to collect both LTPP sections and UDOT highway sections (both new design and Overlays) to validate and calibrate bottom-up fatigue cracking, transverse cracking, rutting, and IRI-smoothness models.
  - 26 New flexible sections (LTPP and UDOT).
  - 04 Overlay UDOT sections
- **2013 Data Collection:** Validation and calibration Rutting models was prime objective.
  - 14 Additional sections (both new design and overlay sections).
  - 03 Additional overlay UDOT sections.

ARA

Data collection for flexible pavements

- **2019 Data Collection:** Validation and calibration all models again including new design and overlay's for same models above.
  - 13 New asphalt new pavement sections (11 UDOT and 2 LTPP)
  - 03 Overlay Asphalt UDOT sections.
  - ARA

Data collection for flexible pavements

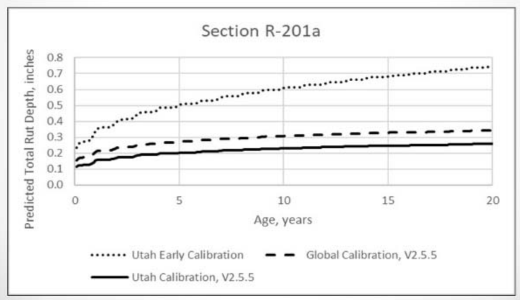


- ARA

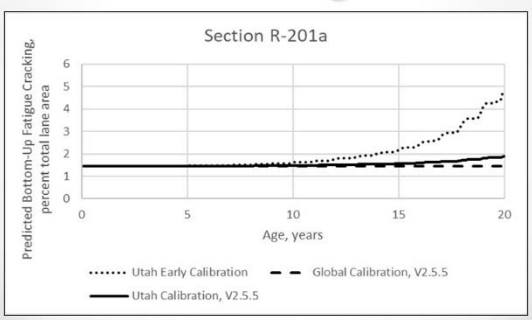
Data collection for flexible pavements

- **Preventative Maintenance**
  - UDOT regularly applies preventatives seal coats and overlays on flexible pavements.
  - This approach has a very beneficial effect on pavement performance.
  - Some of these include SMA, OGSC, BWC, micro-surfacing, chip seals, and thin overlays. These affect the measurement of fatigue wheelpath cracking, rutting, transverse cracking, and IRI. So this is all included in the performance of these sections.
  - ARA

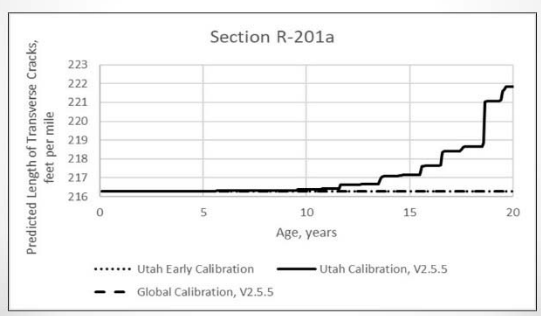
Results – Rut depth



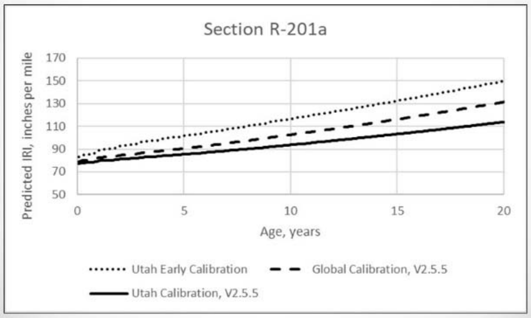
Results – Bottom-up cracking



Results – Transverse cracking



Results - IRI



Interstate.........95% Reliability

I-15 MP 37 to 40..11" to 13.5"

I-15_Millard Juab County line to EOC...........................8" to 10"

I-15 Utah County Line 12300 South..........................9" to 13.5"

I-215 4700 South Redwood Rd..................................8" to 10.5"

Non-Interstate......90% Reliability

SR 10 MP 46..6" to 5"

SR 36 Tooele Main Street.......................................8" to 9.5"

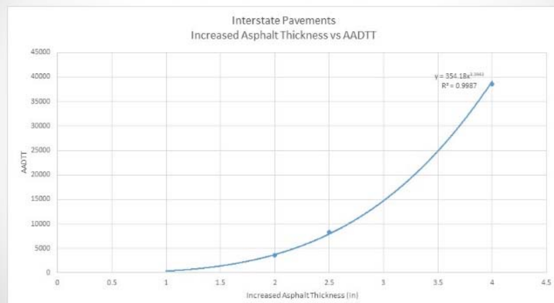
SR 45 Bonanza..6" to 4" >but 2"- Passed (4" minimum thickness from MOI)

SR 209 Redwood Rd to I-15.....................................7" to 7.5"

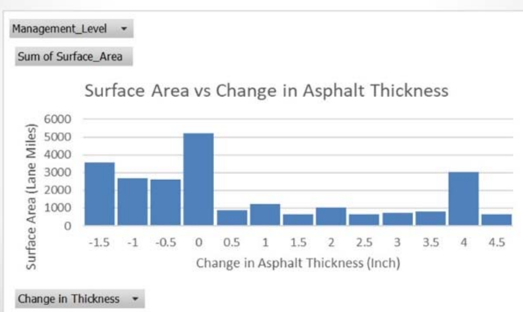
US-6 MP 237...7" to 8"

US 40 MP 35.1 to 40.3...7" to 7.5"

Interstate Pavements



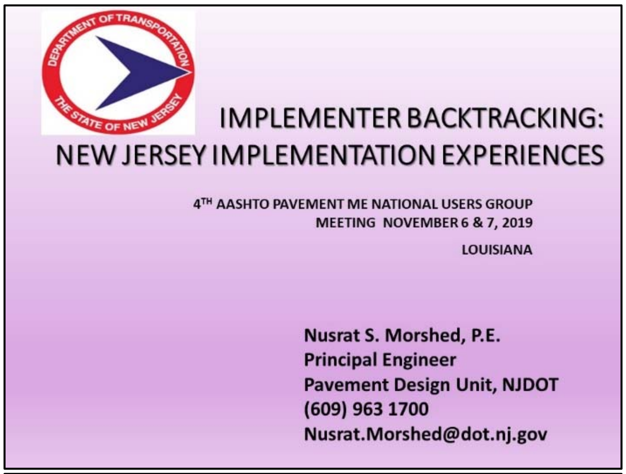
How does this affect our pavements statewide?

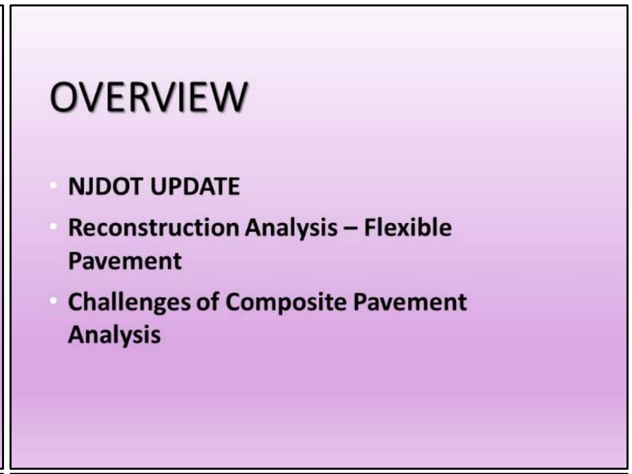


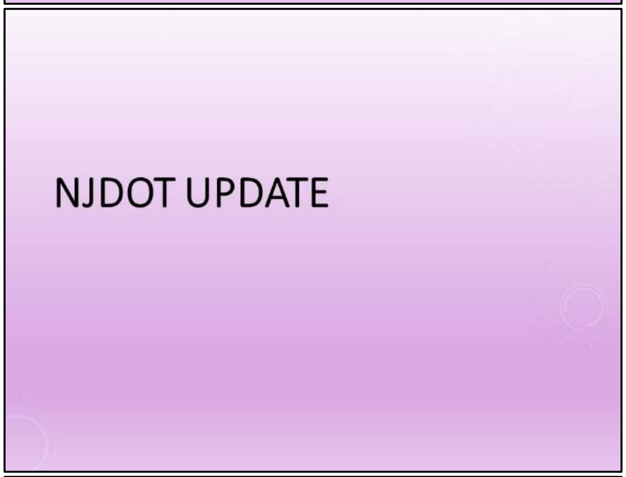
Ask not what your road can do for you.

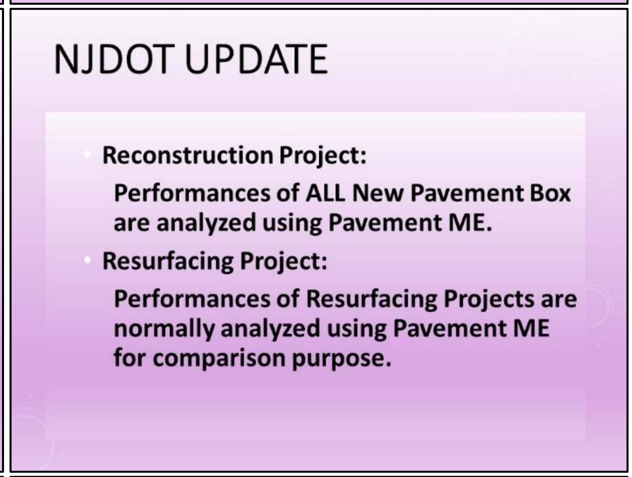
Ask what you can do for your road.

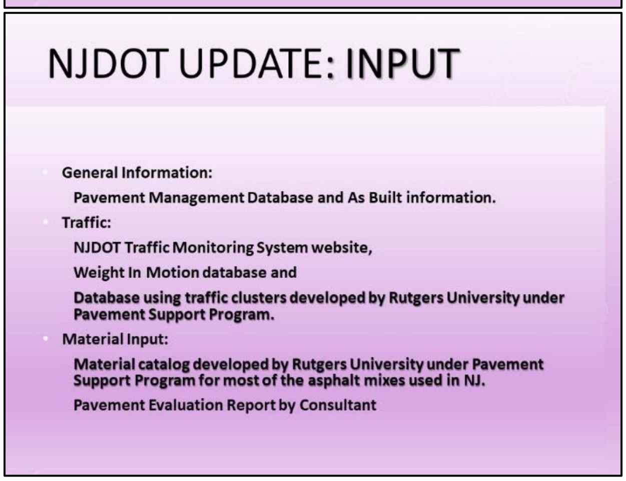
Presentation 10—Nusrat Morshed, New Jersey DOT









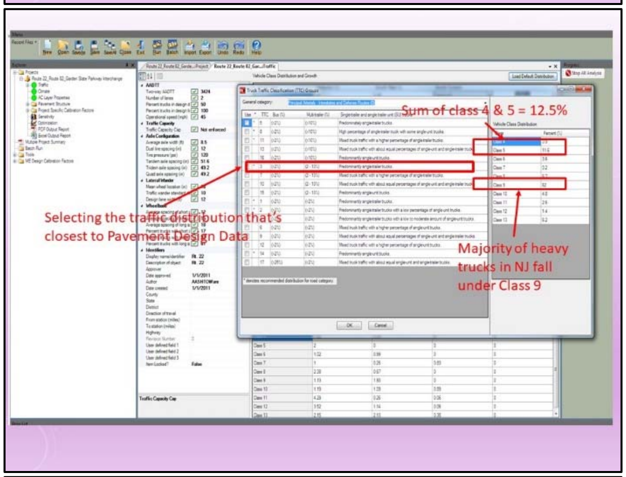


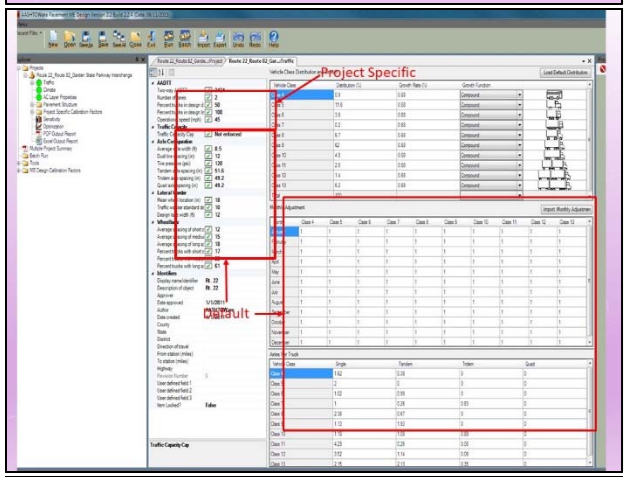
PROJECT 1

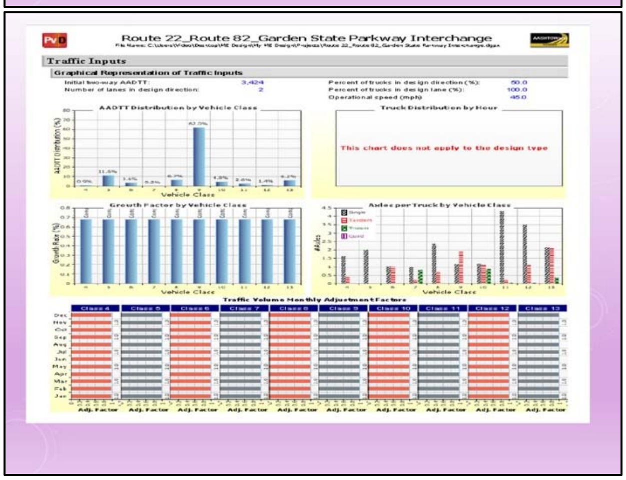
- Route 22/Route 82/Garden State Parkway Interchange Project
- Route 22: MP 55.26-56.16
- Existing Pavement
  - Route 22 EB: Primarily reinforced PCC
  - Route 22 WB: AC over reinforced PCC
- Reconstruction was considered one of the alternatives in the bare PCC section where no raise in profile was allowed due to the presence of overpass
- Consultant: Advanced Infrastructure Design Inc.

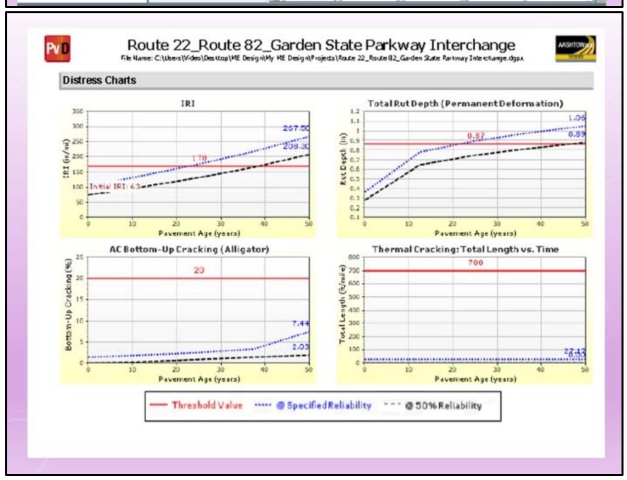
PAVEMENT DESIGN DATA

- 2016 ADT (1 Way) = 53,010 vpd
- 2022 ADT (1 Way) = 55,210 vpd
- 2032 ADT (1 Way) = 59,080 vpd
- 2042 ADT (1 Way) = 63,230 vpd
- Growth Factor = 0.68%
- Heavy (Class 6-13) Truck % in 24 hours = 2.7%
- Total (Class 4-13) Truck % in 24 hours = 3.1%
- % of Light (Class 4-5) Truck = ~13%
- % of Heavy (Class 6-13) Truck = ~87%









Route 22_Route 82_Garden State Parkway Interchange

File Name: C:\Users\Video\Desktop\ME Design\My ME Design\Projects\Route 22_Route 82_Garden State Parkway Interchange.dgpx

Design Inputs

Design Life: 50 years
Design Type: Flexible Pavement
Base construction: May, 2021
Pavement construction: June, 2022
Traffic opening: September, 2022
Climate Data Sources (Lat/Lon): 40.683, -74.169

Design Structure

Layer type	Material Type	Thickness (in)
Flexible	NJDOT: SMA 12.5 (2015/04/07)	2.0
Flexible	NJDOT: HMA 12.5M64 (Bound Brook) (2015/04/13)	3.0
Flexible	NJDOT: HMA 25.0M64 (2015/04/13)	6.0
NonStabilized	NJDOT: DGABC (North Region) (2015/04/07)	12.0
Subgrade	A-1-b	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	14.3
Air voids (%)	7.0

Traffic

Age (year)	Heavy Trucks (cumulative)
2022 (initial)	3,424
2047 (25 years)	16,977,400
2072 (50 years)	37,089,200

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	170.00	267.55	90.00	20.41	Fail
Permanent deformation - total pavement (in)	0.87	1.06	90.00	45.25	Fail
AC bottom-up fatigue cracking (% lane area)	20.00	7.44	90.00	100.00	Pass
AC thermal cracking (ft/mile)	700.00	27.17	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	2000.00	265.46	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.50	0.43	90.00	97.82	Pass

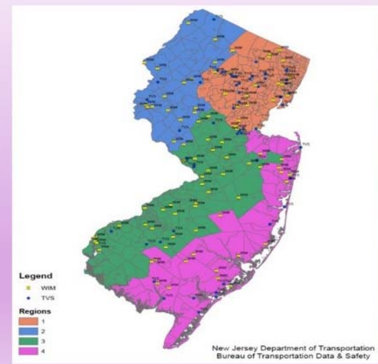
PROJECT 2

- Project: Route 80, Riverview Drive to Polify Road
- Limit of the project: WB MP 56.0-MP65.4
- Type of Project: Reconstruction
- Status: PE Phase
- Construction Year: 2024
- Consultant: Michael Baker International,Inc.

PROJECT 2

- Existing Pavement
  - 9" Concrete Pavement
- The concrete pavement of I-80 WB within the project limit is more than 50 years old.
- The existing concrete is poor condition.

NJDOT BUREAU OF TRANSPORTATION DATA AND SAFETY REGION MAP



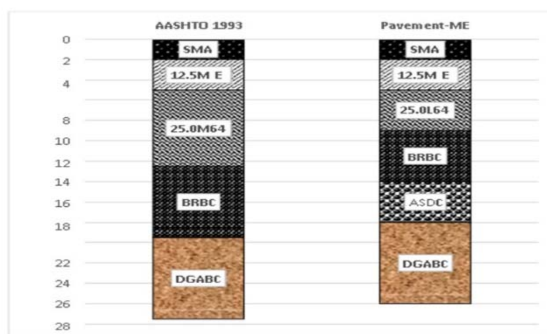
VEHICLE CLASS DISTRIBUTION:

New Jersey Department of Transportation
Bureau of Transportation Data & Safety
Traffic & Technology Section

DAILY AVERAGE VEHICLE CLASSIFICATION - COMBINED WEEKDAYS AND WEEKENDS
FHWA 13 CLASSIFICATION SCHEME PLUS UNCLASSIFIED

LOCATION: I-80 MP 38.1, Rockaway Twp., Morris(00080C) ~ EB/WB
F.C.=11

MONTH	DIR	Unclass 0	Motor-cycle 1	Auto 2	2-Axle 4-Tire 3	Bus 4	2-Axle 6-Tire 5	3-Axle 1-Unit 6	4-Axle 1-Unit 7	≥4-Axl -Traile 8	5-Axle 1-Trailer 9	≥6-Axl -Traile 10	≥6-Axl -Traile 11	6-Axle -Traile 12	≥7-Axl -Traile 13	MONTHLY ADT EB WB	MONTHLY ADT COMBINE
JAN 2013	EB	311	2	55,691	10,472	156	1,132	389	258	216	2,834	62	71	25	3	71,621	
	WB																71,621
FEB 2013	EB	190	2	51,792	9,910	151	1,076	438	169	204	2,888	62	73	25	3	66,980	
	WB	1,499	3	48,719	11,137	179	904	341	61	153	2,115	45	43	23	1	65,223	132,204
MAR 2013	EB	748	3	57,923	10,821	188	1,250	391	342	204	2,918	65	76	29	3	74,961	
	WB	2,499	58	53,428	12,609	238	1,039	667	91	189	2,442	63	66	31	4	73,420	148,381
APR 2013	EB	301	15	60,653	11,607	204	1,261	472	592	215	3,259	82	79	29	3	78,772	
	WB	1,417	33	56,116	13,672	275	1,092	824	115	200	2,786	69	66	28	3	76,695	155,467
MAY 2013	EB	235	24	61,513	12,606	225	1,434	481	658	220	3,311	77	85	34	2	80,905	
	WB																80,905
JUN 2013	EB	254	51	62,457	12,942	223	1,368	495	626	223	3,283	78	80	35	2	82,117	
	WB																82,117
JUL 2013	EB	252	50	63,529	13,441	225	1,303	493	636	204	3,149	83	74	30	2	83,470	
	WB																83,470
AUG 2013	EB	250	41	64,770	12,716	241	1,324	498	714	222	3,231	79	81	34	2	84,203	
	WB																84,203
SEP 2013	EB	249	27	61,407	11,375	200	1,300	456	680	214	3,188	77	74	31	3	79,279	
	WB	722	40	55,540	14,378	283	1,279	943	89	203	2,934	65	65	30	2	76,574	155,853
OCT 2013	EB	230	13	61,723	11,665	197	1,350	522	731	221	3,242	73	83	34	2	80,084	
	WB	647	21	56,320	14,860	279	1,354	1,030	144	216	3,086	67	78	34	2	78,140	158,224
NOV 2013	EB	309	4	58,870	11,096	186	1,162	436	715	208	3,010	63	74	30	2	76,164	
	WB																76,164
DEC 2013	EB	222	4	58,890	11,472	181	1,139	407	340	200	2,795	58	57	24	2	75,790	
	WB																75,790
AVERAGE	EB	296	20	59,935	11,677	198	1,258	457	538	213	3,092	72	75	30	2	77,862	
	WB	1,357	31	54,025	13,331	251	1,133	761	100	192	2,673	62	64	29	2	74,010	151,873
TOTAL		1,652	51	113,960	25,008	449	2,392	1,218	638	405	5,765	133	139	59	5	151,873	
%DAILY	EB	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	
	WB	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	
%TOTAL		0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	



I-80 Pavement Design Cross-Section

I80 New - 5 Inch BRBC - 7 Inch 12_5ME - 50 Yr D

File Name: C:\Users\Tom\Documents\Michael Baker\I80 - Perpetual Pavement with BRBC\I80 New - 5 Inch BRBC - 7 Inch

Design Inputs

Design Life: 50 years
Design Type: Flexible Pavement
Base construction: May, 2015
Pavement construction: June, 2016
Traffic opening: September, 2016
Climate Da
Sources (L

Layer type	Material Type	Thickness (in.):
Flexible	12.5mm SMA	2.0
Flexible	12.5ME	7.0
Flexible	BRBC	5.0
NonStabilized	BSDC	4.0
NonStabilized	Crushed stone	8.0

Volumetric at Construction:	
Effective binder content (%)	13.0
Air voids (%)	6.0

Age (year)	Heavy Trucks (cumulative)
2016 (initial)	19,710
2041 (25 years)	78,715,200
2066 (50 years)	170,971,000

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	172.00	279.89	90.00	16.15	Fail
Permanent deformation - total pavement (in.)	1.00	0.97	90.00	93.75	Pass
AC bottom-up fatigue cracking (percent)	25.00	1.73	90.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	27.17	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	2000.00	256.68	90.00	100.00	Pass
Permanent deformation - AC only (in.)	0.50	0.45	90.00	96.30	Pass

Challenges of Composite Pavement Analysis

COMPOSITE PAVEMENT:

TOTAL NJDOT LANE MILES: 8400 APPROXIMATELY

NJDOT Composite Pavement = Between 50% to 60%.

PROJECT 3

- **Project : Route 130 Farnsworth Ave Intersection Improvement Project**
- **Construction Year: 2022**
- **Analysis: In House**

PROJECT 3

Existing Pavement :

3 " Asphalt Concrete

9.8" Portland Cement Concrete (PCC)

2" Crushed Gravel

CHALLENGES: PAVEMENT ME ANALYSIS FOR COMPOSITE PAVEMENT

Design Life: 10 years
Design Type: ACC_JPCP
Existing construction: May, 1990
Pavement construction: June, 2018
Traffic opening: August, 2018
Climate Data Sources (Lat/Lon): 39.941, -74.841

Design Structure

Layer type	Material Type	Thickness (in)
Flexible (OL)	Default asphalt concrete	3.0
PCC	JPCP Default	9.8
NonStabilized	Crushed gravel	2.0
Subgrade	A-4	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	10.0
Air voids (%)	4.8

Traffic

Age (year)	Heavy Trucks (cumulative)
2018 (initial)	3,530
2023 (5 years)	3,084,290
2028 (10 years)	6,224,500

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	112.14	90.00	99.99	Pass
Permanent deformation - AC only (in)	0.50	0.25	90.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	1.45	90.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	3000.00	4270.14	90.00	0.00	Fail
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	2000.00	259.59	90.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	0.96	90.00	100.00	Pass

Design Life: 10 years
Design Type: ACC_JPCP
Existing construction: May, 1950
Pavement construction: June, 2018
Traffic opening: August, 2018
Climate Data Sources (Lat/Lon): 39.941, -74.841

Design Structure

Layer type	Material Type	Thickness (in)
Flexible (OL)	Default asphalt concrete	8.0
PCC	JPCP Default	9.8
NonStabilized	Crushed gravel	2.0
Subgrade	A-4	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	10.7
Air voids (%)	7.0

Traffic

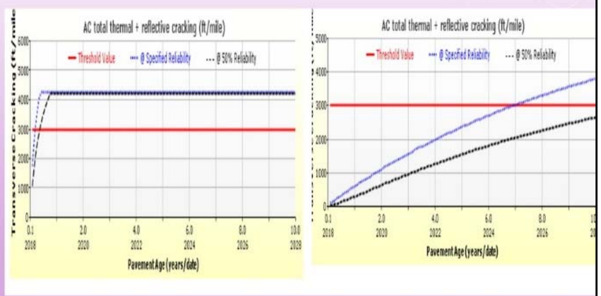
Age (year)	Heavy Trucks (cumulative)
2018 (initial)	3,530
2023 (5 years)	3,084,290
2028 (10 years)	6,224,500

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	107.46	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.50	0.21	90.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	1.45	90.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	3000.00	3802.32	90.00	65.05	Fail
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	2000.00	1253.96	90.00	98.01	Pass
JPCP transverse cracking (percent slabs)	15.00	0.96	90.00	100.00	Pass

Challenges: Pavement ME Analysis for Composite Pavement



3" AC Over JPCP

8" AC Over JPCP

Design Life:	20 years	Base construction:	May, 2019	Climate Data Sources (Lat/Lon)	39.941, -74.841
Design Type:	FLEXIBLE	Pavement construction:	June, 2019		
		Traffic opening:	September, 2019		

Design Structure

Layer type	Material Type	Thickness (in)
Flexible	Default asphalt concrete	2.0
Flexible	Default asphalt concrete	3.0
Flexible	Default asphalt concrete	5.0
NonStabilized	Crushed gravel	10.0
Subgrade	A-5	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.6
Air voids (%)	7.0

Traffic

Age (year)	Heavy Trucks (cumulative)
2019 (initial)	3,530
2029 (10 years)	6,407,400
2039 (20 years)	13,485,200

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	174.58	90.00	88.63	Fail
Permanent deformation - total pavement (in)	1.00	1.09	90.00	74.39	Fail
AC bottom-up fatigue cracking (% lane area)	25.00	1.96	90.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	27.17	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	2000.00	268.18	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.50	0.53	90.00	84.65	Fail

---

PROJECT 4

- Project: Route 1 MP 58-60
- Type of Project : Resurfacing Project
- Construction Year: 2019
- Analysis: In House

PROJECT 4

Existing Pavement :
4 " Asphalt Concrete
9" Portland Cement Concrete (PCC)
6" Subbase

Proposed Pavement Treatment:

- Mill 2.5" and Overlay with
- 2.5" Stone Matrix Asphalt (SMA)

CHALLENGES: PAVEMENT ME ANALYSIS FOR COMPOSITE PAVEMENT

Design Structure

Layer type	Material Type	Thickness (in)
Flexible	12.5M-SMA (National Paving)	2.5
Flexible (existing)	12.5M64 (Stavola - Bound Brook, NJ)	1.5
Cement_Base	Soil cement	9.0
NonStabilized	A-1-a	6.0
Subgrade	A-1-a	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	10.7
Air voids (%)	7.0

Traffic

Age (year)	Heavy Trucks (cumulative)
2019 (initial)	3,500
2024 (5 years)	3,074,640
2029 (10 years)	6,247,350

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	170.00	147.44	90.00	97.79	Pass
Permanent deformation - total pavement (in)	0.75	0.44	90.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	53.08	90.00	0.00	Fail
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	205.53	90.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	2000.00	320.08	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.13	90.00	100.00	Pass

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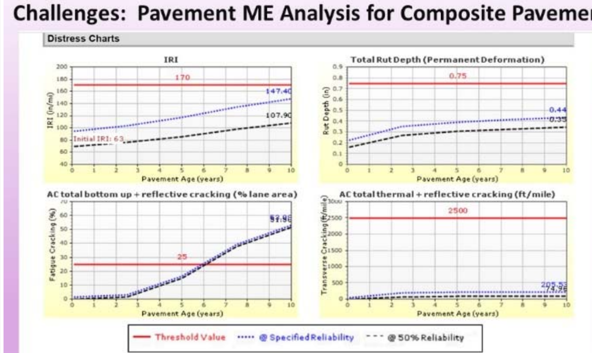
Challenges: Pavement ME Analysis for Composite Pavement



PROJECT 5:

- Project: Route 70
  Type of Project:
  Pavement Rubblization and Resurfacing

  Limit of the project:
  MP 31.17 to MP 38.45
  Total Lane Miles of the project: 15
- Letting Date: April 17, 2018
- Consultant: Advanced Infrastructure Design Inc.
- Project Status: Under Construction

PROJECT 5

Existing Pavement (Majority portion):
3 to 4" Asphalt Concrete
8" Portland Cement Concrete (PCC)
12" Subbase

Proposed Pavement Treatment:
- 2" Stone Matrix Asphalt (SMA)
- Minimum 3" & Var. Bottom Rich Base Course (BRBC)
- 8" Rubblized PCC
- 12" Subbase

Design Life: 50 years
Design Type: AC_FRAC_JPCP
Base construction: May, 1953
Pavement construction: March, 2018
Traffic opening: June, 2018
Climate Data Sources (Lat/Lon): 39.941, -74.841

Design Structure

Layer type	Material Type	Thickness (in)
Flexible (OL)	NJDOT: SMA 12.5 (2015/04/07)	2.0
Flexible (OL)	BRBC-NJDOT	3.0
Stabilized	Fractured JPCP	8.0
NonStabilized	A-2-4	12.0
Subgrade	A-2-4	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	13.0
Air voids (%)	7.0

Traffic

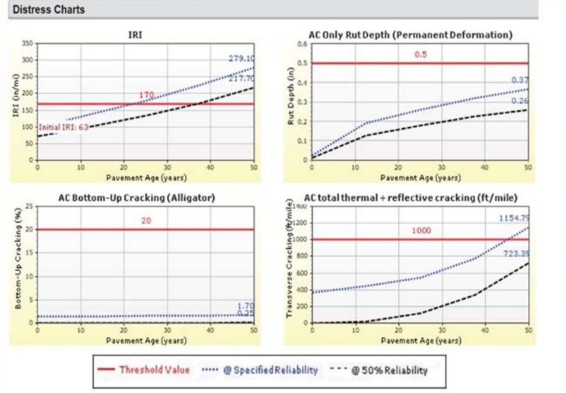
Age (year)	Heavy Trucks (cumulative)
2018 (initial)	1,120
2043 (25 years)	5,645,600
2068 (50 years)	12,559,600

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	170.00	279.12	90.00	16.01	Fail
Permanent deformation - AC only (in)	0.50	0.37	90.00	99.78	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	1.70	90.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	1000.00	1154.79	90.00	79.49	Fail
AC thermal cracking (ft/mile)	700.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	2000.00	776.54	90.00	99.95	Pass

Distress Charts



COMPARISON OF MODULUS VALUES:

Pavement Layer	Modulus (Pavement ME)- Ksi	Modulus (FWD- After construction)- Ksi
Rubblized Concrete	65	104
Subbase	18	18
Subgrade	4.5	4.6

COMPARISON OF SERVICE LIFE:

Pavement Recommendation	Expected Service Life (Years)	
	AASHTO 1993	Pavement ME
2" Stone Matrix Asphalt (SMA) 3" Bottom Rich Base Course (BRBC) 8" Rubblized PCC 12" Subbase	≥20	≥50

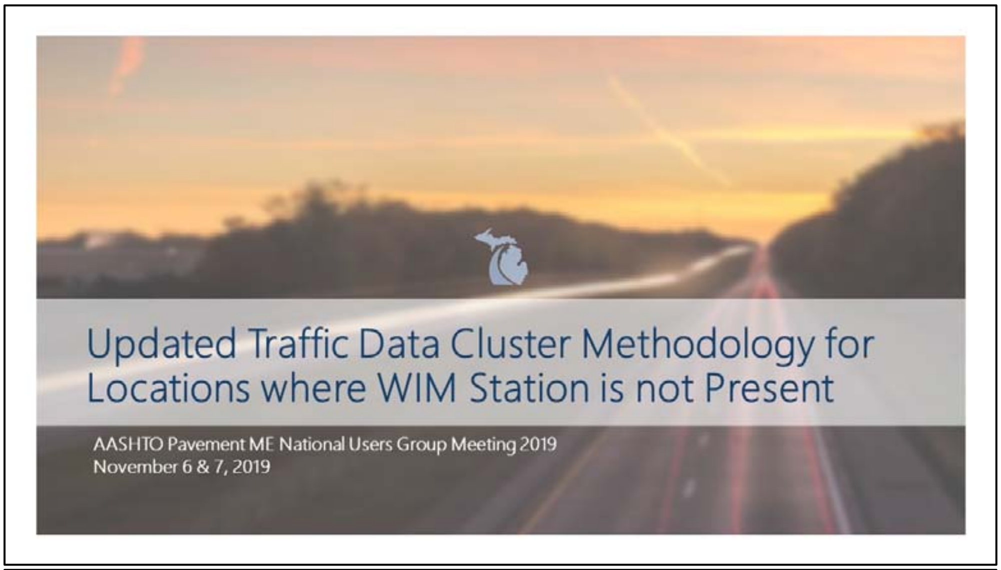
CONCLUSION BASED ON EXPERIENCE:

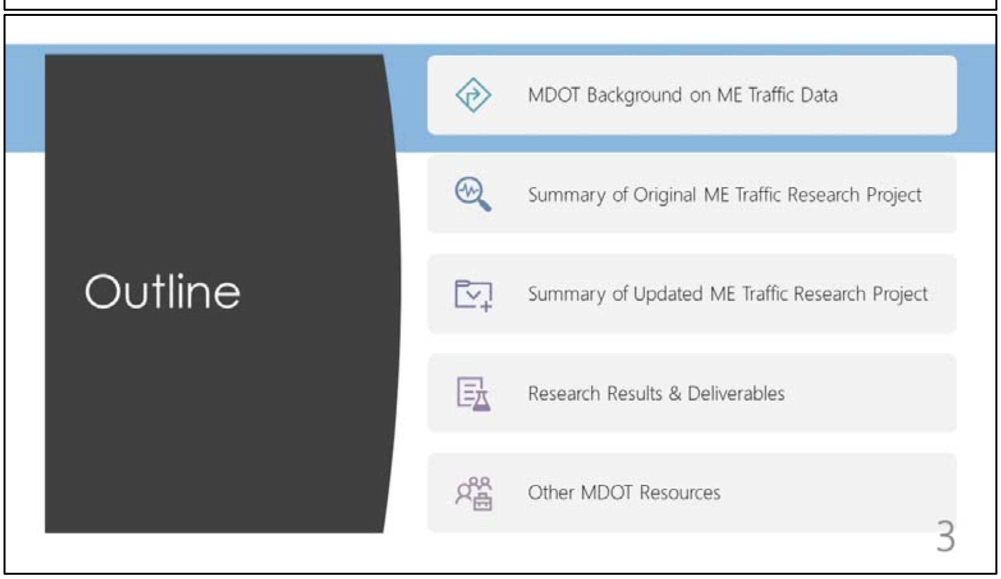
Performances/benefits of specialized mixes such as Stone Matrix Asphalt (SMA) or Bottom Rich Base Course (BRBC) cannot be captured by *AASHTO 1993* design.
Material properties of specialized mixes can be modeled using *Pavement ME,* thus allowing pavement engineers to predict performances of pavement boxes with these mixes.

QUESTIONS?

Nusrat.Morshed@dot.nj.gov

Presentation 11—Justin Schenkel, Michigan DOT





MDOT Background on ME Traffic Data

4

MDOT ME Related Research to Date

- Concrete CTE (RC-1503) - January 2008
- Evaluation of 1-37A Project (RC-1516) – October 2008
- Subgrade Resilient Modulus (RC-1531) – July 2009
- Traffic Characterization (RC-1537) – December 2009
- Unbound Materials Resilient Modulus (RC-1548) – August 2011
- HMA Characterization, Part 1 (RC-1593) – March 2013
- Rehab Design Sensitivity, Part 2 (RC-1594) – August 2013
- ME Calibration, Part 3 (RC-1595) – November 2014
- Improve MI ME Climate Data (RC-1626) – October 2015
- ME Recalibration (SPR-1668) – September 2017
- Update of Traffic Characterization (SPR-1678) – August 2018

Legend:
- Materials
- Evaluation of ME
- Traffic
- Climate
- Calibration

5

Other ME Related Research

- Traffic & Data Preparation for AASHTO MEPDG Analysis and Design (PrepME)
  - *National pooled fund study - TPF-5(242)*
  - Software to convert PTR to ME inputs
    - Replaces TrafLoad
  - Runs QC on the data
  - Tools for correcting data
  - Options for 3 traffic input levels or other cluster methods.
  - Includes other modules:
    - Climate
    - Material:
      - FWD, HMA E*, PCC CTE, Soil Map

6

PrepME Preparation

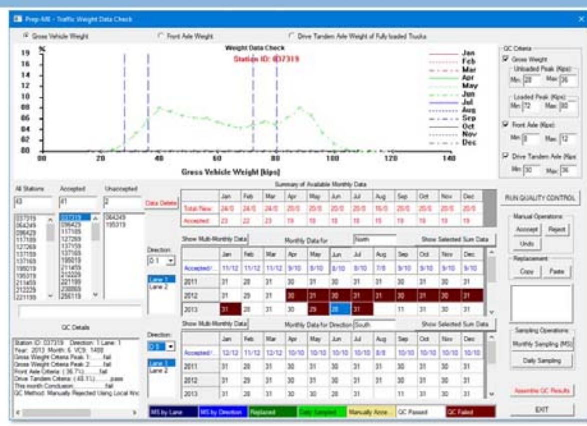
- Meet with PTR MDOT staff to review data
  - Notes for corrections to be made in PrepME

- General Notes
  - This is a summary document of the QA decisions on PrepME weight data QC results. All months that are rejected by the PrepME software are examined by the QA team. A decision is then made on whether to accept that month, replace it with another month, or do nothing (which keeps it rejected).
  - Use the following QC Criteria:
    - Class 9 Unloaded Peak (kips) = 28 to 36
    - Class 9 Loaded Peak (kips) = 72 to 80
    - Front Axle (kips) = 8 to **13**
    - Drive Tandem Axle (kips) = 30 to 36
  - A month is flagged showing 'QC Failed' when both peaks fail (unloaded and loaded), front axle fails, or drive tandem axle fails.
  - Legend:
    - **Bold** = Decisions made
    - *Italic* = Special note (including PTR expert comment)
- 037319
  - July 9, 2014
    - North, lane 1, Nov. 2012 and June/July 2013
      - Loaded gross peak is out, probably due to a calibration shift → **reject**
  - December 1, 2016
    - *No QC fails.*
  - March 1, 2017
    - *No QC fails.*
- 064249
  - June 2, 2014
    - *This site was terminated as a WIM in June 2011*

7

PrepME QC

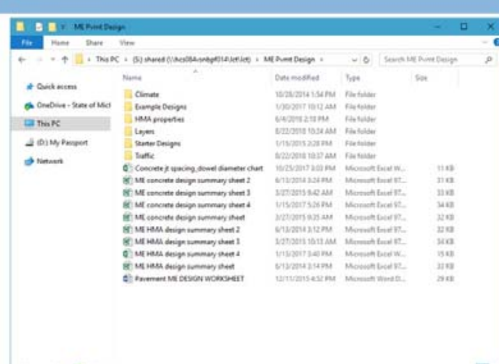
- Data changes made in PrepME



8

MDOT ME Data Import

- ME Pavement Design *Internal* MDOT Folder
  - Traffic, Layers, & HMA inputs for import
    - HMA inputs = D(t), IDT, E*, & G*
    - Too many variation in HMA to create layers
  - MI Research Climate HCD files
  - Starter & Example design files
  - ME design worksheets



9

Summary of Original ME Traffic Research Project

10

Original ME Traffic Research Project Need

- In ME, traffic characterization is significant & detailed inputs required
- The ME traffic inputs include:
  - Annual average daily truck traffic (**AADTT**),
  - Truck volume distribution by vehicle class (**VCD**),
  - Monthly truck volume distribution factors by vehicle class (**MAF**),
  - Hourly truck volume distribution factors (**HDF**),
  - Number of axle groups per vehicle (**AGPV**), and
  - Axle load distributions/spectra (**ALS**) by vehicle class and axle group (single, tandem, tridem, quad).

11

Original ME Traffic Research Project

- Characterization of Truck Traffic in Michigan for the New Mechanistic Empirical Pavement Design Guide
  - Report No.: RC-1537
  - Final Report Date: December 2009
- Author(s):
  - Neeraj Buch, Syed W. Haider, Joel Brown and Karim Chatti
  - Michigan State University

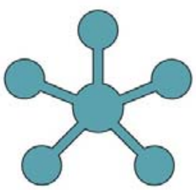
12

Original ME Traffic Research Project

- ME Traffic characteristics evaluated
- 44 WIM and classification stations
  - Data from 2005 to 2007
- Level 1 Data - PTR traffic volumes & axle load data in MI
- Level 2 - Cluster analyses to group sites with similar characteristics
- Level 3 - Data from all sites were averaged for statewide inputs
- Study recommended:
  - ME traffic inputs be re-evaluated every 5 years
- Significant ME traffic inputs identified – HDF, VCD, & Tandem ALS

13

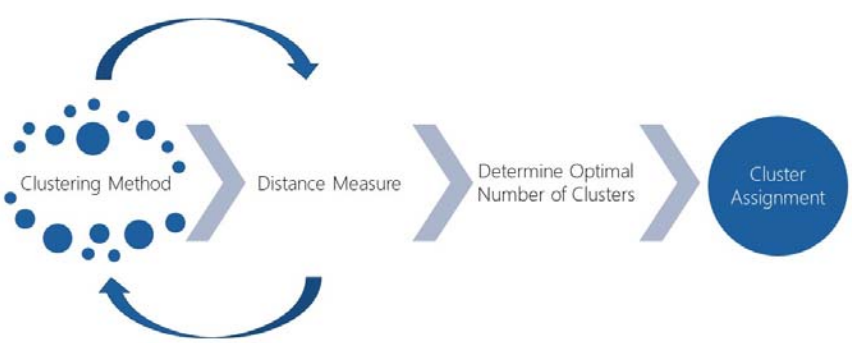
Original ME Traffic Research Project Level 2 Clustering



- Cluster Analyses
  - Identifies homogeneous subsets of data (also known as clusters) within a dataset using only the information found in the data.
  - The objects within a subset are similar to one another and are different from those in other subsets.
  - Entire collection of clusters is commonly referred to as a clustering.
  - The most commonly used technique is agglomerative hierarchical clustering.
  - Advantages of statistical cluster analyses:
    - Groups are formed objectively (based on a mathematical function)
    - Finds patterns that are not intuitively obvious
  - Disadvantage:
    - Lack of guidelines on establishing the optimal number of clusters.
    - Various techniques developed to identify the optimal number of clusters, but none are perfect.

14

Clustering Process



15

Original ME Traffic Research Project Cluster Method

- Hierarchical (statistical) clustering method:
  - Mathematical algorithm to group similar sites.
  - Process:
    1. All sites are individual clusters.
    2. A "distance" is measured.
    3. Algorithm groups based on "distance" measure and successive clusters are made.
  - Ward's –
    - The next cluster to be formed minimizes the sum of squares for all cases within the whole cluster.
    - Most efficient, good size/spherical clusters, and widely used.
- Squared Euclidean distance:
  - Allows more sensitivity to outliers, which is ideal for distinguishing variables in a site that are distinct from each other

16

Original ME Traffic Research Project Cluster Assignment

- Discriminant analyses
  - Develops a set of linear regression equations (one less than the number of dependent variable categories)
  - Uses a group of known parameters (predictor variables) as inputs into the equation and uses the output of that equation to select the appropriate cluster group for the dependent variable.
  - Dependent variable:
    - An ME traffic input (i.e VCD, MDF, Tandem ALS)
  - Predictor variable:
    - Known site property (ie. Functional class, AADTT, geographic location, etc.)

17

Original ME Traffic Research Project Problems

- More than 5 years had passed
- Changes to PTR sites – added & downgraded
- Used global coefficients (MDOT calibration now available)
- TrafLoad used to assemble PTR data (PrepME now available)

- Cluster method:
  - Lacked step-by-step procedures (for updating)
  - Discriminant function to determine site cluster (complex)
  - Needed a dataset not available for all roads (freight commodity routes)
  - Difficult for MDOT to update and make changes to in the future

18

Summary of Updated ME Traffic Research Project

19

Updated ME Traffic Research Project

- Updated Analysis of Michigan Traffic Inputs for Pavement-ME Design
  - Report No.: SPR-1678
  - Final Report Date: August 2018
- Author(s):
  - Syed W. Haider, Gopikrishna Musunuru, Neeraj Buch, Olga Selezneva, Praveen Desaraju, and Joshua Li
  - Michigan State University
- Project Manager:
  - Justin Schenkel
- Principle Investigator:
  - Dr. Syed Haider

20

Research Work Plan

- Task 1: Literature review
- Task 2: Review of the existing practices
- Task 3: Methodology for clustering
- Task 4: Generation of new clusters for Level 2 data
- Task 5: Significant traffic inputs
- Task 6: Evaluation of PrepME software
- Task 7: Data collection recommendations
- Task 8: Final report and technology transfer

21

Updated ME Traffic Research Project

- 59 PTR sites:
  - 18 Classification (blue)
  - 41 WIM (pink)
  - Data from 2011 to 2015

22

Updated ME Traffic Research Project

- Level 1 - PTR traffic volumes & axle load data in MI
- Level 2 -
  - 2A: Improve existing methodology (cluster analyses)
  - 2B: Simplified methodology (averages based on road attributes)
- Level 3 -
  - 3A: Averages based on freeway & non-freeway
  - 3B: Statewide averages

23

Task 3: Methodology for Clustering

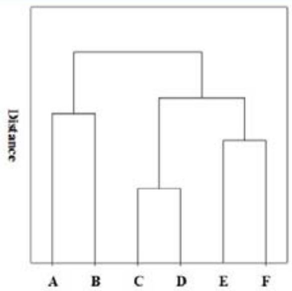
- Approach 1: Improve existing methodology (**Level 2A**)
  - Enhance the existing clustering method per updated PTR data.
- Approach 2: Alternative simplified methodology (**Level 2B**)
  - Use available MDOT traffic data (attributes) to identify ranges of values for different ME traffic inputs.
  - ME traffic inputs based on average of sites in each individual group are established.

24

Approach 1: Improve MDOT's Existing Cluster Methodology

- Agglomerative Hierarchical Clustering
  - Euclidean distance and Ward's method

$$proximity(A,B)=\sqrt{\frac{2\times n_A\times n_B}{n_A+n_B}}\times dist(C_A,C_B)$$



25

Approach 1: Improve MDOT's Existing Optimal Number of Clusters

- Optimal number of clusters
  - Methods:
    - Calinski-Harabasz Criterion (variance ratio)
    - Gap criteria
  - The optimal number of clusters have large between-cluster variance and small within.

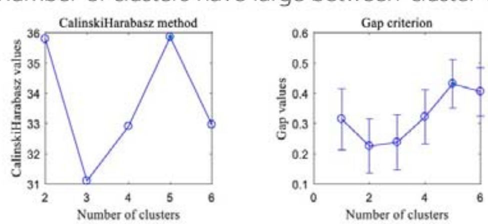
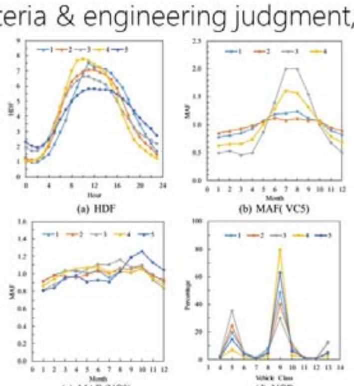


Figure 3-8 Optimum number of clusters for HDF

26

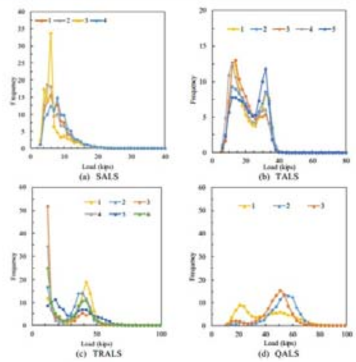
Approach 1: Improve MDOT's Existing Cluster Results

- Using optimal cluster number criteria & engineering judgment, number of clusters:
  - HDF – 5 clusters
  - MAF (VC5) – 4 clusters
  - MAF (VC9) – 5 clusters
  - VCD – 5 clusters
  - Single ALS (SALS) – 4 clusters
  - Tandem ALS (TALS) – 5 clusters
  - Tridem ALS (TRALS) – 6 clusters
  - Quad ALS (QALS) – 3 clusters



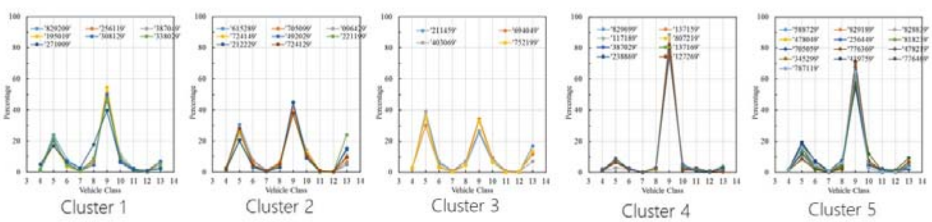
27

Approach 1: Improve MDOT's Existing Cluster Results



28

Sites in Each Cluster Example – VCD



29

Approach 1: Improve MDOT's Existing Assignment

30

Approach 1: Improve MDOT's Existing Assignment

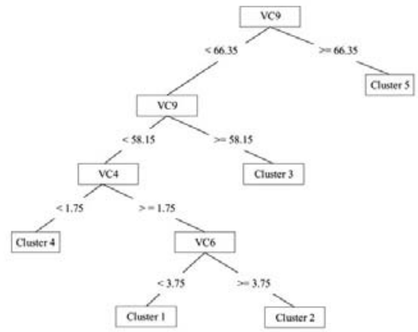


Figure 4-13 Single decision tree for HDF using entire data

31

Approach 2: Simplified Approach

- Challenges:
  - Traditional approach is more subjective (less mathematical).
  - Identifying a combo of attributes for grouping.
  - Groups should be distinct.
  - Accuracy in ME could be worse.
- An automated process was developed to help identify such combinations of attributes.
- Attributes used to classify groups don't need to be the same for all the traffic inputs and can depend on the type of traffic input.

32

Approach 2: Simplified Approach

- Available attributes initially chosen for grouping PTR locations:
  - Functional classification (Freeway vs. Non-Freeway)
  - Development type (Urban vs. Rural)
  - AADTT level (<1000, 1000-3000, >3000)
  - Corridors of highest significance (National, Regional and Statewide),
  - Number of lanes (2, 3 and 4), and
  - Road type (divided, freeway etc.)
  - Vehicle class 9 (VC 9) distribution levels (< 45, 45-70, >70)
- *All above data available for all sites*

33

Approach 2: Simplified Approach

- Possible combination of attributes using two at a time

Attribute 1	Attribute 2
F_NF	Road_Type
F_NF	Num_Lanes
F_NF	COMM_AADT_Bracket
F_NF	COHS_TYPE
F_NF	Development_Type
F_NF	VCD_Bracket
Road_Type	Num_Lanes
Road_Type	COMM_AADT_Bracket
Road_Type	COHS_TYPE
Road_Type	Development_Type
Road_Type	VCD_Bracket
Num_Lanes	COMM_AADT_Bracket
Num_Lanes	COHS_TYPE
Num_Lanes	Development_Type
Num_Lanes	VCD_Bracket
COMM_AADT_Bracket	COHS_TYPE
COMM_AADT_Bracket	Development_Type
COMM_AADT_Bracket	VCD_Bracket
COHS_TYPE	Development_Type
COHS_TYPE	VCD_Bracket
Development_Type	VCD_Bracket

21 combinations

34

Approach 2: Simplified Approach

- Possible combination of attributes using three at a time

Attribute 1	Attribute 2	Attribute 3
F_NF	Road_Type	Num_Lanes
F_NF	Road_Type	COMM_AADT_Bracket
F_NF	Road_Type	COHS_TYPE
F_NF	Road_Type	Development_Type
F_NF	Road_Type	VCD_Bracket
F_NF	Num_Lanes	COMM_AADT_Bracket
F_NF	Num_Lanes	COHS_TYPE
F_NF	Num_Lanes	Development_Type
F_NF	Num_Lanes	VCD_Bracket
F_NF	COMM_AADT_Bracket	COHS_TYPE
F_NF	COMM_AADT_Bracket	Development_Type
F_NF	COMM_AADT_Bracket	VCD_Bracket
F_NF	COHS_TYPE	Development_Type
F_NF	COHS_TYPE	VCD_Bracket
F_NF	Development_Type	VCD_Bracket
Road_Type	Num_Lanes	COMM_AADT_Bracket
Road_Type	Num_Lanes	COHS_TYPE
Road_Type	Num_Lanes	Development_Type
Road_Type	Num_Lanes	VCD_Bracket
Road_Type	COMM_AADT_Bracket	COHS_TYPE
Road_Type	COMM_AADT_Bracket	Development_Type
Road_Type	COMM_AADT_Bracket	VCD_Bracket
Road_Type	COHS_TYPE	Development_Type
Road_Type	COHS_TYPE	VCD_Bracket
Road_Type	Development_Type	VCD_Bracket
Num_Lanes	COMM_AADT_Bracket	COHS_TYPE
Num_Lanes	COMM_AADT_Bracket	Development_Type
Num_Lanes	COMM_AADT_Bracket	VCD_Bracket
Num_Lanes	COHS_TYPE	Development_Type
Num_Lanes	COHS_TYPE	VCD_Bracket
Num_Lanes	Development_Type	VCD_Bracket
COMM_AADT_Bracket	COHS_TYPE	Development_Type
COMM_AADT_Bracket	COHS_TYPE	VCD_Bracket
COMM_AADT_Bracket	Development_Type	VCD_Bracket
COHS_TYPE	Development_Type	VCD_Bracket

35 combinations

35

Approach 2: Simplified Approach

- Possible combination of attributes using two at a time

Attribute 1	Attribute 2
F_NF	Road_Type
F_NF	Num_Lanes
F_NF	COMM_AADT_Bracket
F_NF	COHS_TYPE
F_NF	Development_Type
F_NF	VCD_Bracket
Road_Type	Num_Lanes
Road_Type	COMM_AADT_Bracket
Road_Type	COHS_TYPE
Road_Type	Development_Type
Road_Type	VCD_Bracket
Num_Lanes	COMM_AADT_Bracket
Num_Lanes	COHS_TYPE
Num_Lanes	Development_Type
Num_Lanes	VCD_Bracket
COMM_AADT_Bracket	COHS_TYPE
COMM_AADT_Bracket	Development_Type
COMM_AADT_Bracket	VCD_Bracket
COHS_TYPE	Development_Type
COHS_TYPE	VCD_Bracket
Development_Type	VCD_Bracket

36

Approach 2: Simplified Approach - VCD

- VCD traffic inputs for the combination of functional class and development type

Sublevel	Sublevel	VC4	VC5	VC6	VC7	VC8	VC9	VC10	VC11	VC12	VC13
F	R	1.6	14.8	3.5	0.4	4.1	62.4	6.7	1.3	0.6	4.7
F	U	1.5	18.4	5.1	0.8	5.4	55.7	6.1	1.3	0.6	5.0
NF	R	2.3	25.0	4.7	0.9	6.1	40.8	7.4	0.8	0.4	11.5
NF	U	0.8	18.8	4.7	0.7	5.1	49.8	11.2	1.8	0.3	6.8

- Pairwise Euclidean distances between the sublevel combinations

Sublevel combination	F_R	F_U	NF_R	NF_U
F_R	0.0	8.0	24.9	14.2
F_U	8.0	0.0	17.6	8.0
NF_R	24.9	17.6	0.0	12.6
NF_U	14.2	8.0	12.6	0.0

37

Approach 2: Simplified Approach - VCD

Attribute 1	Attribute 2	Pairwise Euclidean distances between the sublevel combinations					Sublevel combinations			
		Max	Min	Avg.	Std.	Range	Total	Available	With only one PTR location	Missing
VCD Level	**Development Type**	**50.0**	**1.5**	**26.5**	**15.1**	**48.5**	**6**	**6**	**0**	**0**
Commercial AADT	Development Type	46.8	1.9	21.3	11.9	44.9	6	6	0	0
COHS	Development Type	28.3	2.9	18.0	7.1	25.4	6	6	1	0
Road Type	Development Type	27.7	4.8	17.6	6.8	22.9	6	6	3	0
Functional Class	Development Type	25.9	4.8	17.2	7.4	21.1	4	4	0	0
Functional Class	VCD Level	50.4	6.7	25.5	14.4	43.7	6	5	0	1
Number of Lanes	Development Type	41.6	4.3	19.0	16.1	37.3	6	5	2	1
Functional Class	Commercial AADT	40.2	5.4	21.1	11.5	34.8	6	5	0	1
Functional Class	COHS	28.7	8.0	15.9	6.7	20.7	6	5	0	1
COHS	VCD Level	54.5	2.5	23.0	13.2	52.1	9	7	1	2
Commercial AADT	VCD Level	50.3	1.9	24.3	14.3	48.4	9	7	0	2
Commercial AADT	COHS	42.0	4.2	22.0	11.9	37.9	9	7	1	2
Road Type	COHS	28.7	2.1	16.1	7.7	26.7	9	7	3	2
Functional Class	Number of Lanes	28.0	6.9	15.8	7.8	21.2	6	4	1	2
Road Type	VCD Level	56.1	7.6	25.3	14.0	48.5	9	6	0	3
Number of Lanes	VCD Level	53.2	1.7	23.9	14.7	51.4	9	6	1	3
Road Type	Commercial AADT	42.7	5.4	21.0	10.9	37.3	9	6	0	3
Number of Lanes	Commercial AADT	42.3	1.1	18.1	11.0	41.1	9	6	1	3
Functional Class	Road Type	23.1	9.7	17.8	7.2	13.5	6	3	0	3
Road Type	Number of Lanes	28.8	6.9	16.4	7.5	22.0	9	5	1	4
Number of Lanes	COHS	26.1	5.5	14.9	7.0	20.6	9	5	1	4

Note: Shaded cells indicate the selected attribute combination for generation of Level 2B inputs

38

Approach 2: Simplified Approach

- Best possible 2-way combinations for Level 2B groupings

Traffic Input	Attribute 1	Attribute 2	Pairwise Euclidean distances between the sublevel combinations					Sublevel Combinations			
			Max	Min	Average	Std	Range	Total	Available	With only one PTR	Missing
VCD	VCD Level	Develop. Type	50	1.5	26.5	15.1	48.5	6	6	0	0
HDF	VCD Level	Develop. Type	7.5	0.7	3.9	2	6.8	6	6	0	0
MAF	CADTT Level	Develop. Type	0.88	0.10	0.38	0.28	0.79	6	6	0	0
SALS	COHS	Develop. Type	27.3	1.2	11.1	9.2	26.2	6	6	1	0
TALS	No. of Lanes	Develop. Type	15.1	1.9	7.9	4.9	13.2	6	5	2	1
TRALS	COHS	Develop. Type	35	3.5	15.1	10.5	31.5	6	6	1	0
QALS	COHS	Develop. Type	21.7	2.5	11.5	6.3	19.3	6	6	1	0

39

Task 5: Significant Traffic Inputs

- Level 2 (cluster) inputs evaluated in two ways:
  - Option 1:
    - All inputs at **Level 1**, then change one input at a time to **Level 2/Level 3**
  - Option 2:
    - All inputs at **Level 3**, then change one input at a time to **Level 2**

40

Task 5: Significant Traffic Inputs OPTION 1

- Sensitivity Analyses – Option 1
  - Started designs with level 1 inputs,
    - For flexible pavement:
      - HMA thickness (top layer) designed for each PTR location to achieve 20-year design per:
        - Bottom-up fatigue cracking (20%)
        - Rut depth (0.5")
    - For rigid pavement:
      - JPCP thickness was designed to achieve a 20-year design per:
        - IRI (172 inches/mile)
        - Faulting (0.125")
        - Transverse cracking (15%)
  - Next, one traffic input at a time changed to Level 2A, 2B, 3A, and 3B to determine input effect on design life.
    - The difference in design lives (Level 1 – Level X) was quantified.

41

Task 5: Significant Traffic Inputs OPTION 1

- Sensitivity Analyses – Option 1
  - <u>2 analyses types</u>:
    - Statistical tests (ANOVA/t-test for comparison of means)
      - Statistical difference between *the clusters*.
      - **Significant** (dissimilar) if the p-value is below 0.05.
    - Maximum life difference (MLD) in years
      - Raw number of difference in number of years for *each PTR* in cluster.
      - **Significant** if at least one site changed by 2 or more years.

42

Task 5: Significant Traffic Inputs OPTION 1

- Impact designation on predicted pavement performance

Designation of impact	Maximum life difference (years)
Significant	MLD > 5
Moderate Significant	2 < MLD < 5
Negligible	MLD < 2

43

Task 5: Significant Traffic Inputs OPTION 2

- Sensitivity Analyses – Option 2
  - Started designs with level 3A inputs, and used base fwy & non-fwy design
    - For flexible pavement sections:

Layer	Layer thickness, inches	
	Freeways	Non-Freeways
HMA top course	2	1.5
HMA leveling course	3	2
HMA base course	3.5	3
Non-stabilized GAB	6	6
Sand subbase	18	18
Sandy clay subgrade	Semi-infinite	Semi-infinite

    - For rigid pavement sections:

Layer	Layer thickness, inches	
	Freeways	Non-Freeways
PCC	11	8
Non-stabilized GAB	6	6
Sand subbase	10	10
Sandy clay subgrade	Semi-infinite	Semi-infinite

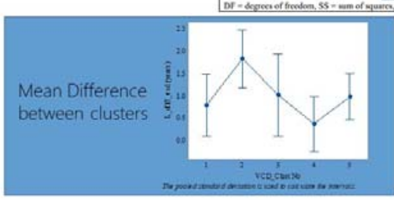
44

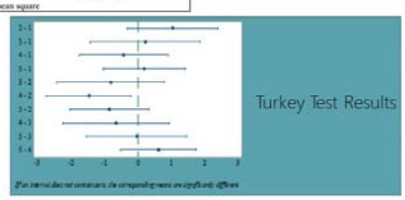
Task 5 : Significant Traffic Inputs – OPTION 1 - (VCD, Level 2A) Example

- ANOVA results for Level 2A VCD clusters for flexible pavements, *Bottom-up Fatigue Cracking*

Source	DF	Adj SS	Adj MS	F-value	p-value
VCD Cluster	4	9.454	2.3634	2.78	0.041
Error	36	30.599	0.85		
Total	40	40.052			
VCD Cluster	N	Mean	StDev	95% CI	
1	7	0.794	0.35	(0.087, 1.501)	
2	8	1.834	1.568	(1.173, 2.495)	
3	4	1.02	1.193	(0.085, 1.955)	
4	9	0.379	0.399	(-0.244, 1.002)	
5	13	0.872	0.77	(0.353, 1.390)	

DF = degrees of freedom, SS = sum of squares, MS = mean square

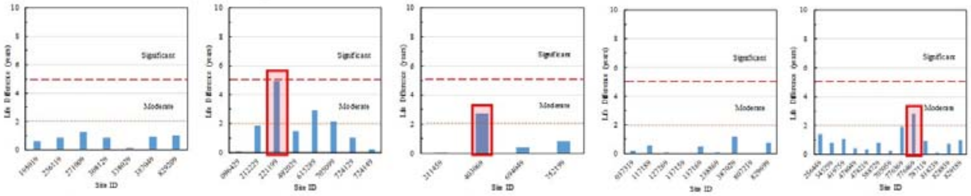




45

Task 5 : Significant Traffic Inputs – OPTION 1 - (VCD, Level 2A) Example

- MLD Results for Level 2A VCD clusters for flexible pavements, Bottom-up Fatigue Cracking



46

Task 5: Significant Traffic Inputs – OPTION 1

- Sensitivity to statistical significance – Level 2A

Traffic Input	Flexible pavements		Rigid pavements		
	Rut depth (in)	Bottom-up Fatigue Cracking (%)	IRI (in/mile)	Faulting (in)	Transverse Cracking (%)
VCD	Y	Y	N	Y	Y
HDF	-	-	N	N	Y
MAF	N	N	N	N	Y
SALS	N	N	N	N	N
TALS	N	N	N	N	N
TRALS	N	N	N	N	N
QALS	N	Y	N	N	N

47

Task 5: Significant Traffic Inputs – OPTION 1

- Sensitivity to MLD – Level 2A

Traffic Input	Flexible pavements		Rigid pavements		
	Rut depth (in)	Bottom-up Fatigue Cracking (%)	IRI (in/mile)	Faulting (in)	Transverse Cracking (%)
VCD	Y	Y	N	Y	Y
HDF	-	-	N	N	Y
MAF	N	N	N	N	N
SALS	Y	Y	N	N	N
TALS	Y	Y	N	N	Y
TRALS	N	N	N	N	N
QALS	N	N	N	N	N

48

Task 5: Significant Traffic Inputs – OPTION 1

- Sensitivity to statistical significance – Level 2B

Traffic Input	Flexible pavements		Rigid pavements		
	Rut depth (in)	Bottom-up Fatigue Cracking (%)	IRI (in/mile)	Faulting (in)	Transverse Cracking (%)
VCD	N	N	N	N	N
HDF	-	-	Y	N	Y
MAF	N	N	N	N	N
SALS	N	Y	N	Y	N
TALS	N	N	N	N	N
TRALS	N	N	N	N	N
QALS	N	Y	N	N	N

49

Task 5: Significant Traffic Inputs – OPTION 1

- Sensitivity to MLD – Level 2B

Traffic Input	Flexible pavements		Rigid pavements		
	Rut depth (in)	Bottom-up Fatigue Cracking (%)	IRI (in/mile)	Faulting (in)	Transverse Cracking (%)
VCD	Y	Y	N	Y	Y
HDF	-	-	N	N	Y
MAF	N	N	N	N	N
SALS	N	Y	N	N	N
TALS	Y	Y	N	N	Y
TRALS	N	N	N	N	N
QALS	N	N	N	N	N

50

Task 5: Significant Traffic Inputs – OPTION 1

- Sensitivity to statistical significance – Level 3A

Traffic Input	Flexible pavements		Rigid pavements		
	Rut depth (in)	Bottom-up Fatigue Cracking (%)	IRI (in/mile)	Faulting (in)	Transverse Cracking (%)
VCD	Y	Y	N	N	N
HDF	-	-	N	N	N
MAF	N	N	N	N	Y
SALS	N	Y	N	N	N
TALS	N	Y	N	Y	N
TRALS	N	Y	N	N	N
QALS	N	N	N	N	N

51

Task 5: Significant Traffic Inputs – OPTION 1

- Sensitivity to MLD – Level 3A

Traffic Input	Flexible pavements		Rigid pavements		
	Rut depth (in)	Bottom-up Fatigue Cracking (%)	IRI (in/mile)	Faulting (in)	Transverse Cracking (%)
VCD	Y	Y	N	Y	Y
HDF	-	-	N	N	Y
MAF	N	N	N	N	Y
SALS	N	Y	N	N	Y
TALS	Y	N	N	N	Y
TRALS	N	N	N	N	N
QALS	N	N	N	N	N

52

Task 5: Significant Traffic Inputs – Level 2A vs 2B

- If Option 1 criteria shows Level 2A or 2B inputs are significant:
  - Next step, identify if there are differences between Levels 2A and 2B.
- If no differences, then Level 2B (or 2A) can be used
  - 2B will simplify the input selection process.
- Level 2A vs 2B significance determination:
  - Paired t-test for difference of ($|Life_{Level 1} - Life_{Level 2A}|$) and ($|Life_{Level 1} - Life_{Level 2B}|$)
  - Number of times overdesigned or under designed using Level 2A and 2B

53

Task 5: Significant Traffic Inputs – Level 2A vs 2B

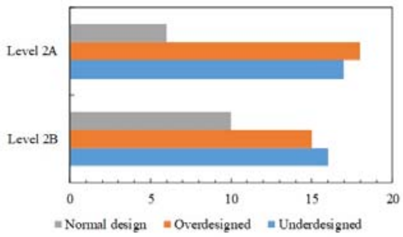
- Sensitivity to statistical significance – Level 2A vs 2B

Traffic Input	Flexible pavements		Rigid pavements		
	Rut depth (in)	Bottom-up Fatigue Cracking (%)	IRI (in/mile)	Faulting (in)	Transverse Cracking (%)
VCD	Y	N	N	N	N
HDF	-	-	Y	N	Y
MAF	N	N	N	N	N
SALS	N	N	N	N	N
TALS	N	N	Y	Y	N
TRALS	N	N	N	N	N
QALS	N	N	N	N	N

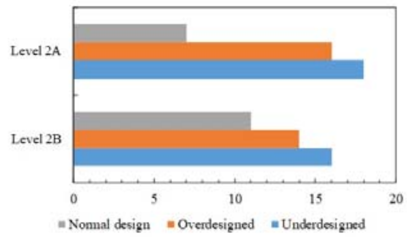
54

Task 5: Significant Traffic Inputs – Level 2A vs 2B - (VCD)

Rutting



Fatigue Cracking



If $Life_{Level1} - Life_{Level2} > 0$, Over designed
If $Life_{Level1} - Life_{Level2} < 0$, Under designed
If $Life_{Level1} - Life_{Level2} = 0$, Normal designed

55

Task 5: Significant Traffic Inputs – Level 2A vs 2B - (VCD)

Descriptor	Ldiff Rut 2B	Ldiff Rut 2A	Ldiff AC 2B	Ldiff AC 2A
Number of under-designed (U.D) sites	16	17	16	18
Number of over-designed (O.D) sites	15	18	14	16
Number of normal designed sites	10	6	11	7
Average U.D life (years)	-1.3	-1.3	-1.3	-1.1
Average O.D life (years)	0.7	1.2	0.6	0.8
Max U.D life	-0.08	-0.08	-0.17	-0.08
Min U.D life	-5.00	-4.83	-5.00	-4.92
Max O.D life	3.17	3.08	3.08	2.92
Min O.D life	0.08	0.17	0.08	0.08

56

Task 5: Significant Traffic Inputs – Level 3A vs 3B

- Sensitivity to statistical significance – Level 3A vs 3B

	Flexible pavements		Rigid pavements		
Traffic Input	Rut depth (in)	Bottom-up Fatigue Cracking (%)	IRI (in/mile)	Faulting (in)	Transverse Cracking (%)
VCD	N	N	N	N	N
HDF	-	-	N	N	N
MAF	N	N	N	N	Y
SALS	N	N	N	N	Y
TALS	N	N	N	N	Y
TRALS	N	N	N	N	N
QALS	N	N	Y	Y	N

57

Task 5: Significant Traffic Inputs OPTION 2

- *No significance detected when using Option 2*

58

Research Results & Deliverables

59

Task 5: Significant Traffic Inputs – Summary

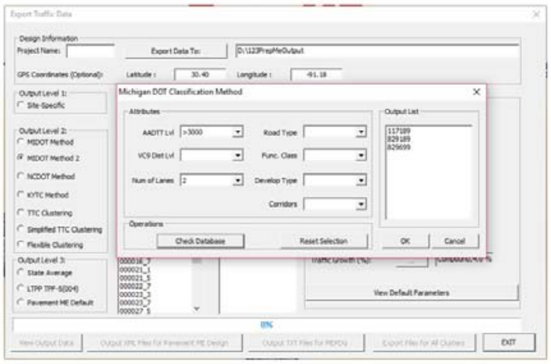
- Recommended Traffic Input Levels

Traffic Input	Recommended Traffic Input Level (when Level 1 not available)	
	Flexible Pavement	Rigid Pavement
VCD	2B	
HDF	-	2B
MAF	3A	
AGPV	3B	
SALS	3A	
TALS	2B	
TRALS	3A	
QALS	3A	

60

Task 6: Evaluation of PrepME

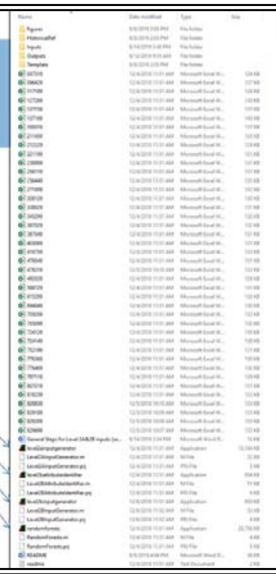
- Level 2B, two-way combination grouping included in PrepME



61

Task 6: Evaluation of PrepME

- Macros for calculation outside of PrepME
  - Includes 2A & 2B cluster automation.



62

Macro General Steps for Level 2A & 2B inputs

- 2A Input Generation
  1. Input Files
     a) WIM Data Files
     b) 'Optimal Clusters'
  2. Run 'level2ainputgenerator' macro
  3. Output
     a) 'Level 2A Inputs' – Number of clusters & their ME inputs
  4. Project input file & add to 'Random Forests Inputs'
  5. Run 'randomforests' macro
  6. Output
     a) Determine what cluster a new site belongs to
     b) Error rate

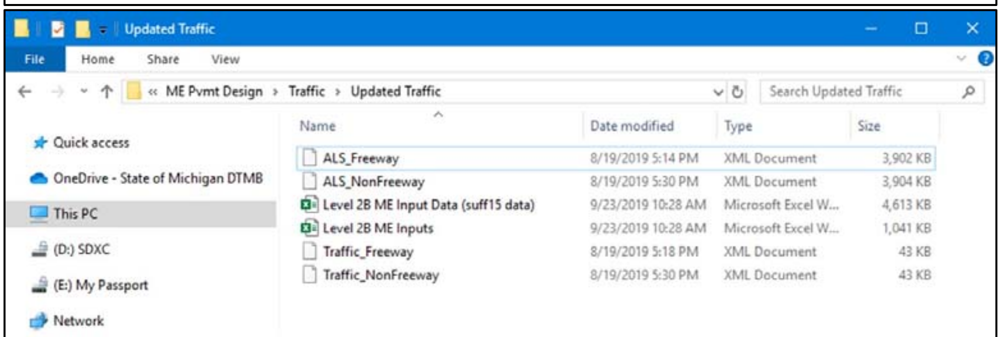
63

Macro General Steps for Level 2A & 2B inputs

- 2B Input Generation
  1. Input files
     a) WIM data files
     b) 'Optimal Attributes'
     c) 'PTR Attributes'
  2. Run 'level2battributeidentifier' macro
  3. Output
     a) 'Summary' file (for decision making)
  4. Input file
     a) 'Optimal Attributes' for each input
     b) 'PTR Attributes'
  5. Run 'level2binputgenerator' macro*
  6. Output
     a) 'Level 2B Inputs' – Averages of each cluster selection per ME inputs

* *Note that PrepME could be used here, but it's attributes are hardcoded per current WIM attributes, so the macro is preferred.*

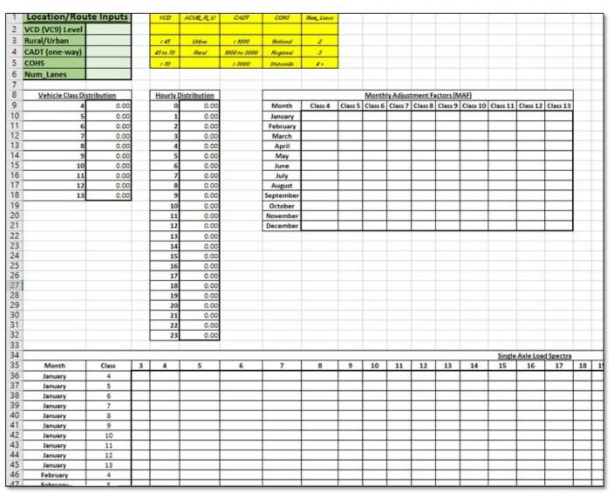
64



MDOT Implementation

65

Level 2B Spreadsheet



66

Level 2B Spreadsheet (continued)

Attributes		Vehicle Class Distribution									
Attr 1	Attr 2	4	5	6	7	8	9	10	11	12	13
> 70	Rural	1.30	7.01	2.09	0.16	2.63	78.39	3.40	1.55	0.55	2.75
> 70	Urban	1.10	8.45	2.55	0.15	1.90	78.95	4.00	1.05	0.55	3.30
< 45	Rural	2.20	28.34	4.38	0.60	3.19	33.67	9.80	0.58	0.53	12.49
< 45	Urban	3.40	23.85	7.05	2.00	11.90	38.95	7.90	1.00	0.85	3.10
45 to 70	Rural	1.01	10.31	3.06	0.34	4.73	38.06	6.40	1.31	0.67	3.90
45 to 70	Urban	1.48	17.33	4.79	0.74	3.11	58.33	7.28	1.41	0.38	4.77

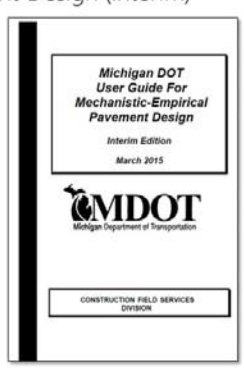
67

Other MDOT Resources

68

MDOT References

- MDOT User Guide for Mechanistic-Empirical Pavement Design (Interim)
  - *Started in 2013*
  - 14 Chapters:
    1. Intro
    2. Software Operation
    3. Design Process
    4. General Inputs
    5. Performance Criteria & Reliability
    6. Calibration Coefficients
    7. Traffic Inputs
    8. Climate Inputs
    9. Asphalt Pavement (New) Layer Inputs
    10. Concrete Pavement (New) Layer Inputs
    11. Base/Subbase Layer Inputs
    12. Subgrade Layer Inputs
    13. Existing Layer Inputs for Rehab Design (not yet complete)
    14. Assessing the Results/Modifying the Design



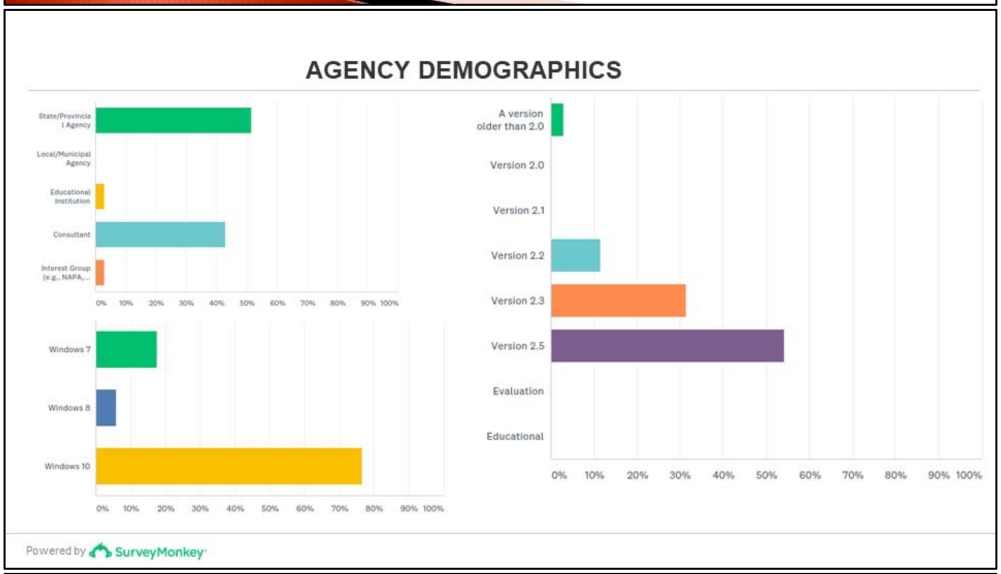
69

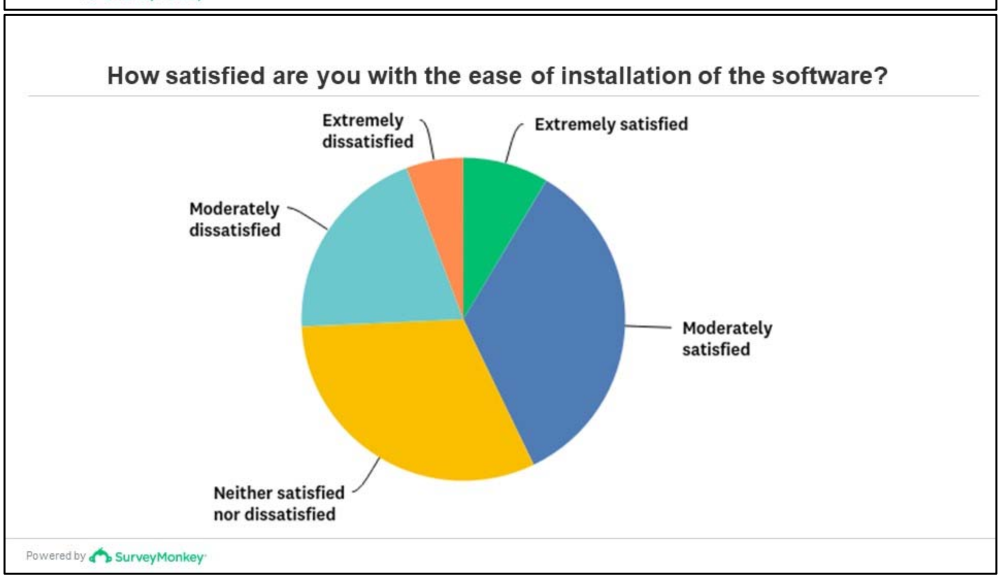
MDOT References *(continued…)*

- MDOT ME Website:
  - https://www.michigan.gov/mdot/0,4616,7-151-9623_26663_27303_27336_63969---,00.html

70

Presentation 12—Bob Shugart, Alabama DOT

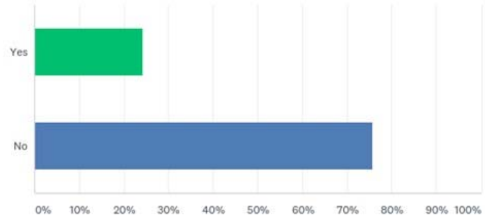




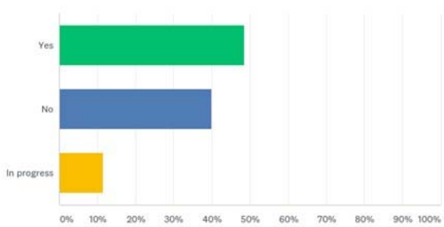
AGENCY DEMOGRAPHICS

ANSWER CHOICES	RESPONSES	
Internet Explorer	44.12%	15
Microsoft Edge	5.88%	2
Mozilla Firefox	5.88%	2
Google Chrome	41.18%	14
TOTAL		34

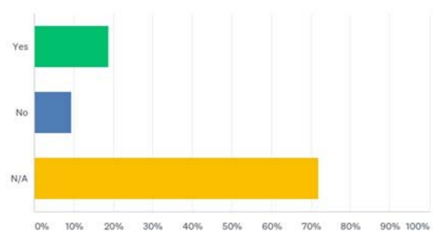
Would you use Pavement ME on a tablet or iPad if it were available?



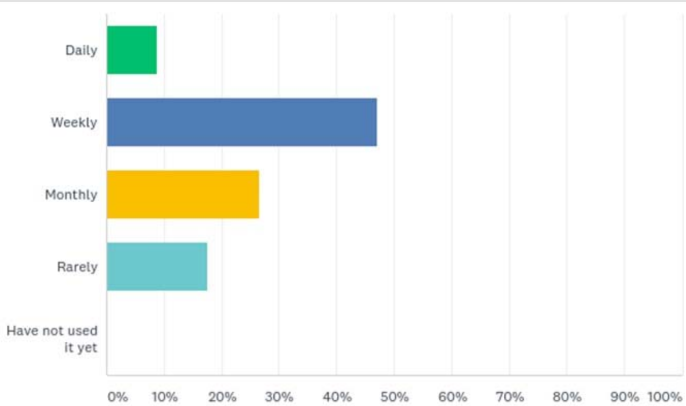
Completed Local Calibration



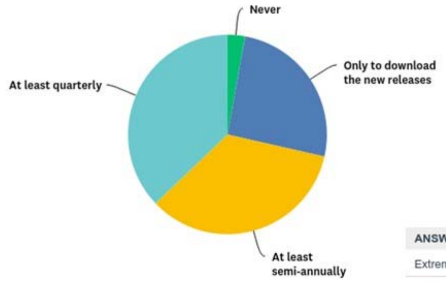
Planning for Future Local Calibration



How often do you use the software?



How frequently do you visit the AASHTOWare Pavement ME website?



ANSWER CHOICES	RESPONSES	
Extremely satisfied	8.57%	3
Moderately satisfied	54.29%	19
Neither satisfied nor dissatisfied	20.00%	7
Moderately dissatisfied	5.71%	2
Extremely dissatisfied	2.86%	1
N/A	8.57%	3
TOTAL		35

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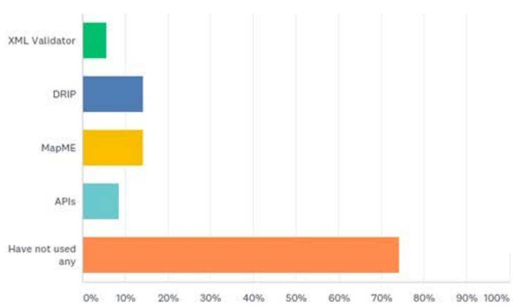
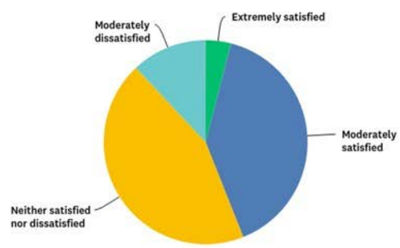
Have you used any of the tools on the Pavement ME website (XML Validator, DRIP, MapME, APIs)? (select all that apply)





How satisfied are you with tools you have used?

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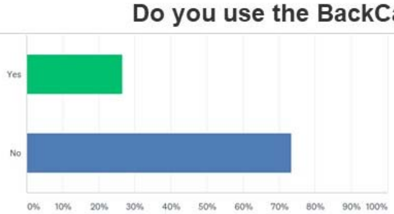
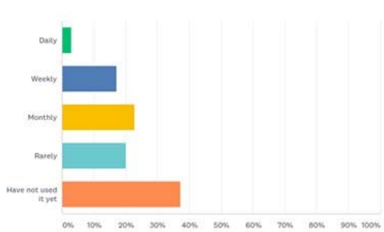
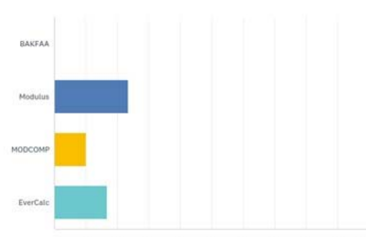
Do you use the BackCalculator Tool (BcT)?







If you do not use it, which Backcalculation software do you prefer to use?

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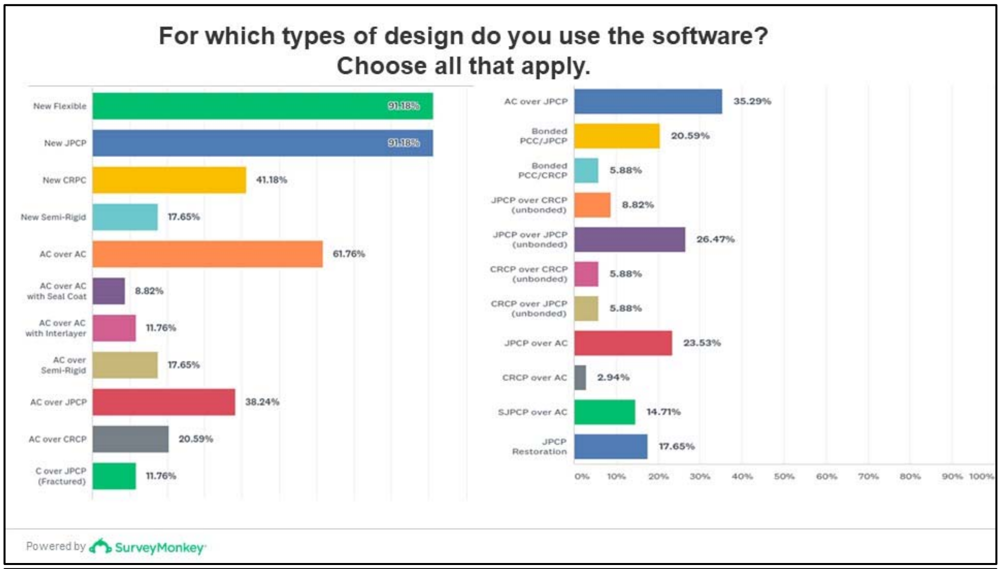
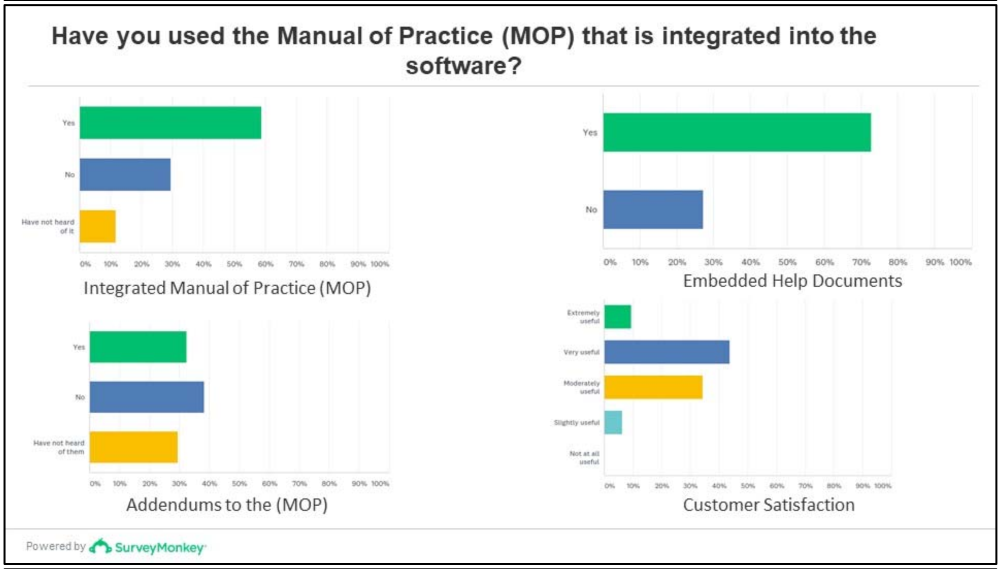
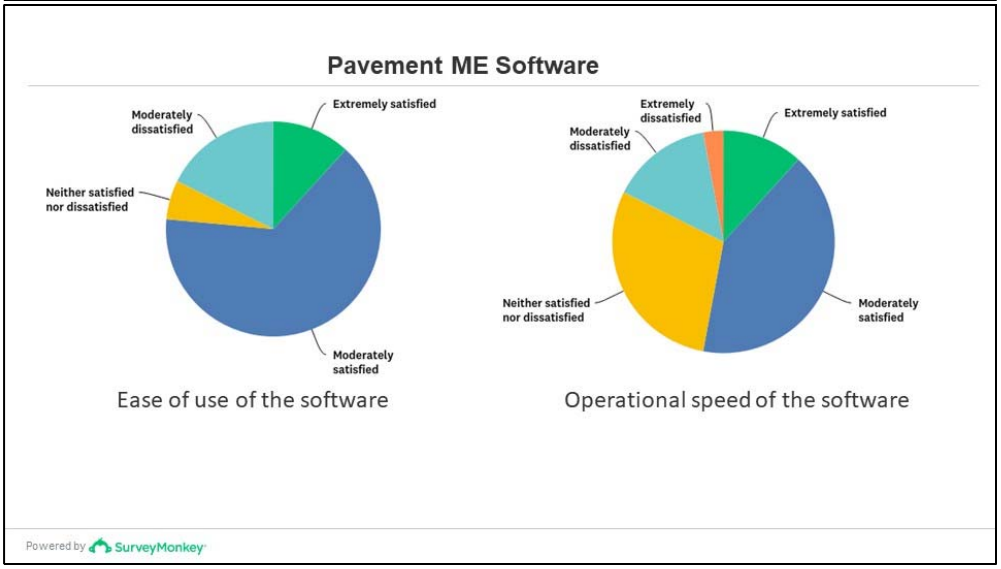

For which types of design do you use the software?
Choose all that apply.
New Flexible 91.18%
New JPCP 91.18%
New CRPC 41.18%
New Semi-Rigid 17.65%
AC over AC 61.76%
AC over AC with Seal Coat 8.82%
AC over AC with Interlayer 11.76%
AC over Semi-Rigid 17.65%
AC over JPCP 38.24%
AC over CRCP 20.59%
C over JPCP (Fractured) 11.76%
AC over JPCP 35.29%
Bonded PCC/JPCP 20.59%
Bonded PCC/CRCP 5.88%
JPCP over CRCP (unbonded) 8.82%
JPCP over JPCP (unbonded) 26.47%
CRCP over CRCP (unbonded) 5.88%
CRCP over JPCP (unbonded) 5.88%
JPCP over AC 23.53%
CRCP over AC 2.94%
SJPCP over AC 14.71%
JPCP Restoration 17.65%
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Powered by SurveyMonkey


Have you used the Manual of Practice (MOP) that is integrated into the software?
Yes
No
Have not heard of it
Integrated Manual of Practice (MOP)
Yes
No
Embedded Help Documents
Yes
No
Have not heard of them
Addendums to the (MOP)
Extremely useful
Very useful
Moderately useful
Slightly useful
Not at all useful
Customer Satisfaction
Powered by SurveyMonkey


Pavement ME Software
Moderately dissatisfied
Extremely satisfied
Neither satisfied nor dissatisfied
Moderately satisfied
Ease of use of the software
Extremely dissatisfied
Moderately dissatisfied
Extremely satisfied
Neither satisfied nor dissatisfied
Moderately satisfied
Operational speed of the software
Powered by SurveyMonkey

SOFTWARE ENHANCEMENTS

Recent enhancements to the software include the incorporation of Bonded Concrete Overlays (i.e. Short JPCP on AC), climate data updates, the integration of the Manual of Practice, report customization, enhanced project comparison ability, a maintenance strategy tool, tensile strength Level 1 inputs, and software recalibration. How satisfied are you with the enhancements that have been made to the software?

ANSWER CHOICES	RESPONSES	
Extremely satisfied	21.21%	7
Moderately satisfied	36.36%	12
Neither satisfied nor dissatisfied	36.36%	12
Moderately dissatisfied	3.03%	1
Extremely dissatisfied	0.00%	0
TOTAL		33

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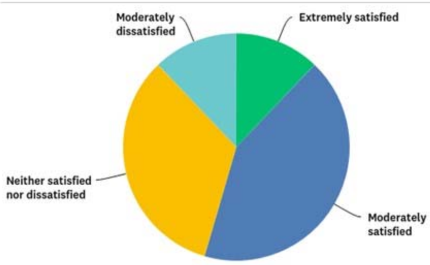
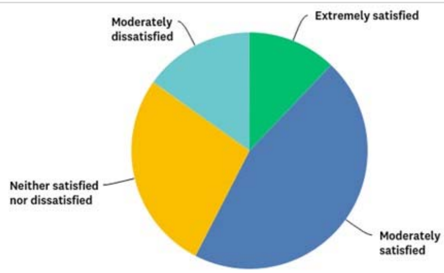
How satisfied are you with the release schedule of enhancements to the software?



How satisfied are you with the **release schedule** of enhancements to the software?



How satisfied are you with the **pace** of enhancements to the software?

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A list of 23 requested enhancements was included in the survey. Here are the nine most desired:

Allowing for multiple maintenance events	**10**
Batch editing for multiple projects	**10**
Add CIR, FDR and pulverized asphalt material properties into sandwich construction	**9**
Multi-project compare tool	**8**
Incorporation of New Composite pavements as a new pavement design option	**7**
Incorporate Pavement preservation (structural preservation, NCHRP 1-48)	**7**
Additional parameters for sensitivity analysis	**7**
Incorporation of one-time super heavy load analysis feature	**7**
Incorporation of faulting and IRI to SJPCP design parameters	**6**

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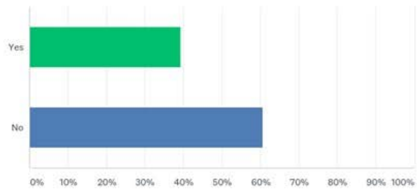
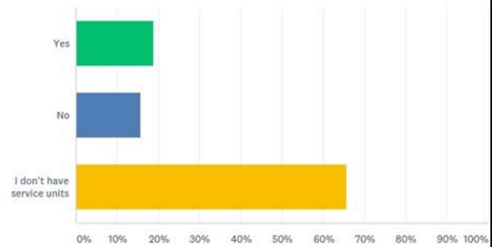
Are you familiar with AASHTOWare Service Units and what they can be used for?



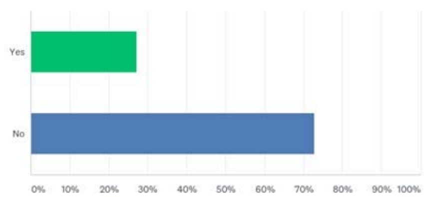
Are you familiar with AASHTOWare Service Units and what they can be used for?



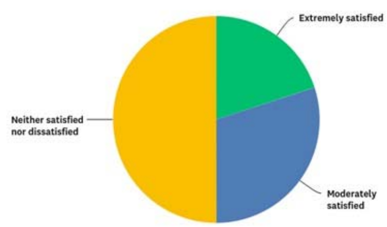
Would you be willing to use your Service Units to fund software features or model integration?

Powered by SurveyMonkey

Have you used the new Bug Reporting Tool available as a link on the website?



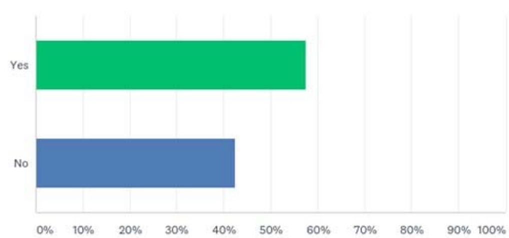
Use of the Bug Reporting Tool



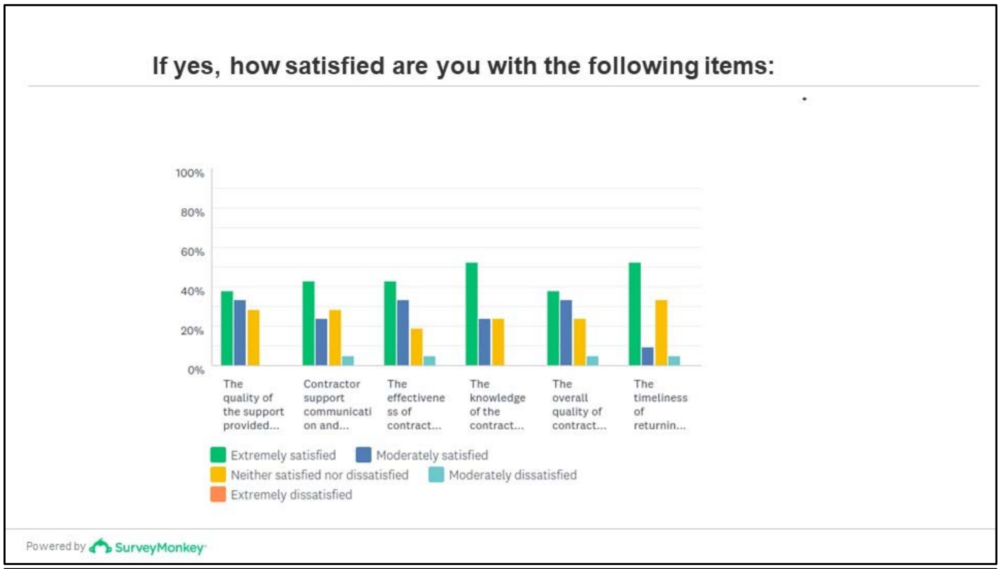
Customer Satisfaction

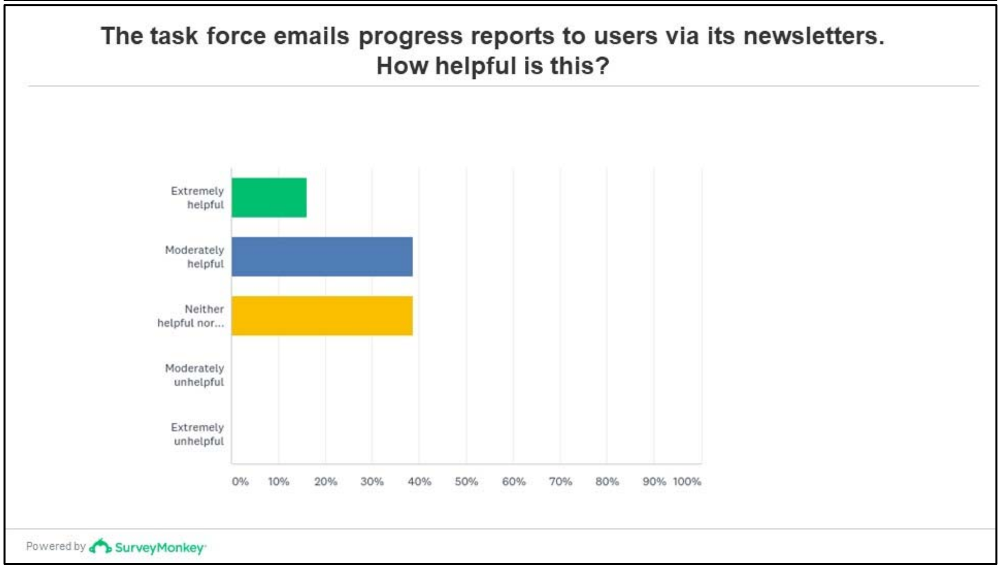
Powered by SurveyMonkey

Have you used the help desk support services from the contractor?

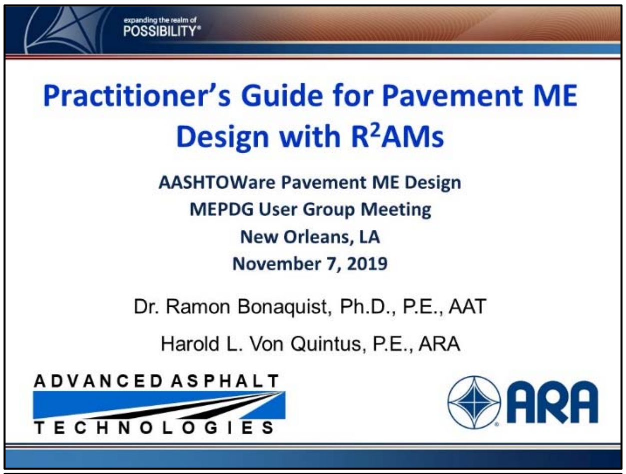


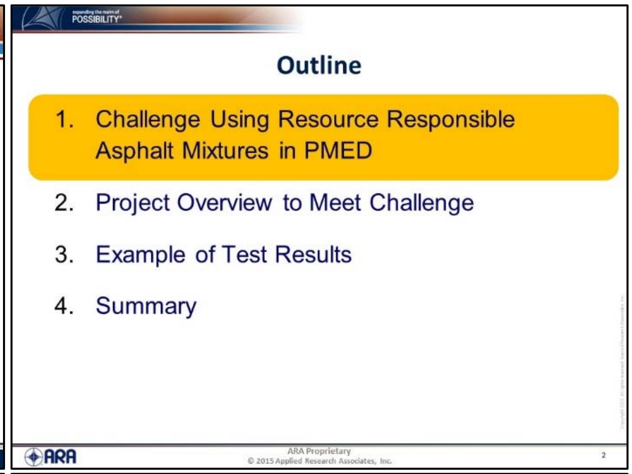
Powered by SurveyMonkey

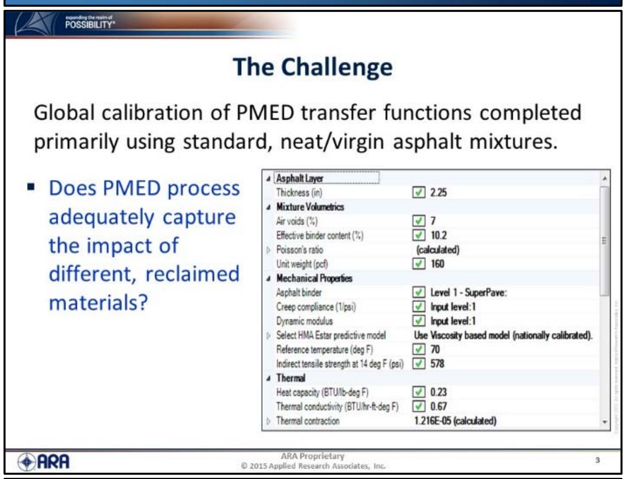

If yes, how satisfied are you with the following items:
100%
80%
60%
40%
20%
0%
The quality of the support provided...
Contractor support communication and...
The effectiveness of contract...
The knowledge of the contract...
The overall quality of contract...
The timeliness of returnin...
Extremely satisfied
Moderately satisfied
Neither satisfied nor dissatisfied
Moderately dissatisfied
Extremely dissatisfied
Powered by SurveyMonkey

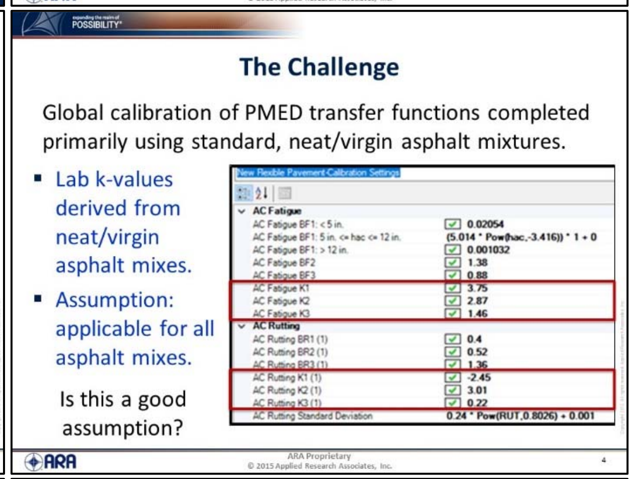

The task force emails progress reports to users via its newsletters.
How helpful is this?
Extremely helpful
Moderately helpful
Neither helpful nor...
Moderately unhelpful
Extremely unhelpful
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Powered by SurveyMonkey

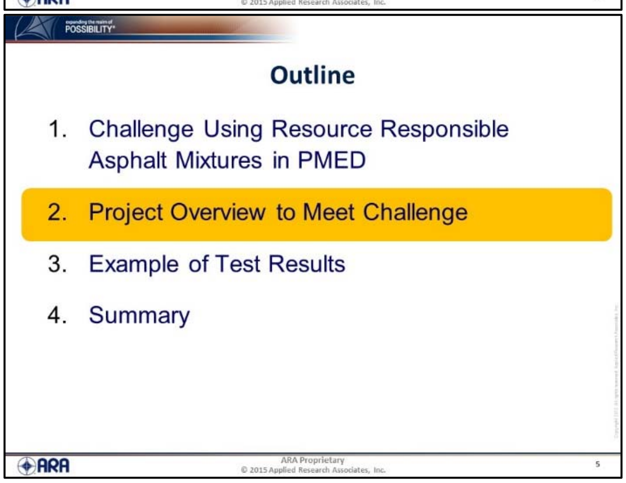
Presentation 13—Harold Von Quintus, ARA

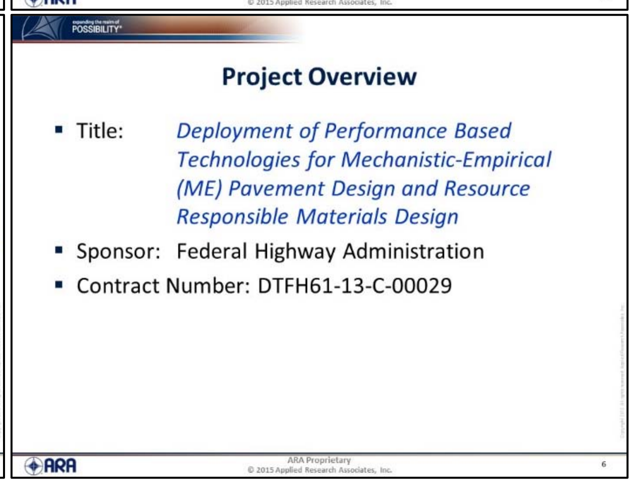












Objectives

1. Expedite adoption of performance-based technologies for ME Pavement Design:
   - New and innovative resource responsible asphalt mixtures (R^2AMs), and practices to improve performance, cost effectiveness, safety, and user satisfaction.
2. R^2AMs; asphalt mixtures containing:
   - High recycled asphalt pavement (RAP)
   - Recycled asphalt shingles (RAS)
   - Ground-tire rubber (GTR)
   - Combinations of reclaimed products

 7

Deliverables/Outcomes

Practitioner's Guides for:

1. **Performance testing** of R^2AMs, such as GTR, RAP, and RAS mixtures.
2. **Use of** performance testing results in PMED software and related analysis
   - Includes appendices showing examples of data interpretation.

In publication, including section 508 conformance.

 8

Asphalt Mixtures included in Test Program

Type	Environmental Zone	Mixture
High Recycle	Wet Freeze	WI STH 73 Surface
High Recycle	Wet Freeze	WI STH 73 Base
High Recycle	Wet No Freeze	NC Surface
High Recycle	Wet No Freeze	NC Intermediate
High Recycle	Wet No Freeze	NC Base
Asphalt Rubber	Wet Freeze	PA Surface
Polymer Modified	Wet Freeze	PA Surface
Asphalt Rubber	Wet No Freeze	FL Dense Graded
Asphalt Rubber	Wet Freeze	MA Gap Graded

 9

Asphalt Mixture Properties for PMED

1. Dynamic Modulus, E*, AASHTO T 342 or T 378
2. Plastic Strain Coefficients, modified AASHTO T 378 (NCHRP 9-30A)
3. IDT Creep Compliance, AASHTO T 322
4. IDT Strength, AASHTO T 322
5. Fatigue Strength (Life) Coefficients, AASHTO T 321
6. Endurance Limit, AASHTO T 321

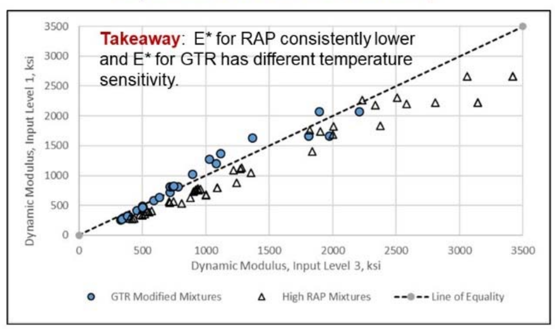
 10

Outline

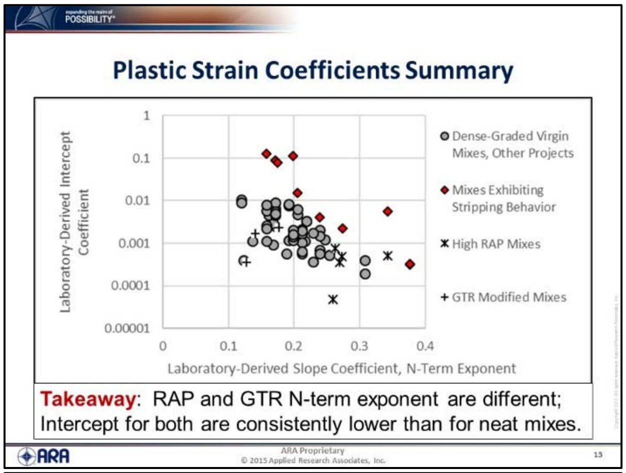
1. Challenge for Resource Responsible Asphalt Mixtures in PMED
2. Project Overview to Meet Challenge
3. Example of Test Results
4. Summary

 11

Dynamic Modulus Summary



 12


Plastic Strain Coefficients Summary
Laboratory-Derived Intercept Coefficient
Laboratory-Derived Slope Coefficient, N-Term Exponent
Dense-Graded Virgin Mixes, Other Projects
Mixes Exhibiting Stripping Behavior
High RAP Mixes
GTR Modified Mixes
Takeaway: RAP and GTR N-term exponent are different; Intercept for both are consistently lower than for neat mixes.
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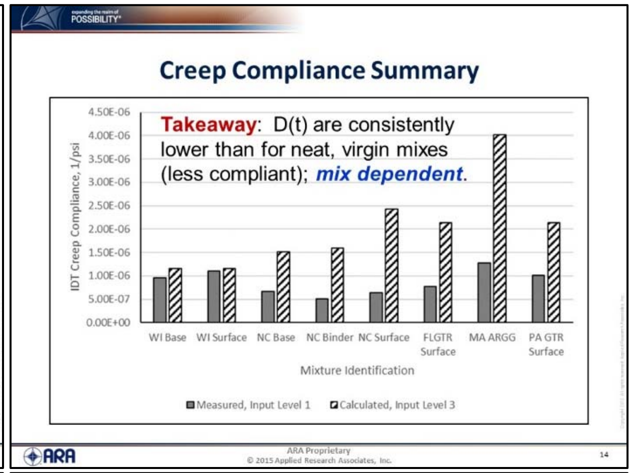
Creep Compliance Summary
Takeaway: D(t) are consistently lower than for neat, virgin mixes (less compliant); mix dependent.
IDT Creep Compliance, 1/psi
WI Base
WI Surface
NC Base
NC Binder
NC Surface
FLGTR Surface
MA ARGG
PA GTR Surface
Mixture Identification
Measured, Input Level 1
Calculated, Input Level 3
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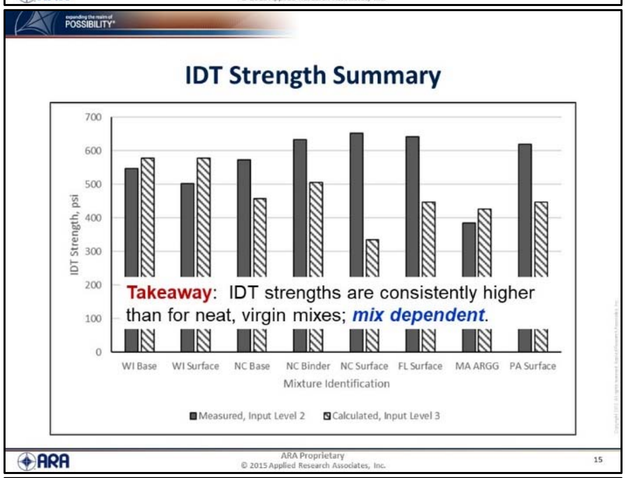
IDT Strength Summary
IDT Strength, psi
Takeaway: IDT strengths are consistently higher than for neat, virgin mixes; mix dependent.
WI Base
WI Surface
NC Base
NC Binder
NC Surface
FL Surface
MA ARGG
PA Surface
Mixture Identification
Measured, Input Level 2
Calculated, Input Level 3
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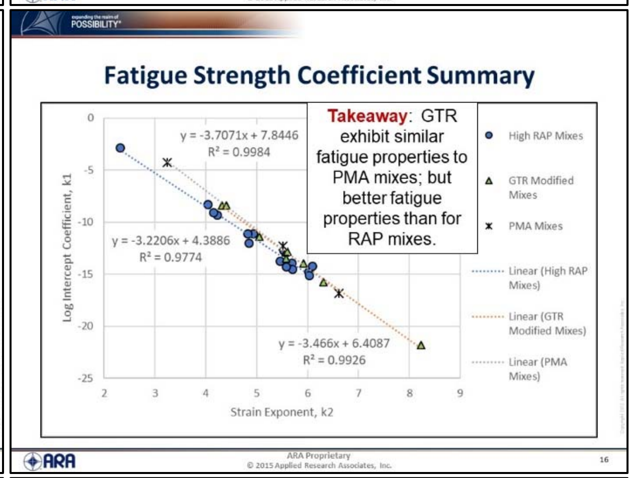
Fatigue Strength Coefficient Summary
Takeaway: GTR exhibit similar fatigue properties to PMA mixes; but better fatigue properties than for RAP mixes.
y = -3.7071x + 7.8446
R² = 0.9984
y = -3.2206x + 4.3886
R² = 0.9774
y = -3.466x + 6.4087
R² = 0.9926
Log Intercept Coefficient, k1
Strain Exponent, k2
High RAP Mixes
GTR Modified Mixes
PMA Mixes
Linear (High RAP Mixes)
Linear (GTR Modified Mixes)
Linear (PMA Mixes)
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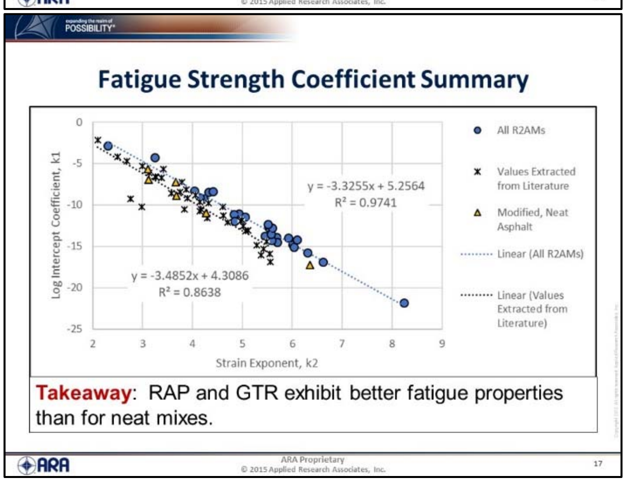
16


Fatigue Strength Coefficient Summary
y = -3.3255x + 5.2564
R² = 0.9741
y = -3.4852x + 4.3086
R² = 0.8638
Log Intercept Coefficient, k1
Strain Exponent, k2
All R2AMs
Values Extracted from Literature
Modified, Neat Asphalt
Linear (All R2AMs)
Linear (Values Extracted from Literature)
Takeaway: RAP and GTR exhibit better fatigue properties than for neat mixes.
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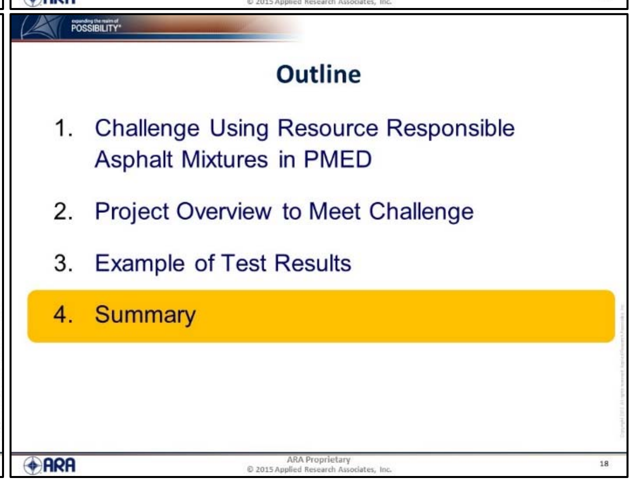
Outline
1. Challenge Using Resource Responsible Asphalt Mixtures in PMED
2. Project Overview to Meet Challenge
3. Example of Test Results
4. Summary
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18

Summary of Observations

Asphalt Mix Property	Distresses Impacted	AASHTO Test Standard	Added Data Manipulation from Laboratory Test Data	Input Level 3 Properties Applicable to R^2AMs
Dynamic Modulus; E*	• Rut depth in asphalt layers • Bottom-up fatigue cracking • Top-down fatigue cracking	T 342; Preferred	***None Required***	***No***
		T 378	***Yes;*** E* needs to be calculated for test temperatures: 14 and 130 °F.	
		TP 132 (small scale specimens, Part 1 of the Guide)		

Summary of Observations

Asphalt Mix Property	Distresses Impacted	AASHTO Test Standard	Added Data Manipulation from Laboratory Test Data	Input Level 3 Properties Applicable to R^2AMs
Plastic Strain Coefficients; k_{1r}, k_{2r}, k_{3r}	• Rut depth in asphalt layers	Modified T 378; [NCHRP 9-30A (Von Quintus, et al., 2013)]	***Yes;*** Section 2.2.2 includes the procedure to determine the values.	***No***

Summary of Observations

Asphalt Mix Property	Distresses Impacted	AASHTO Test Standard	Added Data Manipulation from Laboratory Test Data	Input Level 3 Properties Applicable to R^2AMs
IDT Creep Compliance; D(t)	• Transverse cracks	T 322	***None Required***	***No***
IDT Strength; F_T	• Transverse cracks	T 322	***None Required***	***No***

Summary of Observations

Asphalt Mix Property	Distresses Impacted	AASHTO Test Standard	Added Data Manipulation from Laboratory Test Data	Input Level 3 Properties Applicable to R^2AMs
Fatigue Strength Coefficients; k_{1f}, k_{2f}, k_{3f}	• Bottom-up alligator fatigue cracks	T 321	***Yes;*** Section 2.4.2 includes the procedure to determine the values.	***No***
	• Top-down longitudinal fatigue cracks	T 321		

Summary – Comparison of Mixture Properties

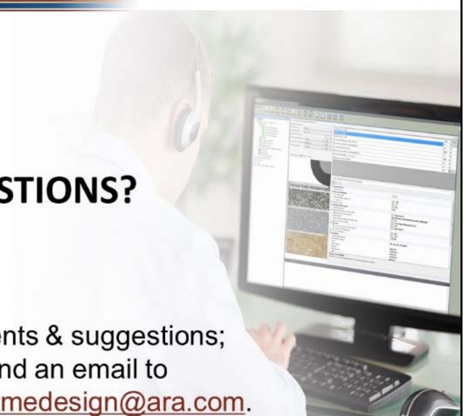
Mixture Type	Plastic Strain Coefficients		
	Log k_{1r}, Intercept	k_{3r}, N Exponent	k_{2r}, T Exponent
Global Default Values: Neat, Virgin Asphalt Mixes	*-2.45*	*0.220*	*3.010*
High Recycle (RAP and/or RAS)	-3.505	0.2718	2.935
GTR Modified	-2.954	0.166	2.472

Summary – Comparison of Mixture Properties

Type of Asphalt Mixture	Fatigue Strength Coefficient		
	Intercept, k_{1f}	Response Exponent, k_{2f}	Modulus Exponent, k_{3f}
Default Values; Neat Asphalt Mixtures	*3.75E-03*	*2.870*	*1.460*
High RAP; V_{be} Less Than 11 percent (4 Mixes)	8.55E-02	4.859	1.601
High RAP; V_{be} More Than 11 percent (1 Mix)	5.93E-02	5.642	2.010
GTR Modified; V_{be} More Than 11 percent (3 Mixes)	3.10E-02	5.693	2.023

Remember

1. Calibration factors for the shift between the laboratory measured/derived values and field observations are assumed to be the same for all asphalt mixes.
2. Suggestion: Include reclaimed mixtures in the agency's materials library, if used on a day-to-day basis.



QUESTIONS?

Comments & suggestions;
Send an email to
pavementmedesign@ara.com.

Presentation 14—Hari Nair, Virginia DOT

VTRC
Virginia Transportation Research Council
We bring innovation to transportation.

Characterization of Base, Intermediate, SMA, and Polymer-Modified Asphalt Mixtures for Pavement ME

Hari Nair, Ph.D., P.E

AASHTO Pavement ME National Users Group Meeting
November 6-7, 2019
New Orleans, Louisiana

Research Team

- Hari Nair, Ph.D., P.E, VTRC
- Girum Merine, P.E, VDOT
- Affan Habib, P.E, VDOT
- Bipad Saha, P.E, VDOT
- Michael Wells, P.E, VDOT

2

Introduction

Virginia Department of Transportation (VDOT)

- Maintains a roadway network of more than 126,000 lane-miles.

~$500 Million Paving Program

Estimated tons of asphalt plant mix produced for VDOT

Year	Base	Intermediate	Surface	SMA	Total
2017	820,642	585,901	3,918,489	297,467	5,622,499
2016	878,533	711,441	3,598,924	351,262	5,540,160

3

Introduction

- VDOT implemented MEPDG in January 2018
- VDOT uses MEPDG procedure to design:
  - ✓ New alignment
  - ✓ Reconstruction
  - ✓ Lane widening

PvD AASHTOWare Pavement ME Design

4

VDOT Pavement ME Design Implementation Steps

1. Material Characterization
2. Traffic Inputs
3. Local Calibration of Performance Models
4. Developing Performance Thresholds
5. ME User Manual
6. Training
7. Identification of Issues
8. Outreach

More Details: 2019 AAPT paper

5

Asphalt Materials Inputs

-Using one SM, IM and BM mix values (Average values)
- SMA and SM E (Polymer Modified) not included
- Created Library functions of material inputs (e.g.: VDOT BM)

-Same rutting calibration coefficients for all layers

-Using Version 2.2

Need for additional testing:
- Very limited BM, IM mixes tested during initial material characterization
- Mixes tested were produced in years 2006-2008
- Spec change (allowed more RAP %)
- Lower gyration level for mix design

6

BM Mixes

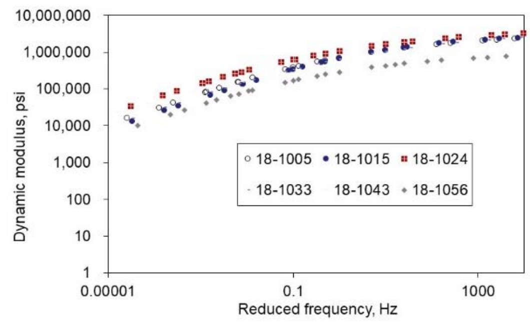
Similar Gradations
Base Binder: PG 64S-22 (PG 64-22)

Input in pavement ME

Mix Type	Asphalt content (% by weight)	RAP %	Extracted Binder Grade	Effective Binder content (by Volume) %
BM 25 D+0.8	5.2%	26%	PG 76-16	12.7%
BM 25 A	4.4%	20%	PG 76-22	11.8%
BM 25 D+0.4	4.7%	26%	PG 70-16	11.6%
BM 25 A	4.6%	35%	PG 76-16	10.7%
BM 25 A	4.6%	35%	PG 82-16	10.8%
BM 25 D+0.4	4.8%	30%	PG 76-16	10.8%

7

Dynamic Modulus- BM Mixes



8

In-place Air Voids for BM mixes

Mix Type	Avg. In place Air voids	Specification
BM 25+0.8%	<2% (one project)	4%
BM 25+0.4%	4%	6%
BM 25	6%	7.8%

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$$

$$C = 10^M$$

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

AC Fatigue Model

9

VDOT Design Criteria/Threshold Limit

Pavement Type	Distress	Limit	Limit at Year
Flexible Pavements	Total Rut Depth	0.26 inches	15 years
	Total Bottom-Up Fatigue Cracking	6 percent	30 years

10

Pavement ME predictions

Mix Type	Air Voids (%)	Fatigue Cracking (%)			Rutting (in)		
		Traffic (Two Way AADTT)			Traffic (Two Way AADTT)		
		2000	4000	8000	2000	4000	8000
BM (Average) Current value	6.3	5.76	5.51	5.89	0.22	0.22	0.23
BM 25 +0.8	2	3.52	3.41	3.58	0.22	0.22	0.23
	4	4.29	4.13	4.37	0.22	0.22	0.23
BM 25+0.4	4	4.13	3.98	4.20	0.22	0.22	0.23
	6	4.95	4.74	5.04	0.22	0.22	0.23
BM 25	6	5.28	5.06	5.39	0.22	0.22	0.23
	6	5.63	5.38	5.75	0.22	0.22	0.23
Thickness:		SM - 2" IM – 2" BM- 7"	SM - 2" IM – 2" BM- 9"	SM - 2" IM – 2" BM- 10"			

Aggregate base: 6", A-7-6 subgrade

11

Rutting Model

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1} T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$$

$$C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$$

Where:

H_{ac} = total AC thickness(in)

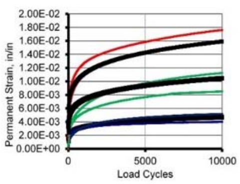
ε_p = plastic strain(in/in)
ε_r = resilient strain(in/in)
T = layer temperature(°F)
N = number of load repetitions

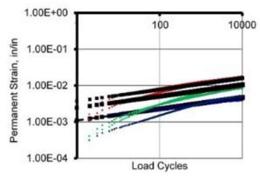
Coefficient	V 2.2	VDOT local Calibration (V 2.2)
K1	-3.35417	-3.35417
K2	1.5606	1.5606
K3	**0.4791**	**0.4791**
β1	1	0.687
β2	1	1
β3	1	1

12

Rutting Model

Repeated Load Permanent Deformation Test: BM Mixes





$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1} T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}$$

13

Rutting Model – BM Mixes

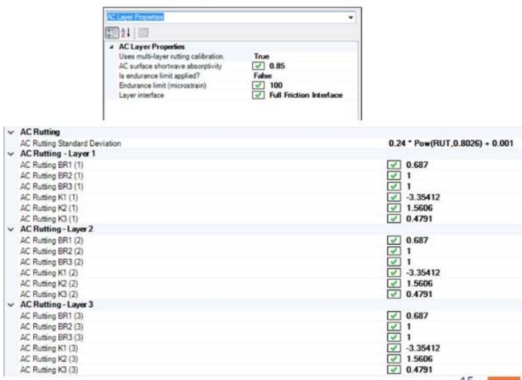
Coefficient	V 2.2	VDOT local Calibration (V 2.2)	V 2.5	VTRC Lab Testing	
				BM 25	BM 25+0.8
K1	-3.35417	-3.35417	-2.45	**-7.66**	**-11.39**
K2	1.5606	1.5606	3.01	**2.41**	**4.08**
K3	0.4791	0.4791	0.22	**0.15**	**0.26**
β1	1	0.687	0.40		
β2	1	1	0.52		
β3	1	1	1.36		

K values- combination of lab and field results

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1} T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}$$

14

Rutting Model



15

Pavement ME fatigue cracking Model

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$$

$$C = 10^M$$

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

AC Fatigue Model

Fatigue cracking model verification- Ongoing

- Beam Fatigue Test
- S-VECD

	VDOT local calibration (V2.2)	V2.5
K1	0.007566	3.75
K2	1.281	1.46
K3	3.95	2.87
βf1	42.87	New values based on thickness
βf2	1	0.88
βf3	1	1.38

IM Mixes

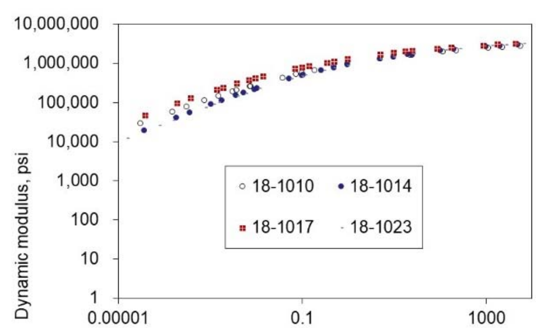
Similar Gradations
Base Binder: PG 64S-22 (PG 64-22)

Mix Type	Asphalt content (% by weight)	RAP %	Extracted Binder Grade	Effective Binder content (by Volume) %
IM-1	4.7%	30%	PG 76-16	11.3%
IM-2	4.9%	10%	PG 70-16	11.3%
IM-3	5.0%	30%	PG 76-16	11.9%
IM-4	4.8%	26%	PG 70-22	11.7%

Average In-place air voids: 6%

17

Dynamic Modulus- IM Mixes



18

Pavement ME predictions

Mix Type	Air Voids (%)	Fatigue Cracking (%)			Rutting (in)		
		Traffic (Two Way AADTT)			Traffic (Two Way AADTT)		
		2000	4000	8000	2000	4000	8000
IM (Average) Current value	5.3	5.76	5.56	5.89	0.22	0.22	0.24
IM-1	6	5.71	5.52	5.86	0.20	0.20	0.21
IM-2	6	5.67	5.51	5.85	0.19	0.20	0.21
IM-3	6	5.72	5.47	5.82	0.21	0.19	0.20
IM-4	6	5.71	5.52	5.86	0.20	0.21	0.22

19

Rutting Model –IM Mixes

Coefficient	V 2.2	VDOT local Calibration (V 2.2)	V 2.5	VTRC Lab Testing
K1	-3.35417	-3.35417	-2.45	-7.62
K2	1.5606	1.5606	3.01	2.42
K3	0.4791	0.4791	0.22	0.15
β1	1	0.687	0.40	
β2	1	1	0.52	
β3	1	1	1.36	

K values- combination of lab and field results

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1} T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}$$

20

SMA and SM E Mixes

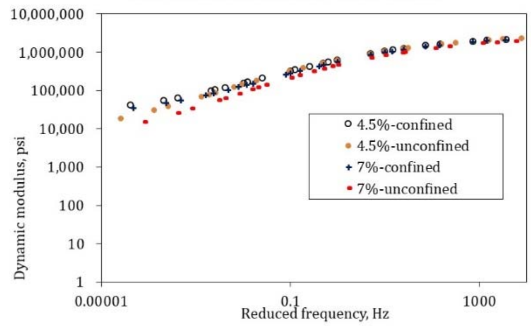
SMA	Asphalt Content (%)	SM E	Asphalt Content (%)
1	6.4%	1	5.5%
2	6.4%	2	5.9%
3	6.4%	3	5.7%
4	6.8%	4	5.2%
5	6.7%	5	5.8%
6	6.7%	6	5.4%


SMA

RAP ~15%
Base Binder: PG 64E-22 (PG 76-22)

21

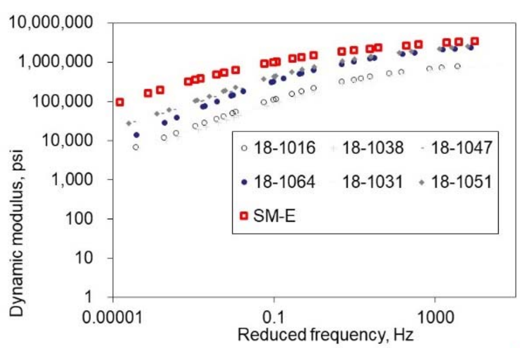
Dynamic Modulus- SMA
Confinement and Air void effect



Average in-place air voids:4.5%, Specification:6%

22

Dynamic Modulus- SMA Vs SM E



23

Rutting Model –SMA Mixes

Coefficient	V 2.2	VDOT local Calibration (V 2.2)	V 2.5	VTRC Lab Testing (From two mixes)
K1	-3.35417	-3.35417	-2.45	-15.94
K2	1.5606	1.5606	3.01	6.25
K3	0.4791	0.4791	0.22	0.55
β1	1	0.687	0.40	
β2	1	1	0.52	
β3	1	1	1.36	

Tests on-going for SMA and SM E mixes

24

Observations

- Dynamic Modulus as measured in the lab is not enough to explain the difference among mixes

- Continue with average dynamic modulus values for BM and IM

- Mix specific rutting coefficients?

- Separate rutting calibration for SMA mixes?

25

Future Steps

- Implementing MEPDG on rehabilitation design

- Adopting the latest version
  Version 2.2 to 2.5

- Sensitivity analysis for new versions
  - NARR to MERRA climate data
  - Changes that will adjust the models based on NCHRP studies
  - Local Calibration of Rutting and Cracking Model – V2.5

26

Thank You

Questions?

Hari Nair, Ph.D., P.E
Senior Research Scientist, VTRC
harikrishnan.nair@vdot.virginia.gov

27

Presentation 15—Mohammadreza Mirzahosseini, Purdue University

Sensitivity of Fatigue Cracking Models to Effective Binder Content

4th Annual Pavement ME Users Group Meeting

Tommy Nantung, Jusang Lee, Jan Olek,
Mohammadreza Mirzahosseini, and Jongmyung Jeon

New Orleans, November, 2019

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Introduction

- The main contributing factors to pavement performance are HMA materials and mix design, pavement structure design, asphalt concrete (AC)–mix production, AC–mix construction, climate condition.
- The effect of material quality on performance of the hot-mix asphalt (HMA) pavement over its lifetime is important.
- As the first possible strategy in improving pavement performance, many researchers have looked into improving the material quality and mix design.
- Among the material quality measures affecting the pavement performance, VMA_{Design}, a basic yet important characteristic of asphalt pavement, plays a key role.
- When designing a pavement structure, a designer uses typical materials inputs with assuming that material or mix quality meets requirements.
- This study varied mix quality (in terms of VMA_{Design}) and evaluated the Pavement ME sensitivity to it.

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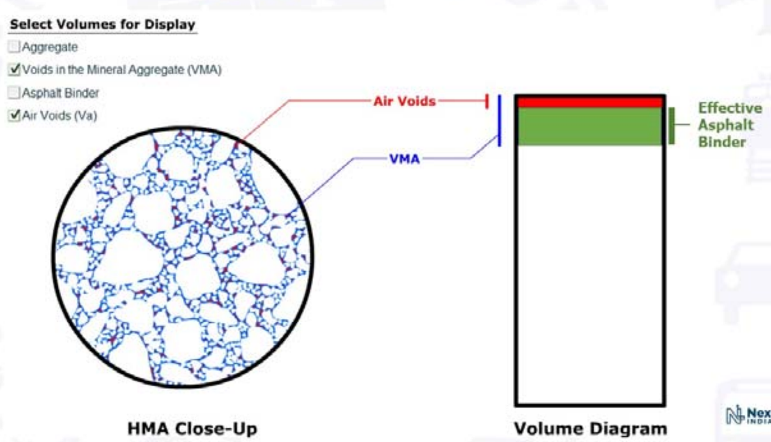
2

Voids in Mineral Aggregate (VMA)



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3

VMA Measurement and Requirement

$$VMA = 100 - \frac{G_{mb} \times P_s}{G_{sb}}$$

Where:

VMA = voids in the mineral aggregate, percent of bulk volume

G_{sb} = bulk specific gravity of total aggregate

G_{mb} = bulk specific gravity of compacted mixture

P_s = aggregate content, percent by total mass of mixture

Standard Specification for Superpave Volumetric Mix Design

AASHTO Designation: M 323-17[1]

Technical Subcommittee: 2d, Proportioning of Asphalt–Aggregate Mixtures

Release: Group 3 (July)

AASHTO

Table 7—Superpave asphalt mixture Design Requirements

Design ESALs,[a] million	Required Relative Density, Percent of Theoretical Maximum Specific Gravity			Voids in the Mineral Aggregate (VMA), % Minimum — Nominal Maximum Aggregate Size, mm						Voids Filled with Asphalt (VFA) Range,[b] %	Dust-to-Binder Ratio Range[c]
	$N_{initial}$	N_{design}	N_{max}	37.5	25.0	19.0	12.5	9.5	4.75		
<0.3	≤91.5	96.0	≤98.0	11.0	12.0	13.0	14.0	15.0	16.0	70–80[d,e]	0.6–1.2
0.3 to <3	≤90.5	96.0	≤98.0	11.0	12.0	13.0	14.0	15.0	16.0	65–78[f]	0.6–1.2
3 to <10	≤89.0	96.0	≤98.0	11.0	12.0	13.0	14.0	15.0	16.0	65–75[e,f,g]	0.6–1.2
10 to <30	≤89.0	96.0	≤98.0	11.0	12.0	13.0	14.0	15.0	16.0	65–75[e,f,g]	0.6–1.2
≥30	≤89.0	96.0	≤98.0	11.0	12.0	13.0	14.0	15.0	16.0	65–75[g]	0.6–1.2

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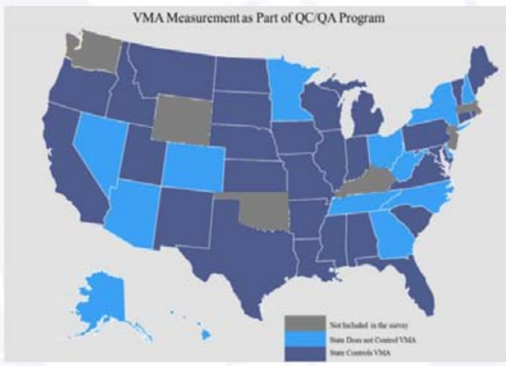
4

VMA in QC/QA

- According to a recent study in 2018, **32 states use VMA** as part of their **QC/QA programs**.



Ahmed Faheem (2018)

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5

Problem Statement

Is Pavement ME fatigue crack models sensitive enough to VMA/V_{be}?

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6

Mixes

- Mix design with varying VMAs from the minimum requirements
  - VMA minimum requirements
    - 15% VMA for 9.5 mm mixes
    - 13% VMA for 19 mm mixes
  - VMA deficiencies (ΔVMA_{Design})
    - Approximately 0%, −1.5%, and −3.0%
  - Gyratory compaction effort
    - N_{design} = 100
  - Air voids are 4% for all mixes.
  - Aggregates: crushed aggregates of limestone and natural sand
  - PGs
    - 70-22 for 9.5 mm mixes
    - 64-22 for 19 mm mixes

Mix Type	Design (Values from the Pills)				
	VMA_{Design}	ΔVMA_{Design}	V_{be}	V_a	P_b
9.5 A	15.3%	0.3%	11.20%	4.1%	6.3%
9.5 S	13.4%	-1.6%	9.50%	3.9%	5.3%
9.5 D	12.1%	-2.9%	8.00%	4.1%	4.7%
19 A	13.0%	0.0%	9.00%	4.0%	5.5%
19 S	11.6%	-1.4%	7.50%	4.1%	4.6%
19 D	10.1%	-2.9%	6.00%	4.1%	4.0%

7

Dynamic Modulus (|E*|) Test for MEPDG Leve1 Inputs

Standard Method of Test for

Determining the Dynamic Modulus for Asphalt Mixtures Using Small Specimens in the Asphalt Mixture Performance Tester (AMPT)

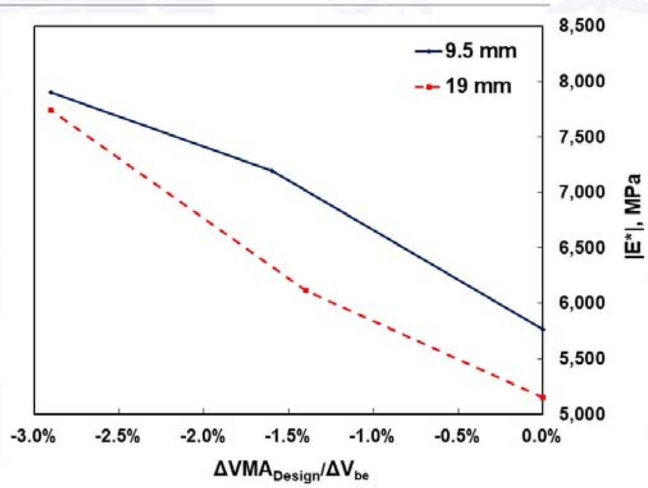
AASHTO Designation: TP XX-XX

- Specimen size: 38 mm (1.5 in.) diameter by 110 (4.33 in.) tall
- Specimen air voids (%): 7±0.5
- Temperatures (°C): 4, 20, and 40
- Frequencies (Hz): 10, 1, and 0.1

Mix Type	|E*| Specimen (Cylindrical Cores)	
	V_a	V_{be}
9.5 A	7.0	10.9
9.5 S	6.8	9.2
9.5 D	6.8	7.8
19 A	7.0	8.7
19 S	6.8	7.1
19 D	6.8	5.4

|E*| at 25°C and 10 Hz

- 9.5 mm NMAS mixes had higher |E*| than 9.5 mm NMAS mixes.
- Another point is the effect of ΔVMA_{Design} level on |E*| variability in each mix. Within the VMA_{Design} range used for this study, the more negative ΔVMA_{Design} of a given mix, which means lower effective binder volume (V_{be}), the higher the modulus of the mix.



Pavement ME Modeling

- Analysis years: 20
- Location: Indianapolis
- 7,000 AADTT≈ 30 million ESALs (threshold between CAT 4 and CAT 5)
- Two ways and one lane per direction
- Asphalt full-depth pavement
  - AC thicknesses: 1.5" Surface + 2.5" Intermediate + 5" Base = 9 " in total
- Subgrade annual representative M_r = 8,900 psi

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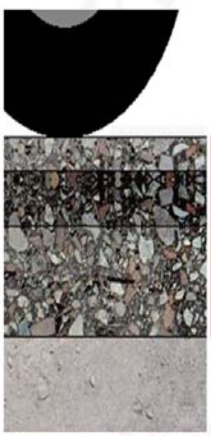
10

AC Input Cases



Case 1

AC Surface	9.5 A
	9.5 SD
	9.5 D
AC Intermediate	19 A
AC Base	19 A

Case 2

AC Surface	9.5 A
AC Intermediate	19 A
	19 SD
	19 D
AC Base	19 A

Case 3

AC Surface	9.5 A
AC Intermediate	19 A
AC Base	19 A
	19 SD
	19 D

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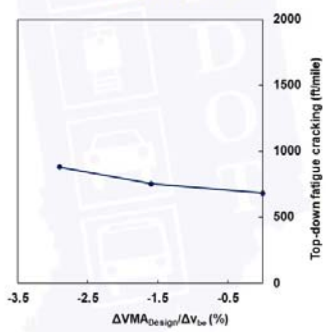
11

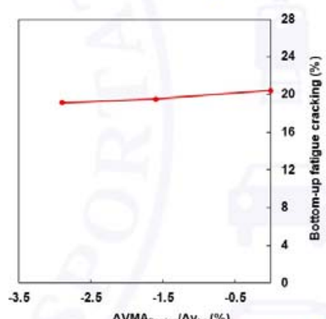
Case 1

AC Surface	9.5 A
	9.5 SD
	9.5 D
AC Intermediate	19 A
AC Base	19 A

Top-down



Bottom-up



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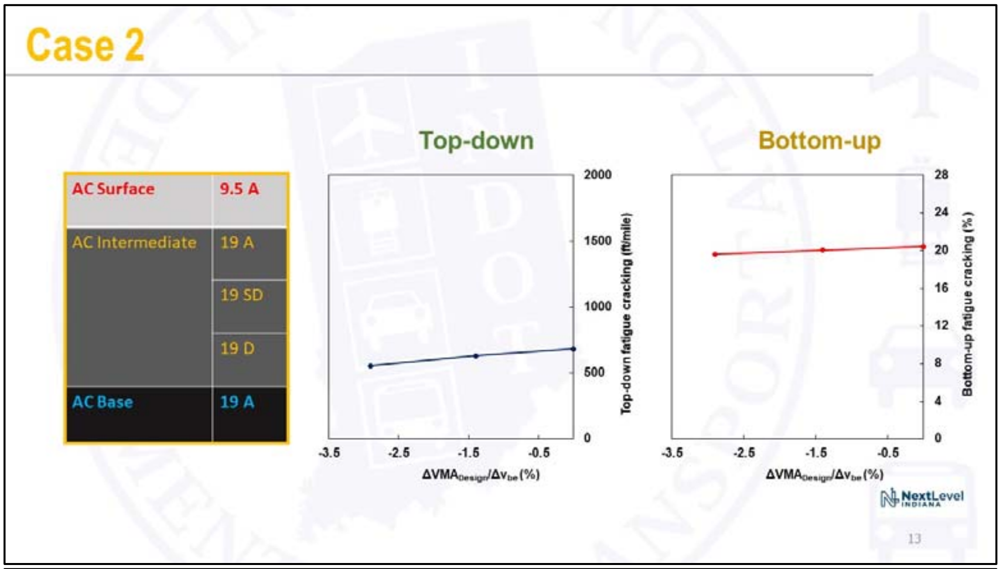
12


Case 2
Top-down
Bottom-up
AC Surface
9.5 A
AC Intermediate
19 A
19 SD
19 D
AC Base
19 A
Top-down fatigue cracking (ft/mile)
ΔVMA_Design/Δv_be (%)
Bottom-up fatigue cracking (%)
ΔVMA_Design/Δv_be (%)
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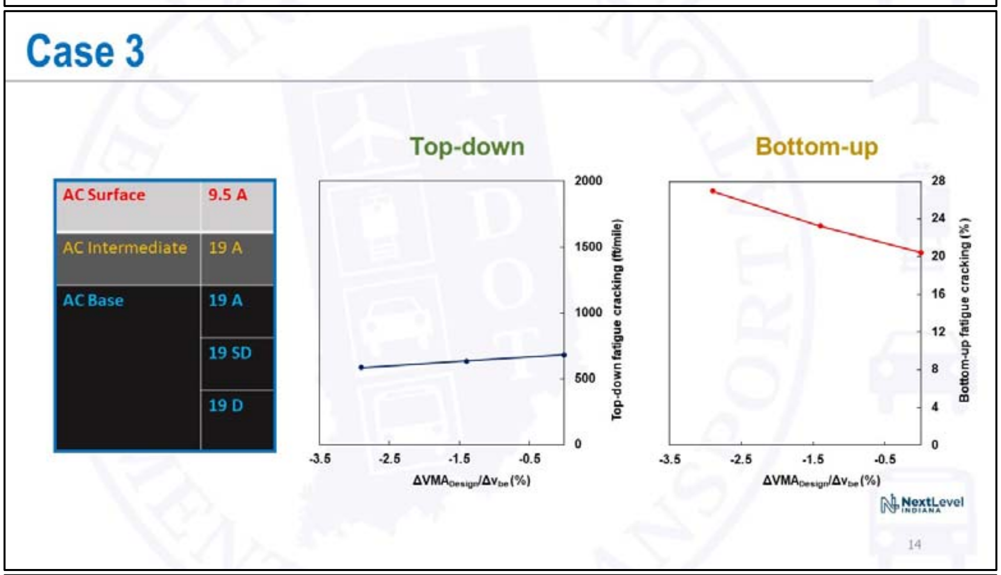
13


Case 3
Top-down
Bottom-up
AC Surface
9.5 A
AC Intermediate
19 A
AC Base
19 A
19 SD
19 D
Top-down fatigue cracking (ft/mile)
ΔVMA_Design/Δv_be (%)
Bottom-up fatigue cracking (%)
ΔVMA_Design/Δv_be (%)
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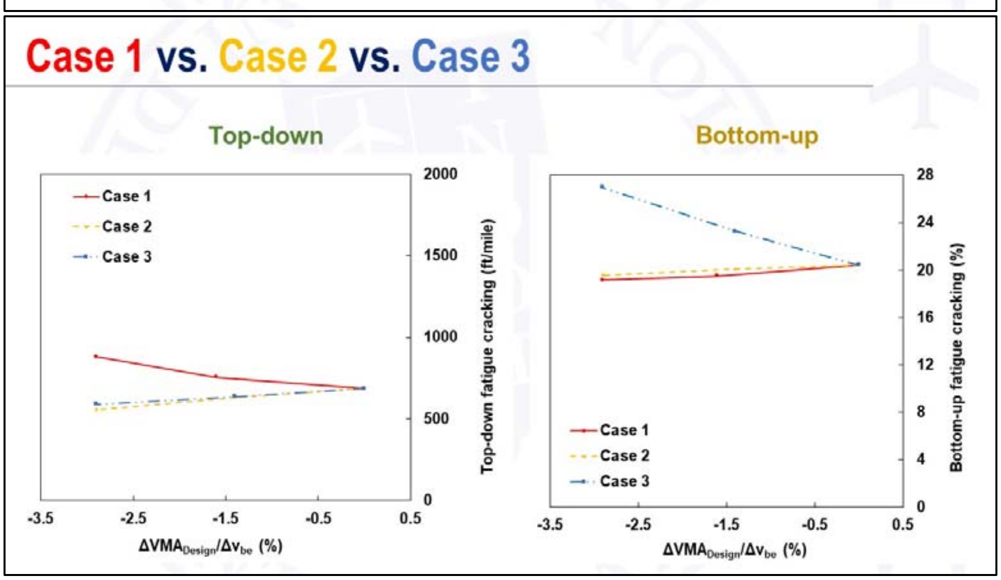
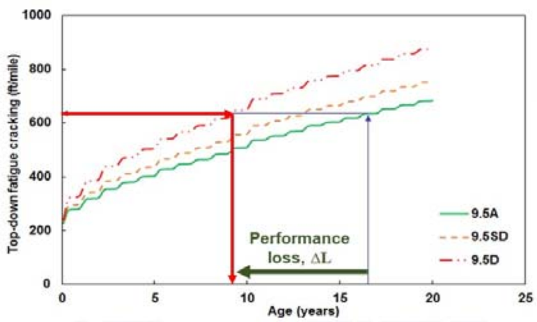
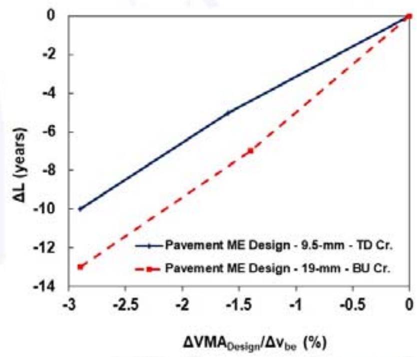
14


Case 1 vs. Case 2 vs. Case 3
Top-down
Bottom-up
Case 1
Case 2
Case 3
Top-down fatigue cracking (ft/mile)
ΔVMA_Design/Δv_be (%)
Bottom-up fatigue cracking (%)
ΔVMA_Design/Δv_be (%)

Life Reduction Due to VMA deficiency





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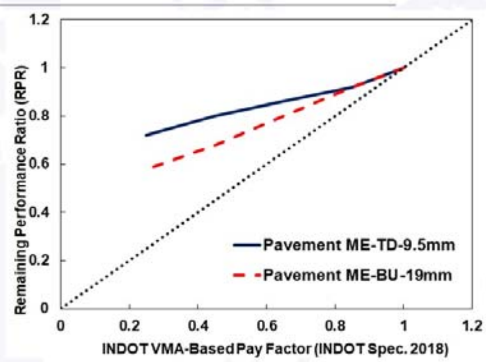
16

INDOT VMA Pay Factor

- Pavement fatigue performance loss appears to form a rational base for establishing pay factors for as-constructed pavements.
- The results of the life reduction model were compared to the INDOT VMA pay factor presented in section 401.19 (INDOT, 2018) to **evaluate the reasonableness** of the model outputs.
- life reduction values were then converted to **remaining performance ratio (RPR)**:

$$RPR = \frac{20 - Life\ Reduction}{20}$$



- Compared to pay factors specified by both INDOT's Standard Specifications in 2018, life reduction values obtained in this study offer **higher** RPR. This is because RPRs are **merely** based on two types of cracking (i.e., TD and BU cracking), while pavement performance depends on many other types of parameters.
- INDOT uses one pay factor for different pavement courses (9.5 mm NMAS and 19 mm NMAS mixes), while the finding of this comparative study showed that RPR can be a function of mix type.

Summary

- Among the different cases we studied, TD and BU cracking models of Pavement ME are just sensitive to VMA/V_{be} deficiency in surface course (TD-Case I) and base course (BU-Case III), respectively. For other scenarios, Pavement ME did not show sensitivity to VMA/V_{be} deficiency.
- For the cases to which Pavement ME showed sensitivity, the ΔVMA_{Design} deficiency could reduce pavement cracking performance up to 50% for TD cracking and 60% for BU cracking.
- A comparison between the VMA pay factor in INDOT's Standard Specifications and RPRs supports the reasonableness of the performance reduction model developed in this study.

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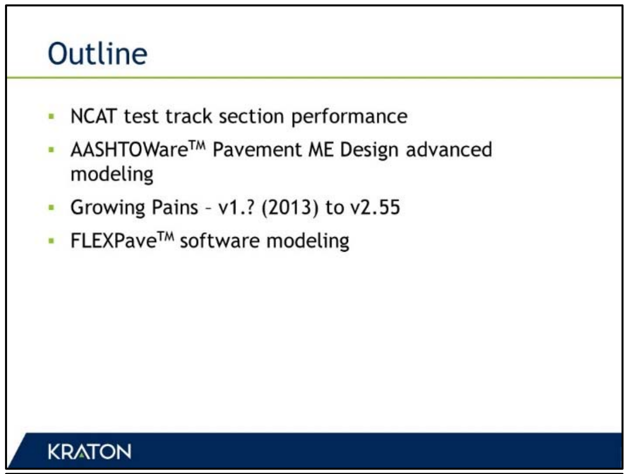
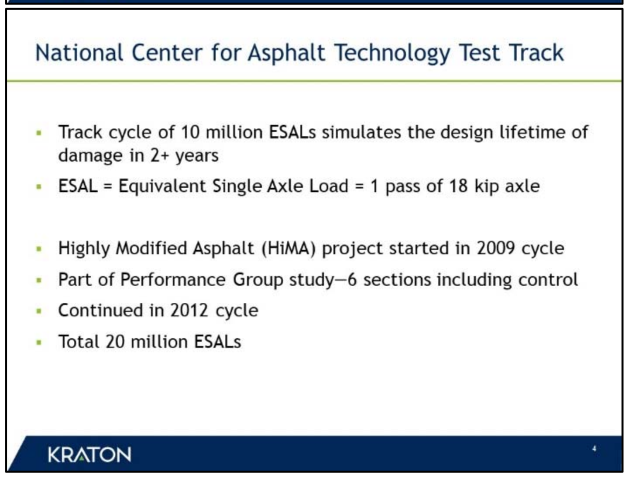
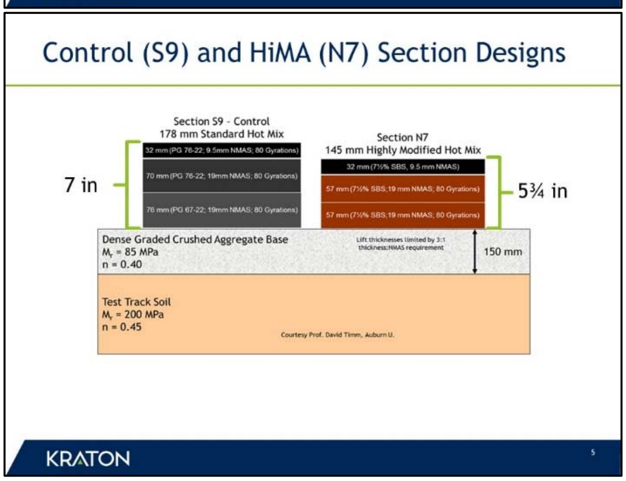
18

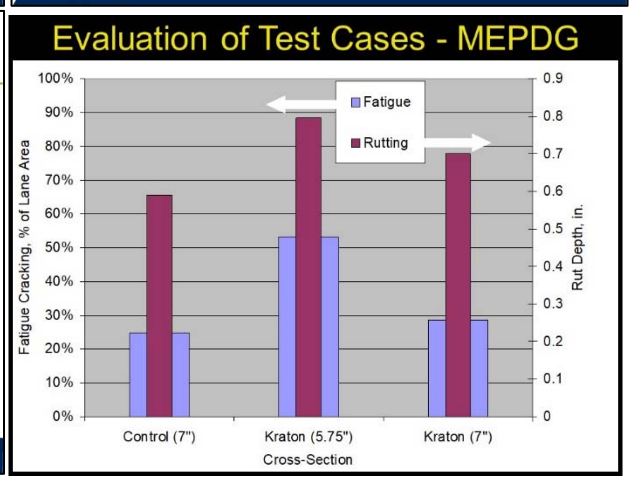

Thanks!
Questions?

Presentation 16—Bob Klutz, Kraton Polymers







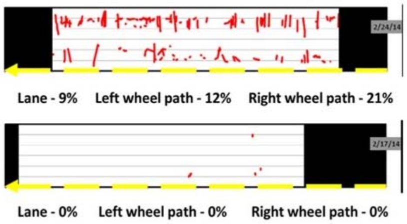


Crack Maps at 17 Million ESALs

3/14 Rutting | 2/14 Crack Maps

S9 6.0 mm

N7 1.6 mm



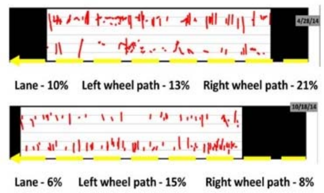
KRATON 7

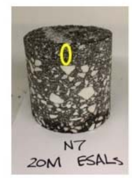
N7 Crack Map at 20 Million ESALs

S9 resurfaced at 17 million ESALs

S9

N7





N7 cracking is superficial top-down

KRATON 8

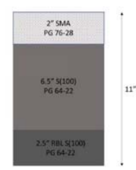
Kiewit

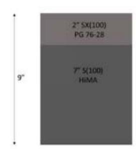
How do you implement new technology using Pavement ME?

Kiewit

Case Study: HiMA Asphalt Layer

- Traditional Design
- Innovative Design





M_R = 8,750 psi

M_R = 8,750 psi

Kiewit

Pavement Design

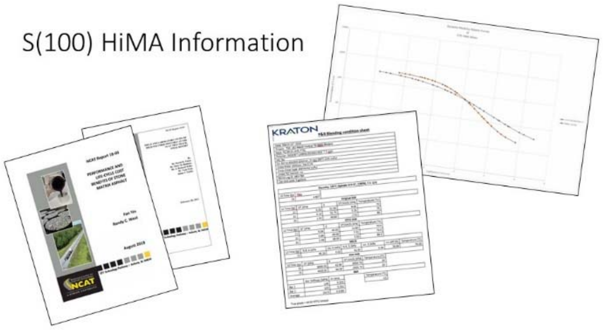
- Pavement Design objective: Using Pavement ME shows that the "innovative" design is equal or better than the "traditional" design
- Pavement ME Distress Models being evaluated:
  - Ride / IRI
  - Total Rut Depth
  - Thermal Cracking
  - AC Bottom-Up Cracking (Alligator)

Kiewit

Pavement ME Inputs

- Traditional Pavement
  - Surface Mix—SMA PG76-28
    - ❖ Agency defined Level 1 Inputs
      - ✓ Mixture Volumetrics
      - ✓ Binder Characterization
      - ✓ Mixture Dynamic Modulus
  - Intermediate Mix—S(100) PG64-22
    - ❖ Agency defined Level 1 Inputs
      - ✓ Mixture Volumetrics
      - ✓ Binder Characterization
      - ✓ Mixture Dynamic Modulus
  - Bottom Mix—RBL S(100) PG64-22
    - ❖ Level 3 Inputs
- Innovative Pavement
  - Surface Mix—SX(100) PG76-28
    - ❖ Agency defined Level 1 Inputs
      - ✓ Mixture Volumetrics
      - ✓ Binder Characterization
      - ✓ Mixture Dynamic Modulus
  - Intermediate Mix—S(100) HiMA
    - ❖ Laboratory determined Level 1 Inputs
      - ✓ Mixture Volumetrics
      - ✓ Binder Characterization
      - ✓ Mixture Dynamic Modulus

S(100) HiMA Information



Pavement ME Modeling

- Traditional Pavement
  - ✓Level 1 Inputs
    - Surface (PMA Mixture)
    - Intermediate (Non PMA Mixture)
    - Bottom (Non PMA Mixture)
  - ✓Agency PMA Local Calibration
  - ✓Agency Non PMA Local Calibration
- Innovative Pavement
  - ✓Level 1 Inputs
    - Surface (PMA Mixture)
    - Lower (HiMA Mixture)
  - ✓Agency PMA Local Calibration
  - ✓HiMA Calibration

>>>Pavement ME only allows one set of calibration factors
How would you model???

Pavement ME Models – Permanent Deformation

- $\Delta_{p(HMA)} = \varepsilon_{p(HMA)} h_{HMA} = \beta_{r1} k_z \varepsilon_{r(HMA)} 10^{k_{r1}} \eta^{k_{r2}\beta_{r2}} T^{k_{r3}\beta_{r3}}$
- Where:
- $\Delta_{p(HMA)}$ = Accumulated vertical plastic (permanent) deformation
- $\varepsilon_{p(HMA)}$ = Accumulated axial plastic strain
- $\varepsilon_{r(HMA)}$ = Calculated mid-depth resilient strain
- h_{HMA} = Thickness
- η = number of axle load repetitions
- T = pavement temperature
- k_z = depth confinement factor
- $k_{r1,r2,r3}$ = global field calibration parameters
- $\beta_{r1,r2,r3}$ = local or mixture field calibration factors

KRATON 15

Pavement ME Models – Fatigue Damage – Alligator (bottom up) and Longitudinal (top down)

- $N_{f\text{-}HMA} = k_{f1}(C)(C_H)\beta_{f1}(\varepsilon_t)^{k_{f2}\beta_{f2}}(E_{HMA})^{k_{f3}\beta_{f3}}$
- Where:
- $N_{f\text{-}HMA}$ = Allowable axle load applications
- ε_t = Tensile strain
- E_{HMA} = Dynamic modulus measured in compression
- $k_{f1,f2,f3}$ = Global field calibration parameters
- $\beta_{f1,f2,f3}$ = local or mixture field calibration factors
- C = volumetrics parameter (asphalt content and air voids)
- C_H = Thickness correction term (depends on type of cracking)

KRATON 16

Pavement ME Design – Design Levels

- There are three design level options for MEPDG:

Level 3 – Just mix gradation and binder PG grade

Level 2 – Mix gradation and binder modulus data

Level 1 – Mix modulus data

KRATON 17

Pavement ME Design – Level 1 Input

- Mixture mastercurve – dynamic modulus at 10, 40, 68, 100 & 130 °F. Usual practice is to only run middle 3 temps, but for HiMA the standard sigmoidal fit may not be very good so we require the 130 °F data.
- Endurance limit – default is 100 $\mu\varepsilon$
- Binder mastercurve – dynamic modulus at same temperatures
- Indirect tensile data at 0 °C, -10 °C and -20 °C for thermal cracking
- For unbound base – Poisson's ratio and modulus or CBR
- For subgrade – same

KRATON 18

ME Design Strategy for HiMA

- Level 1 Design
- Mixture mastercurve including 130 °F data.
- Endurance limit from fatigue testing
- Revised fatigue global calibration factors from fatigue testing
- Revised rutting global calibration factors from deformation testing

KRATON 19

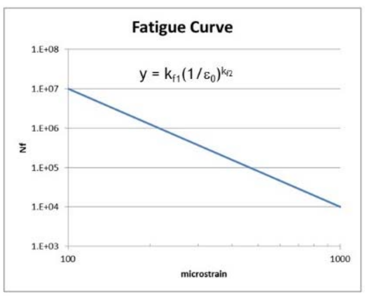
Fatigue Calibration

- Determine N_f versus strain curve
- Fit k_{f1} and k_{f2} to curve
- Measure modulus and reverse fit k_{f3}
- Extrapolate to N_f = 50MM for endurance limit

- Options for fatigue testing:
- Standard 4 point bending beam
- NCSU S-VCED model and procedure using AMPT
- AAT S-VECD model and procedure using AMPT

KRATON 20

AMPT or Four-Point Bending Beam Fatigue Curve



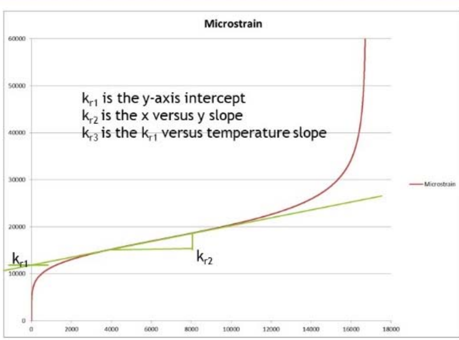
KRATON 21

Rutting Calibration – NCHRP 9-30A Protocol

- This is the 9-30A protocol, but similar data can be generated with, e.g., Hamburg or APA
- Run AMPT Flow Number (F_n) at 3 temperatures, 70 psi load, 10 psi confinement. Temperatures are 20 °C, (LTTP 50% reliability temp -5 °C) and midpoint. Typical would be 20 °C, (64-5) = 59 °C and 39.5 °C
- k_{r1} = y axis intercept of secondary flow tangent
- k_{r2} = slope of secondary flow
- k_{r3} = slope of k_{r1} versus temperature plot

KRATON 22

AMPT Flow Number Data Microstrain Versus Time



KRATON 23

Timeline for Complete Project

- AMPT E* at 4 temperatures, 2 specimens – 1-2 days
- AMPT push-pull fatigue test protocol – 2 days
- AMPT F_n testing – 2 days
- So full material property input can be generated in a little more than a week.
- Flexible test methods can be selected per regional preferences.

KRATON 24

Crucial Point for Pavement ME Design

- Note that we adjusted the global calibration parameters in this analysis, not the local calibration factors.
- Local calibration requires data from actual local pavement performance and materials which we do not have.
- Consequently, we cannot do an "absolute" pavement design and predict performance.
- What we can do is a relative pavement design, comparing a HiMA pavement to a standard one, and give a high confidence expectation of relative performance.

KRATON 25

Fatigue Calibration Factors for Section N7

	k_{f1}	k_{f2}	k_{f3}
MEPDG Standard Values	7.566E-3	3.9492	1.2810
S9 Calculated Values	1.4964E-2	3.9492	1.2810
N7 Calculated Values	7.5721E-5	7.3135	2.3655
Ratios	0.9762	0.7595	0.0491
N7 Adjusted Values	7.386E-3	2.9994	0.0630

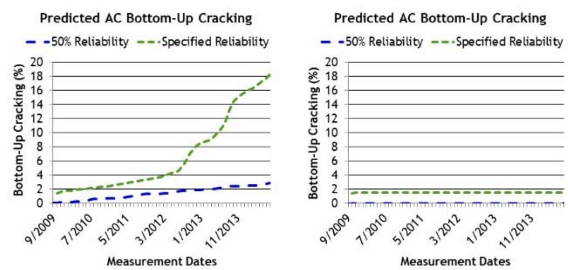
KRATON 26

Rutting Calibration Factors for Section N7

	k_{r1}	k_{r2}	k_{r3}
MEPDG Standard Values	-3.3541	0.4719	1.5606
S9 Calculated Values	-3.7902	0.4719	1.5606
Ratios	0.8045	0.4791	1.0000
N7 Adjusted Values	-2.6985	0.2261	1.5606

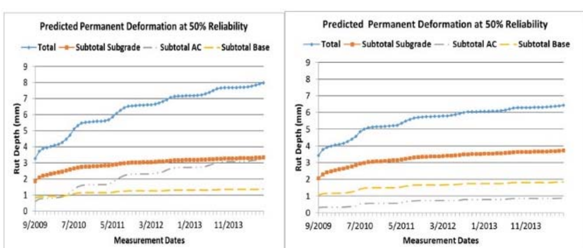
KRATON 27

S9 Predicted Cracking N7



KRATON 28

S9 Predicted Rutting N7



KRATON 29

Predicted damage summary

Pavement Distress	S9	N7
Total Permanent Deformation, mm	10.2	8.4
AC Permanent Deformation, mm	6.4	1.5
Bottom-Up Cracking, % Area	18	1.5

Measured damage summary

Pavement Distress	S9	N7
Total Permanent Deformation, mm	6.0	1.6
AC Permanent Deformation, mm	6.0	1.6
Bottom-Up Cracking, % Area	10	0

KRATON 30

PMED v1.? (2013) versus v2.55

- Be careful with calibration factor identity!
- Local calibration factors now start with a ≠1 value
- Global calibration factors versus project calibration factors - which should be adjusted or does it matter?
- MERRA database takes some learning

KRATON 31

PMED v1.? (2013) versus v2.55

N7	Target	v1	v2.55 β=def	v2.55 β=1
Terminal IRI (in/mile)	172	105	100	107
Total deformation (in)	0.75	0.33	0.23	0.36
Bottom up cracking (%)	25	1.45	1.45	2
Thermal cracking (ft/mile)	1000	27	440	440
Top Down cracking (ft/mile)	2000	378	260	3500
AC deformation (in)	0.25	0.06	0.01	0.17
S9				
Terminal IRI (in/mile)	172	114	108	470
Total deformation (in)	0.75	0.4	0.34	8
Bottom up cracking (%)	25	18	9	100
Thermal cracking (ft/mile)	1000	27	440	440
Top Down cracking (ft/mile)	2000	8000	5200	14000
AC deformation (in)	0.25	0.19	0.17	8

KRATON 32

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FlexPAVE™ 1.0

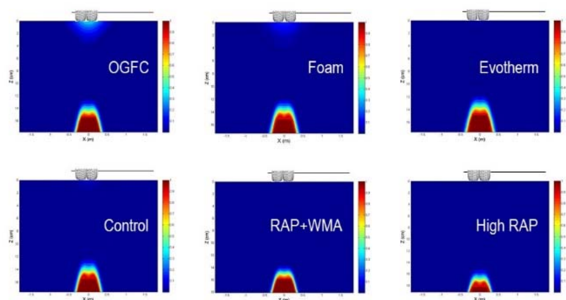
- Three dimensional layered viscoelastic analysis for moving loads and thermal stresses
- Fatigue performance analysis based on Viscoelastic Continuum Damage (VECD) Model
- Rutting performance analysis based on the shift model
- Support for multiple axle and multiple wheel loading
- Integrated with EICM software to capture temperature variation for thermal stress analysis and material properties
- Integrated GUI that includes pre and post processors

33

NC STATE UNIVERSITY

FlexPAVE™ Simulation

NCAT Test Track 2009 Performance Group



34

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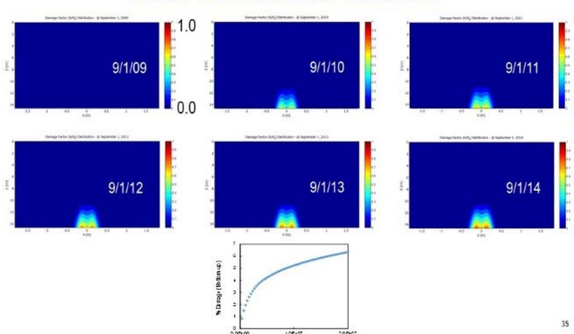
FlexPAVE™ Simulation

NCAT Test Track 2009 Section N7



35

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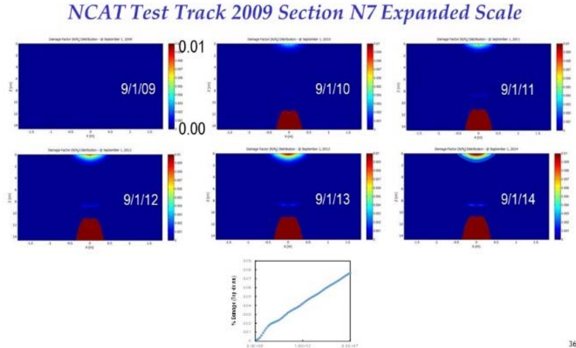
FlexPAVE™ Simulation

NCAT Test Track 2009 Section N7 Expanded Scale



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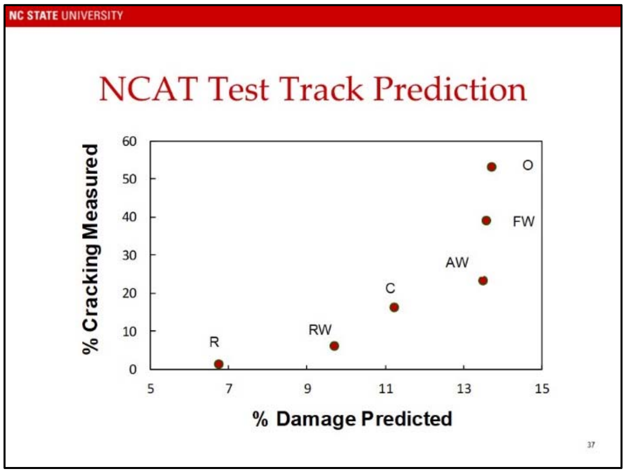
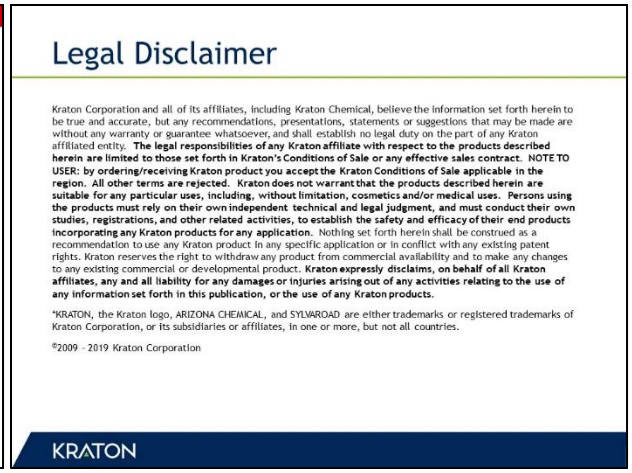

NC STATE UNIVERSITY
NCAT Test Track Prediction
% Cracking Measured
0
10
20
30
40
50
60
5
7
9
11
13
15
% Damage Predicted
R
RW
C
AW
FW
O
37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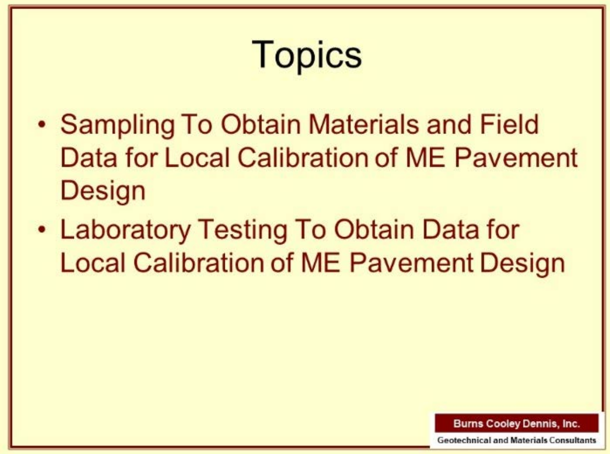
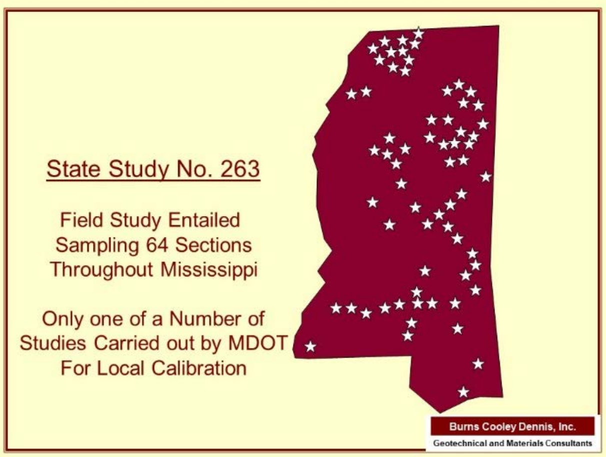
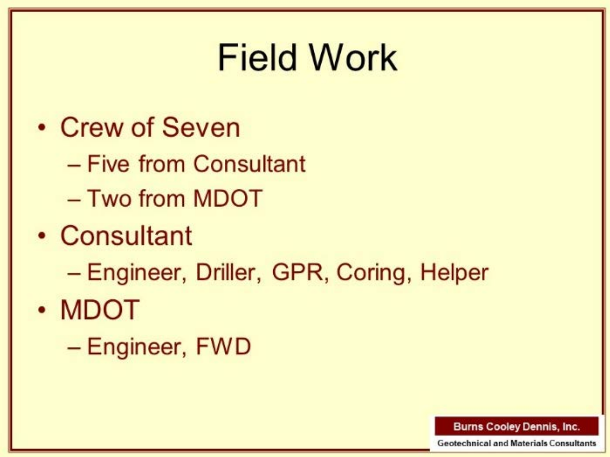
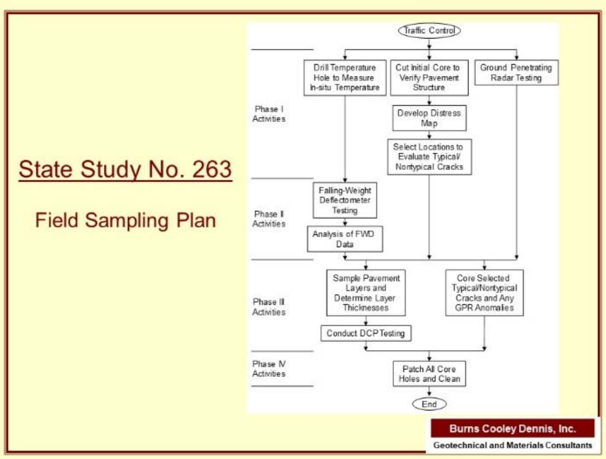
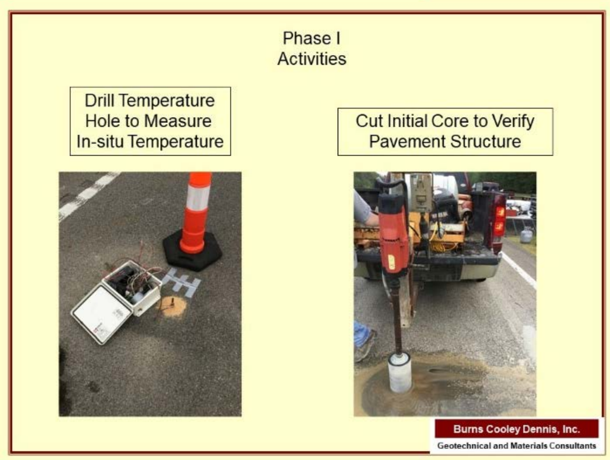
Presentation 17—Allen Cooley, Burns Cooley Dennis

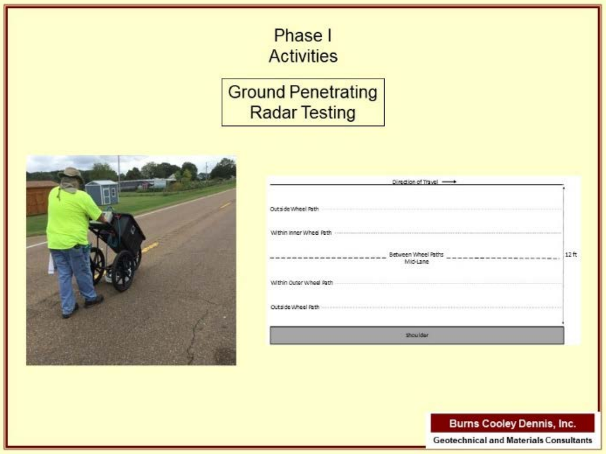











Phase I
Activities
Ground Penetrating
Radar Testing
Direction of Travel
Outside Wheel Path
Within Inner Wheel Path
Between Wheel Paths
Mid-Lane
12 ft
Within Outer Wheel Path
Outside Wheel Path
Shoulder
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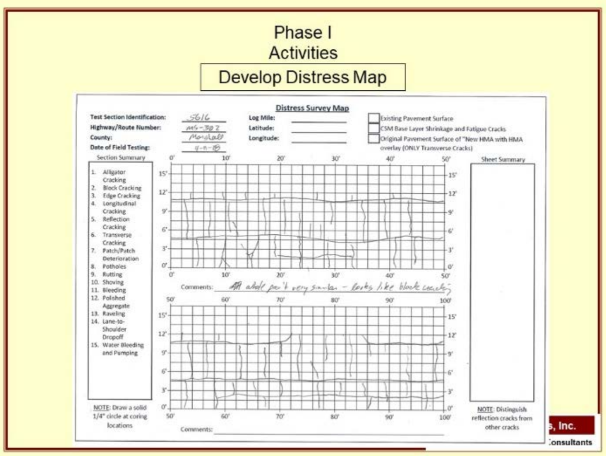
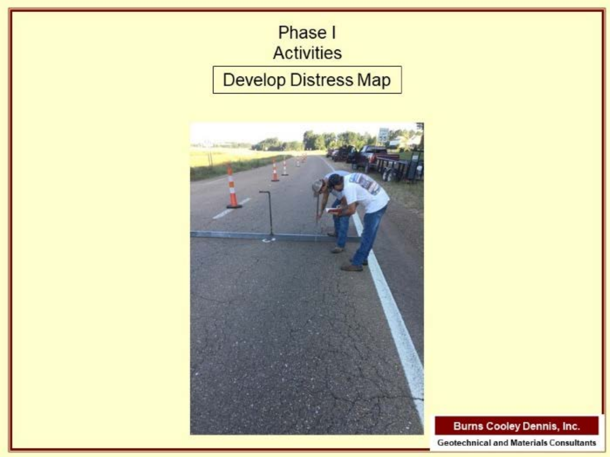

Phase I
Activities
Develop Distress Map
Distress Survey Map
Test Section Identification:
Highway/Route Number:
County:
Date of Field Testing:
Log Mile:
Latitude:
Longitude:
Existing Pavement Surface
CSM Base Layer Shrinkage and Fatigue Cracks
Original Pavement Surface of "New HMA with HMA overlay (ONLY Transverse Cracks)
Section Summary
Sheet Summary
Comments:
NOTE: Draw a solid 1/4" circle at coring locations
NOTE: Distinguish reflection cracks from other cracks


Phase I
Activities
Develop Distress Map
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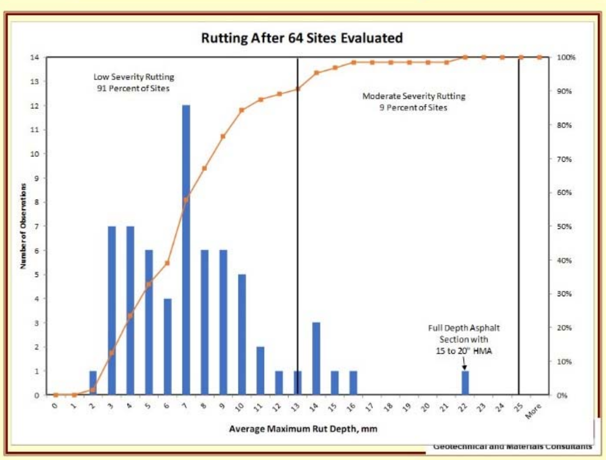
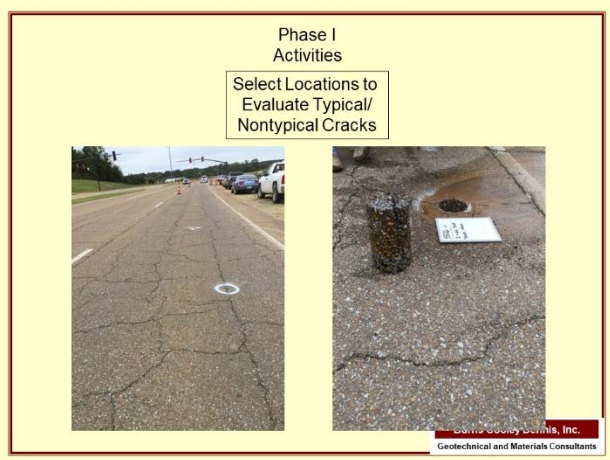
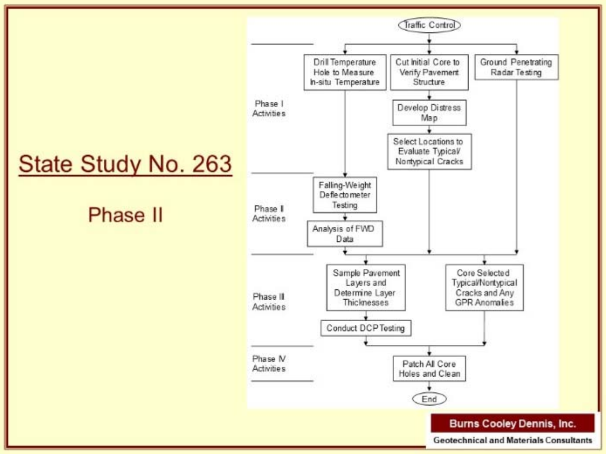

Rutting After 64 Sites Evaluated
Low Severity Rutting
91 Percent of Sites
Moderate Severity Rutting
9 Percent of Sites
Full Depth Asphalt
Section with
15 to 20" HMA
Number of Observations
Average Maximum Rut Depth, mm


Phase I
Activities
Select Locations to
Evaluate Typical/
Nontypical Cracks
Geotechnical and Materials Consultants


State Study No. 263
Phase II
Traffic Control
Drill Temperature Hole to Measure In-situ Temperature
Cut Initial Core to Verify Pavement Structure
Ground Penetrating Radar Testing
Phase I Activities
Develop Distress Map
Select Locations to Evaluate Typical/ Nontypical Cracks
Falling-Weight Deflectometer Testing
Phase II Activities
Analysis of FWD Data
Sample Pavement Layers and Determine Layer Thicknesses
Core Selected Typical/Nontypical Cracks and Any GPR Anomalies
Phase III Activities
Conduct DCP Testing
Phase IV Activities
Patch All Core Holes and Clean
End
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Phase II
Activities
Falling-Weight Deflectometer Testing
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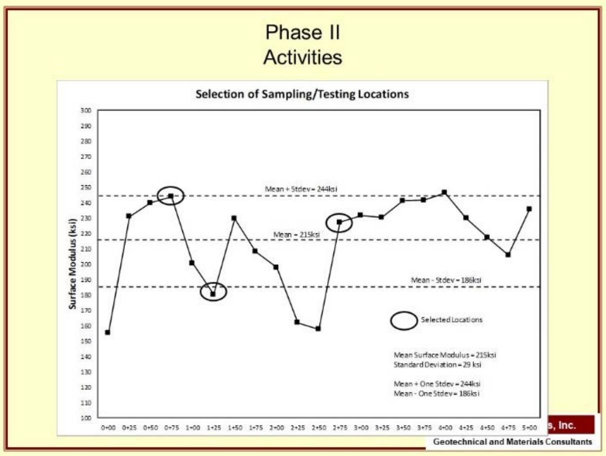
Phase II
Activities
Selection of Sampling/Testing Locations
Surface Modulus (ksi)
Mean + Stdev = 244ksi
Mean = 215ksi
Mean - Stdev = 186ksi
Selected Locations
Mean Surface Modulus = 215ksi
Standard Deviation = 29 ksi
Mean + One Stdev = 244ksi
Mean - One Stdev = 186ksi
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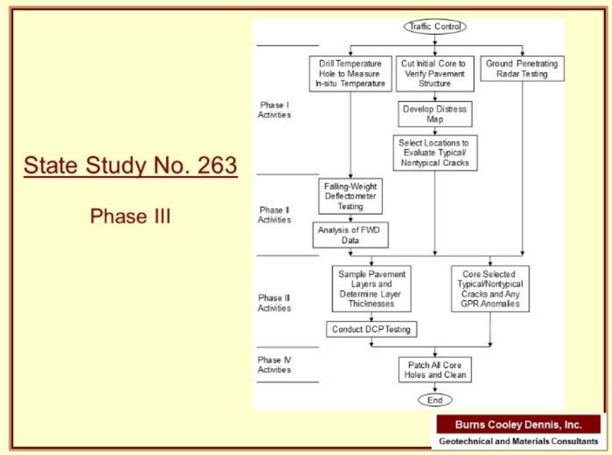
State Study No. 263
Phase III
Traffic Control
Drill Temperature Hole to Measure In-situ Temperature
Cut Initial Core to Verify Pavement Structure
Ground Penetrating Radar Testing
Phase I Activities
Develop Distress Map
Select Locations to Evaluate Typical/ Nontypical Cracks
Falling-Weight Deflectometer Testing
Phase II Activities
Analysis of FWD Data
Sample Pavement Layers and Determine Layer Thicknesses
Core Selected Typical/Nontypical Cracks and Any GPR Anomalies
Phase III Activities
Conduct DCP Testing
Phase IV Activities
Patch All Core Holes and Clean
End
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Phase III
Activities
Sample Pavement Layers and Determine Layer Thicknesses
HMA
Subgrade
Stabilized Layers
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4784
3+25 C-5
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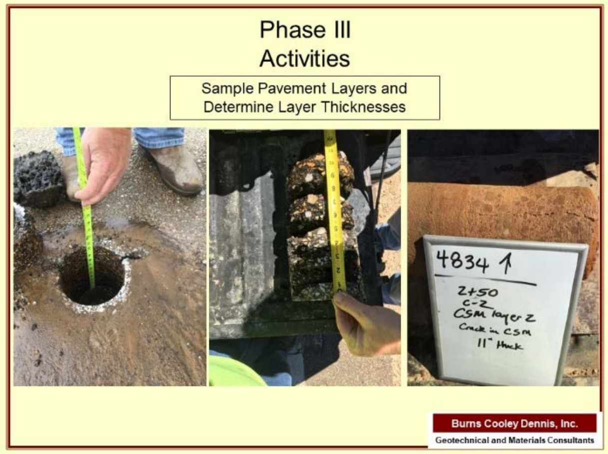
Phase III
Activities
Sample Pavement Layers and
Determine Layer Thicknesses
4834
2+50
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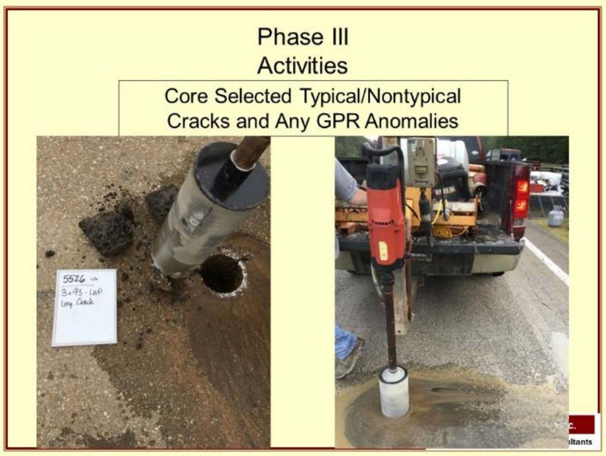
Phase III
Activities
Core Selected Typical/Nontypical
Cracks and Any GPR Anomalies


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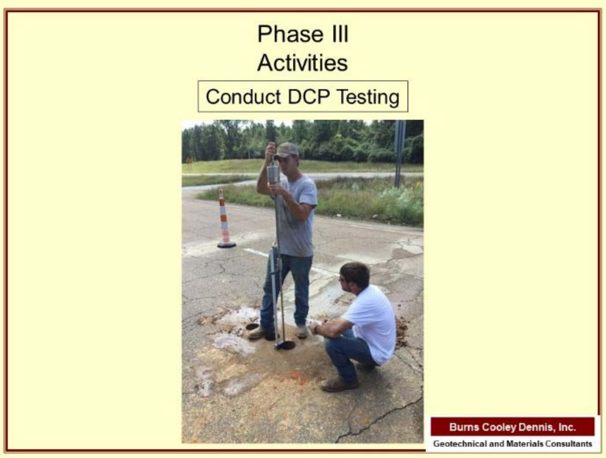
Phase III
Activities
Conduct DCP Testing
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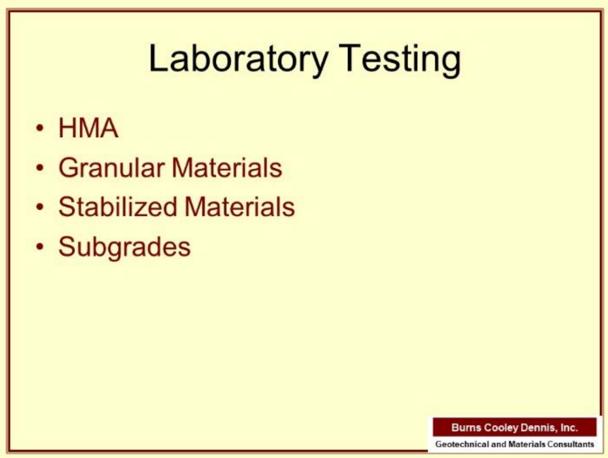
Laboratory Testing
• HMA
• Granular Materials
• Stabilized Materials
• Subgrades
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Laboratory Testing

- HMA, Granular and Subgrades were typical of testing the materials
  - HMA – Density, Pb, Gradation, etc.
  - Granular and Subgrade – Limits, m/c, gradation, etc.

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Stabilized Layers

- Indirect Tensile Test - NCHRP Report 789
- Modulus of Elasticity
- Unconfined Compressive Strength

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Typical CSM Samples

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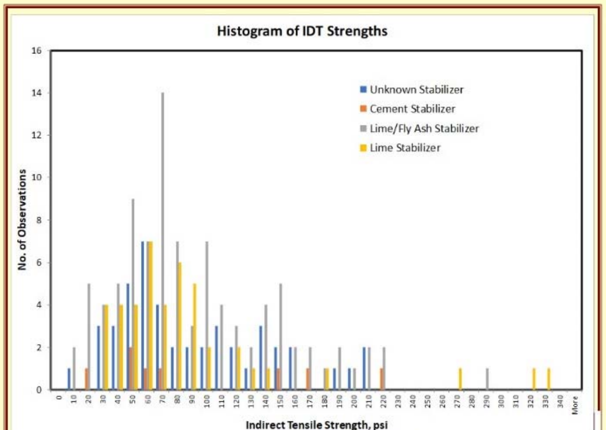
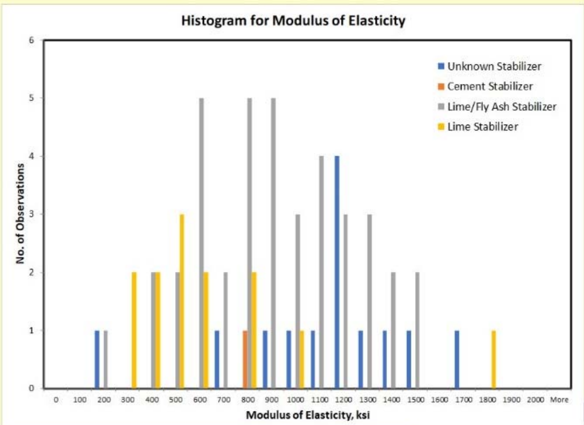
IDT Testing of CSM

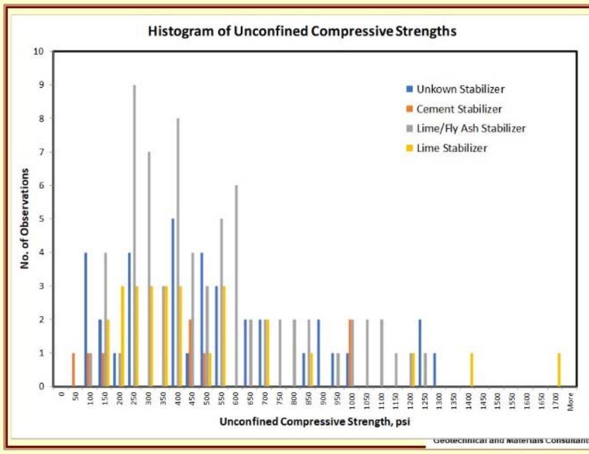
Geotechnical and Materials Consultants



MOE Testing of CSM

Burns Cooley Dennis, Inc.
Geotechnical and Materials Consultants





Summary

- Consultant is providing:
  - Field Observations
    - Distress Types and Mechanisms
    - Straightedge Rutting
  - Sampling Information
  - Material Properties
- Two Sections were Removed from the Data Set

Burns Cooley Dennis, Inc.
Geotechnical and Materials Consultants

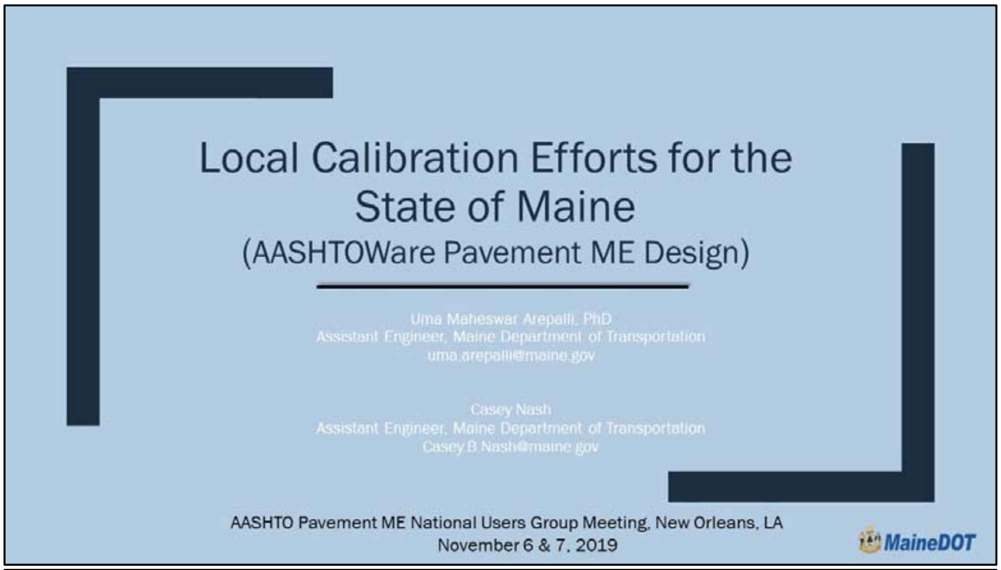
AASHTO Pavement ME National Users Group Meeting

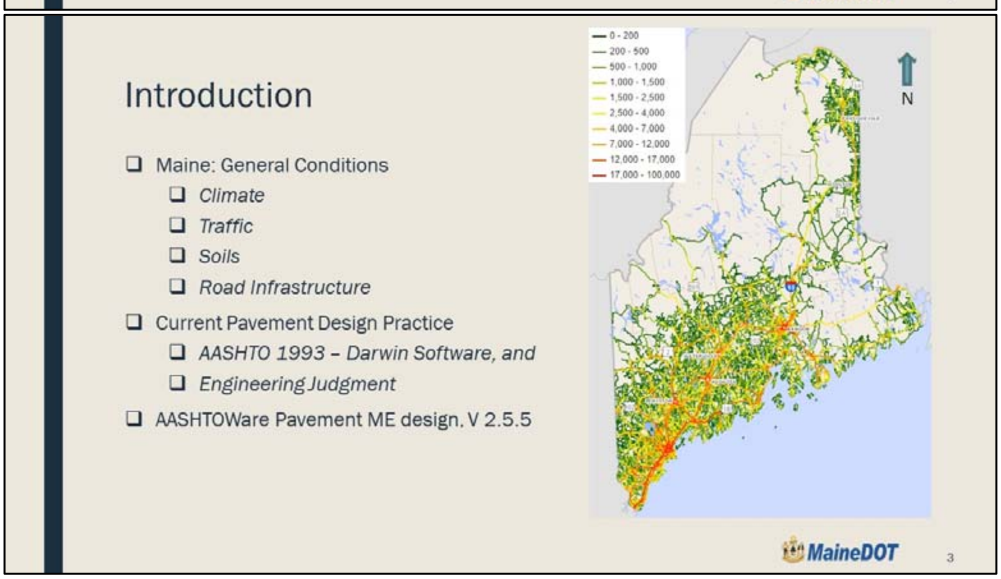
The Mötley Crüe

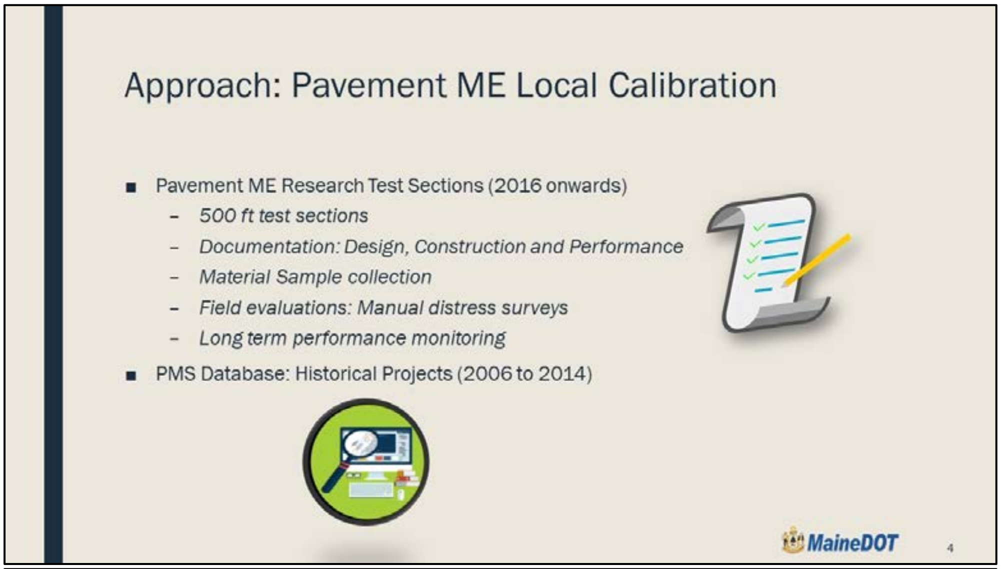
Allen Cooley, Ph.D.
(601) 856-2332
acooley@bcdgeo.com

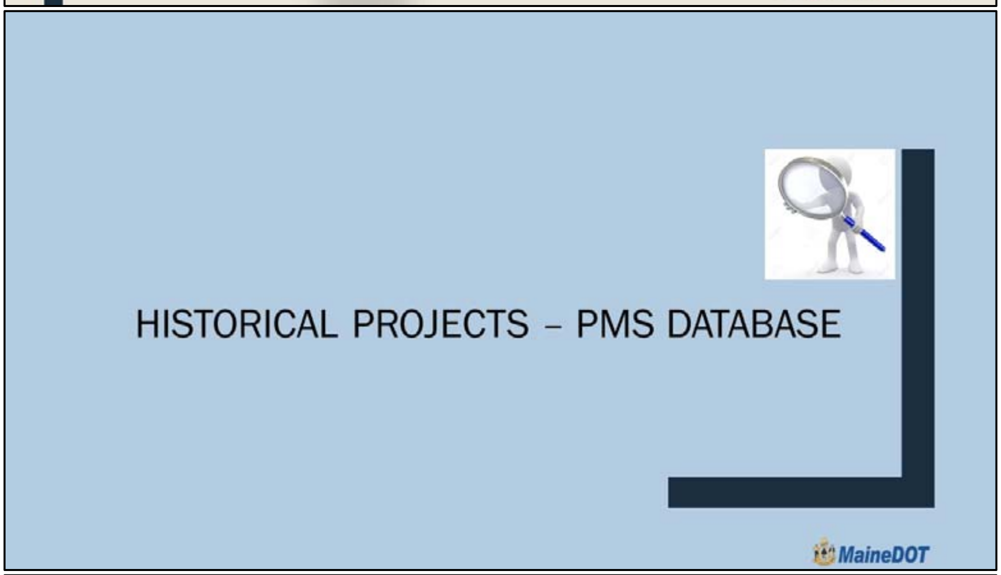
Burns Cooley Dennis, Inc.
Geotechnical and Materials Consultants

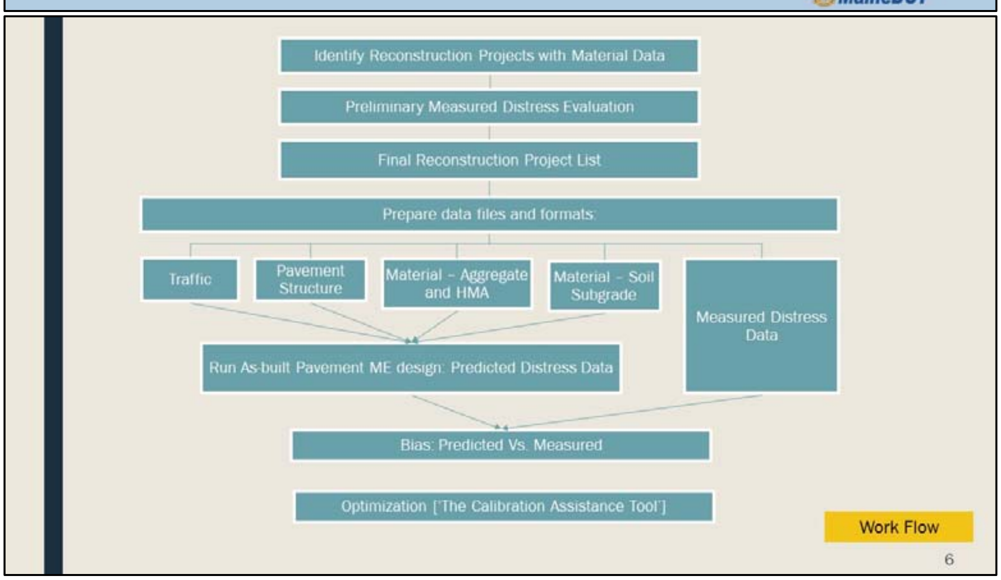
Presentation 18—Casey Nash, Maine DOT






Approach: Pavement ME Local Calibration
Pavement ME Research Test Sections (2016 onwards)
– 500 ft test sections
– Documentation: Design, Construction and Performance
– Material Sample collection
– Field evaluations: Manual distress surveys
– Long term performance monitoring
PMS Database: Historical Projects (2006 to 2014)
MaineDOT
4


HISTORICAL PROJECTS – PMS DATABASE
MaineDOT


Identify Reconstruction Projects with Material Data
Preliminary Measured Distress Evaluation
Final Reconstruction Project List
Prepare data files and formats
Traffic
Pavement Structure
Material – Aggregate and HMA
Material – Soil Subgrade
Measured Distress Data
Run As-built Pavement ME design: Predicted Distress Data
Bias: Predicted Vs. Measured
Optimization ['The Calibration Assistance Tool']
Work Flow
6

S. No	Town / City	PIN	Year Paved
1	Corinna	007710.00	2006
2	Abbot, Guilford	011075.00	2008
3	Milo	010012.00	2008
4	Houlton	009192.00	2009
5	Dixfield	010015.00	2009
6	Madrid Twp	010019.00	2009
7	Cross Lake Twp	010005.00	2009
8	Portland	010544.00	2009
9	Castle Hill	011071.00	2009
10	Dover-Foxcroft	009199.00	2009
11	Bethel, Gilead	009184.30	2010
12	Norway	010020.10	2010
13	Gilead	009184.50	2011

S. No.	Town / City	PIN	Year Paved
14	Winterport	002762.60	2011
15	Ellsworth	010007.00	2011
16	Norway	010020.00	2011
17	Township D	008670.10	2011
18	Poland	017883.00	2014
19	Berwick	017328.00	2014
20	Old Town	014794.00	2014
21	Warren	017889.00	2015

Total Reviewed Projects – Around 50
- Rehab (Wrong descriptions)
- RAP Layers or missing layer information
- Distress not following typical trends

Final Project List

7

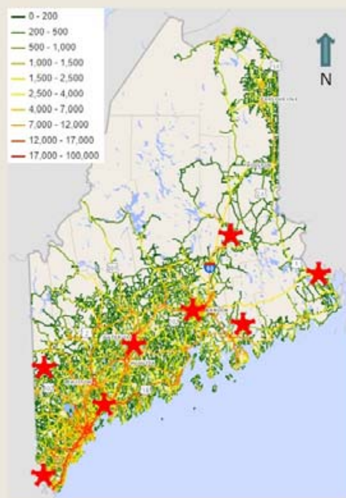
Traffic data inputs

- Truck Classification Distribution
- Axle Load Spectra (WIM data)

} Similar roadways

"Bureau of Traffic Planning"

- Challenges: "Superior Engineering Judgement"
  - *Expertise needed for identifying these similar roadways*
  - *Possible bias: Improper selection*

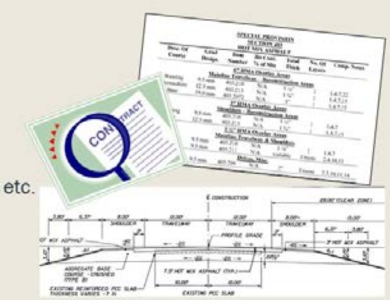


MaineDOT 8

Pavement Structure

- Contract Plans [ME Plans]
- Contract Bid Documents – Spec 403, Amendments etc.
- Thickness and number of layers

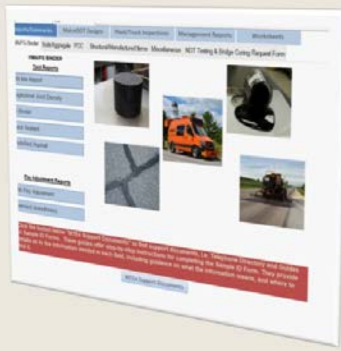
- Challenges:
  - *Multiple designs: Amendments*
  - *Change of Units: US customary to Metric*



MaineDOT 9

Material: Aggregate and HMA

- TIMS database
  - *Data available from 2005 onwards*
- Aggregate
  - *Gradation*
  - *Optimum Density and Water Content*
- HMA
  - *% Air voids*
  - *Effective Binder Content, %*



MaineDOT 10

Material: Subgrade

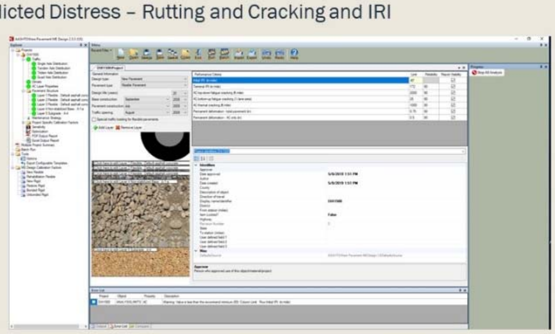
- Maine DOT uses existing soil for the subgrade with minimal preparation
  - *So, soil test data was not available*
  - *However, typical soil characteristic data was obtained using 'NRCS website' based on the project location*
- Challenges:
  - *Variable soils across the project length*

"Representative"

MaineDOT 11

As- Built Designs: Pavement ME Software

- AASHTOWare Pavement ME Version 2.5.5
- Predicted Distress – Rutting and Cracking and IRI



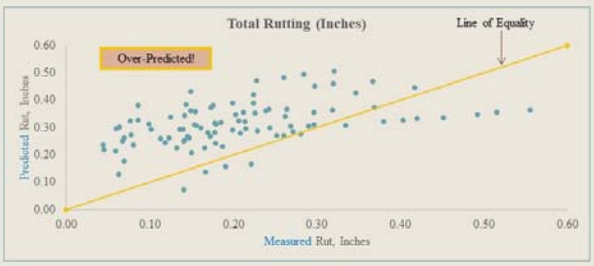
MaineDOT 12

Measured Distress data

- Rutting
- IRI
- Cracking

- Challenges:
  - *Variable distress data*
  - *Non typical distress - Very low or high magnitudes with age*
  - *ARAN Vehicle model change [2015 onwards – new]*
  - *Cracking database: data collection differences - PMS Vs. Pavement ME*
    - Longitudinal/Transverse vs Fatigue/Thermal

MaineDOT 13



- Total projects: 21
- Distress data points @ every 2 years (mostly) for each project

Bias Chart

14

THE CALIBRATOR TOOL

Beta testing version

MaineDOT

Data files

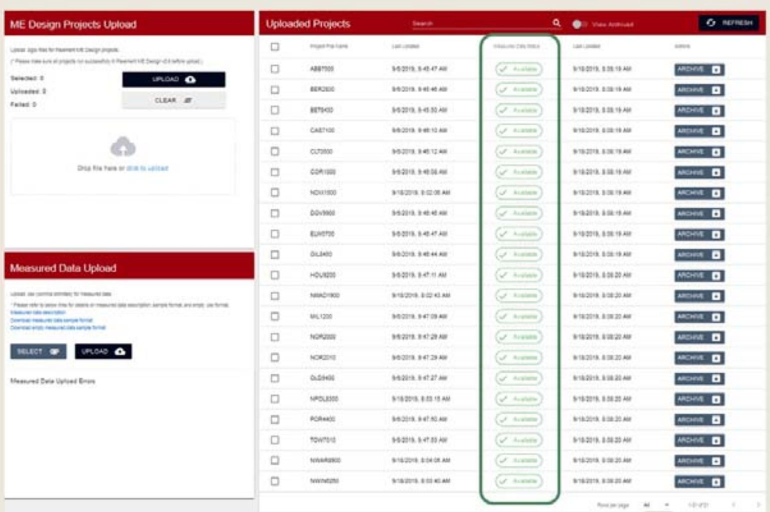
- Dgpx: AASHTOWare Pavement ME
- Csv: Measured data

'Format'

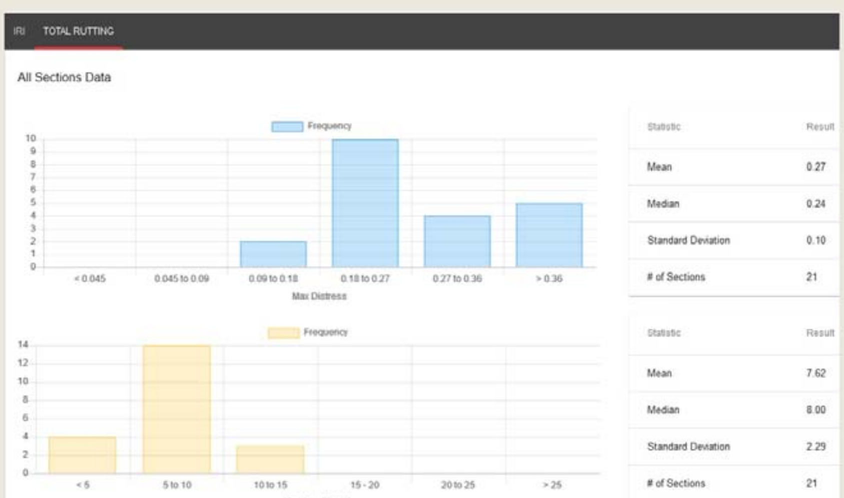
Id	AgeMonth	FatigueBU	FatigueTD	Rutting	Transverse Cracking	Iri
ABB7500	0					56.4
ABB7500	48			0.123		67
ABB7500	72			0.169		72.2
ABB7500	96			0.244		77.1
ABB7500	108			0.268		79.8
ABB7500	120			0.297		83.1

ABB7500.dgpx
BER2800.dgpx
BET8430.dgpx
CAS7100.dgpx
CLT0500.dgpx
COR1000.dgpx
DIX1500.dgpx
DOV9900.dgpx
ELW0700.dgpx
GIL8450.dgpx
HOU9200.dgpx
MAD1900.dgpx
MIL1200.dgpx
NOR2000.dgpx
NOR2010.dgpx
OLD9400.dgpx
POL8300.dgpx
POR4400.dgpx
TOW7010.dgpx
WAR8900.dgpx
WIN6260.dgpx

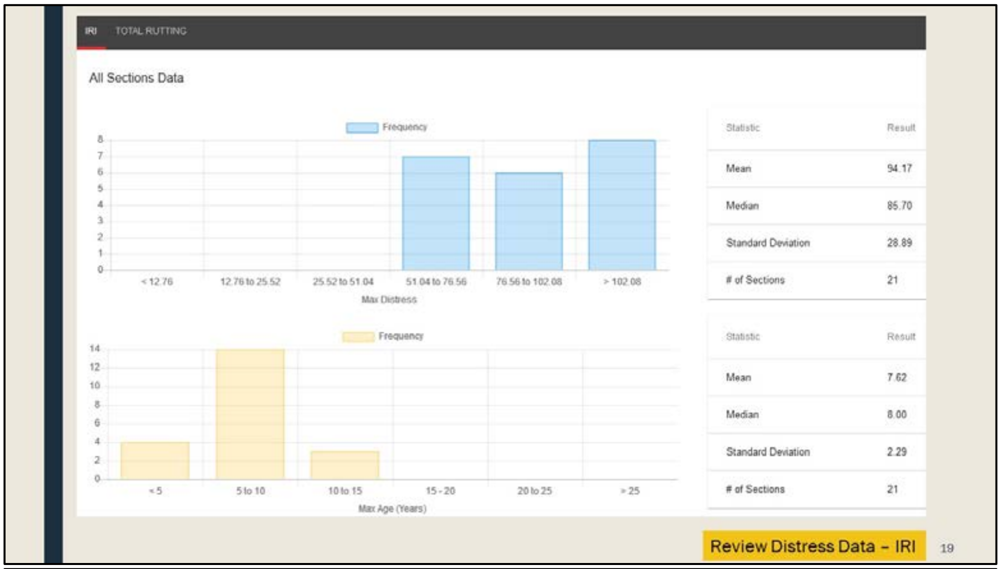
MaineDOT 16

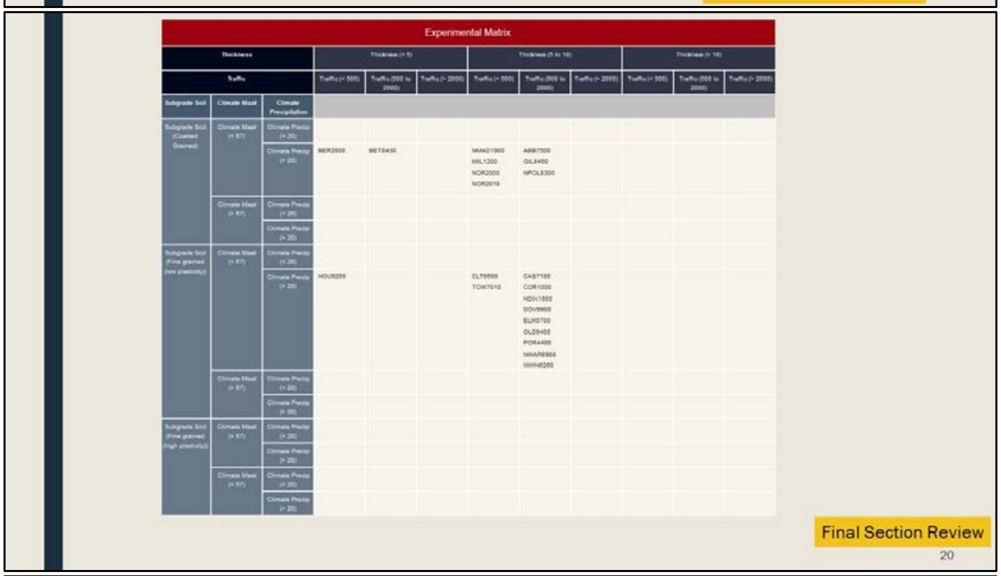


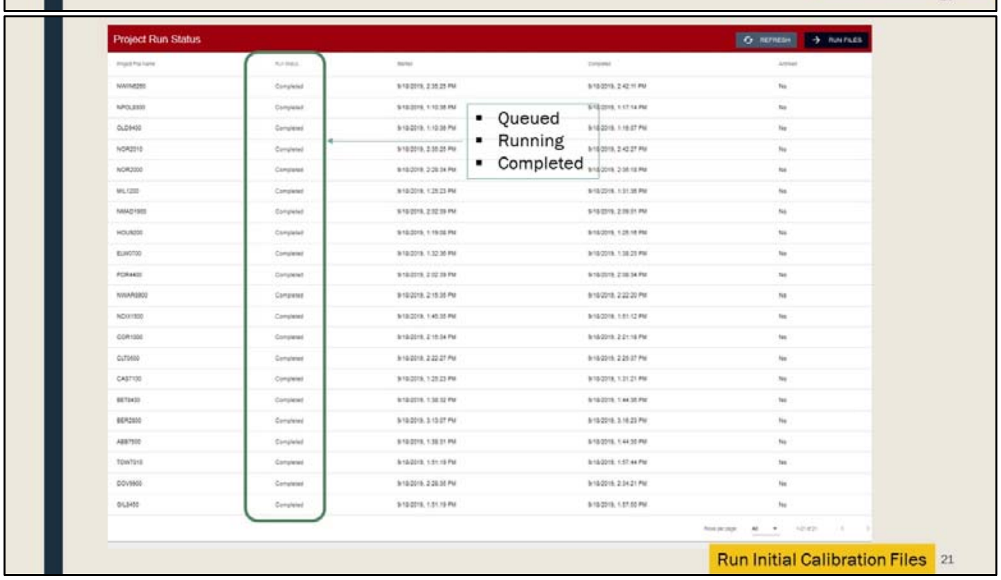
Projects and Measured Data Upload 17

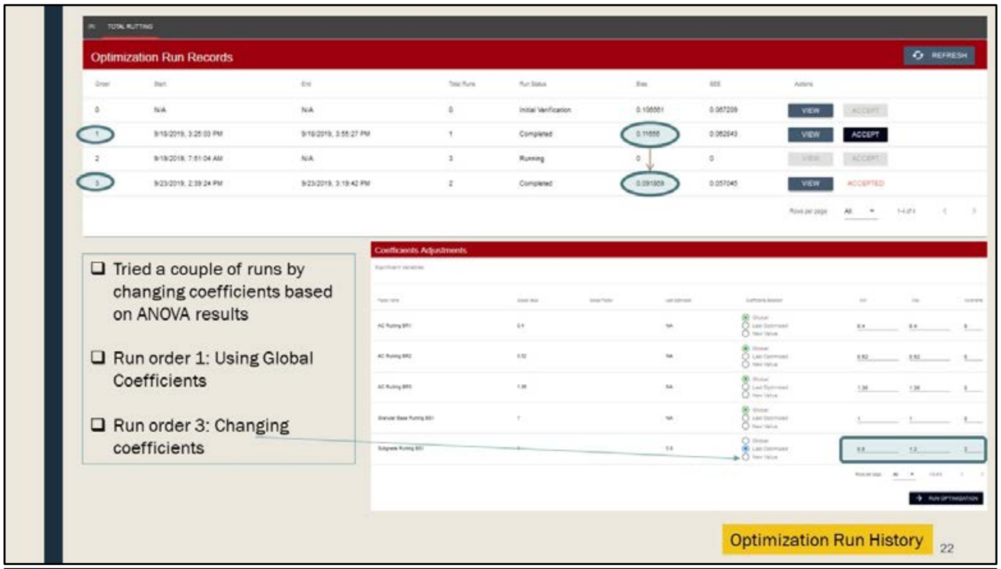


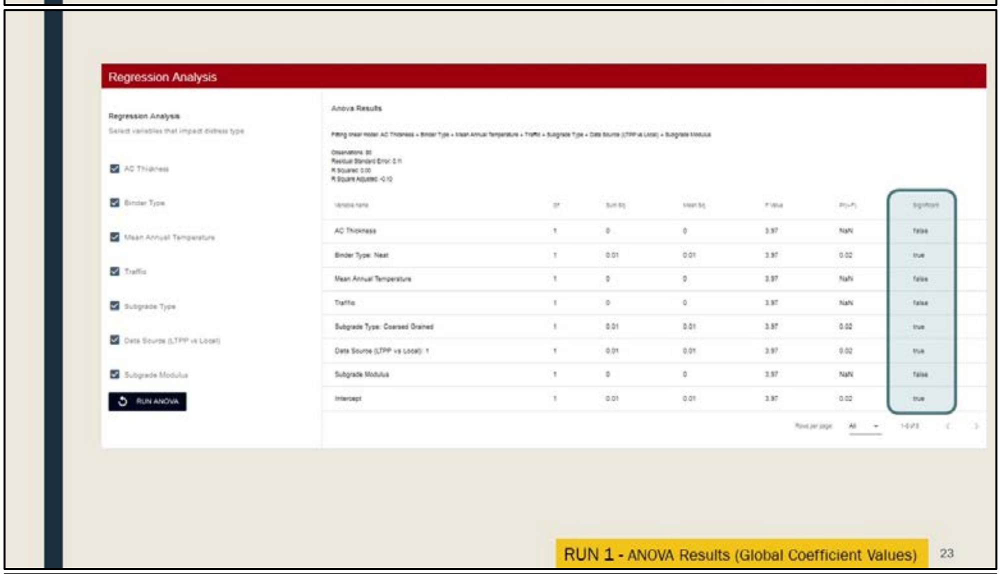
Review Distress Data – Total Rutting 18

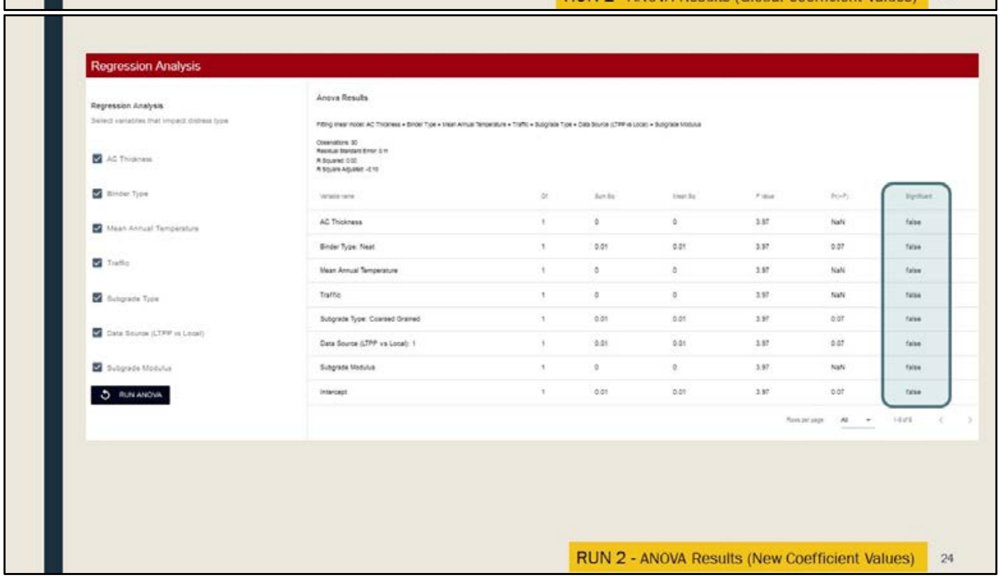

IRI
TOTAL RUTTING
All Sections Data
Frequency
< 12.76
12.76 to 25.52
25.52 to 51.04
51.04 to 76.56
76.56 to 102.08
> 102.08
Max Distress
Statistic
Result
Mean
94.17
Median
85.70
Standard Deviation
28.89
# of Sections
21
Frequency
< 5
5 to 10
10 to 15
15 - 20
20 to 25
> 25
Max Age (Years)
Statistic
Result
Mean
7.62
Median
8.00
Standard Deviation
2.29
# of Sections
21
Review Distress Data – IRI
19

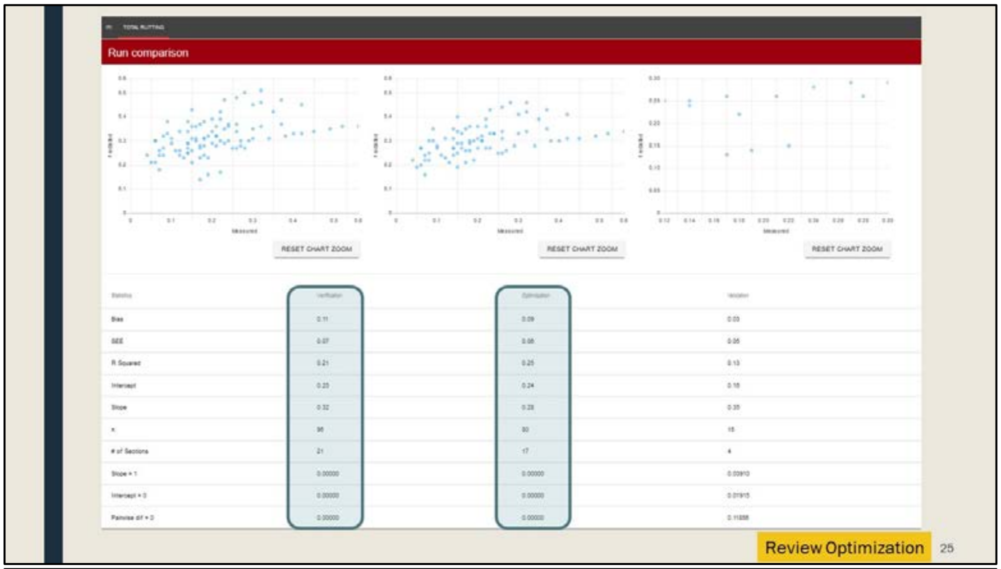

Experimental Matrix
Final Section Review
20

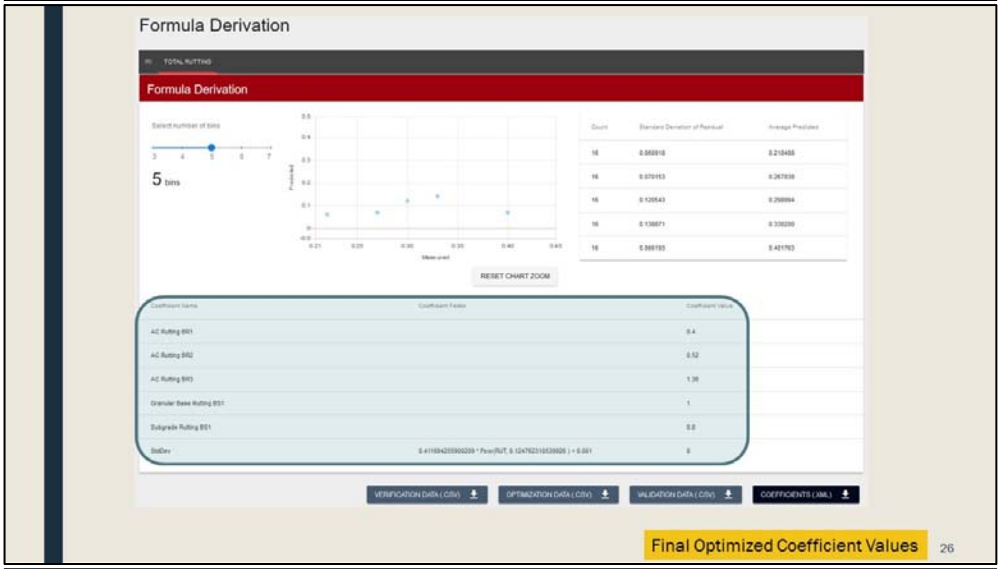

Project Run Status
Queued
Running
Completed
Run Initial Calibration Files
21


Optimization Run Records
REFRESH
Coefficients Adjustments
Tried a couple of runs by changing coefficients based on ANOVA results
Run order 1: Using Global Coefficients
Run order 3: Changing coefficients
Optimization Run History
22


Regression Analysis
Anova Results
AC Thickness
Binder Type
Mean Annual Temperature
Traffic
Subgrade Type
Data Source (LTPP vs Local)
Subgrade Modulus
RUN ANOVA
RUN 1 - ANOVA Results (Global Coefficient Values)
23


Regression Analysis
Anova Results
AC Thickness
Binder Type
Mean Annual Temperature
Traffic
Subgrade Type
Data Source (LTPP vs Local)
Subgrade Modulus
RUN ANOVA
RUN 2 - ANOVA Results (New Coefficient Values)
24


Run comparison
RESET CHART ZOOM
RESET CHART ZOOM
RESET CHART ZOOM
Review Optimization
25


Formula Derivation
Formula Derivation
5 bins
RESET CHART ZOOM
Final Optimized Coefficient Values
26


RESEARCH
TEST
SECTIONS
2016 ONWARDS

Ongoing efforts

- 12 Projects are either completed or to be completed in 2019
- Additional four to five projects per year
- Materials saved indefinitely – LTPP Lite
- Effort to look backward – forensics
- This will take time & commitment
- Potential expansion to preservation and rehabilitation paving

MaineDOT 28

Work Plan

- Pre-Construction
  - *Identify the project: Reconstruction and Rehabilitation*
  - *Locate the test section: Based on site conditions, 500ft length, level surface, avoid intersections, grades, and other etc.*
- During Construction
  - *Field Coordinator*
  - *Collect material samples and send to laboratory*
- After Construction
  - *Immediately after 0-3 months*
    - Collect initial ARAN – IRI and Distress, and FWD data
    - Collect Traffic data, as-built year
  - *After 1 year onwards*
    - Field evaluations and/or Manual distress surveys

MaineDOT 29

"Calibration" Sites

- 12 buckets of subgrade
  - *Density, M_R, lab proctor, gradation, Atterberg limits*
- 12 buckets of base gravel
  - *Density, M_R, lab proctor, gradation, Atterberg limits*
- 16 boxes of HMA from each lift
  - *AC, Voids, VMA, VFB, F/B_e, Gradation, AMPT(DM, CF, SSR), HWT, IDEAL-CT, Others?*
- Five cores of HMA from each lift
  - *Density*
- Four quarts of binder from each lift
  - *PG Grading, ΔT_c, XRF/FTIR fingerprinting, Others?*

MaineDOT 30

Use this data in many ways...

- Input for "as-constructed" designs for PavementME calibration
- Comparison between testing methods, potential correlation
  - *Some are suited for Design, some for suited for QA*
- Examine effect of volumetrics on performance
- Develop libraries of different mixes

MaineDOT 31

Field Investigations: Manual Distress Survey (Fall 2019)

- Construction Issues
  - *Fog Sealed*
- Material Issues
  - *Aggregate loss*

MaineDOT 32

Summary

- Local Calibration Work: Historical Projects and PMS database
  - *Successfully used historical data for rut optimization*
  - *Pick a scope and begin creating ME designs*
  - *'The Calibrator Tool' enables easy optimization*
  - *To Do: Get crack measurements into Calibrator .csv format*
  - *Complete initial local calibration using 'The Calibrator Tool'*

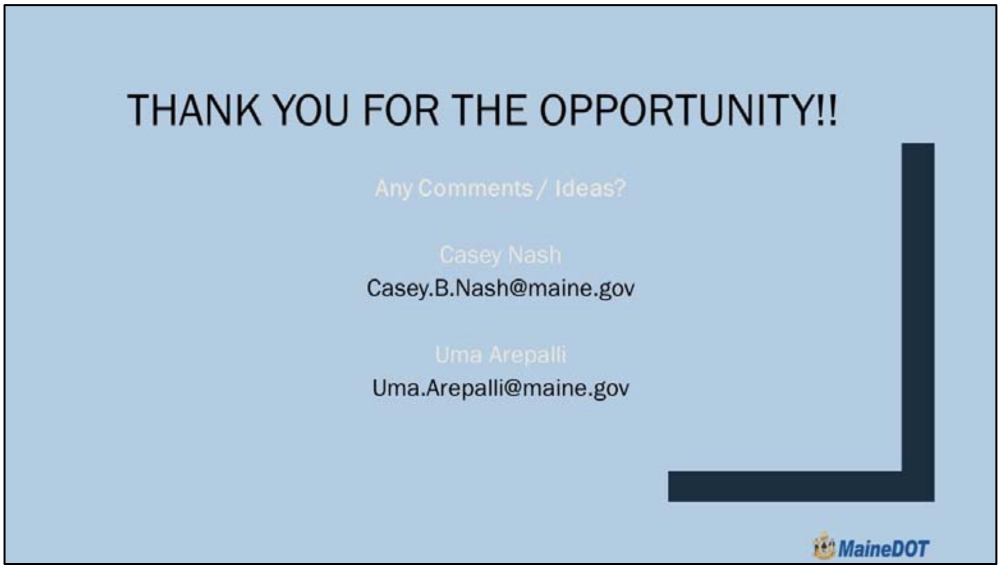
Expected Completion: May 2020

- Pavement ME Research Test Sections (Level 1 calibration)
  - *As-built PavementME projects created at construction*
  - *Long term pavement performance monitoring*

Request

- Interested in hearing other states solutions for cracking calibration and how they differentiated between top-down/bottom-up and thermal

MaineDOT 33


THANK YOU FOR THE OPPORTUNITY!!
Any Comments / Ideas?
Casey Nash
Casey.B.Nash@maine.gov
Uma Arepalli
Uma.Arepalli@maine.gov
MaineDOT

Presentation 19—Harold Von Quintus, ARA

Demonstration-Based Training Example Applications

AASHTOWare Pavement ME Design
MEPDG User Group Meeting
New Orleans, LA
November 7, 2019

Harold L. Von Quintus, P.E., ARA

Demonstration-Based Training

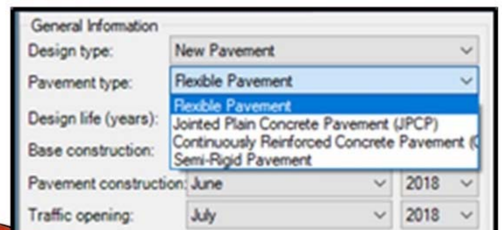
1. Inverted Pavements
2. Semi-Rigid Pavements
3. Responsible Resource Asphalt Mixtures
4. New Composite Pavements; Asphalt over CRCP or JPCP
5. Asphalt Overlay Design of Flexible Pavement with Interlayer for Reflection Cracking.
6. Input Level 1 Rehabilitation Design; Backcalculation of Elastic Layer Moduli

Designing Inverted Pavement with the PMED Software

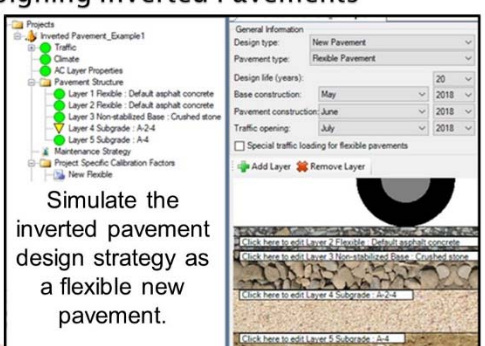
AASHTOWare Pavement ME Design
MEPDG User Group Meeting
New Orleans, LA
November 7, 2019

Designing Inverted Pavements

- Inverted pavements is not included as a pavement design strategy in the PMED software.

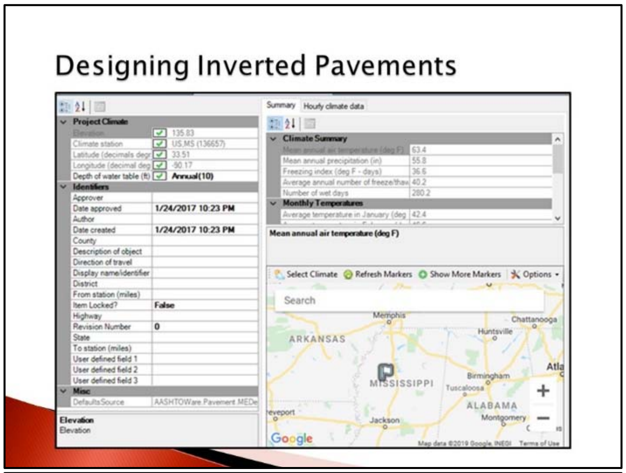


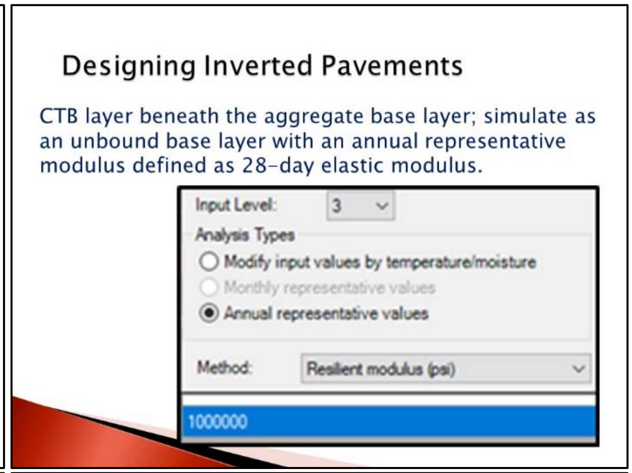
Designing Inverted Pavements

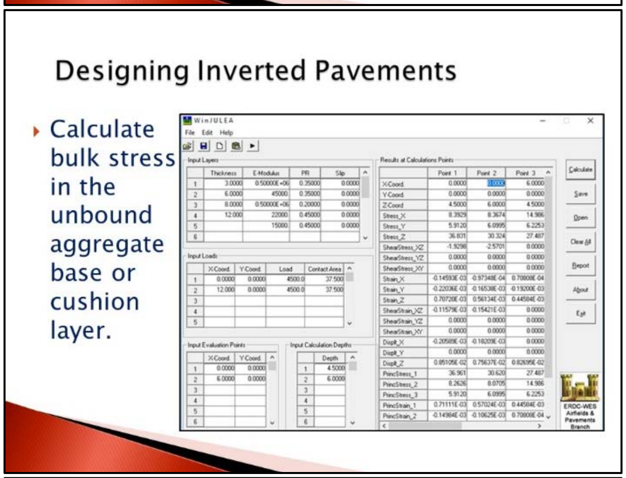


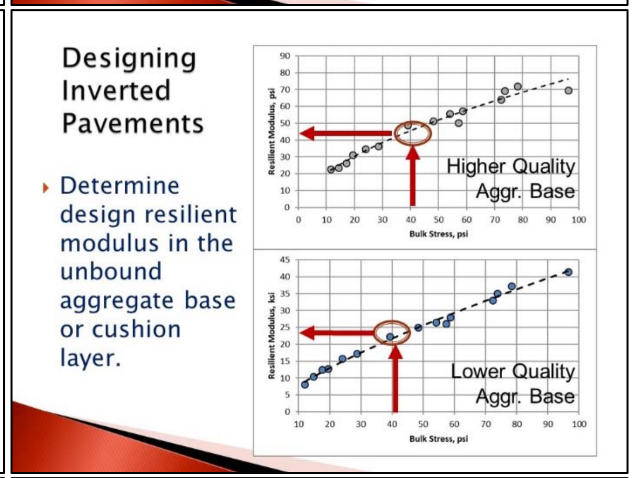
Designing Inverted Pavements

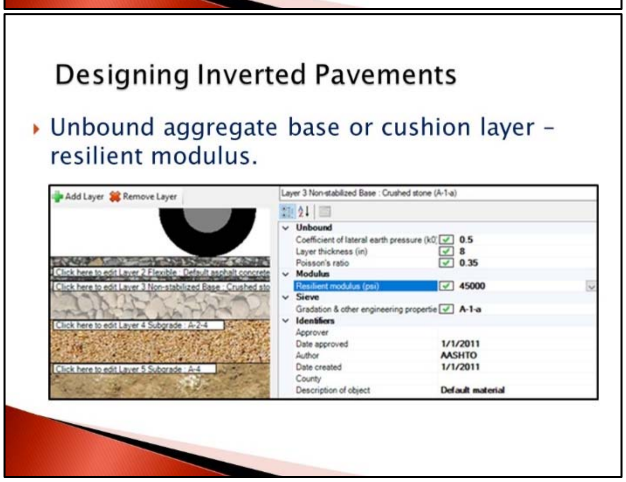
- Assumption: The unbound aggregate base layer eliminates any reflection cracking from the underlying CTB layer.
- Simulation of:
  - Unbound aggregate base or cushion layer – resilient modulus.
  - CTB layer beneath the aggregate base layer.
- Minimum layer thicknesses.
- Applicability of the IRI regression equation.

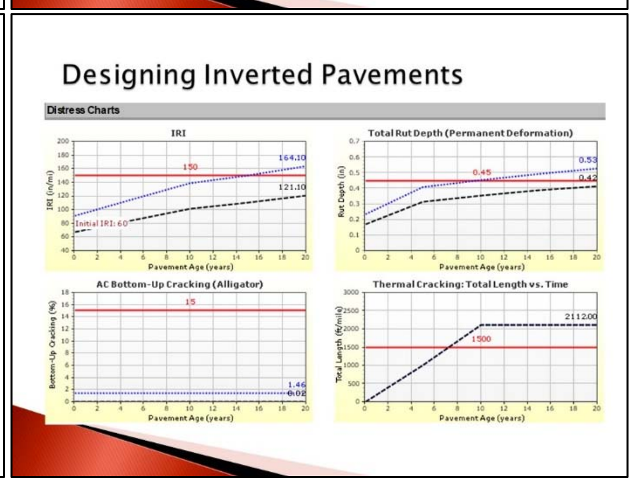

Designing Inverted Pavements


Designing Inverted Pavements
CTB layer beneath the aggregate base layer; simulate as an unbound base layer with an annual representative modulus defined as 28-day elastic modulus.
Input Level:
3
Analysis Types
Modify input values by temperature/moisture
Monthly representative values
Annual representative values
Method:
Resilient modulus (psi)
1000000

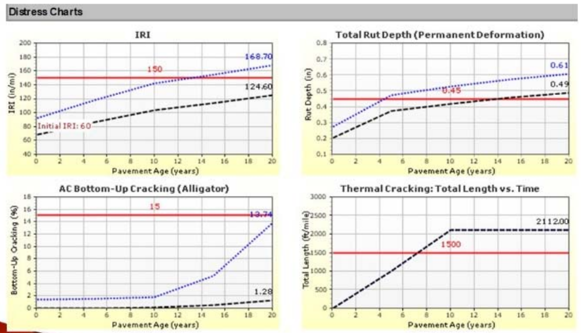

Designing Inverted Pavements
Calculate bulk stress in the unbound aggregate base or cushion layer.


Designing Inverted Pavements
Determine design resilient modulus in the unbound aggregate base or cushion layer.
Higher Quality Aggr. Base
Lower Quality Aggr. Base
Bulk Stress, psi


Designing Inverted Pavements
Unbound aggregate base or cushion layer – resilient modulus.


Designing Inverted Pavements
Distress Charts
IRI
Total Rut Depth (Permanent Deformation)
AC Bottom-Up Cracking (Alligator)
Thermal Cracking: Total Length vs. Time
Pavement Age (years)

Designing Inverted Pavements



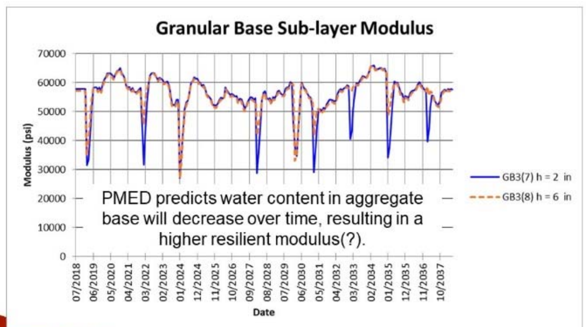
Designing Inverted Pavements

Subgrade rutting will not occur below the CTB layer; exclude rut depth in subgrade for the total rut depth.

High Quality Base
Lower Quality Base

Note: Graphs erroneously switched. Graph on right represents High Quality Base, graph on left represents Lower Quality Base

Designing Inverted Pavements



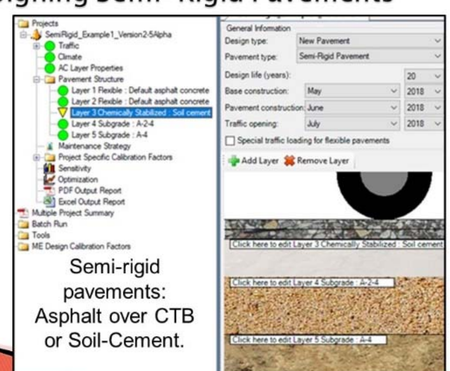
Designing Inverted Pavements

- Assumption: The unbound aggregate base layer eliminates any reflection cracking from the underlying CTB layer.
- Simulation of:
  - Unbound aggregate base or cushion layer – resilient modulus.
  - CTB layer beneath the aggregate base layer.
- Minimum layer thicknesses.
- Applicability of the IRI regression equation.

Designing Semi-Rigid Pavements with the PMED Software

AASHTOWare Pavement ME Design
MEPDG User Group Meeting
New Orleans, LA
November 7, 2019

Designing Semi-Rigid Pavements



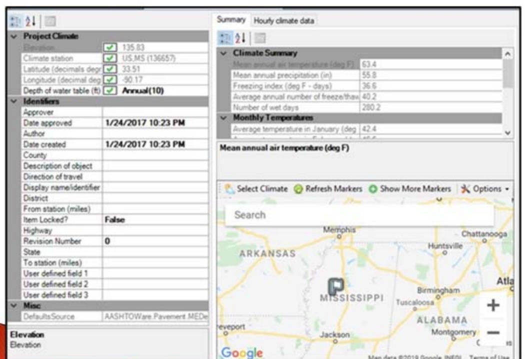
Designing Semi-Rigid Pavements

1. Cement Stabilized Layer: Relationship between the Elastic Modulus and Modulus of Rupture.
2. Minimum layer thicknesses for the asphalt and cement stabilized layers.
3. Full bond retained between the asphalt and cement stabilized layers over the design period.
4. Exclude rut depth in the layers below the CTB or Soil-Cement layer.

Designing Semi-Rigid Pavements

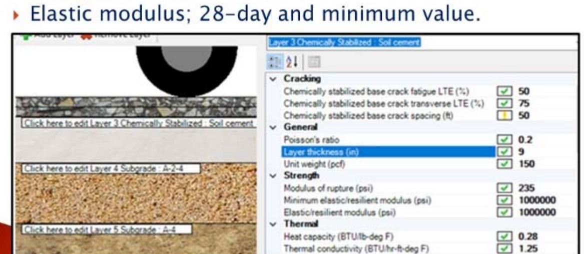
5. Load transfer efficiency of fatigue cracks; this is a calibration parameter.
6. Load transfer efficiency of transverse cracks; this can be measured.
7. Spacing of shrinkage cracks; this is a calibration parameter, but can be defined by cement content.

Designing Semi-Rigid Pavements



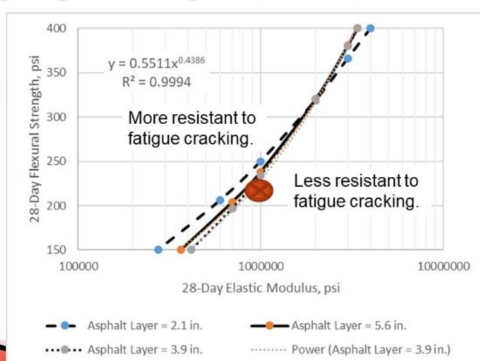
Designing Semi-Rigid Pavements

- LTE for fatigue and transverse cracking
- Shrinkage crack spacing.
- Strength/modulus of rupture.
- Elastic modulus; 28-day and minimum value.

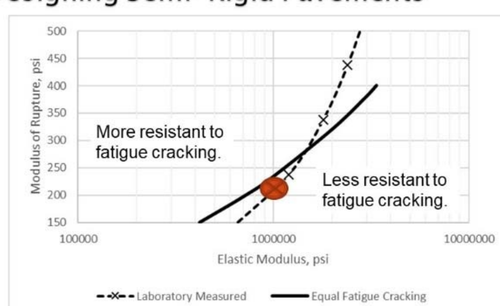


Designing Semi-Rigid Pavements

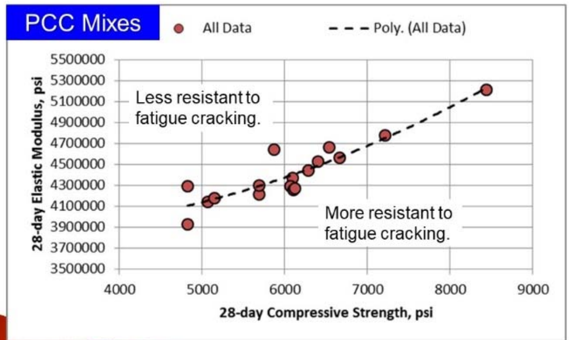
CTB or soil cement layer.



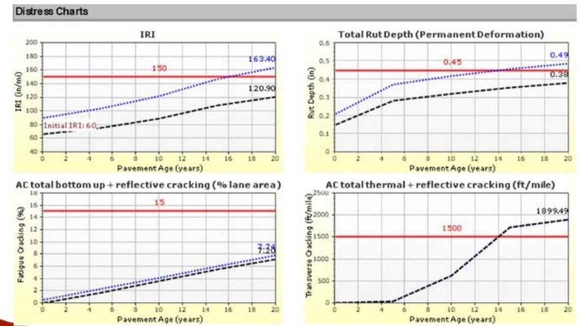
Designing Semi-Rigid Pavements



Designing Semi-Rigid Pavements



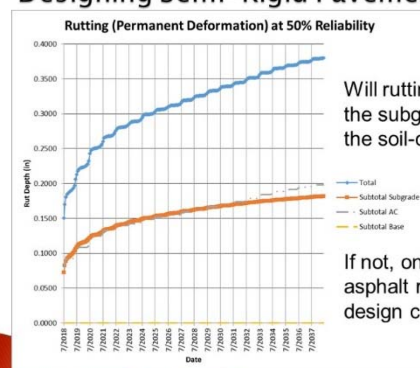
Designing Semi-Rigid Pavements



Designing Semi-Rigid Pavements

Pavement Age (years)	Heavy Trucks (cum.)	Crack Depth (in)	Crack Spacing (ft)	Mean Predicted Distress								
				IRI (in/mi)	Permanent deformation - total pavement (in)	Permanent deformation - AC only (in)	AC total fatigue cracking: bottom up + reflective (% lane area)	AC total transverse cracking: thermal + reflective (ft/mile)	AC bottom-up fatigue cracking (% lane area)	AC top-down fatigue cracking (ft/mile)	AC thermal cracking (ft/mile)
19.50	######	1.37	50	119.6	0.379	0.20	7.070	1,885.847	0.000	0.0895	1151.04
19.58	######	1.37	50	119.8	0.379	0.20	7.080	1,886.392	0.000	0.0895	1151.04
19.67	######	1.38	50	120.1	0.379	0.20	7.090	1,897.484	0.000	0.0895	1161.6
19.75	######	1.39	50	120.3	0.379	0.20	7.110	1,898.003	0.000	0.0895	1161.6
19.83	######	1.39	50	120.4	0.379	0.20	7.130	1,898.510	0.000	0.0895	1161.6
19.92	######	1.39	50	120.6	0.380	0.20	7.160	1,899.004	0.000	0.0895	1161.6
20.00	######	1.39	50	120.9	0.380	0.20	7.200	1,899.488	0.000	0.0895	1161.6

Designing Semi-Rigid Pavements



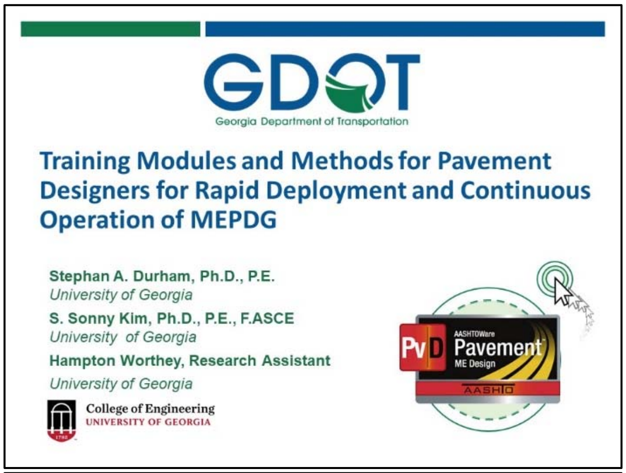
Will rutting occur in the subgrade beneath the soil-cement layer?

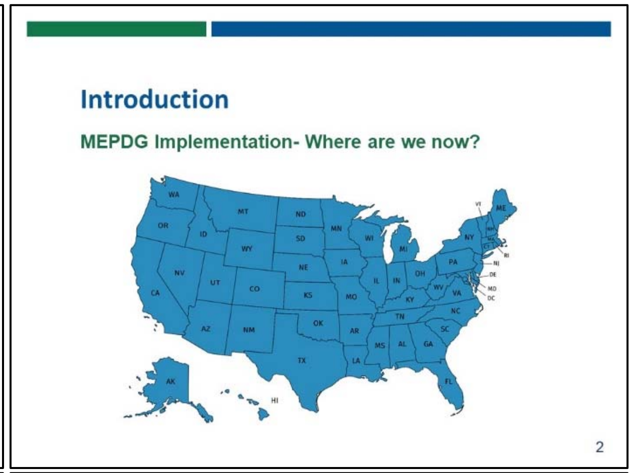
If not, only consider asphalt rutting as the design criterial.

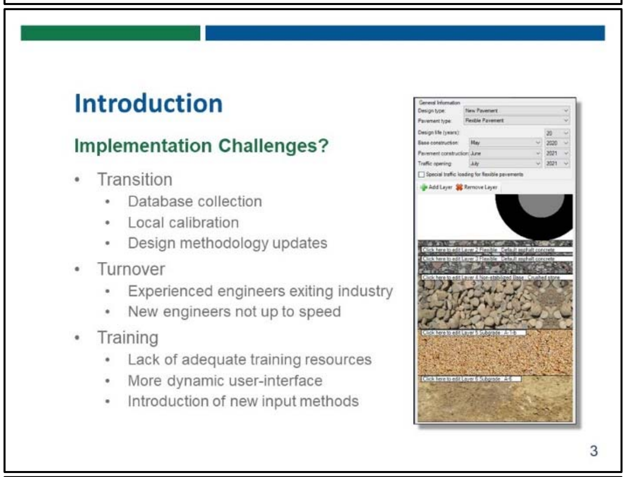
Designing Semi-Rigid Pavements

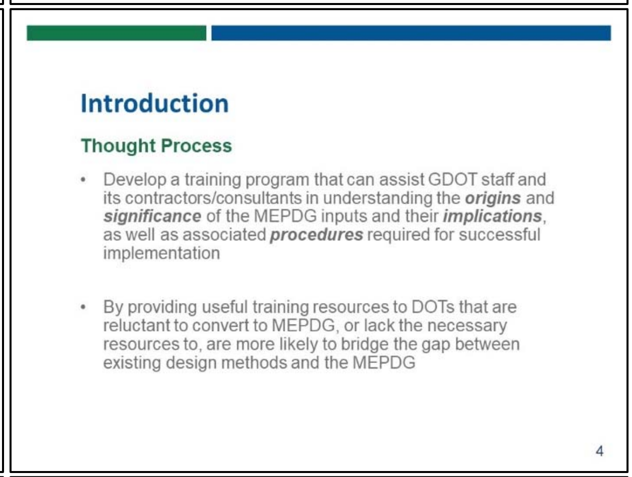
1. Cement Stabilized Layer: Relationship between the Elastic Modulus and Modulus of Rupture.
2. Minimum layer thicknesses for the asphalt and cement stabilized layers.
3. Full bond retained between the asphalt and cement stabilized layers over the design period.
4. Exclude rut depth in the layers below the CTB or Soil-Cement layer.

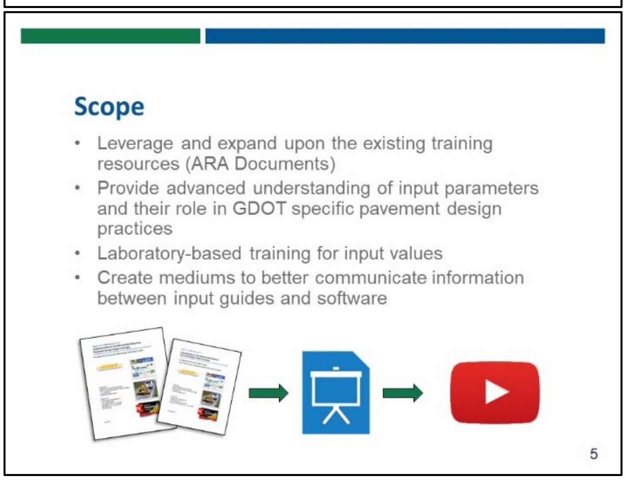
Presentation 20—Stephan Durham, Sung-Hee Kim, and Hampton Worthey (University of Georgia)

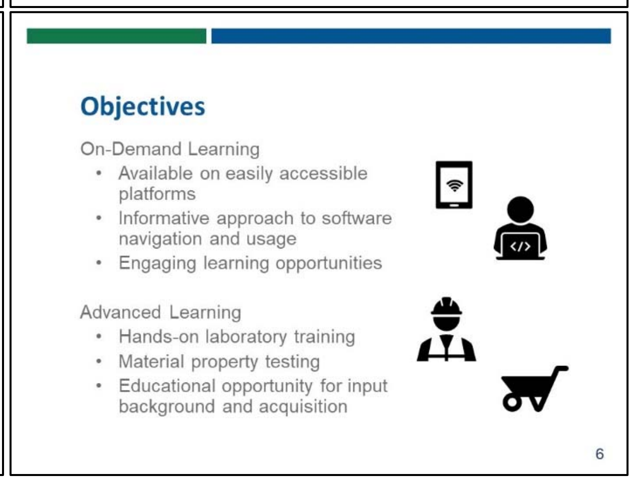












Training Program

Module Development

- Using guidelines provided by AASHTO and ARA, the training modules are divided into a series of six learning modules
- With consideration to input level hierarchy, the first series of modules cover Level 3 design inputs
- Subsequent modules will look to expand upon these principles and discuss Level 2 and Level 1 inputs in detail
- Organized for "lunch and learn" style of consumption

Level 3 Series C | Level 2 Series B | Level 1 Series A

7

Training Program

Module Development

Module 1- *MEPDG Basics*

Module 2- *MEPDG Inputs and Implementation for Subgrade and Base Materials*

Module 3- *MEPDG Inputs and Implementation for AC Pavement*

Module 4- *MEPDG Inputs and Implementation for JPCP*

Module 5- *MEPDG Inputs and Implementation for CRCP*

Module 6- *Hands-on Laboratory Training Workshop at University of Georgia (UGA) Engineering Research Education Center (EREC)*

- Resilient Modulus
- California Bearing Ratio
- Dynamic Modulus
- Coefficient of Thermal Expansion
- Poisson's Ratio
- Compressive Strength
- Elastic Modulus

8

Module Overview

Video Demonstration

9

Module Overview

Module 6- Hands-on Laboratory Training Workshops at UGA Engineering Research and Education Center (EREC)

- 2 or 3 day-long learning workshops
- Hands-on laboratory learning experience for determining MEPDG input parameters
- Supplementary instructional videos provide employees with reference for critical input values

10

Next Steps

Integration of Modules into GDOT's Learning Management System (LMS)

Continual improvement of training module videos
- Configure using future software versions
- Changes to user-defined inputs

Update MEPDG Training documents with growing material research database
- RP 16-19, "Effects of Asphalt Mixture Characteristics on |E*|and Fatigue Performance"
- RP 17-18, "Development of Innovative & Effective Training Modules and Methods for Pavement Engineers for Rapid Deployment and Continuous Operation of MEPDG"
- RP 18-03, "Development of Concrete Material Property Database for Pavement ME Input"
- RP 18-04, "Development of Traffic Inputs for Georgia Pavement Design"
- RP 18-05, "Updated Layer Coefficients for GDOT Flexible Pavement Design"

12

Next Steps

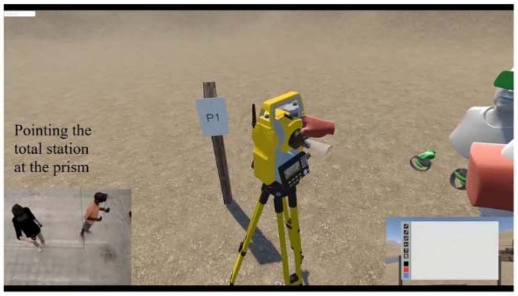
Virtual Reality (VR) Experiences for Laboratory Training
- Looking for participating DOTs to develop VR experiences for laboratory testings (i.e. dynamic modulus, resilient modulus, CTE)

Testing Procedures for MEPDG Material Inputs

Video Series	Material	Procedure	Location
1	Subgrade	Resilient Modulus	GeoMat Lab
2	Subgrade	California Bearing Ratio	GeoMat Lab
3	Asphalt	Dynamic Modulus	GeoMat Lab
4	Concrete	Coefficient of Thermal Expansion	Strength Lab
5	Concrete	Poisson's Ratio	Strength Lab
		Compressive Strength	
		Elastic Modulus	

12

Next Steps



13

Conclusions

- Facilitate MEPDG implementation through effective and engaging learning opportunities for pavement engineers
- Implement informative Pavement ME training modules outlining important design procedures and updates for MEPDG
- Familiarize engineers with MEPDG input parameters through on-site laboratory testing and virtual reality experiences

Ultimate Goal: Development of national training program for MEPDG in cooperation with ARA and NCHRP

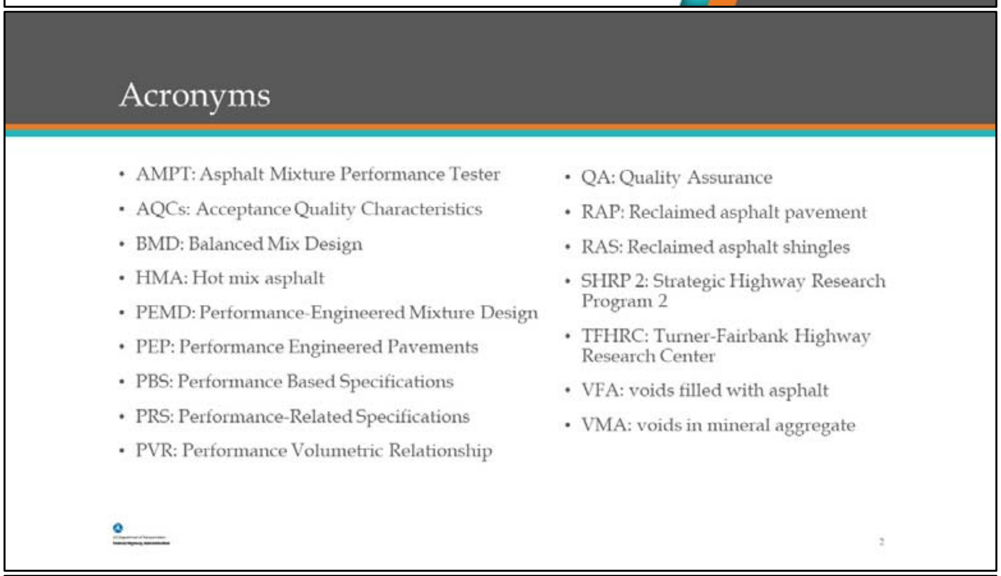
14

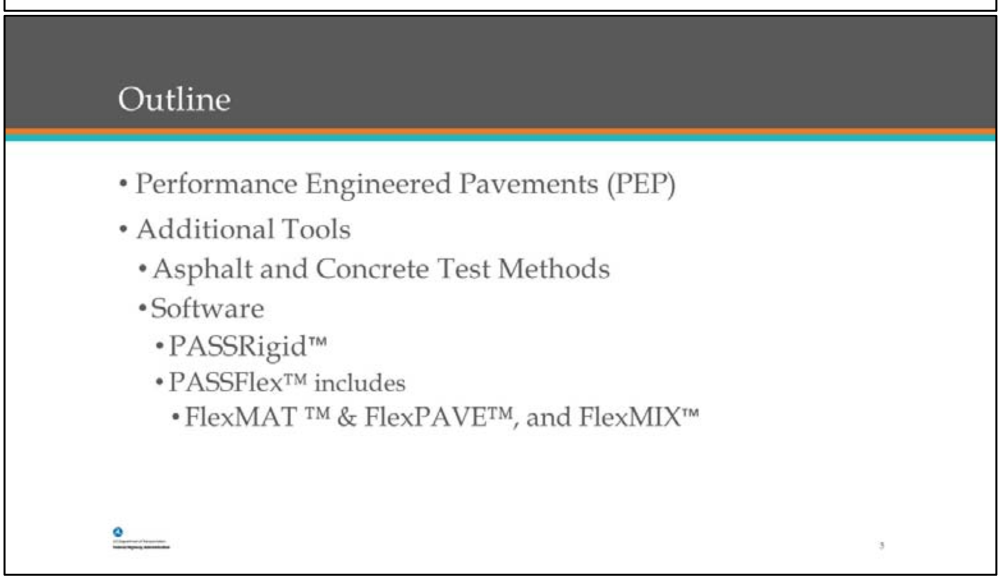
Questions?

irish@dot.ga.gov
sdurham@uga.edu
kims@uga.edu

15

Presentation 21—Richard Duval, FHWA



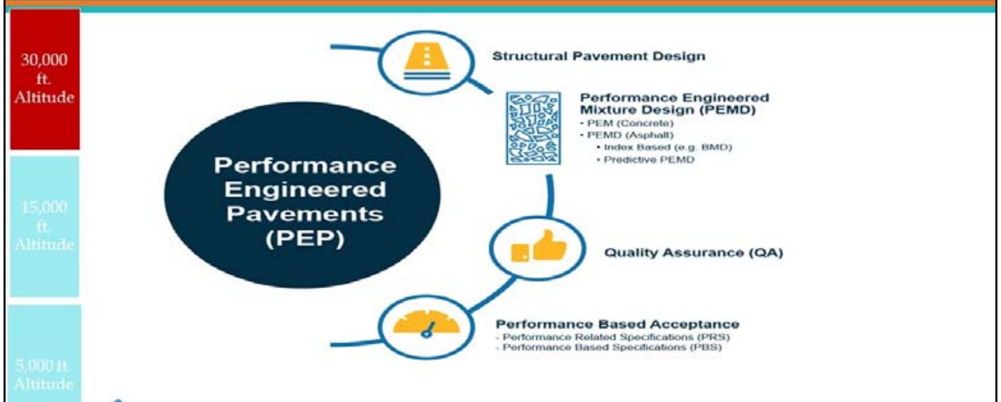


Performance Engineered Pavements (PEP)

- The PEP initiative unifies several existing performance focused programs under a single strategic program vision.
- PEP integrates corporate long-term performance with structural pavement design, mixture design, construction, and materials acceptance of our nation's asphalt and concrete pavement infrastructure.

4

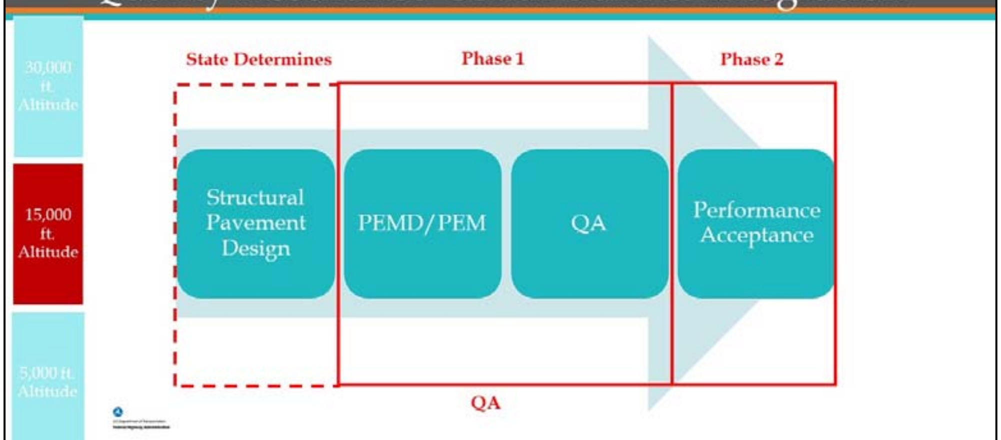
Performance Engineered Pavements



All images provided by FHWA

5

Performance Engineered Pavements Quality Assurance Continuum & Integration



Facts about FHWA PEP & Software

- FHWA is NOT trying to replace PAVE ME. The software is an additional tool for the integration to the PEP.
- FHWA is committed to working with States, AASHTO, and Industry.
- FHWA is committed to share with PAVE ME user group the PASSRigid™, FlexMAT™ & FlexPAVE™ tools to evaluate and provide feedback.
- FHWA is considering workshop for using the software. Would this be useful? AMPT Pooled Fund for asphalt?
- FHWA is providing awareness on the new tests provisional standards for Concrete Durability tests, Dynamic Modulus and Cyclic Fatigue Small Specimen testing, and Stress Sweep Rut.
- FHWA would like to share the software with AASHTO PAVE ME Users for evaluation.

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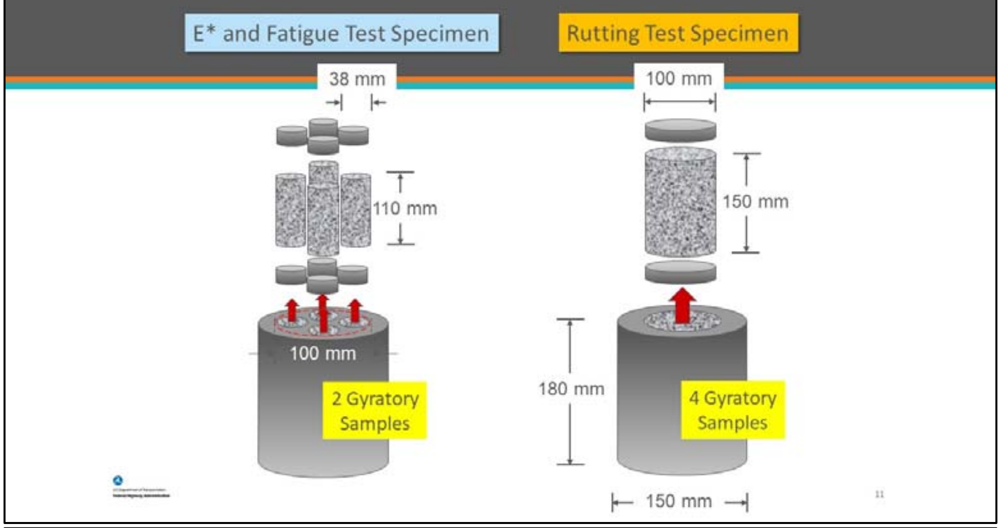
Asphalt Test Methods

Asphalt Mixture Performance Tester

AMPT Performance Testing Suite

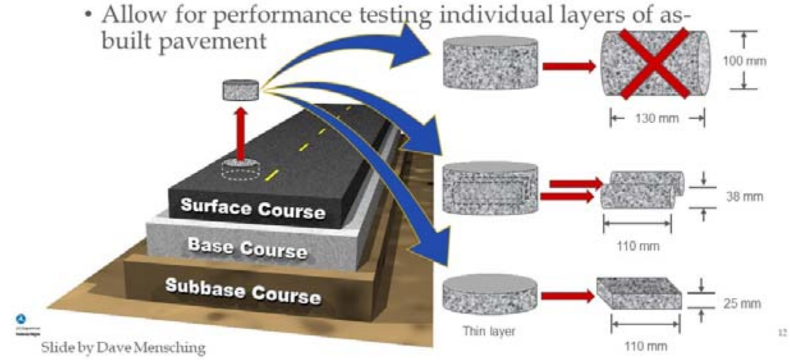
Test Method	AASHTO Spec.	Specimen Geometry	Material Properties	Index Parameter	Required Testing Time
Dynamic Modulus Test	PP 99/TP 132	38 mm D, 110 mm H	|E*|, phase angle, t-T shift factor	N/A	8 hrs
Cyclic Fatigue Test	PP 99/TP 133	38 mm D, 110 mm H	Damage characteristic curve, D^R failure criterion	S_{app}	5 hrs
Stress Sweep Rutting Test	TP 134	100 mm D, 150 mm H	Shift model coefficients	ATR	8 hrs

10



38 mm Specimen from Field Cores

- Asphalt concrete layers are generally thinner than 100 mm
- Allow for performance testing individual layers of as-built pavement



Slide by Dave Mensching

12

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Federal Highway Administration

Concrete Test Methods

PP84 Parameter	Performance Engineered Mixtures (PEM): Lab Mixture Qualification Before Construction	QA and Performance Acceptance: Field Acceptance During/After Construction	
Aggregate Stability	• D-Cracking • Alkali-Aggregate Reactivity	• Not included in PASSRigid®	Mixture qualification only, cannot be controlled by contractor during construction.
Transport Properties	• Choose from water to cementitious materials (w/cm) ratio, formation factor, ionic penetration (F factor)	• Choose from water to cementitous materials (w/cm) ratio or formation factor	Test one or more samples per sublot. Incentives/disincentives computed using PASSRigid®.
Hydrated Cement Paste Durability	• Choose from entrained fresh air content, SAM number, or time to critical saturation	• Choose from entrained fresh air content or SAM number	Test one or more samples per sublot. Incentives/disincentives computed using PASSRigid®.
Hydrated Cement Paste Durability – Salt Damage	• Choose from several options listed in PP84	• Design check only	Enter mix parameters and salt usage rates to check for salt damage. Full model could be added in future.
Slab Warping/Cracking Due to Shrinkage	• Choose from several options listed in PP84	• Not included in PASSRigid®	No calibrated models tying this parameter with long term performance for use in PASSRigid®.
Concrete Strength	• Choose from flexural strength or compressive strength	• Choose from flexural strength or compressive strength	Test one or more samples per sublot. Incentives/disincentives computed using PASSRigid®.
Workability	• Choose from Box test or V-Kelly test	• Not included in PASSRigid®	No calibrated models tying this parameter with long term performance for use in PASSRigid®.
Non Mixture Factors	• Concrete slab thickness, initial smoothiness (IRI), dowel alignment (effective dowel diameter)	• Agency choice of using one, two, or all three factors	Test one or more samples per sublot. Incentives/disincentives computed using PASSRigid®.

Legend Not in PASSRigid® | Currently being included in PASSRigid® | Included in PaveSpec 4.0

Analysis Programs

- System of **"tools"** for **asphalt & concrete pavement design, mix design, and performance based acceptance**
  - Test methods using **Asphalt** Mixture Performance Tester (AMPT) for Dynamic, Modulus, Cyclic Fatigue, Stress Sweep Rut
  - Test methods using **Concrete** Strength, Air, Durability F-Factor/Resistivity, Ride, Dowel Alignment, Thickness.
  - Mechanistic models
  - Software pavement performance analysis programs
- Based on fundamental engineering principles (not so much for concrete)
  - Seamless integration of pavement design, mix design, and performance spec acceptance (PEP)
  - Efficient testing to cover a wide range of loading and environmental conditions (asphalt only)

15

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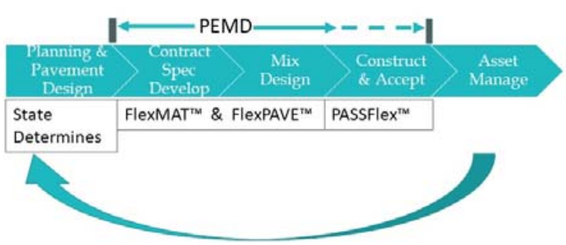
Software

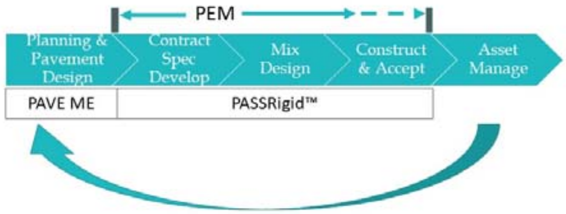
Software

17

Asphalt Performance Software Application PEMD/AMPT



Concrete Performance Software Application PEM (AASHTO PP84)



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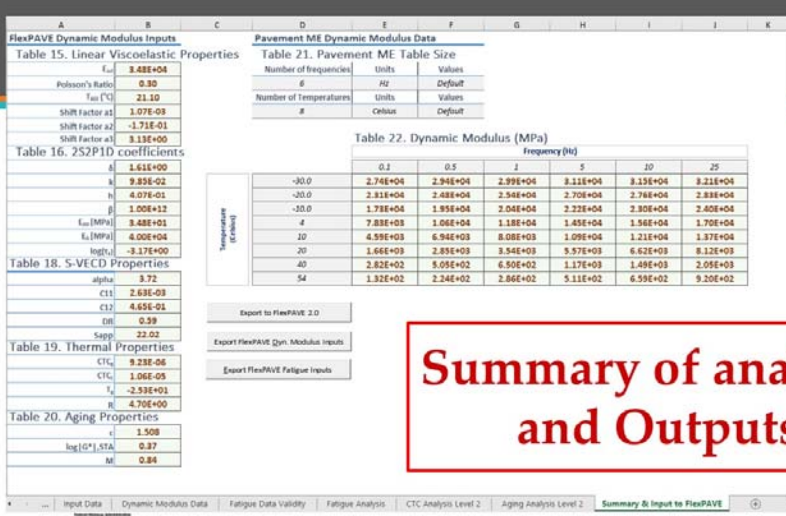
FlexMAT™



FlexPAVE Dynamic Modulus Inputs

Table 15. Linear Viscoelastic Properties

E	3.48E+04
Poisson's Ratio	0.30
T_{ref} (°C)	21.10
Shift Factor a1	1.07E-03
Shift Factor a2	-1.71E-01
Shift Factor a3	3.13E+00

Table 16. 2S2P1D coefficients

δ	1.61E+00
k	9.85E-02
h	4.07E-01
β	1.00E+12
E_∞ [MPa]	3.48E+01
E_0 [MPa]	4.00E+04
$\log(\tau_0)$	-3.17E+00

Table 18. S-VECD Properties

alpha	3.72
C11	2.63E-03
C12	4.65E-01
DR	0.39
Sapp	22.02

Table 19. Thermal Properties

CTC_g	9.23E-06
CTC_l	1.06E-05
T_g	-2.53E+01
R	4.70E+00

Table 20. Aging Properties

c	1.508
log|G*|,STA	0.37
M	0.84

Pavement ME Dynamic Modulus Data

Table 21. Pavement ME Table Size

Number of frequencies	Units	Values
6	Hz	Default
Number of Temperatures	Units	Values
8	Celsius	Default

Table 22. Dynamic Modulus (MPa)

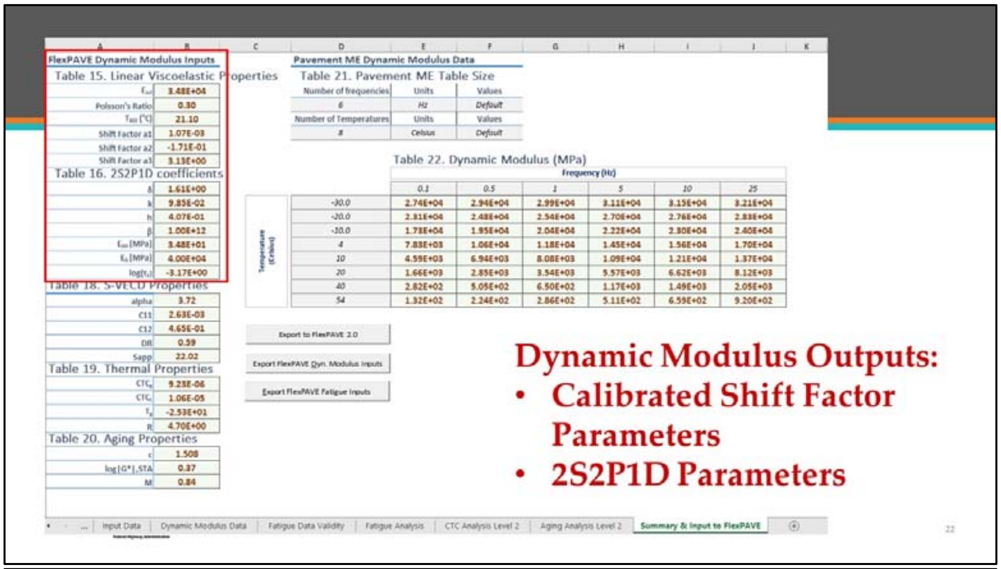
Temperature (Celsius)	Frequency (Hz) 0.1	0.5	1	5	10	25
-30.0	2.74E+04	2.94E+04	2.99E+04	3.11E+04	3.15E+04	3.21E+04
-20.0	2.31E+04	2.48E+04	2.54E+04	2.70E+04	2.76E+04	2.83E+04
-10.0	1.73E+04	1.95E+04	2.04E+04	2.22E+04	2.30E+04	2.40E+04
4	7.83E+03	1.06E+04	1.18E+04	1.45E+04	1.56E+04	1.70E+04
10	4.59E+03	6.94E+03	8.08E+03	1.09E+04	1.21E+04	1.37E+04
20	1.66E+03	2.85E+03	3.54E+03	5.57E+03	6.62E+03	8.12E+03
40	2.82E+02	5.05E+02	6.50E+02	1.17E+03	1.49E+03	2.05E+03
54	1.32E+02	2.24E+02	2.86E+02	5.11E+02	6.59E+02	9.20E+02

Export to FlexPAVE 2.0
Export FlexPAVE Dyn. Modulus Inputs
Export FlexPAVE Fatigue Inputs

Input Data | Dynamic Modulus Data | Fatigue Data Validity | Fatigue Analysis | CTC Analysis Level 2 | Aging Analysis Level 2 | Summary & Input to FlexPAVE

Summary of analysis and Outputs

21


FlexPAVE Dynamic Modulus Inputs
Table 15. Linear Viscoelastic Properties
Table 16. 2S2P1D coefficients
Table 18. S-VECD Properties
Table 19. Thermal Properties
Table 20. Aging Properties
Pavement ME Dynamic Modulus Data
Table 21. Pavement ME Table Size
Table 22. Dynamic Modulus (MPa)
Dynamic Modulus Outputs:
• Calibrated Shift Factor Parameters
• 2S2P1D Parameters

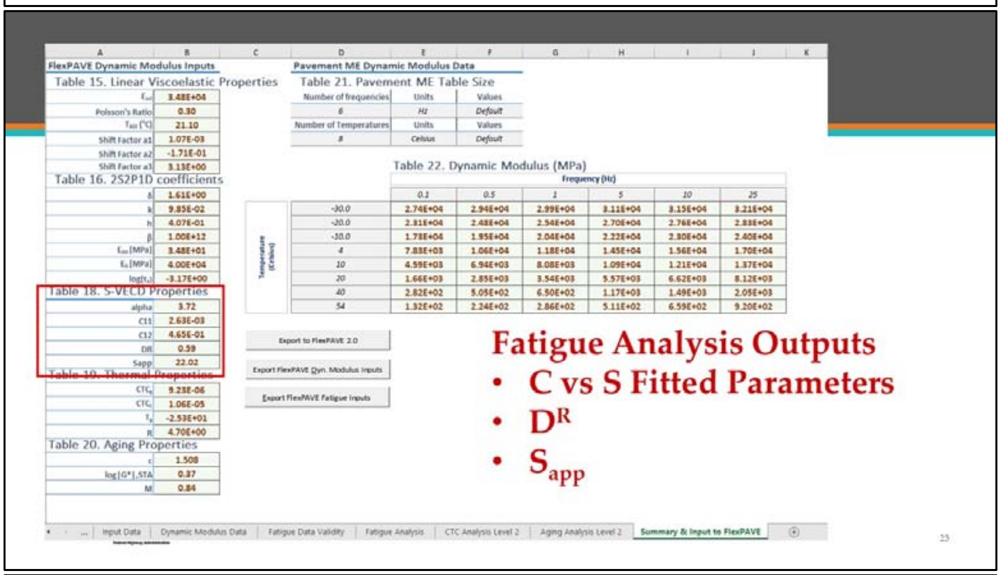

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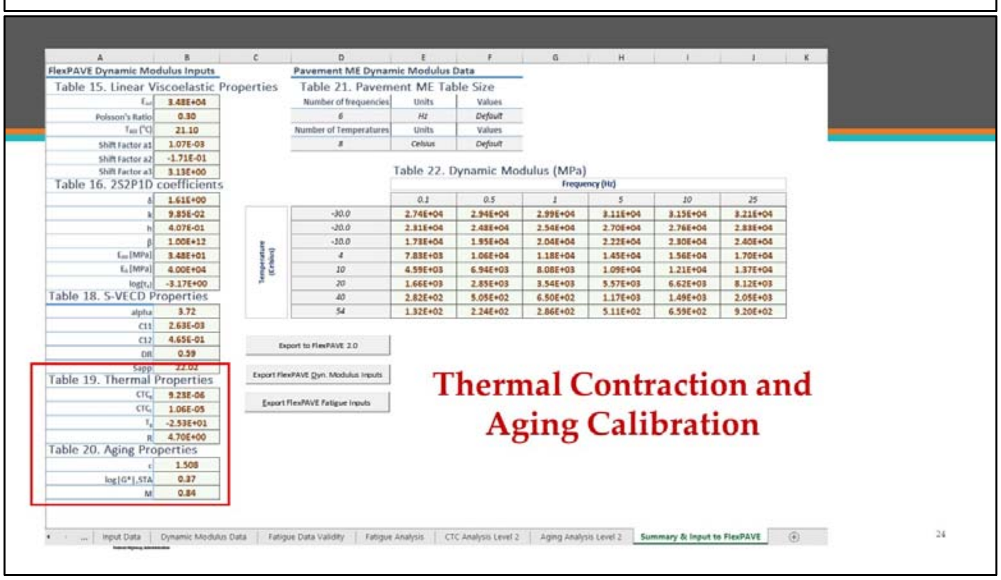
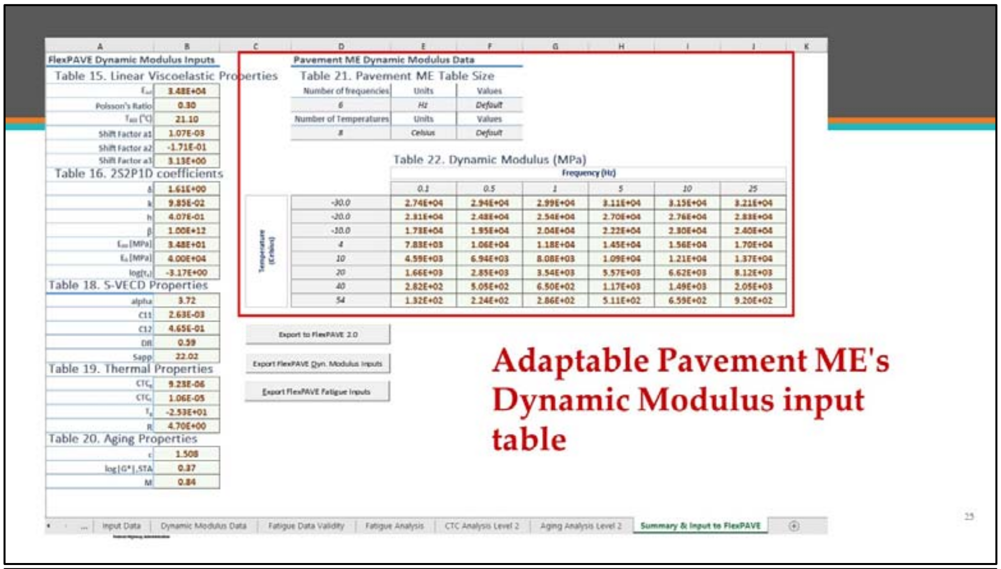
Table 19. Thermal Properties
Table 20. Aging Properties
Pavement ME Dynamic Modulus Data
Table 21. Pavement ME Table Size
Table 22. Dynamic Modulus (MPa)
Fatigue Analysis Outputs
• C vs S Fitted Parameters
• D^R
• S_app


FlexPAVE Dynamic Modulus Inputs
Table 15. Linear Viscoelastic Properties
Table 16. 2S2P1D coefficients
Table 18. S-VECD Properties
Table 19. Thermal Properties
Table 20. Aging Properties
Pavement ME Dynamic Modulus Data
Table 21. Pavement ME Table Size
Table 22. Dynamic Modulus (MPa)
Thermal Contraction and
Aging Calibration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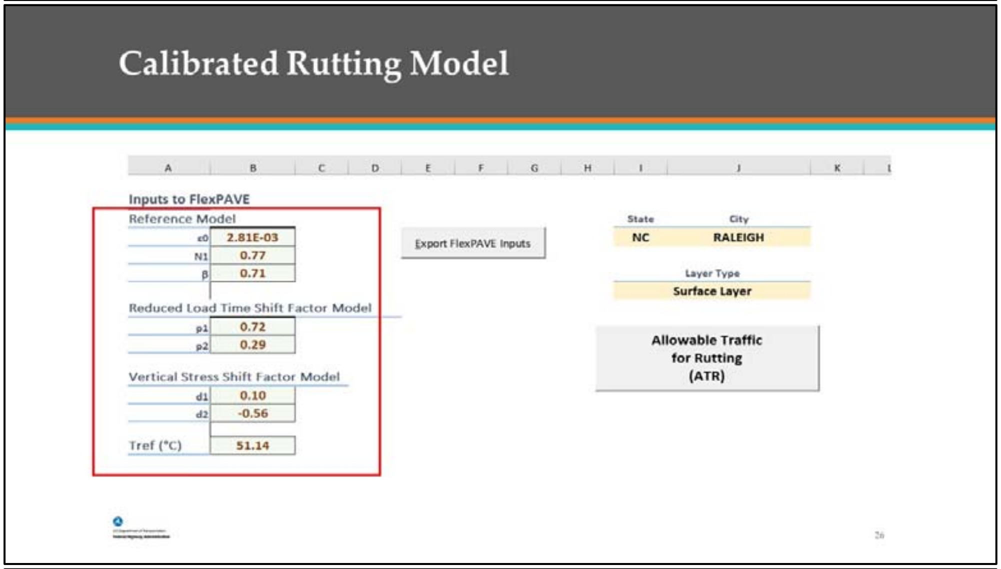
C11 2.63E-03
C12 4.65E-01
DR 0.59
Sapp 22.02
Table 19. Thermal Properties
Table 20. Aging Properties
Pavement ME Dynamic Modulus Data
Table 21. Pavement ME Table Size
Number of frequencies Units Values
6 Hz Default
Number of Temperatures Units Values
8 Celsius Default
Table 22. Dynamic Modulus (MPa)
Frequency (Hz)
0.1 0.5 1 5 10 25
-30.0 2.74E+04 2.94E+04 2.99E+04 3.11E+04 3.15E+04 3.21E+04
-20.0 2.31E+04 2.48E+04 2.54E+04 2.70E+04 2.76E+04 2.83E+04
-10.0 1.73E+04 1.95E+04 2.04E+04 2.22E+04 2.30E+04 2.40E+04
4 7.83E+03 1.06E+04 1.18E+04 1.45E+04 1.56E+04 1.70E+04
10 4.59E+03 6.94E+03 8.08E+03 1.09E+04 1.21E+04 1.37E+04
20 1.66E+03 2.85E+03 3.54E+03 5.57E+03 6.62E+03 8.12E+03
40 2.82E+02 5.05E+02 6.50E+02 1.17E+03 1.49E+03 2.05E+03
54 1.32E+02 2.24E+02 2.86E+02 5.11E+02 6.59E+02 9.20E+02
Export to FlexPAVE 2.0
Export FlexPAVE Dyn. Modulus Inputs
Export FlexPAVE Fatigue Inputs
Adaptable Pavement ME's Dynamic Modulus input table
Input Data
Dynamic Modulus Data
Fatigue Data Validity
Fatigue Analysis
CTC Analysis Level 2
Aging Analysis Level 2
Summary & Input to FlexPAVE


Calibrated Rutting Model
Inputs to FlexPAVE
Reference Model
ε0 2.81E-03
N1 0.77
β 0.71
Reduced Load Time Shift Factor Model
p1 0.72
p2 0.29
Vertical Stress Shift Factor Model
d1 0.10
d2 -0.56
Tref (°C) 51.14
Export FlexPAVE Inputs
State City
NC RALEIGH
Layer Type
Surface Layer
Allowable Traffic for Rutting (ATR)


U.S. Department of Transportation
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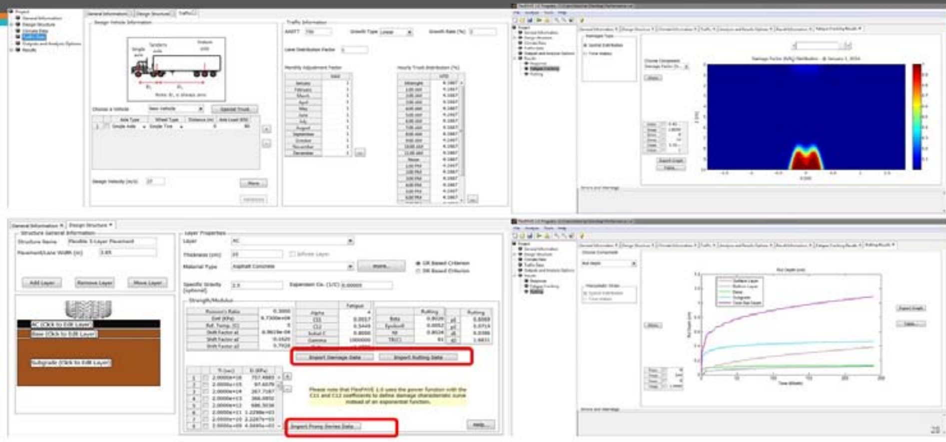
FlexPAVE™

FlexPAVE™ ver 1.1 >> ver 2.0 Early 2020



28

How do I get the software?

FlexPAVE™ & FlexMAT™

- Dr. Richard Kim – NCSU
  - kim@ncsu.edu>
- Matt Corrigan – FHWA
  - Matthew.Corrigan@dot.gov

https://www.fhwa.dot.gov/pavement/**asphalt/analysis/**

PASSRigid™

- Dr. Shreenath Rao – ARA
  - srao@ara.com

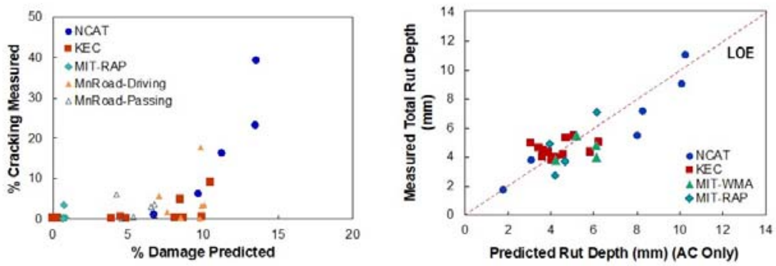
Under Construction
https://www.fhwa.dot.gov/pavement/**concrete/analysis/**

29

Thank you!

30

Field Validation



Images provided by Dr. Richard Kim, NCSU

Concluding Remarks

- PASSFlex™ is a system of test methods, mechanistic models, and software programs.
- PASSFlex™ allows the integration of mix design, pavement design, and ultimately performance acceptance.
- FlexMAT™, FlexPAVE™, and FlexMIX™ are available upon request.