APPENDIX A. MEETING PARTICIPANTS

TAC and Pooled Fund Member Participants

Name	Agency	TAC Member	Pooled Fund Member Tech Rep	Pvt ME Design TF Member	Email Address
Vicki Schofield	AASHTO	Yes	Yes	Yes	vschofield@aashto.org
Tom Yu Chris Wagner	FHWA	Yes Yes	Yes Yes	Liaison No	tom.yu@dot.gov christopher.wagner@dot.gov
Lyndi Blackburn Robert Shugart Jr.	Alabama DOT	Yes No	Yes No	No No	blackburnl@dot.state.al.us shugartr@dot.state.al.us
Scott Weinland Hector Rivas	Arizona DOT	No No	Yes No	No No	sweinland@azdot.gov hrivasbernal@azdot.gov
Mehdi Parvini	California DOT	Yes	Yes	Yes	mehdi_parvini@dot.ca.gov
Jay Goldbaum Melody Perkins Coulter Golden	Colorado DOT	Yes No No	Yes No No	Yes No No	jay.goldbaum@dot.state.co.us melody.perkins@dot.state.co.us coulter.golden@state.co.us
Rhonda Taylor Patrick Overton	Florida DOT	No No	Yes No	No No	rhonda.taylor@dot.state.fl.us patrick.overton@dot.state.fl.us
Chris Brakke	Iowa DOT	No	Yes	No	chris.brakke@iowadot.us
Ryan Barrett Nat Valesquez	Kansas DOT	No No	Yes No	No No	ryan.barrett@ks.gov nat.velasquez@ks.gov
Sunil Saha Joe Tucker	Kentucky TC	No No	Yes Yes	No No	sunil.saha@ky.gov joseph.tucker@ky.gov
Geoffrey Hall	Maryland SHA	No	No	No	ghall1@sha.state.md.us
Justin Schenkel Adnan Iftikhar Greg Bills	Michigan DOT	No No No	No No No	No No No	schenkelj@michigan.gov iftikhara@michigan.gov billsg@michigan.gov
John Donahue Paul Denkler Sarah Kleinschmit	Missouri DOT	No No No	No Yes No	Yes No No	john.donahue@modot.mo.gov paul.denkler@modot.mo.gov sarah.kleinschmit@modot.mo.gov
Yathi Yatheepan	Nevada DOT	No	No	No	vyatheepan@dot.state.nv.us
Clark Morrison	North Carolina DOT	No	No	No	cmorrison@ncdot.gov
Kyle Evert Matthew Luger	North Dakota DOT	No No	No No	No No	kevert@nd.gov mmluger@nd.gov
Susanne Chan Warren Lee	Ontario MOT	No No	Yes No	No No	susannec@gmail.com warren.lee@ontario.ca
Josh Freeman Lydia Peddicord	Pennsylvania DOT	No No	Yes Yes	No No	josfreeman@pa.gov lpeddicord@pa.gov
Jesse Thompson	South Carolina DOT	No	Yes	No	thompsonju@scdot.org
Hari Nair Affan Habib	Virginia DOT	No Yes	Yes Yes	No No	harikrishnan.nair@vdot.virginia.gov affan.habib@vdot.virginia.gov
Laura Fenley Tony Allard	Wisconsin DOT	No No	Yes No	No No	laura.fenley@dot.state.wi.us anthony.allard@dot.wi.gov

Non-TAC / Non-Pooled Fund Member Participation

Name	Agency	Pvt ME Design TF Member	Email Address
Kelly Smith Prashant Ram Kurt Smith	APTech	No No No	klsmith@appliedpavement.com pram@appliedpavement.com ksmith@appliedpavement.com
Linda Pierce	NCE	No	lpierce@ncenet.com
Chad Becker Harold Von Quintus	ARA	No No	cbecker@ara.com hvonquintus@ara.com
Larry Wiser	FHWA	No	larry.wiser@dot.gov
Mike Voth	FHWA Federal Lands	No	michael.voth@dot.gov
Bruce Dietrich	Pavement Analytics LLC	No	bdietrich@pavementanalytics.com
Clark Graves	U. of KY	No	clark.graves@uky.edu
Bradley Putman	Clemson U.	No	putman@clemson.edu
Amy Simpson	AMEC	No	amy.simpson@amecfw.com
Marta Juhasz	Alberta Transp	Yes	marta.juhasz@gov.ab.ca
Brooke Perkins	Arkansas SHTD	No	brooke.perkins@ahtd.ar.gov
Charles Weinrank	Illinois DOT	No	charles.wienrank@illinois.gov
Tommy Nantung Jusang Lee Kumar Dave Lisa Egler-Kellem	Indiana DOT	No No No No	tnantung@indot.in.gov jlee@indot.in.gov kdave@indot.in.gov legler-kellems@indot.in.gov
Xingwei Chen	Louisiana DOTD	No	xingwei.chen@la.gov
Steven Bodge	Maine DOT	No	stephen.bodge@maine.gov
Alauddin Ahammed	Manitoba Transp	No	alauddin.ahammed@gov.mb.ca
Bill Barstis	Mississippi DOT	Yes	wbarstis@mdot.state.ms.us
Nusrat Morshed	New Jersey DOT	No	nusrat.morshed@dot.nj.gov
Jeffrey Mann	New Mexico DOT	No	jeffreys.mann@state.nm.us
Patrick Bierl	Ohio DOT	No	patrick.bierl@dot.ohio.gov
Josh Randell	Oklahoma DOT	No	jrandell@odot.org
Felix Doucet	Quebec MOT	Yes	felix.doucet@transports.gouv.qc.ca
Marcy Montague	Vermont AOT	No	marcy.montague@vermont.gov
Jianhua Li	Washington State DOT	No	lijia@wsdot.wa.gov

APPENDIX B. MEETING AGENDA

Wednesday, December 14

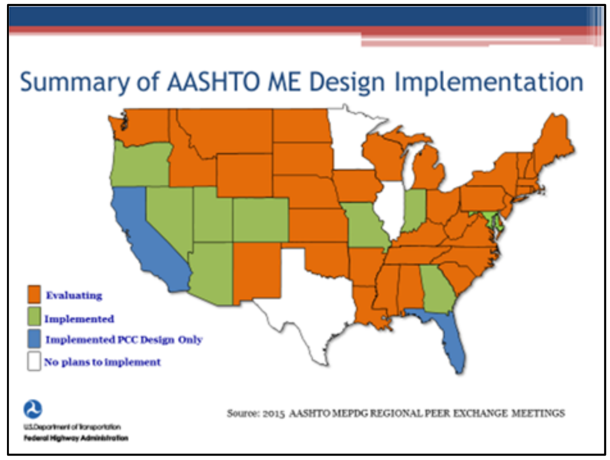
Time	Topic
8–8:45 AM	WELCOME AND INTRODUCTIONS Welcome | Chris Wagner (FHWA). Introduction and remarks | John Donahue (Missouri DOT, Vice-Chair of AASHTO Joint Technical Committee on Pavements and AASHTOWare Pavement ME Design Taskforce). Remarks on Canadian efforts | Felix Doucet (Quebec Ministry of Transportation, Canadian ME Task Force liaison) Review of agenda and meeting goals | Linda Pierce (NCE) and Kelly Smith (Applied Pavement Technology)
8:45–9:45 AM	AGENCY IMPLEMENTATION EXPERIENCES MEPDG to AASHTO Pavement ME: 2004 to Present | Paul Denkler (Missouri DOT) ME Oversight Committee | Adnan Iftikhar (Michigan DOT) Process Issues | Affan Habib (Virginia DOT)
9:45–10 AM	BREAK
10:00–11:15 AM	AGENCY IMPLEMENTATION STATUS Agency updates on implementation plans, timelines, and progress.
11:15 AM–NOON	AASHTOWARE PAVEMENT ME DESIGN SOFTWARE UPDATE Announcements and news regarding latest software and purchasing/licensing | Vicki Schofield (AASHTO) Software enhancements/updates, including new features/capabilities | Chad Becker (ARA)
NOON–1:15 PM	LUNCH (ON YOUR OWN)
1:15–2 PM	DESIGN PARAMETERS: CONDITION THRESHOLD LIMITS, RELIABILITY LEVELS, HIERARCHICAL LEVELS Design Parameters | Geoff Hall (Maryland SHA) Design Catalog and Web-Based Program | Joe Tucker (Kentucky Transportation Cabinet)
2–2:30 PM	CLIMATE Long-Term Pavement Performance Climate Tools for ME Design, including MERRA | Larry Wiser (FHWA)
2:30–2:45 PM	BREAK
2:45–3 PM	TRAFFIC Case-Study Report: Traffic-Related Issues, Resolutions, and Lessons Learned | Nusrat Morshed (New Jersey DOT)
3–3:45 PM	MATERIAL INPUTS I—SUBGRADE AND TREATED AND UNTREATED BASE/SUBBASE MATERIALS Subgrade Soils | Melody Perkins (Colorado DOT) Determination of In-Place Elastic Layer Moduli Through Backcalculation of FWD Data | Harold Von Quintus (ARA)
3:45–4:45 PM	MATERIAL INPUTS II—HOT-MIX ASPHALT MATERIALS (NEW AND REHAB DESIGN) HMA Materials | Lyndi Blackburn (Alabama DOT) Local Calibration of Rutting on Asphalt Full-Depth Pavements | Tommy Nantung and Jusang Lee (Indiana DOT) Incorporating Recycled Materials (GTR, RAP, RAS) | Harold Von Quintus (ARA)
4:45–5 PM	DAY ONE KEY TAKE-AWAYS Discuss key takeaways of day one | All

Thursday, December 15

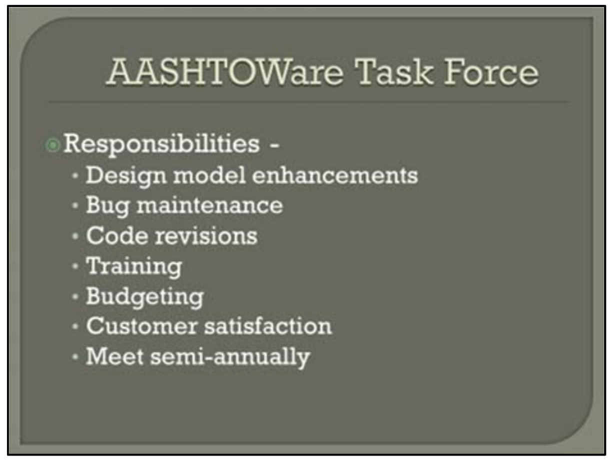
Time	Topic
8–8:45 AM	MATERIAL INPUTS III—PORTLAND CEMENT CONCRETE MATERIALS (NEW AND REHAB DESIGN) MERRA and PCC Pavement Design	Rhonda Taylor (Florida DOT) Update on TPF-5(300), Performance and Load Response of Rigid Pavement Systems	Chris Brakke (Iowa DOT)
8:45–9:45 AM	CALIBRATION/VALIDATION Local Calibration Effort on Flexible Pavement	Warren Lee (Ontario Ministry of Transportation) Calibration and Validation	Ryan Barrett (Kansas DOT) Calibration and User Manual	Justin Schenkel (Michigan DOT) Local Calibration	Affan Habib (Virginia DOT)
9:45–10 AM	BREAK
10 AM–NOON	SOFTWARE TRAINING Demonstration-based training on new software features (e.g., use of MAP-ME and climate data files) and example applications (e.g., rehabilitation design including backcalculation)	Chad Becker and Harold Von Quintus (ARA)
NOON–1:15 PM	LUNCH (ON YOUR OWN)
1:15–1:45 PM	CHALLENGES/ISSUES/ROADBLOCKS Common challenges/issues/roadblocks that can be resolved at the regional level rather than by each SHA.
1:45–2:30 PM	ADDITIONAL NEEDS AND NEXT STEPS MEPDG Clearinghouse Study	Prashant Ram (APTech) Additional training, software, and research needs, including future pavement ME design enhancements, additional web-based training	All agencies SHA next steps and implementation timelines
2:30–2:45 PM	DAY TWO KEY TAKE-AWAYS Discuss key takeaways of day two	All
2:45–3 PM	BREAK
3–5 PM	TAC/POOLED FUND MEMBER MEETING Discussion of key outcomes of Users Group Meeting.

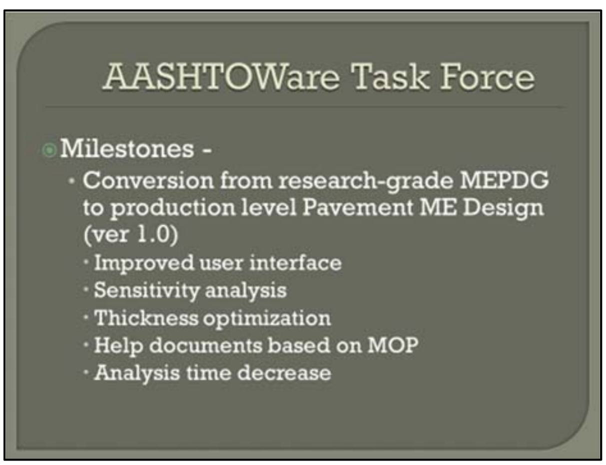
APPENDIX C. MEETING PRESENTATIONS

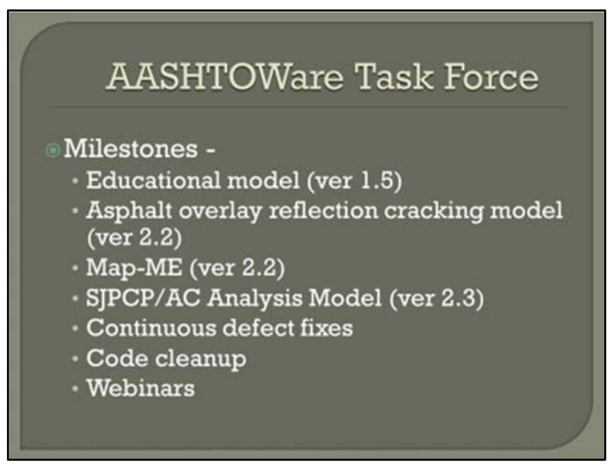
Presentation 1—Chris Wagner, FHWA

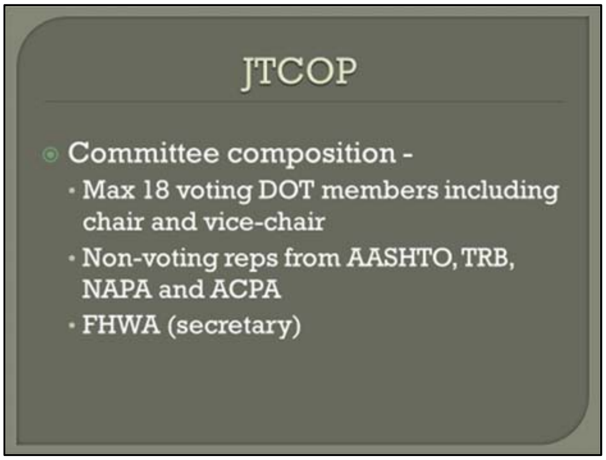


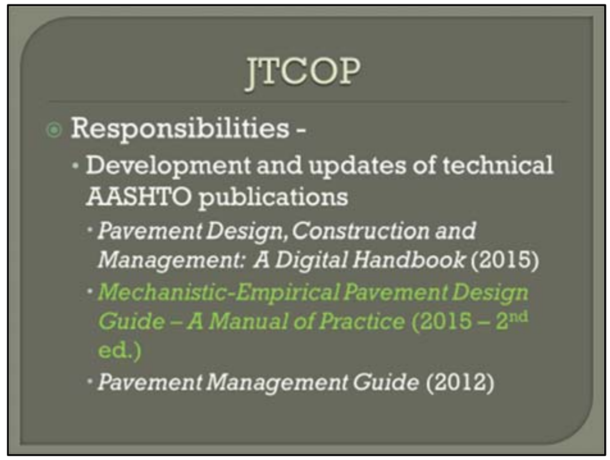
Presentation 2—John Donahue, Missouri DOT

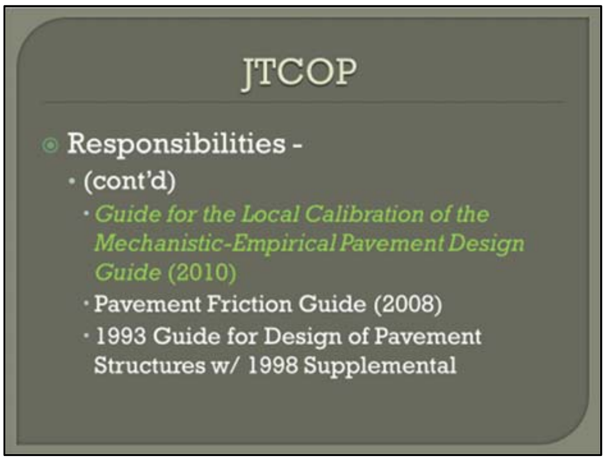


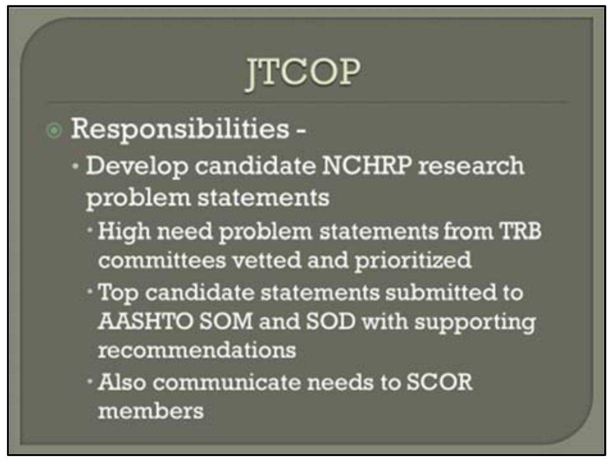


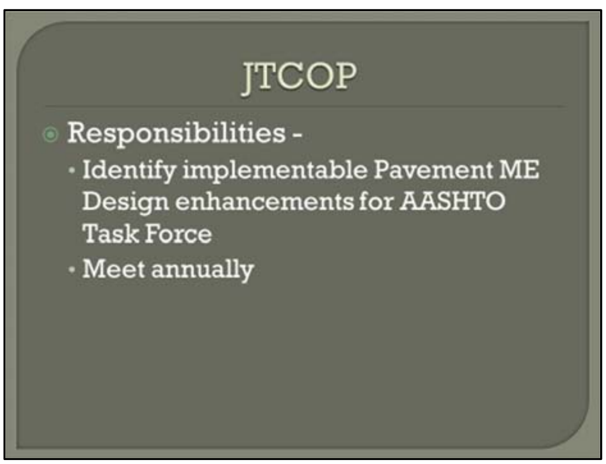



JTCOP
Committee composition -
Max 18 voting DOT members including chair and vice-chair
Non-voting reps from AASHTO, TRB, NAPA and ACPA
FHWA (secretary)


JTCOP
Responsibilities -
Development and updates of technical AASHTO publications
Pavement Design, Construction and Management: A Digital Handbook (2015)
Mechanistic-Empirical Pavement Design Guide – A Manual of Practice (2015 – 2nd ed.)
Pavement Management Guide (2012)


JTCOP
Responsibilities -
(cont'd)
Guide for the Local Calibration of the Mechanistic-Empirical Pavement Design Guide (2010)
Pavement Friction Guide (2008)
1993 Guide for Design of Pavement Structures w/ 1998 Supplemental

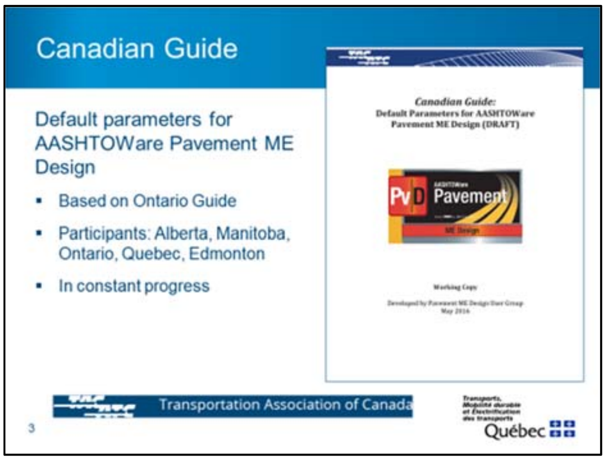

JTCOP
Responsibilities -
Develop candidate NCHRP research problem statements
High need problem statements from TRB committees vetted and prioritized
Top candidate statements submitted to AASHTO SOM and SOD with supporting recommendations
Also communicate needs to SCOR members

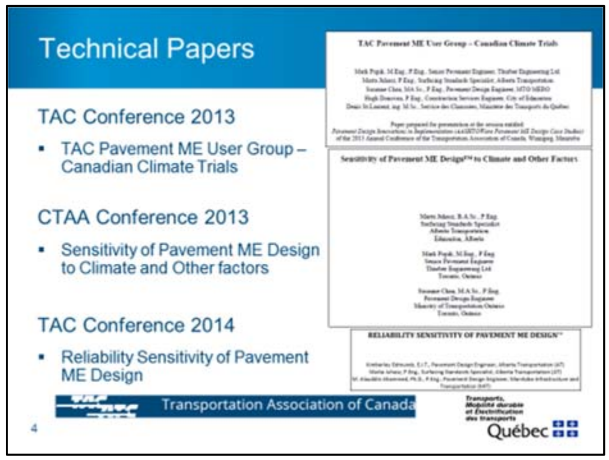

JTCOP
Responsibilities -
Identify implementable Pavement ME Design enhancements for AASHTO Task Force
Meet annually

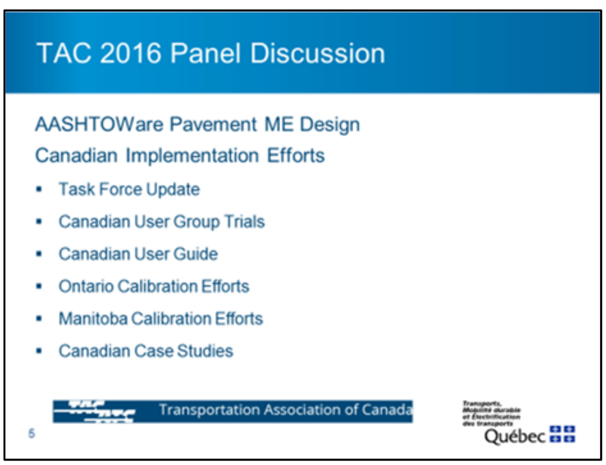

JTCOP-SOM
AASHTO reorganization will create merger between the JTCOP and the Subcommittee on Materials
Details still pending

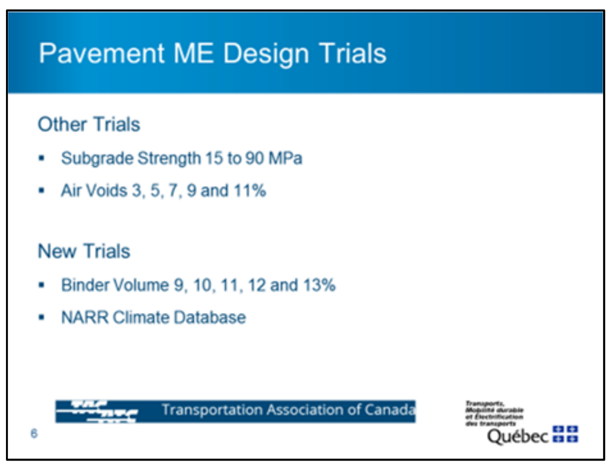

Thank you!
Questions?
john.donahue@modot.mo.gov

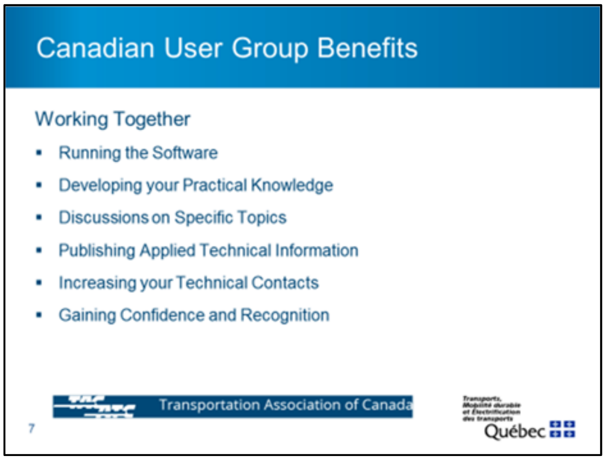
Presentation 3—Felix Doucet, Quebec Ministry of Transportation










Canadian User Group Benefits
Working Together
Running the Software
Developing your Practical Knowledge
Discussions on Specific Topics
Publishing Applied Technical Information
Increasing your Technical Contacts
Gaining Confidence and Recognition
Transportation Association of Canada
Québec
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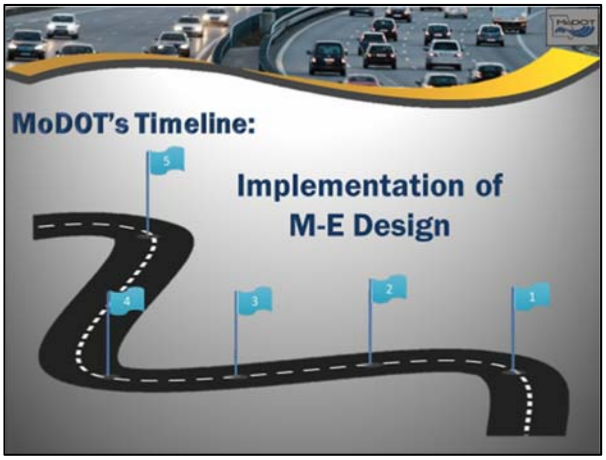
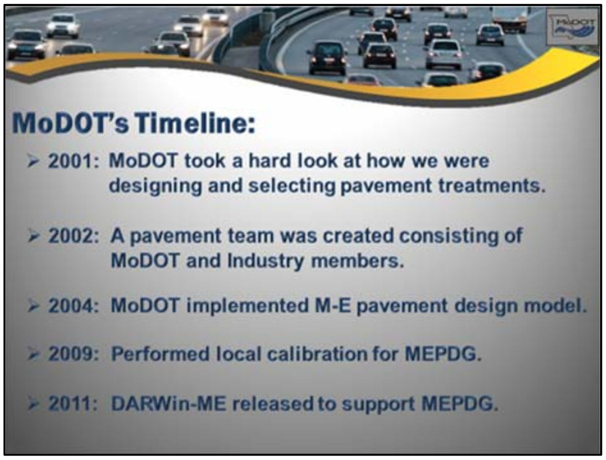
Presentation 4—Paul Denkler, Missouri DOT





Pavement Team:

- **Two Goals:**
  - Provide best pavement product that can be delivered within available resources.
  - Provide the public and stakeholders with a clear understand of the pavement design & selection process.

Pavement Team:

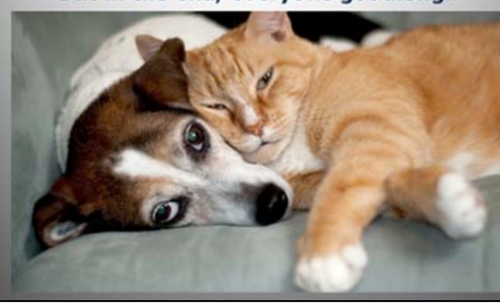
At times was fairly contentious!

Pavement Team:

With MoDOT stuck in the middle!

Pavement Team:

But in the end, everyone got along!



Pavement Team:

...or at least they pretended to!

Pavement Team:

- **Two main outcomes/recommendations:**
  1. Adopt a Mechanistic-Empirical design method.
  2. Advance an Alternate Bidding process for new pavements.

Alternate Bidding Concept:

- MoDOT first looked at alternate bidding in 1996.
- Process of bidding different pavement types with equivalent designs and performance expectations against one another in a competitive environment.
- Involves assumptions for life cycle cost analysis.
- Difficult for pavement team to reach a consensus.

Alternate Bidding Concept:

- HMA assumptions (45 year design life).
  - Mill and replace the surface at years 20 & 33.
- PCCP assumptions (45 year design life).
  - 1.5% pavement repair and diamond grind at year 25.

Alternate Bidding Concept:

- **Maximizing Competition**

- "Structurally Equivalent", PCCP & HMA bid competitively by using LCCA correction factors.

MEPDG Implementation:

- Started using the program in 2004 for JPCP and HMA designs.
- Prior to 2004, used AASHTO 1993 Pavement Guide.
- From 2004 to 2009 used nationally calibrated models.

MEPDG Implementation: (continued)

- Average JPCP thickness was reduced by:
  - ≈2" for high truck volume routes.
  - ≈1" for low to medium truck volume routes.

MEPDG Implementation: (continued)

- Average JPCP thickness was reduced by:
  - ≈2" for high truck volume routes.
  - ≈1" for low to medium truck volume routes.
- Average HMA thickness was reduced by:
  - ≈3-4" for high truck volume routes.
  - ≈1-2" for low to medium truck volume routes.

MEPDG Implementation: (continued)

- Biggest challenges…

Overcoming Fear!

MEPDG Implementation: (continued)

- Biggest challenges…
  - Trusting the results and our inputs.
  - First couple years used both AASHTO '93 & MEPDG.
  - Materials testing for input properties.
    - Granular base testing for modulus.
    - Databases for gradations, effective binder content, total unit weight and other material properties.

MEPDG Implementation: (continued)

- In 2009
  - Performed Model Validation & Recalibration.
    - Validation through historical input data.
    - Predicted performance using M-E models with MO historical data.
    - Compared predicted performance to real-word performance.
    - Models found to be inadequate for local conditions were recalibrated.

MEPDG Implementation: (continued)

- Results of Model Validation and Recalibration.
  - HMA Models.
    - Bottom-up fatigue cracking and thermal cracking were deemed reasonable.
    - Total rutting was found inadequate and was recalibrated. Recalibrated model was deemed reasonable.
  - JPCP Models.
    - Fatigue cracking & faulting were deemed reasonable.
    - IRI model showed bias so it was recalibrated.

MEPDG Implementation: (continued)

- After Model Validation and Recalibration
  - All new pavement designs performed using MEPDG.
- MoDOT's Performance Criteria (developed by pavement team)

Pavement Type	Performance Criteria	Maximum Limits (Trigger Values)	Reliability
HMA Pavement	% Bottom-up Cracking	2.0 % at Year 30	50 %
	Rutting (Asphalt Layers Only)	0.25" at Year 20	50 %
PCC Pavement	% Slabs Cracked	1.5 % at Year 25	50 %
	Faulting	0.15" at Year 25	50 %

- All other criteria uses typical or default values.

MEPDG Implementation: (continued)

- Results of Alt. Bidding and Equivalent Designs…
  - Between 2004 and 2009.
    - 124 Alternate Bid Projects.
      - 118 Full Depth ($1.5 bil)
      - 6 Rehabilitation ($82.6 mil)
    - Full Depth Projects.
      - 40 HMA Awards ($451.7 mil)
      - 78 PCC Awards ($1.1 bil)
    - LCCA Factor determined low bidder 3 times.

MEPDG Implementation: (continued)

- Upgrades…
  - 2011 changed to DARWin-ME.
  - No changes in design thicknesses.
  - 2013 AASHTO Pavement ME.
  - Resulted in some prediction & thickness changes.

AASHTO Pavement ME:

- Trend of New AASHTO ME Design…

ADTT: 1100; Growth Rate: 2.2%; Subgrade: A-7-6; Level 3 Analysis

Design	Old MEPDG Program		New AASTHO ME Program	
Base Type	HMA Design	PCCP Design	HMA Design	PCCP Design
4" Type 5	11.5"(1.6%)	8.5" (0.4%)	11.5" (2.0%)	8.5" (0.9%)
12" Rock Base	9.0" (1.9%)	8.0" (1.5%)	9.0" (2.0%)	8.0" (3.2%) 8.5"(0.7%)
18" Rock Base	8.0" (2.0%)	8.0" (1.3%)	8.0" (2.1%) 8.5" (0.8%)	8.0" (2.7%) 8.5" (0.6%)

AASHTO Pavement ME:

- General Observations…
  - Completely redesigned user interface.
  - Can conduct multiple design analyses simultaneously.
  - Sensitivity analysis replaces running separate designs.
  - Faster analyses run time.
  - Compatibility issues with server (internal issue). Have to run on local C: drive.

AASHTO Pavement ME:

- Detailed Observations…
  - HMA designs more sensitive to base & subgrade.
  - PCC designs more sensitive to widened pavement. (i.e. 13' wide design w/ 12' wide lane.)
  - Level 3 analysis. No benefit given to SMA mixtures over lower type mixtures.
  - Lower freeze/thaw cycles near airports in urban areas.

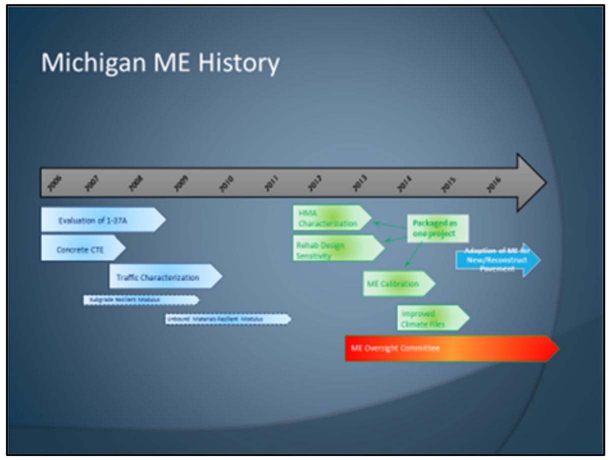
AASHTO Pavement ME:

- Going Forward…
  - HMA designs are based on virgin mixes. Would like to have this include mixtures with recycles.
  - MoDOT current undergoing recalibration. We have included mostly recycled mixes for analysis.
  - Like to learn more about ability to evaluating drainage.
  - Possibility of incorporating MSCR binder grading.
  - Utilize overlay analysis.

Questions?

Presentation 5—Adnan Iftikhar, Michigan DOT


Michigan ME History


Michigan ME History
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
Evaluation of 1-37A
Concrete CTE
Traffic Characterization
HMA Characterization
Rehab Design Sensitivity
Packaged as one project
ME Calibration
Improved Climate Files
ME Oversight Committee


ME Oversight Committee


ME Oversight Committee
Established 2012
Traditionally pavement design procedures, policies, etc., have been the duty of one central office engineer
2012 – added an additional pavement design engineer
Complexity of ME necessitated input from expertise from around the department to help implementation
Assembled a team that represents different areas of expertise


ME Oversight Committee
ME Oversight Committee (cont.)
Membership from various areas
Supervisors of the following general areas:
Pavement Operations Engineer
Pavement Design Program Engineer (chair)
Region Soils Engineers (Region pavement designers)
Concrete and HMA paving industries
FHWA Michigan Division Representative


ME Oversight Committee
Goal of ME Oversight Committee:
Facilitate the implementation of ME as MDOT's standard design method

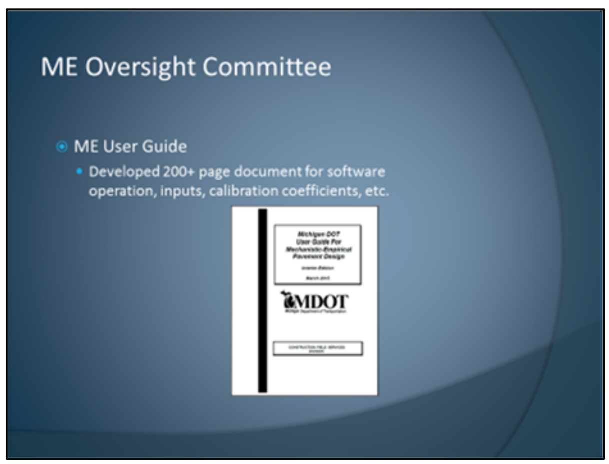

ME Oversight Committee
Facilitate business process changes for pavement design
Who provides the traffic data and how?
Which designs are central office and which are not?
etc.
Decisions on equipment
CTE test
HMA dynamic modulus test
etc.

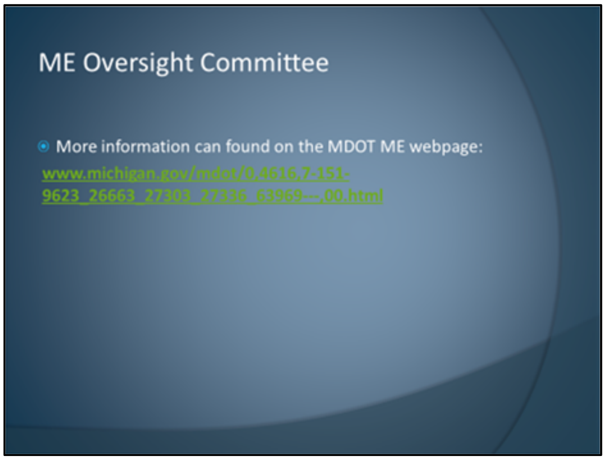

ME Oversight Committee
Help with decisions on design criteria
Distress thresholds
Reliability levels,
etc.
Help with decisions on input values
Time to 50% shrinkage (PCC)
20 year/28 day PCC compressive strength ratio
HMA effective binder content
% air voids
etc.


ME Oversight Committee
Expand department knowledge of the software and the impacts of different inputs and design decisions
Explore research needs
Facilitate industry participation
Decide on and oversee subcommittees, including membership


ME Oversight Committee
Subcommittees
Traffic
HMA
Concrete
Subcommittee goals
Learn the materials/traffic inputs and their impacts in the software
Recommend equipment
Facilitate testing
Make recommendations on input values

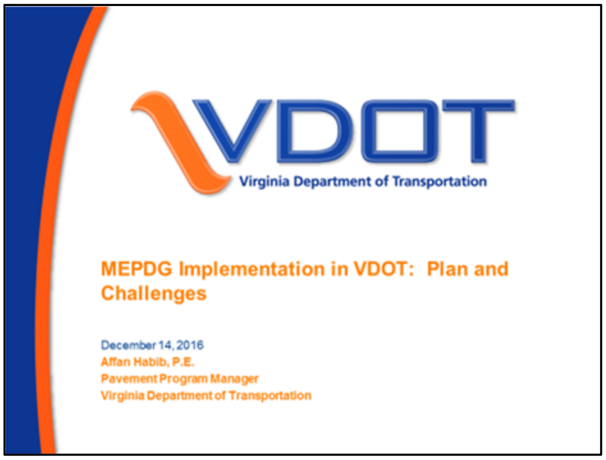

ME Oversight Committee
Subcommittees worked for ~1 ½ years
Subcommittees provided recommendations to Oversight Committee
Oversight Committee made final decisions
End result: Interim ME User Guide
Very important to include paving industry groups
Committee continues to meet every 2 to 3 months to work on issues, software changes, etc., as they pop up

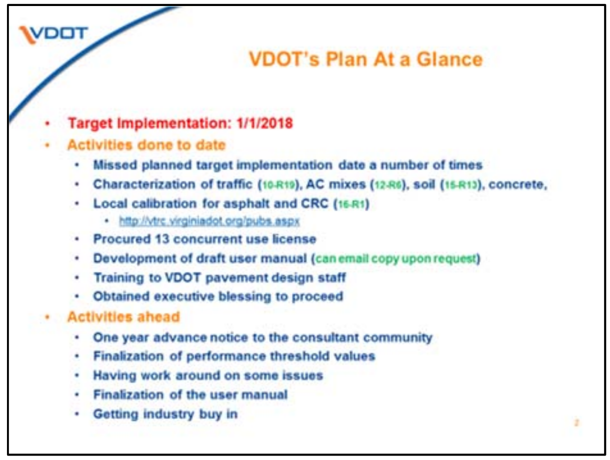

ME Oversight Committee
ME User Guide
Developed 200+ page document for software operation, inputs, calibration coefficients, etc.
MDOT

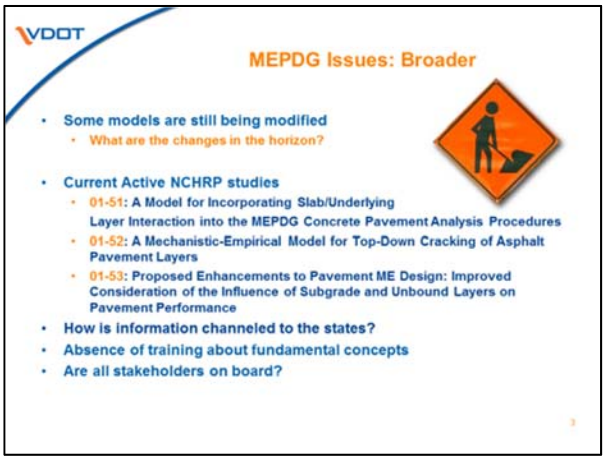

ME Oversight Committee
More information can found on the MDOT ME webpage:
www.michigan.gov/mdot/0,4616,7-151-9623_26663_27303_27336_63969---,00.html

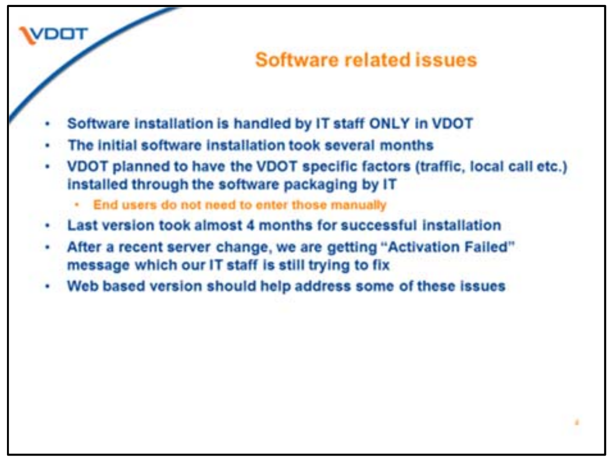

Questions?
Adnan Iftikhar
iftikhara@michigan.gov
517-322-1228
Justin Schenkel
schenkelj@michigan.gov
517-636-6006

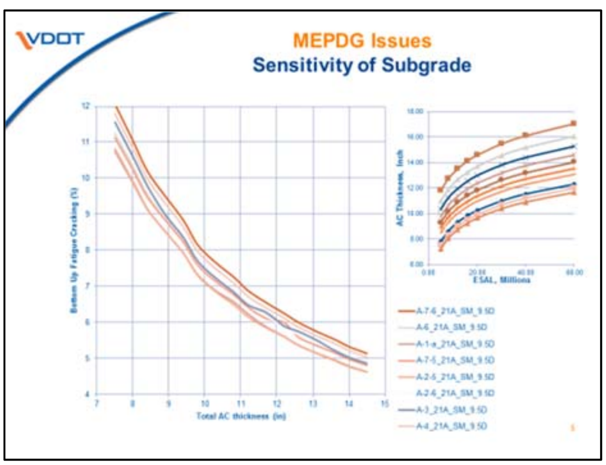
Presentation 6—Affan Habib, Virginia DOT

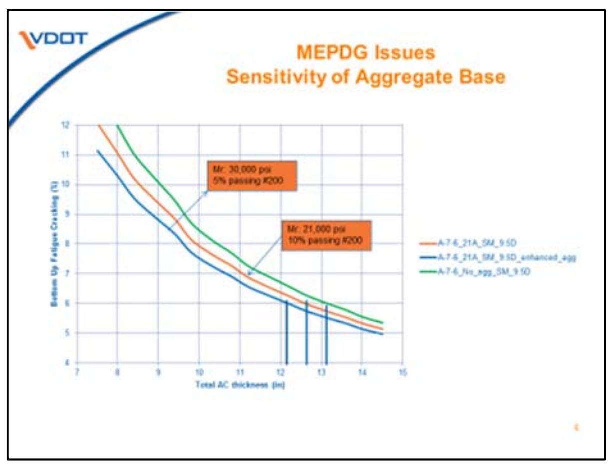












MEPDG Issues
Will 'insensitivity' to subgrade & aggregate change?

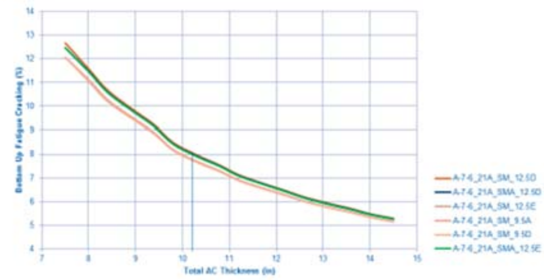
- NCHRP 1-53

OBJECTIVE: The objective of this research is to propose enhancements, as needed, to the Pavement ME Design procedures to better reflect the influence of subgrade and unbound layers (properties and thicknesses) on the performance of flexible and rigid pavements. These enhancements may include modifications of the models contained in the Pavement ME Design and/or the development of new models. The research shall address all types of flexible and rigid pavements included in Pavement ME Design.

- NCHRP study may validate or modify current MEPDG model
- What happens if current model is modified?
  - Redo local calibration?
- What do we do now?
  - Wait or have some work around?

7

MEPDG Issues
Response to various VDOT mixes



8

MEPDG Issues
Response to various VDOT mixes

- SMA/E mixes not showing better performance
- SMA mixes not showing higher stiffness at high temperature
- Is it practical to use different mix types in the design?
- Ideal solution is to have separate local calibration for SMA mixes
  - Did not observe much difference with SMA mixes in our calibration
  - Will separate calibration coefficient be difficult for the designers, consultants to handle?
- Continue characterizing more mixes
  - Will this change the trend?
- What is the work around?
  - Have one SM, IM and BM
  - Continue using current mix selection guideline outside of design

9

MEPDG Issues
Local Calibration

- It needs sections with various structures, materials, traffic loading, distress (especially over the entire design life) etc.
- Not easy to have sections without any maintenance beyond 10-15 years
  - Some states have utilized LTPP section data
  - VA has only 3 SPS section
  - VA's local call. sections did not have much distress
  - It may have some impacts on the outcome
  - Not very practical to establish that many LTPP like calibration sections
  - Used PMS data
- Did not distinguish between top down and bottom up fatigue cracking
  - Consistent with AASHTO guide on local calibration
  - What is the impact of this on the predicted distress?
- What is the impact of not having a 'perfect' local calibration?

10

MEPDG Issues
No local calibration for JCP

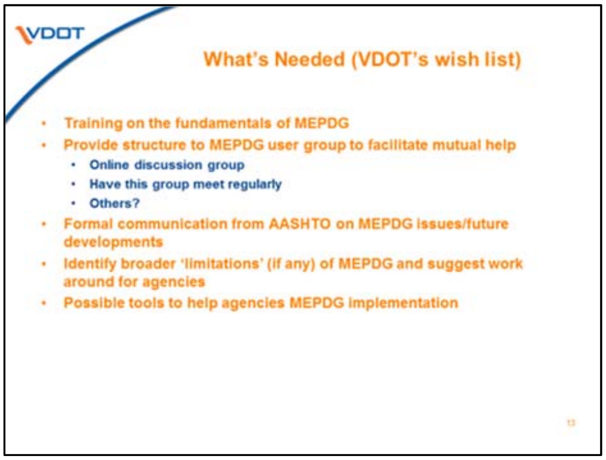
- VA does not have too many JCP with shorter slab length to perform local calibration
- Intend to use global model
- Regional calibration for JCP is a possibility
  - How to materialize that?

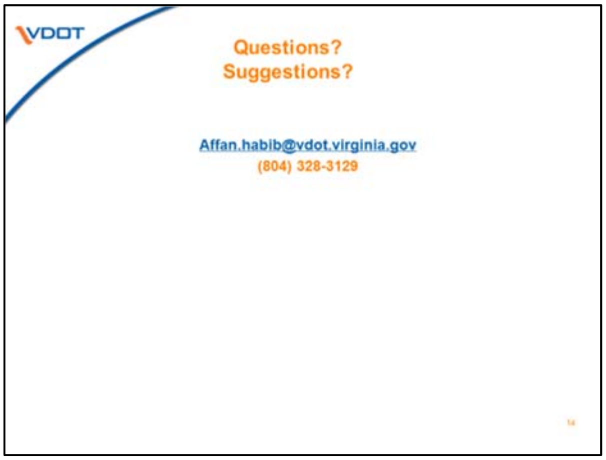
11

MEPDG Issues
What about newer materials?

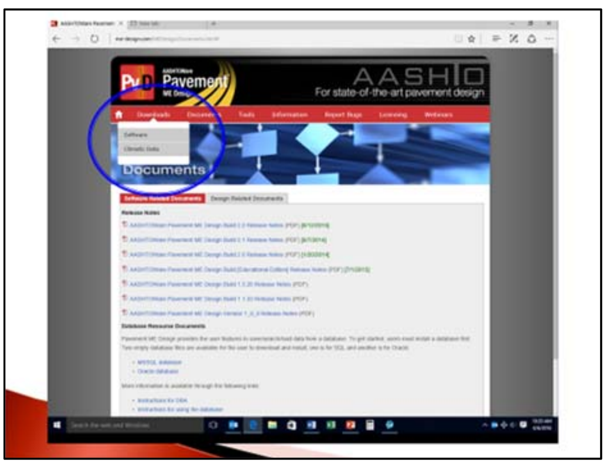
- Not all materials are calibrated in the global models
  - Recycled
  - CTA
  - Other VA specific mixes
- Local calibration strongly recommended for such materials
  - Needs good number of sections
    - What to do without such number of sections?

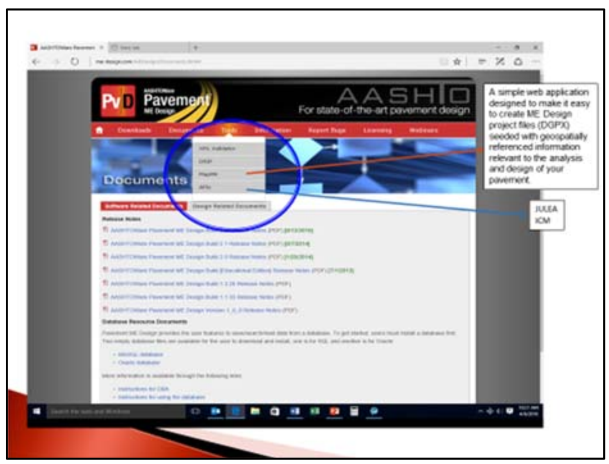
12


VDOT
What's Needed (VDOT's wish list)
• Training on the fundamentals of MEPDG
• Provide structure to MEPDG user group to facilitate mutual help
• Online discussion group
• Have this group meet regularly
• Others?
• Formal communication from AASHTO on MEPDG issues/future developments
• Identify broader 'limitations' (if any) of MEPDG and suggest work around for agencies
• Possible tools to help agencies MEPDG implementation

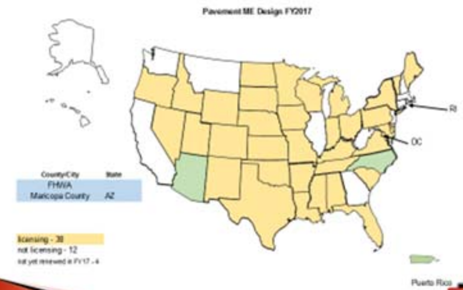

VDOT
Questions?
Suggestions?
Affan.habib@vdot.virginia.gov
(804) 328-3129

Presentation 7—Vicki Schofield, AASHTO





AASHTOWare Pavement ME Design Licensee Map – United States



AASHTOWare Pavement ME Design Licensee Map – Canada

Licensing

Additional License Types

	2016	2017
No Cost Educational	69	51
Private Sector	73	73
Universities	24	17
Local Agencies	1	1
30-Day Evaluation	5	2
International	15	14

2017 –Brazil, China, Colombia, Guatemala, Hong Kong SAR, India, Lebanon, Norway, Qatar, Saudi Arabia, South Korea, Sweden, Turkey, UAE

FUTURE ENHANCEMENTS Under Consideration

1. Allow for the customization of reports
2. Track improvements by others, Agency PMED customizations, Other AASHTOWare software
3. Provide ability to reset performance parameters after interim treatment
4. Lockdown specific input variables
5. Allow for use of K-values for subgrade
6. Grey out performance parameters not used for design - create super user to gray out certain inputs
7. Enhance climate data with MERRA data
8. Implement tensile strength level 1
9. Recalibration for flexible and semi rigid pavements in English and SI units

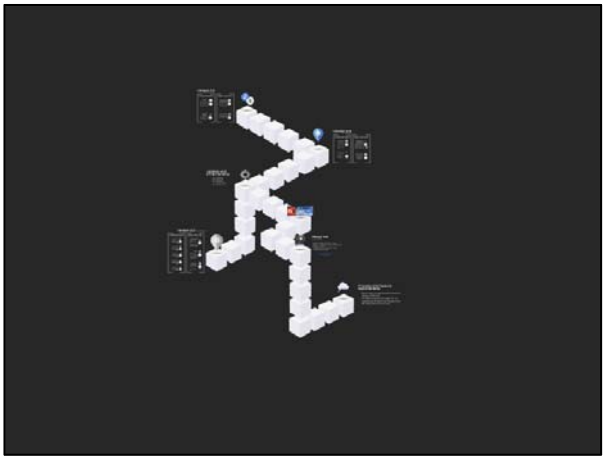
AASHTOWare Pavement ME Design Product Task Force

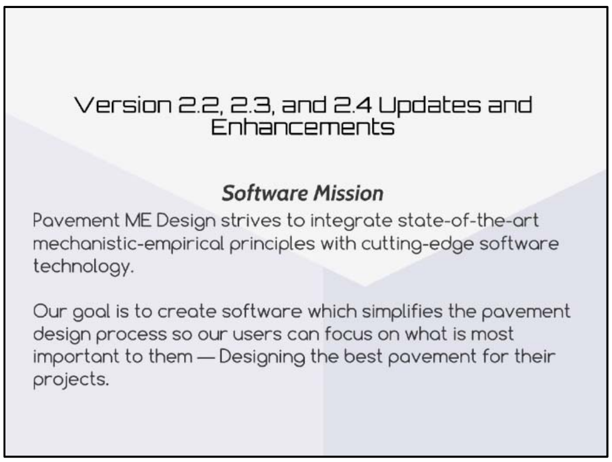
John Donahue, Chair, Missouri DOT
Bill Barstis, Mississippi DOT
Jay Goldbaum, Colorado DOT
Marta Juhasz, Alberta Transportation
Clark Morrison, North Carolina DOT
Mehdi Parvini, California DOT
Robert Shugart, Alabama DOT

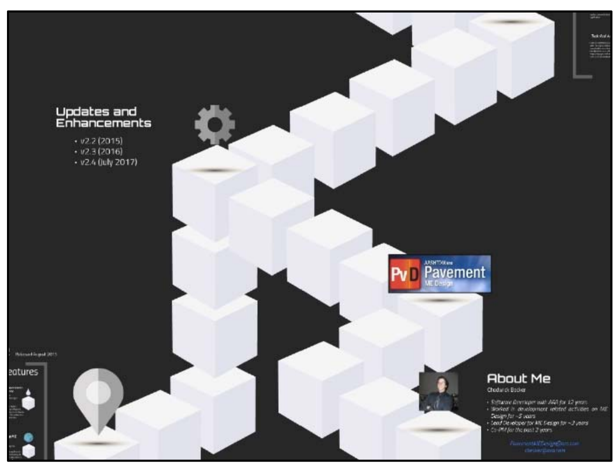
Liaisons:
Tom Yu, FHWA
Felix Doucet, Ministère des Transports du Québec - TAC
Jack Dartman, Montana DOT - TAA
Shane Marshall, Utah DOT - SCOJD

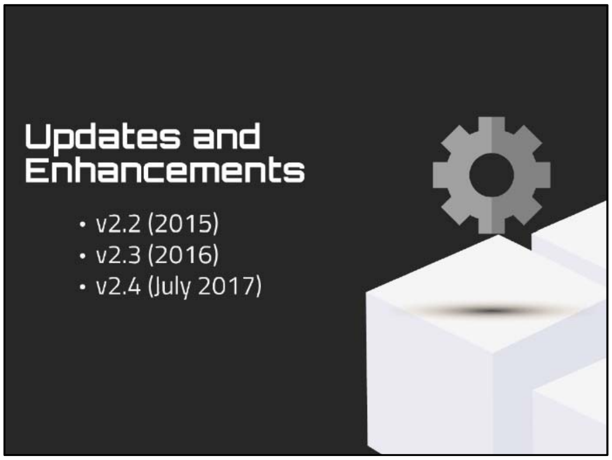

For Additional Information:
Vicki Schofield
AASHTO Project Manager
vschofield@aashto.org
(202) 624-3640

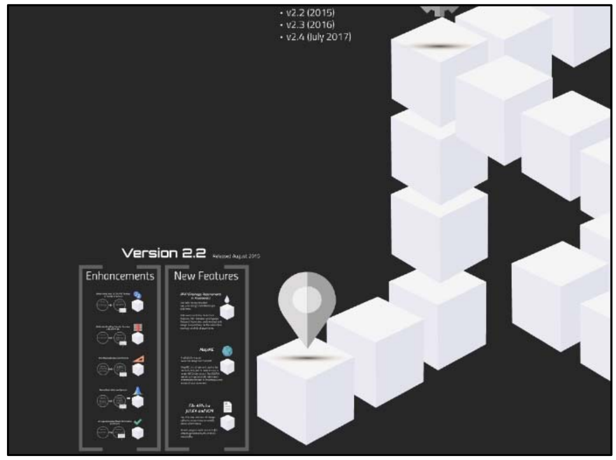
Presentation 8—Chad Becker, Applied Research Associates Inc. (ARA)

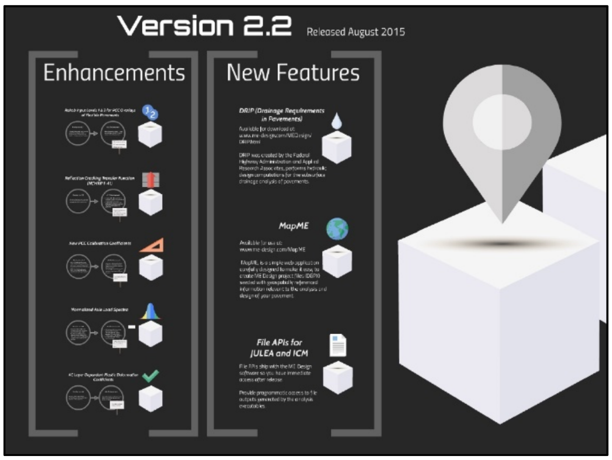


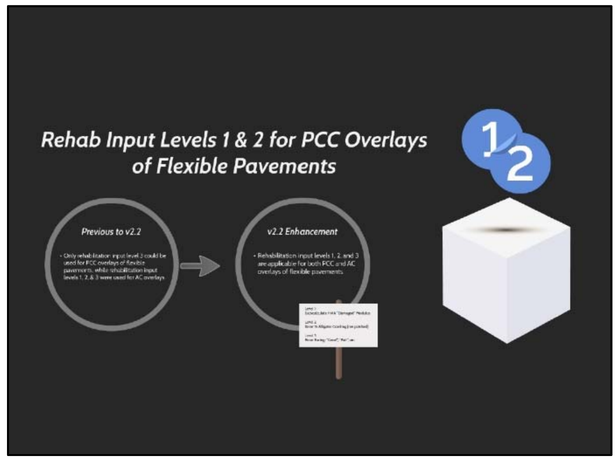


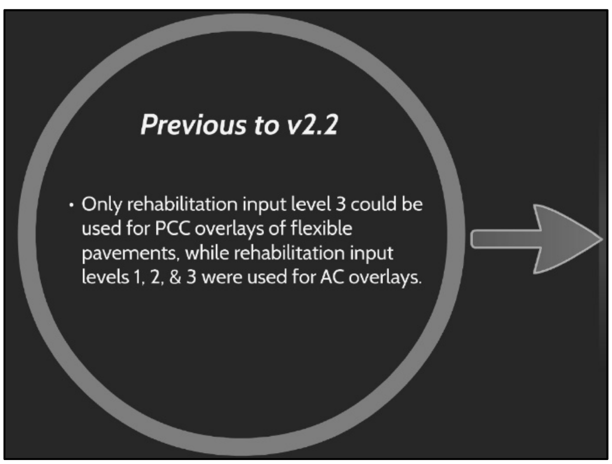


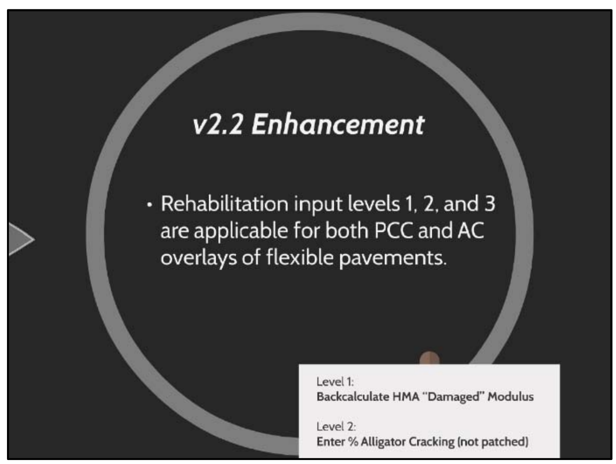

Updates and Enhancements
• v2.2 (2015)
• v2.3 (2016)
• v2.4 (July 2017)

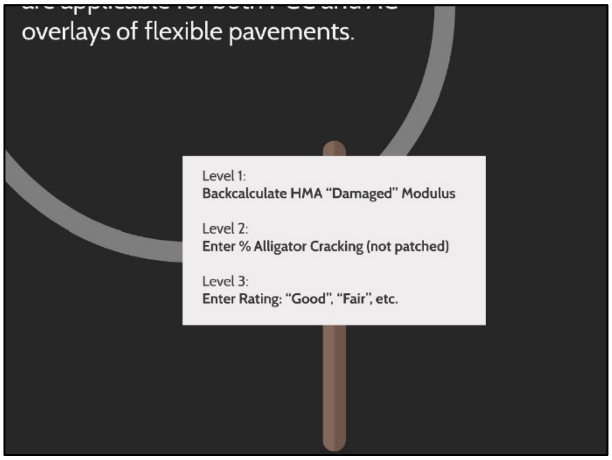

• v2.2 (2015)
• v2.3 (2016)
• v2.4 (July 2017)
Version 2.2
Enhancements
New Features

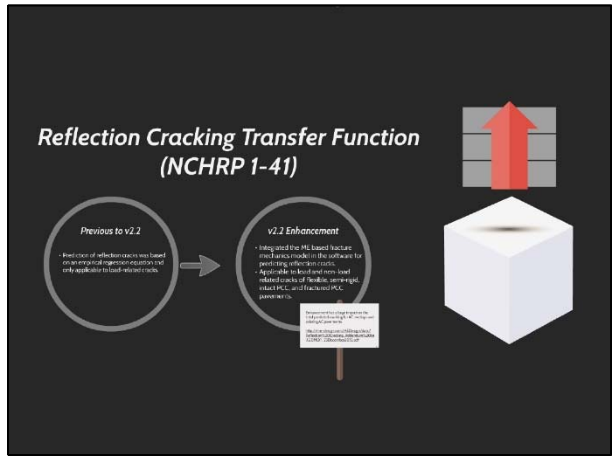

Version 2.2
Released August 2015
Enhancements
New Features
MapME
File APIs for JULEA and ICM

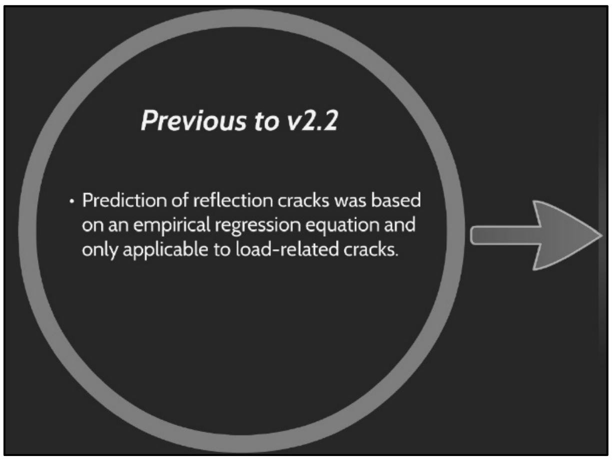

Rehab Input Levels 1 & 2 for PCC Overlays of Flexible Pavements
Previous to v2.2
v2.2 Enhancement

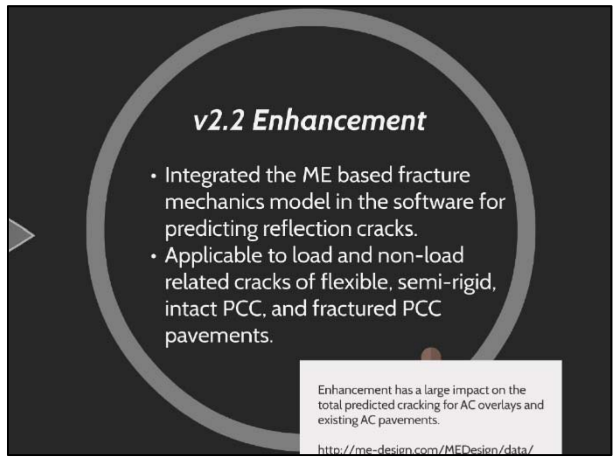

Previous to v2.2
• Only rehabilitation input level 3 could be used for PCC overlays of flexible pavements, while rehabilitation input levels 1, 2, & 3 were used for AC overlays.

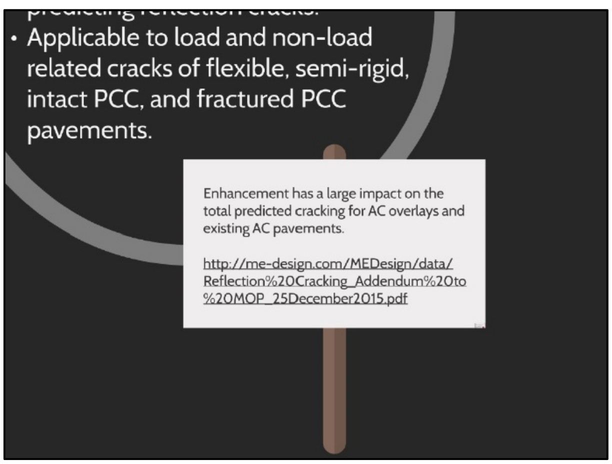

v2.2 Enhancement
• Rehabilitation input levels 1, 2, and 3 are applicable for both PCC and AC overlays of flexible pavements.
Level 1:
Backcalculate HMA "Damaged" Modulus
Level 2:
Enter % Alligator Cracking (not patched)

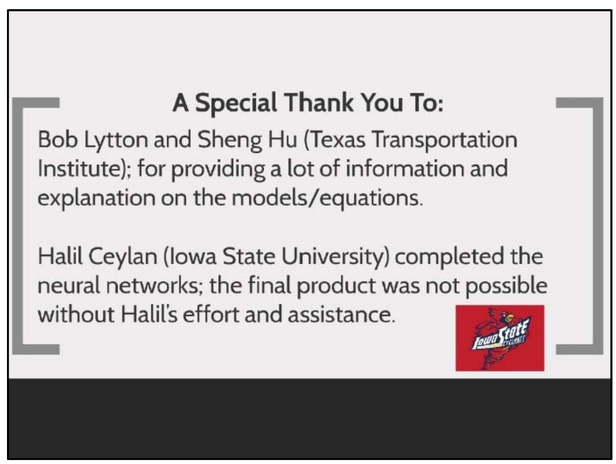

overlays of flexible pavements.
Level 1:
Backcalculate HMA "Damaged" Modulus
Level 2:
Enter % Alligator Cracking (not patched)
Level 3:
Enter Rating: "Good", "Fair", etc.

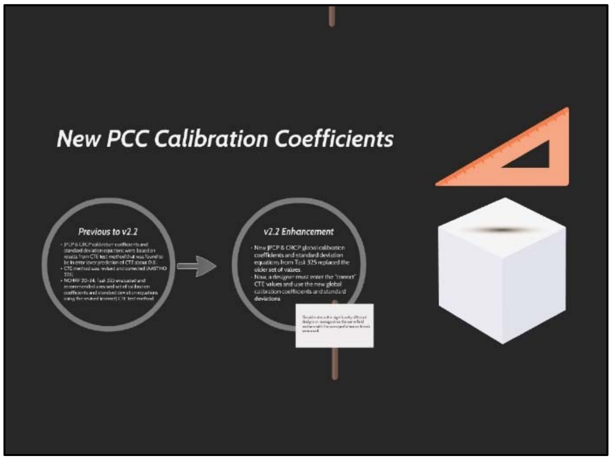

Reflection Cracking Transfer Function
(NCHRP 1-41)
Previous to v2.2
v2.2 Enhancement

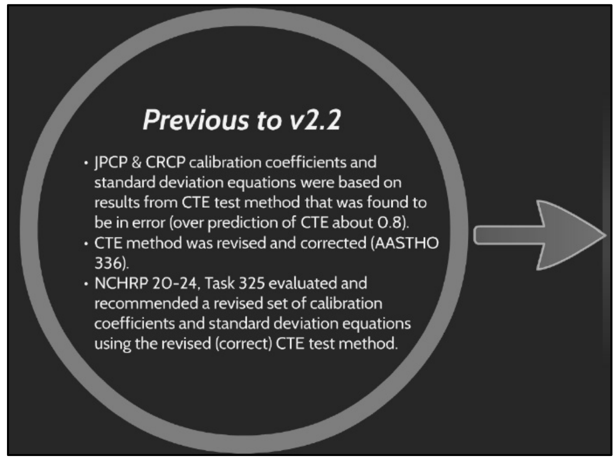

Previous to v2.2
• Prediction of reflection cracks was based on an empirical regression equation and only applicable to load-related cracks.

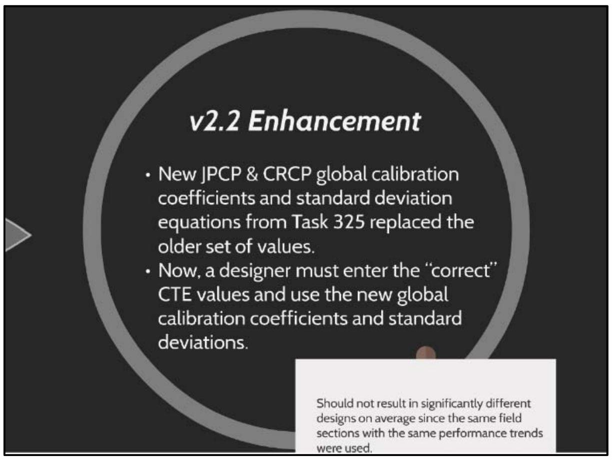

v2.2 Enhancement
• Integrated the ME based fracture mechanics model in the software for predicting reflection cracks.
• Applicable to load and non-load related cracks of flexible, semi-rigid, intact PCC, and fractured PCC pavements.
Enhancement has a large impact on the total predicted cracking for AC overlays and existing AC pavements.

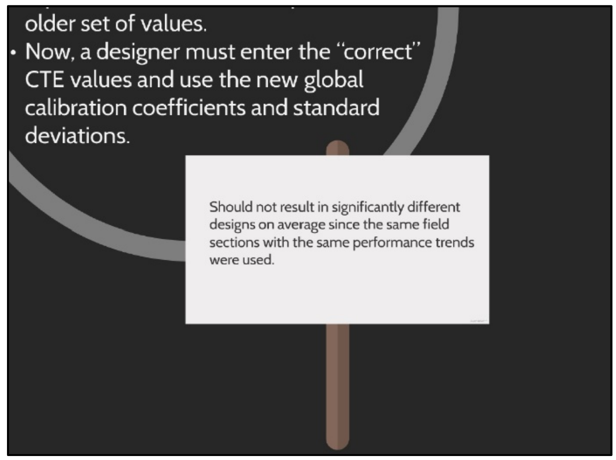

• Applicable to load and non-load related cracks of flexible, semi-rigid, intact PCC, and fractured PCC pavements.
Enhancement has a large impact on the total predicted cracking for AC overlays and existing AC pavements.
http://me-design.com/MEDesign/data/Reflection%20Cracking_Addendum%20to%20MOP_25December2015.pdf

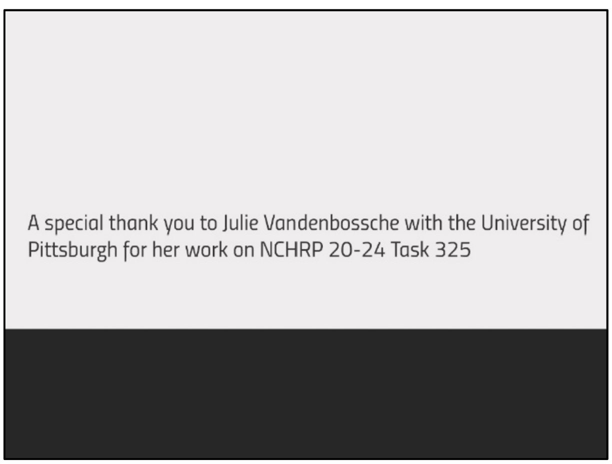

A Special Thank You To:
Bob Lytton and Sheng Hu (Texas Transportation Institute); for providing a lot of information and explanation on the models/equations.
Halil Ceylan (Iowa State University) completed the neural networks; the final product was not possible without Halil's effort and assistance.

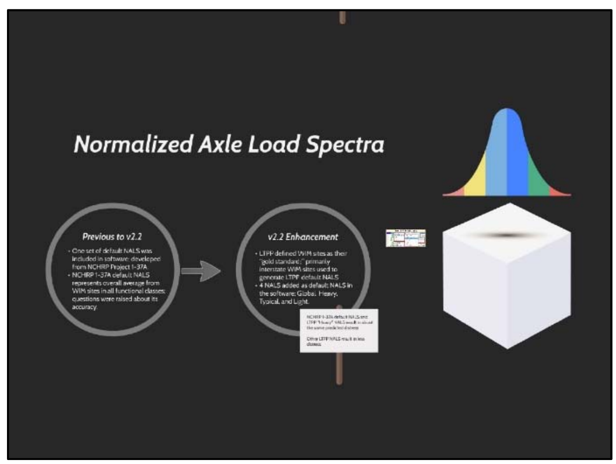

New PCC Calibration Coefficients
Previous to v2.2
v2.2 Enhancement

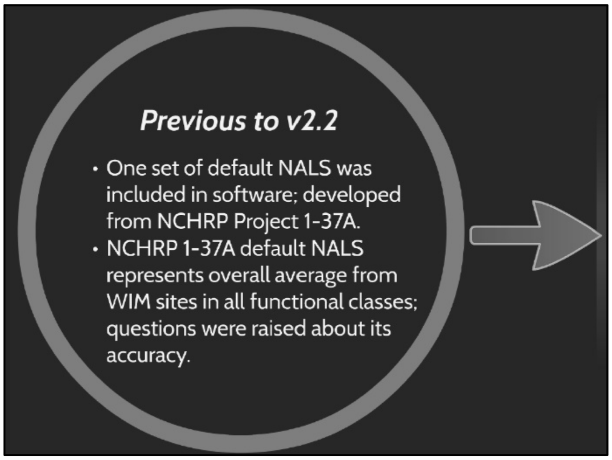

Previous to v2.2
• JPCP & CRCP calibration coefficients and standard deviation equations were based on results from CTE test method that was found to be in error (over prediction of CTE about 0.8).
• CTE method was revised and corrected (AASTHO 336).
• NCHRP 20-24, Task 325 evaluated and recommended a revised set of calibration coefficients and standard deviation equations using the revised (correct) CTE test method.

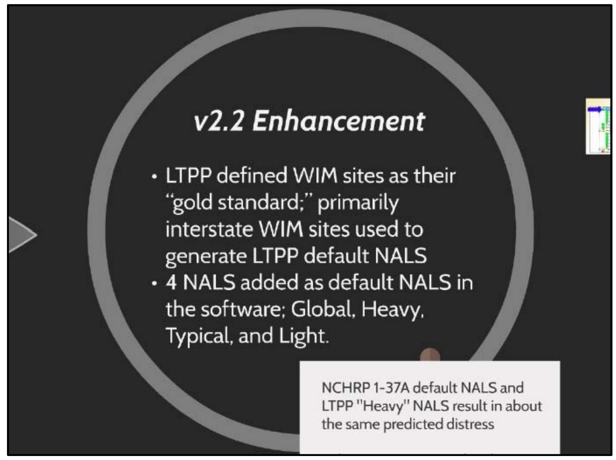

v2.2 Enhancement
• New JPCP & CRCP global calibration coefficients and standard deviation equations from Task 325 replaced the older set of values.
• Now, a designer must enter the "correct" CTE values and use the new global calibration coefficients and standard deviations.
Should not result in significantly different designs on average since the same field sections with the same performance trends were used.

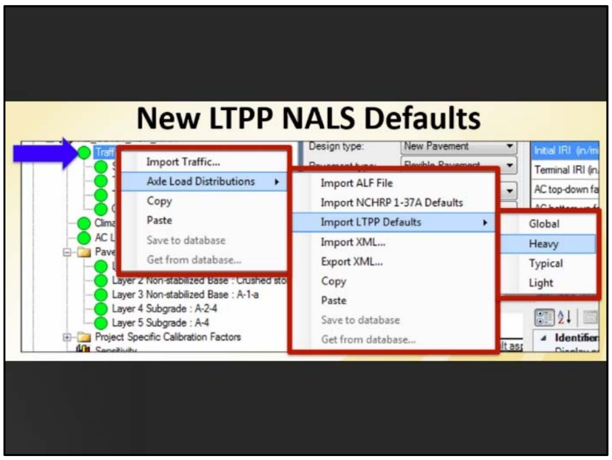

older set of values.
• Now, a designer must enter the "correct" CTE values and use the new global calibration coefficients and standard deviations.
Should not result in significantly different designs on average since the same field sections with the same performance trends were used.

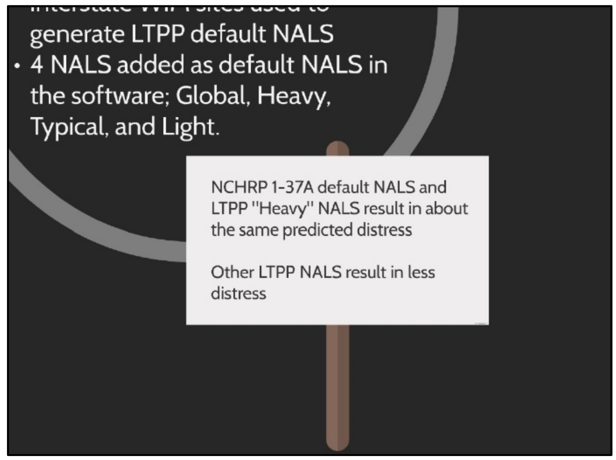

A special thank you to Julie Vandenbossche with the University of Pittsburgh for her work on NCHRP 20-24 Task 325

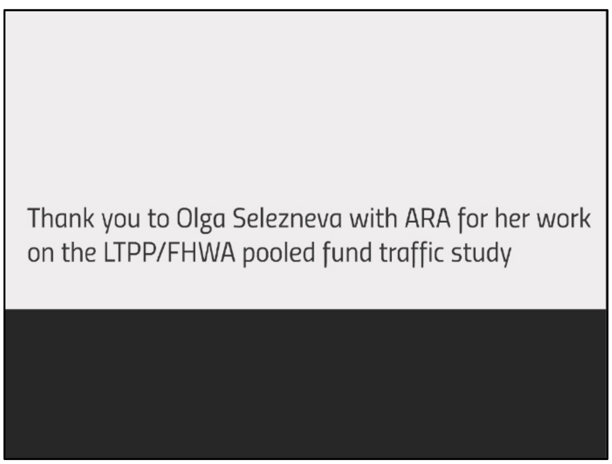

Normalized Axle Load Spectra
Previous to v2.2
v2.2 Enhancement

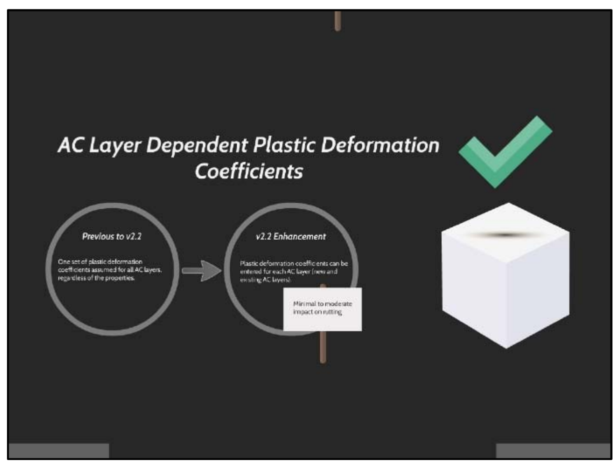

Previous to v2.2
• One set of default NALS was included in software; developed from NCHRP Project 1-37A.
• NCHRP 1-37A default NALS represents overall average from WIM sites in all functional classes; questions were raised about its accuracy.

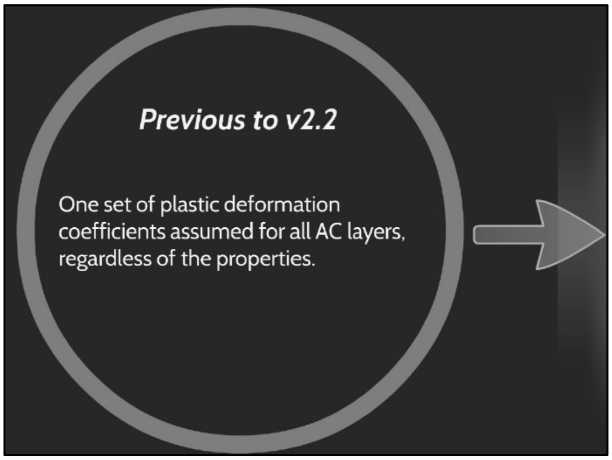

v2.2 Enhancement
• LTPP defined WIM sites as their "gold standard;" primarily interstate WIM sites used to generate LTPP default NALS
• 4 NALS added as default NALS in the software; Global, Heavy, Typical, and Light.
NCHRP 1-37A default NALS and LTPP "Heavy" NALS result in about the same predicted distress

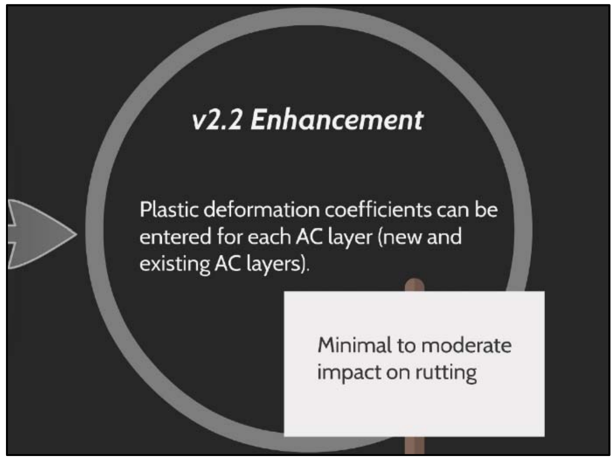

New LTPP NALS Defaults
Import Traffic...
Axle Load Distributions
Copy
Paste
Save to database
Get from database...
Import ALF File
Import NCHRP 1-37A Defaults
Import LTPP Defaults
Import XML...
Export XML...
Copy
Paste
Save to database
Get from database...
Global
Heavy
Typical
Light
Layer 3 Non-stabilized Base : A-1-a
Layer 4 Subgrade : A-2-4
Layer 5 Subgrade : A-4
Project Specific Calibration Factors

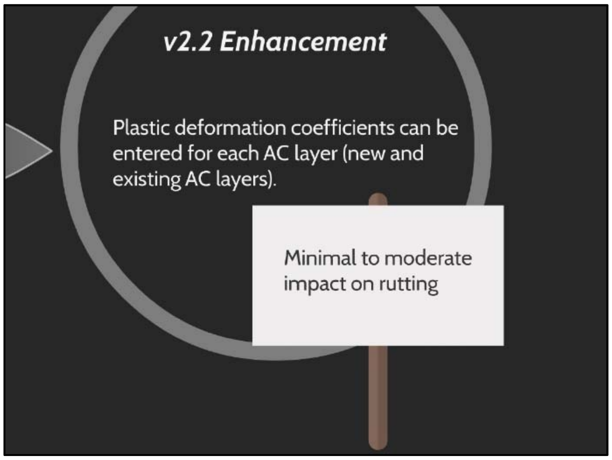

generate LTPP default NALS
• 4 NALS added as default NALS in the software; Global, Heavy, Typical, and Light.
NCHRP 1-37A default NALS and LTPP "Heavy" NALS result in about the same predicted distress
Other LTPP NALS result in less distress

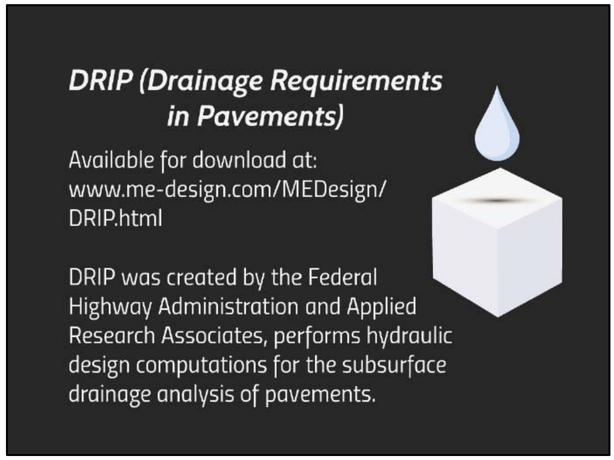

Thank you to Olga Selezneva with ARA for her work on the LTPP/FHWA pooled fund traffic study

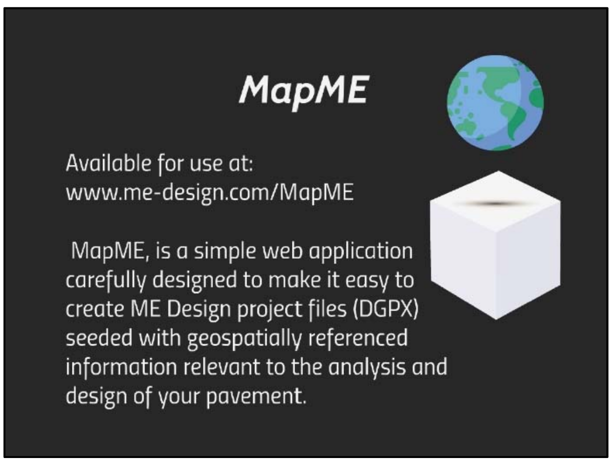

AC Layer Dependent Plastic Deformation Coefficients
Previous to v2.2
v2.2 Enhancement

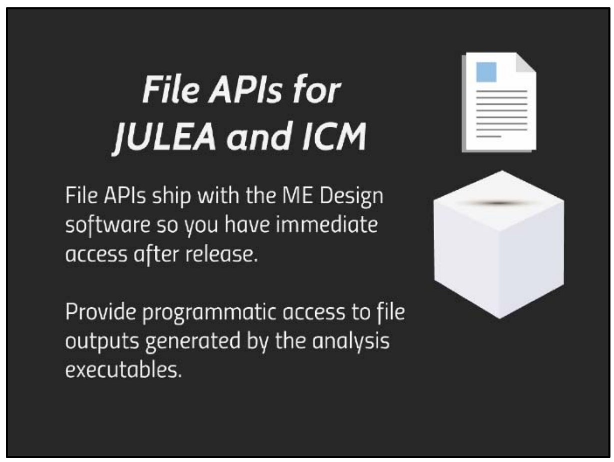

Previous to v2.2
One set of plastic deformation coefficients assumed for all AC layers, regardless of the properties.

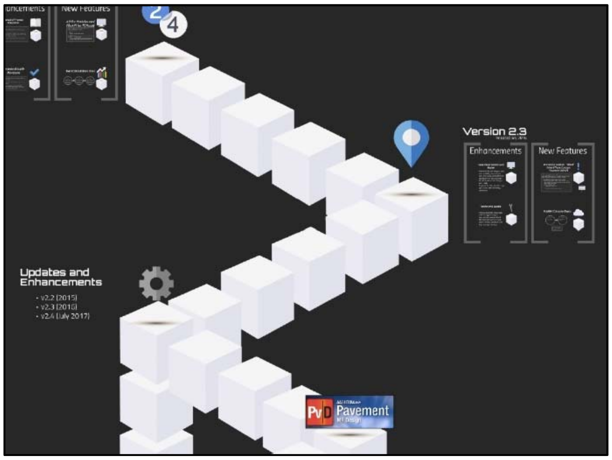

v2.2 Enhancement
Plastic deformation coefficients can be entered for each AC layer (new and existing AC layers).
Minimal to moderate impact on rutting

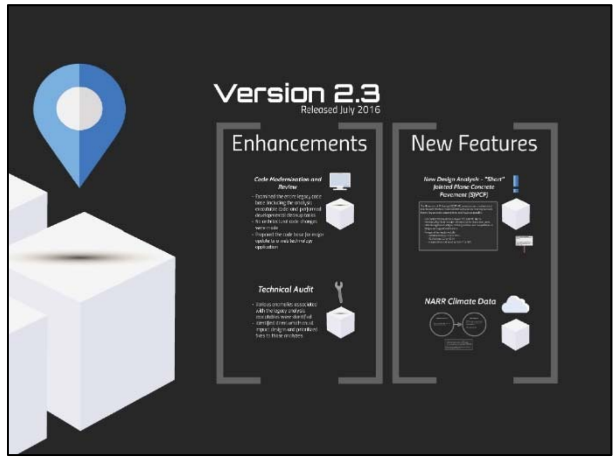

v2.2 Enhancement
Plastic deformation coefficients can be entered for each AC layer (new and existing AC layers).
Minimal to moderate impact on rutting

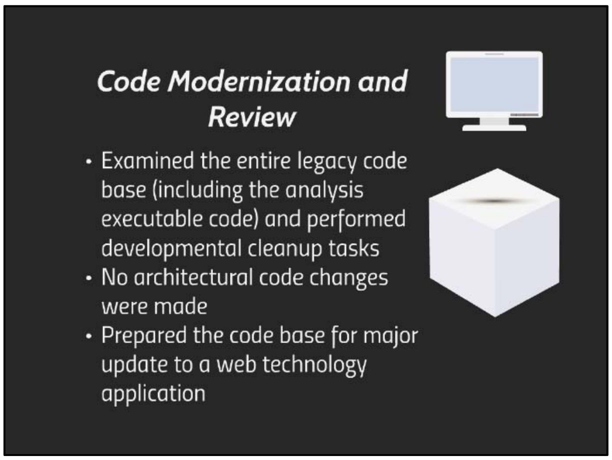

DRIP (Drainage Requirements in Pavements)
Available for download at: www.me-design.com/MEDesign/DRIP.html
DRIP was created by the Federal Highway Administration and Applied Research Associates, performs hydraulic design computations for the subsurface drainage analysis of pavements.

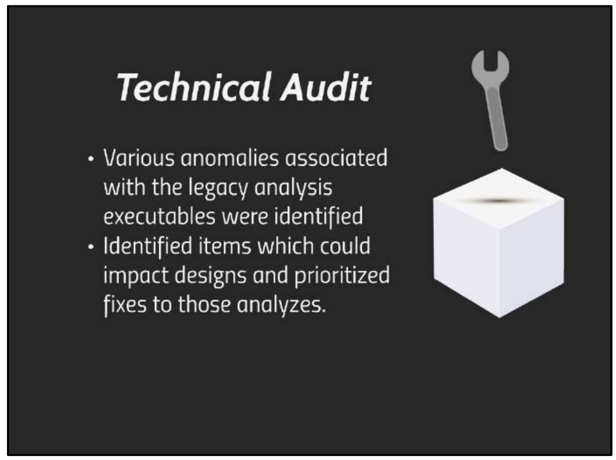

MapME
Available for use at: www.me-design.com/MapME
MapME, is a simple web application carefully designed to make it easy to create ME Design project files (DGPX) seeded with geospatially referenced information relevant to the analysis and design of your pavement.

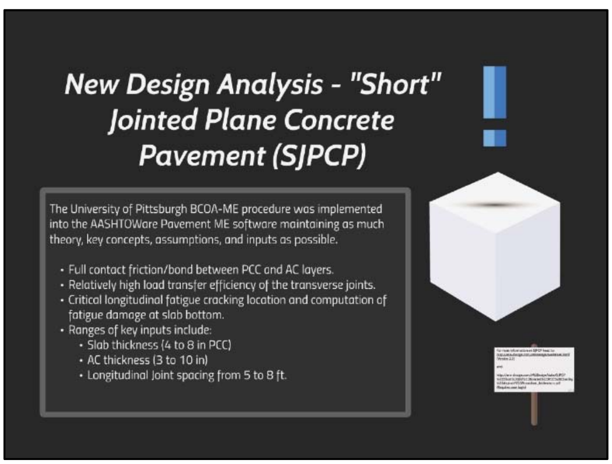

File APIs for JULEA and ICM
File APIs ship with the ME Design software so you have immediate access after release.
Provide programmatic access to file outputs generated by the analysis executables.

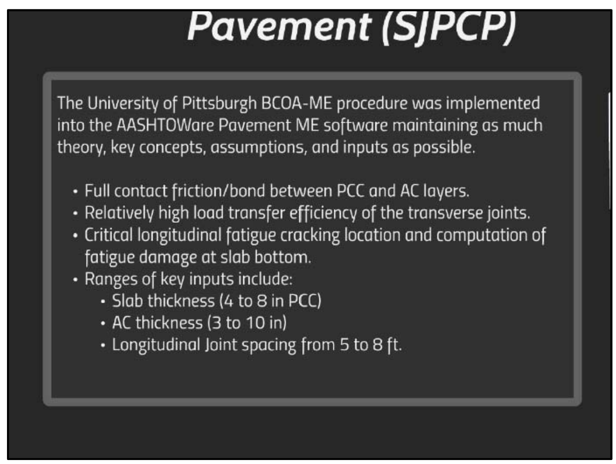

Version 2.3
Enhancements
New Features
Updates and Enhancements
• v2.2 (2015)
• v2.3 (2016)
• v2.4 (July 2017)
Pavement


Version 2.3
Released July 2016
Enhancements
New Features
Code Modernization and Review
Technical Audit
NARR Climate Data


Code Modernization and Review
• Examined the entire legacy code base (including the analysis executable code) and performed developmental cleanup tasks
• No architectural code changes were made
• Prepared the code base for major update to a web technology application


Technical Audit
• Various anomalies associated with the legacy analysis executables were identified
• Identified items which could impact designs and prioritized fixes to those analyzes.


New Design Analysis - "Short" Jointed Plane Concrete Pavement (SJPCP)
The University of Pittsburgh BCOA-ME procedure was implemented into the AASHTOWare Pavement ME software maintaining as much theory, key concepts, assumptions, and inputs as possible.
• Full contact friction/bond between PCC and AC layers.
• Relatively high load transfer efficiency of the transverse joints.
• Critical longitudinal fatigue cracking location and computation of fatigue damage at slab bottom.
• Ranges of key inputs include:
• Slab thickness (4 to 8 in PCC)
• AC thickness (3 to 10 in)
• Longitudinal Joint spacing from 5 to 8 ft.


Pavement (SJPCP)
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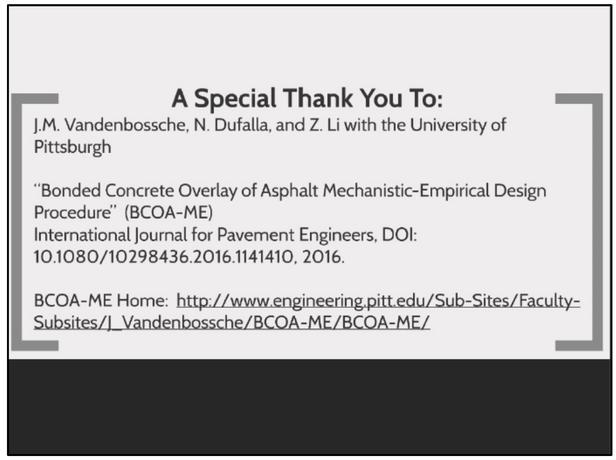
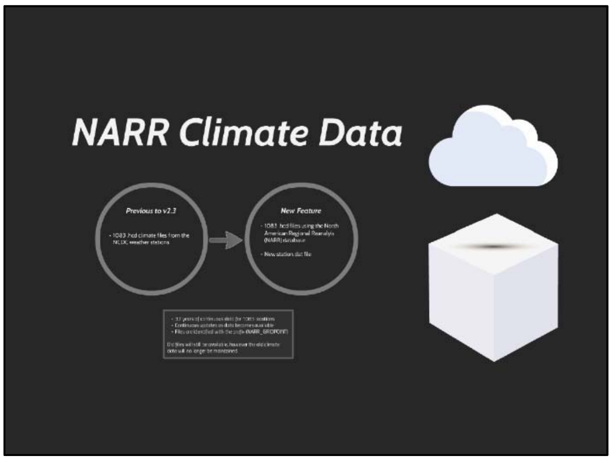
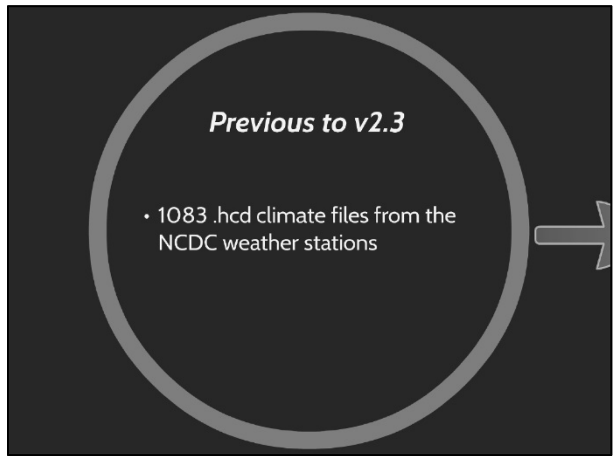
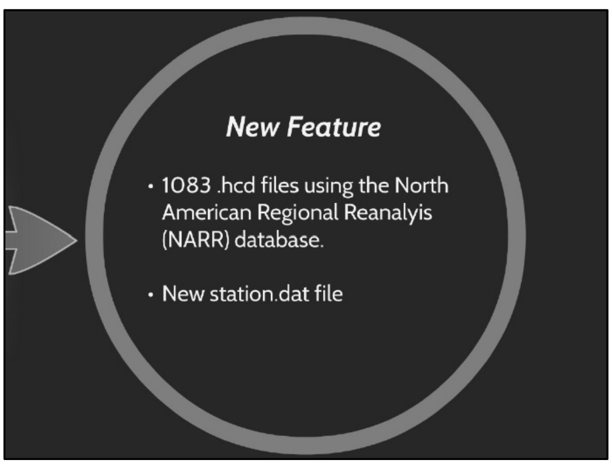
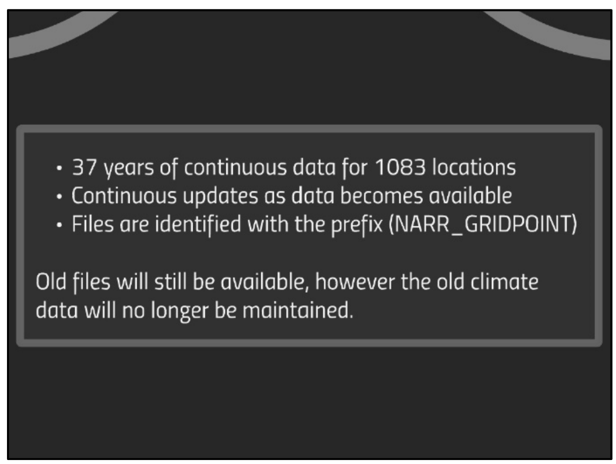
For more information on SJPCP head to:
http://me-design.com/MEDesign/Webinars.html
(Version 2.3)
and:
http://me-design.com/MEDesign/data/SJPCP%20Short%20Jtd%20Bonded%20PCC%20Overlay%20Asphalt%20Procedure_Addendum.pdf
(Requires user login)

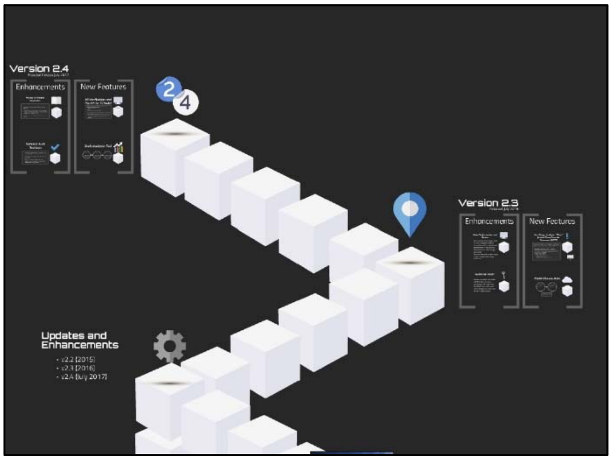

A Special Thank You To:
J.M. Vandenbossche, N. Dufalla, and Z. Li with the University of Pittsburgh
"Bonded Concrete Overlay of Asphalt Mechanistic-Empirical Design Procedure" (BCOA-ME)
International Journal for Pavement Engineers, DOI: 10.1080/10298436.2016.1141410, 2016.
BCOA-ME Home: http://www.engineering.pitt.edu/Sub-Sites/Faculty-Subsites/J_Vandenbossche/BCOA-ME/BCOA-ME/


NARR Climate Data

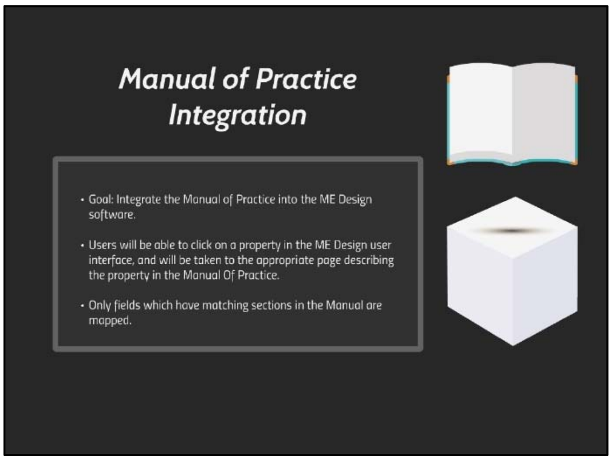

Previous to v2.3
• 1083 .hcd climate files from the NCDC weather stations

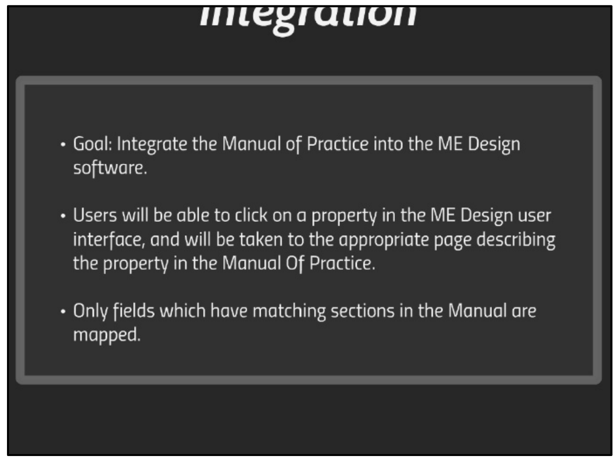

New Feature
• 1083 .hcd files using the North American Regional Reanalyis (NARR) database.
• New station.dat file


• 37 years of continuous data for 1083 locations
• Continuous updates as data becomes available
• Files are identified with the prefix (NARR_GRIDPOINT)
Old files will still be available, however the old climate data will no longer be maintained.


Version 2.4
Enhancements
New Features
Version 2.3
Enhancements
New Features
Updates and Enhancements
• v2.2 (2015)
• v2.3 (2016)
• v2.4 (July 2017)


Version 2.4
Projected Release July 2017
Enhancements
New Features
Manual of Practice Integration
Technical Audit Revisions
API for Modulus and File API for TCModel
Backcalculation Tool
2
4


Manual of Practice Integration
• Goal: Integrate the Manual of Practice into the ME Design software.
• Users will be able to click on a property in the ME Design user interface, and will be taken to the appropriate page describing the property in the Manual Of Practice.
• Only fields which have matching sections in the Manual are mapped.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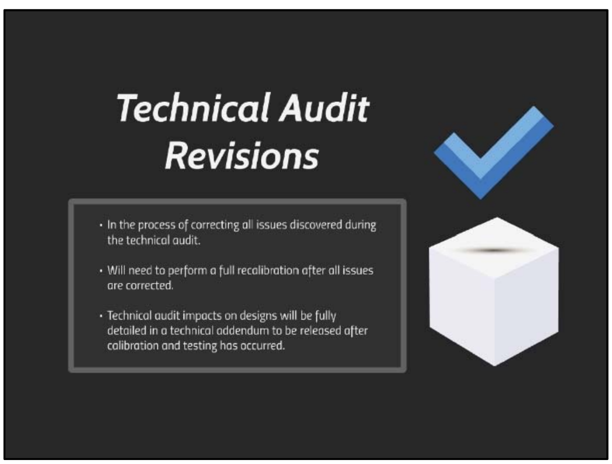
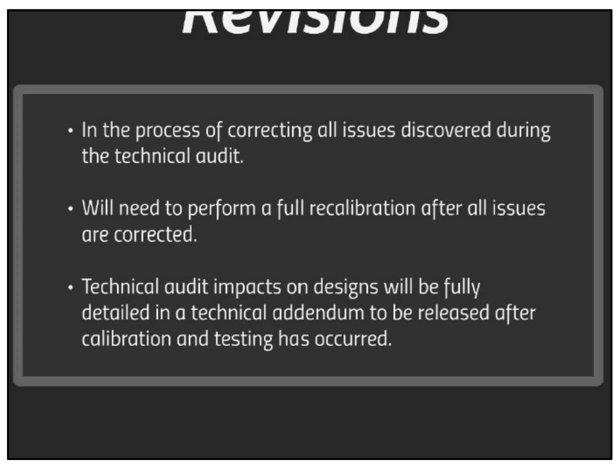

Technical Audit Revisions
• In the process of correcting all issues discovered during the technical audit.
• Will need to perform a full recalibration after all issues are corrected.
• Technical audit impacts on designs will be fully detailed in a technical addendum to be released after calibration and testing has occurred.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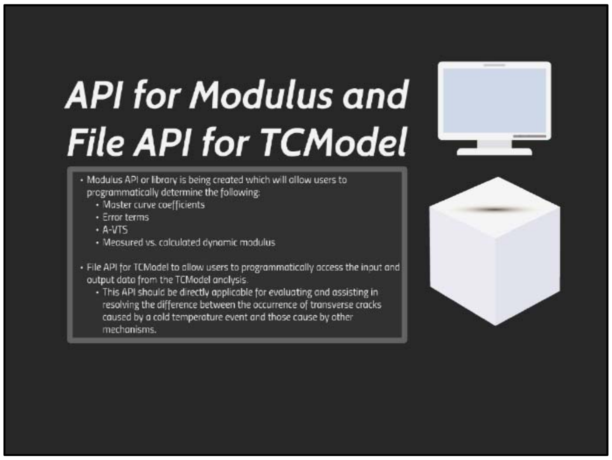
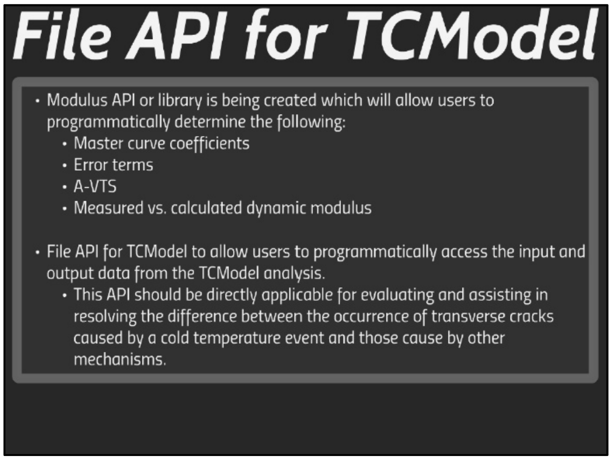

API for Modulus and
File API for TCModel
• Modulus API or library is being created which will allow users to programmatically determine the following:
• Master curve coefficients
• Error terms
• A-VTS
• Measured vs. calculated dynamic modulus
• File API for TCModel to allow users to programmatically access the input and output data from the TCModel analysis.
• This API should be directly applicable for evaluating and assisting in resolving the difference between the occurrence of transverse cracks caused by a cold temperature event and those cause by other mechanisms.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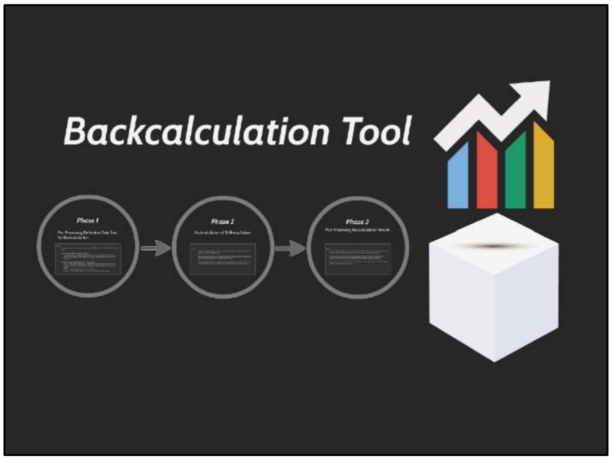
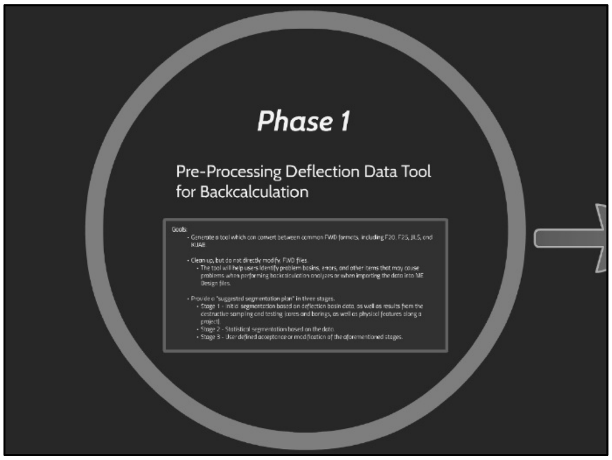
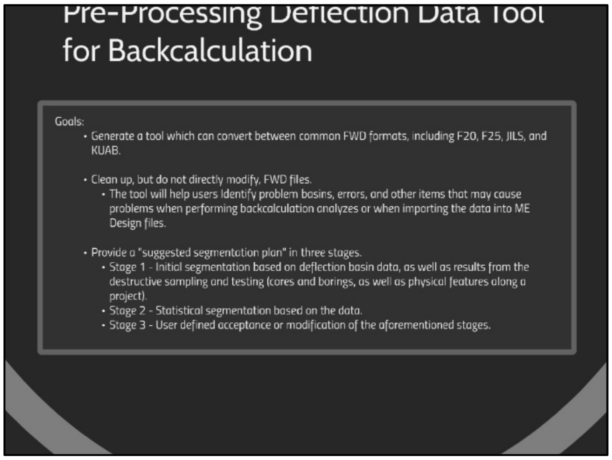

Backcalculation Tool
Phase 1
Phase 2
Phase 3


Phase 1
Pre-Processing Deflection Data Tool for Backcalculation
Goals:
• Generate a tool which can convert between common FWD formats, including F20, F25, JILS, and KUAB.
• Clean up, but do not directly modify, FWD files.
• The tool will help users identify problem basins, errors, and other items that may cause problems when performing backcalculation analyzes or when importing the data into ME Design files.
• Provide a "suggested segmentation plan" in three stages.
• Stage 1 - Initial segmentation based on deflection basin data, as well as results from the destructive sampling and testing (cores and borings, as well as physical features along a project).
• Stage 2 - Statistical segmentation based on the data.
• Stage 3 - User defined acceptance or modification of the aforementioned stages.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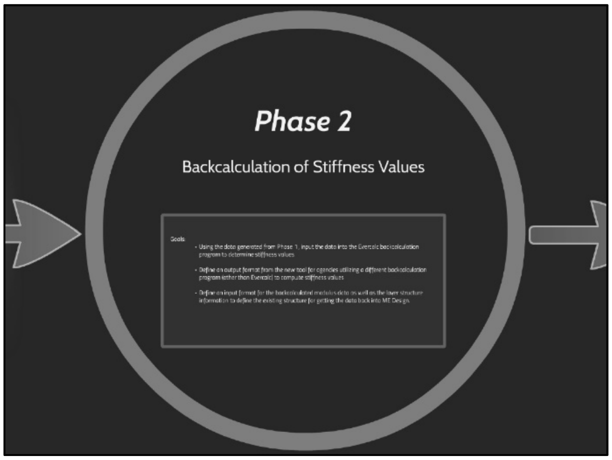
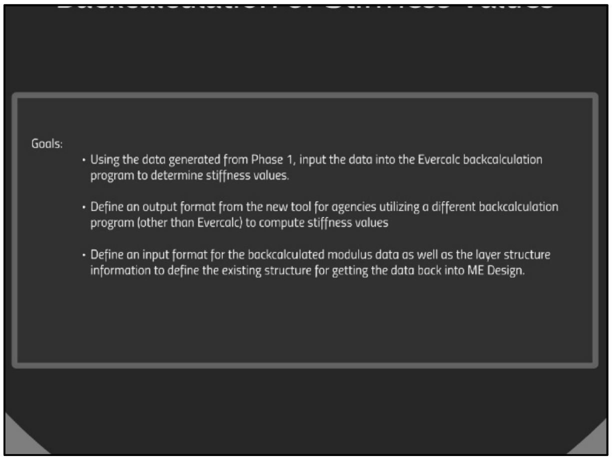

Phase 2
Backcalculation of Stiffness Values
Goals:
• Using the data generated from Phase 1, input the data into the Evercalc backcalculation program to determine stiffness values
• Define an output format from the new tool for agencies utilizing a different backcalculation program (other than Evercalc) to compute stiffness values
• Define an input format for the backcalculated modulus data as well as the layer structure information to define the existing structure for getting the data back into ME Design.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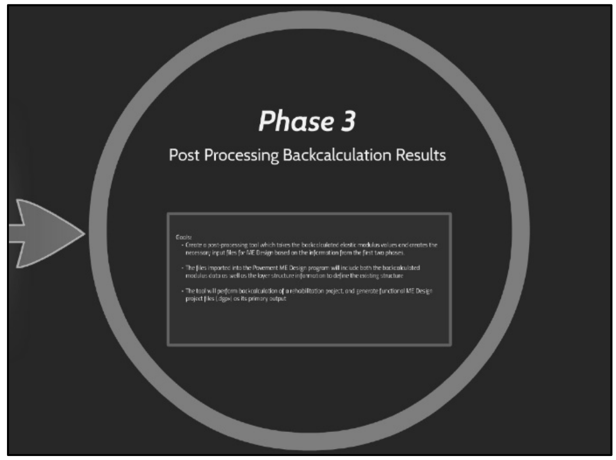
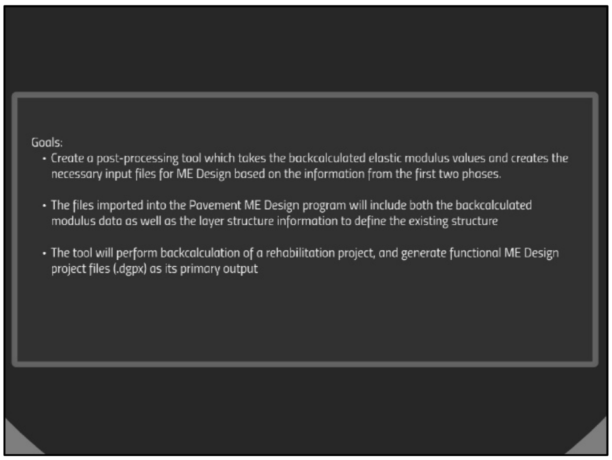
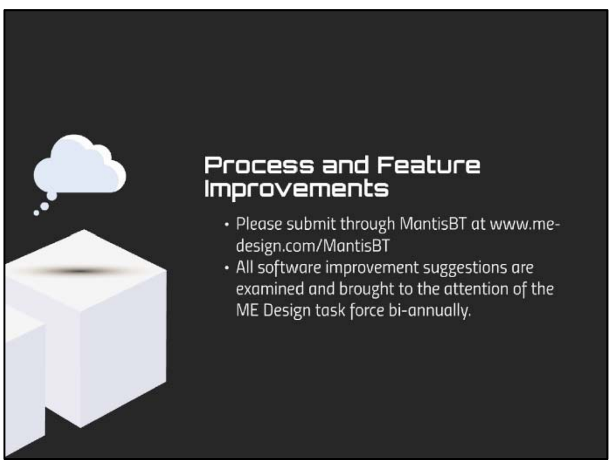

Phase 3
Post Processing Backcalculation Results


Goals:
• Create a post-processing tool which takes the backcalculated elastic modulus values and creates the necessary input files for ME Design based on the information from the first two phases.
• The files imported into the Pavement ME Design program will include both the backcalculated modulus data as well as the layer structure information to define the existing structure
• The tool will perform backcalculation of a rehabilitation project, and generate functional ME Design project files (.dgpx) as its primary output


Process and Feature Improvements
• Please submit through MantisBT at www.me-design.com/MantisBT
• All software improvement suggestions are examined and brought to the attention of the ME Design task force bi-annually.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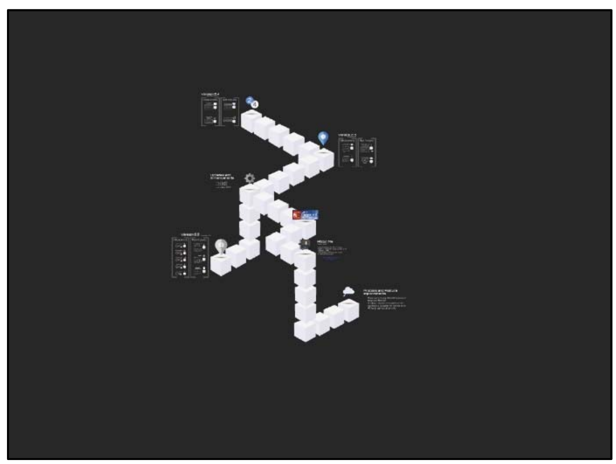


Presentation 9—Geoff Hall, Maryland SHA

Overview

- Distress Threshold limits
  - Initial Performance Target
  - Terminal Performance Targets
- Reliability
- Hierarchical Level

AASHTO ME National Users Group Meeting – 12-14-16 – Design Parameters 2

Background – Performance Targets

- AASHTO 1993: Serviceability
  - 0 to 5 scale
- AASHTO Now: Something we can measure
  - IRI
  - Cracking
  - Rutting/Faulting

AASHTO ME National Users Group Meeting – 12-14-16 – Design Parameters 3

Background – Performance Targets

How does Serviceability compare to performance metrics?

Not very well.

- Serviceability is qualitative.
- Performance metrics are quantitative.

AASHTO ME National Users Group Meeting – 12-14-16 – Design Parameters 4

Background – Performance Targets

AASHTO 1993 Targets

≠

AASHTO ME Targets

Thus, need to start over.

AASHTO ME National Users Group Meeting – 12-14-16 – Design Parameters 5

Performance Targets

Current Defaults:

- **Initial IRI = 63 in/mi**
- **Terminal IRI = 172 in/mi**
- **AC Top-Down Fatigue Cracking = 2000 ft/mi**
- **AC Bottom-Up Fatigue Cracking = 25% lane area**
- **AC Thermal Cracking = 1000 ft/mi**

AASHTO ME National Users Group Meeting – 12-14-16 – Design Parameters 6

Performance Targets

Currently available criteria:

- Total Permanent Deformation = 0.75"
- AC-only Deformation = 0.25"
- JPCP Transverse Cracking = 15% slabs
- JPCP Joint Faulting = 0.12"
- CRCP Punchouts = 10/mile

AASHTO ME National Users Group Meeting – 12-14-16 – Design Parameters 7

Performance Targets

Are these defaults always appropriate?

Should they be the same for all functional classes?

AASHTO ME National Users Group Meeting – 12-14-16 – Design Parameters 8

Performance Targets

Project Example

Urban Principal Arterial – Flexible

Mill & Resurface – What is life extension?

	Before Fix	After Fix	
	Existing	Initial	Terminal
IRI	150	63	172
Fatigue Cracking	1%		25%
Thermal Cracking	10000		1000
Rutting	0.18		0.75

AASHTO ME National Users Group Meeting – 12-14-16 – Design Parameters 9

Initial Performance Target

(It's somewhat complicated)

Target can be project-specific.

Use your data.

- You've paved thousands of projects.
  - Determine typical post-paving values
  - Performance specifications

AASHTO ME National Users Group Meeting – 12-14-16 – Design Parameters 10

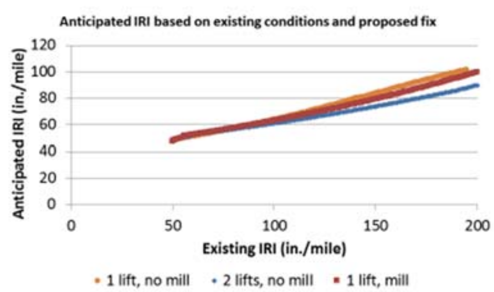
Initial Performance Target

Ride Quality

- Dependent on a few factors
  - Pre-overlay IRI
  - Number of lifts
  - Milling or not

AASHTO ME National Users Group Meeting – 12-14-16 – Design Parameters 11

Initial Performance Target



AASHTO ME National Users Group Meeting – 12-14-16 – Design Parameters 12

Initial Performance Target

Ride Quality

- For examples, visit

http://roads.maryland.gov/index.aspx?pageid=32&d=10

Existing IRI:	150
Number of HMA lifts:	1
Grinding on the project?	Yes
Wedge/Level?	No
Functional Class:	Locals
Anticipated IRI after construction =	79

AASHTO ME National Users Group Meeting – 12-14-16 – Design Parameters 13

Terminal Performance Targets
(It's more complicated)

Targets can be project-specific.

Goal is to determine life extension.

Use your data.

- Terminal targets based on pre-overlay condition.
  - For new, use average
  - For used, use project-specific

AASHTO ME National Users Group Meeting – 12-14-16 – Design Parameters 14

Terminal Performance Targets

Based on existing Remaining Service Life

- Existing IRI, Rut, Crack and Friction are converted to RSL
  - Conversion of distress to RSL varies by functional class

AASHTO ME National Users Group Meeting – 12-14-16 – Design Parameters 15

Terminal Performance Targets

- Lowest RSL controls
- That RSL is converted back to individual distress threshold limits

- For new pavements, RSL target = 20

AASHTO ME National Users Group Meeting – 12-14-16 – Design Parameters 16

Terminal Performance Targets
Example

Urban Principal Arterial

Existing, pre-overlay values:

- IRI = 150 in/mi → **RSL = 21**
- Fatigue Cracking = 1% area → **RSL = 35**
- Thermal Cracking = 10,000 ft/mi → **RSL = 16**
- Rutting = 0.18" → **RSL = 30**
- Skid Number = 40 → **RSL = 20**

AASHTO ME National Users Group Meeting – 12-14-16 – Design Parameters 17

Terminal Performance Targets
Example

Urban Principal Arterial

Existing, pre-overlay values:

- IRI RSL = 21
- Fatigue RSL = 35
- Thermal RSL = 16
- Rut RSL = 30
- Skid RSL = 20

→ **Overall RSL = 16**

AASHTO ME National Users Group Meeting – 12-14-16 – Design Parameters 18

Terminal Performance Targets
Example

Terminal target values:

- IRI RSL = 16 → **IRI = 177 in/mi**
- Fatigue RSL = 16 → **Bottom-Up = 8%**
- Thermal RSL = 16 → **Thermal = 10,000**
- Rut RSL = 16 → **Rut = 0.28"**
- Skid RSL = 16 → **Skid = 39**

AASHTO ME National Users Group Meeting – 12-14-16 – Design Parameters 19

Terminal Performance Targets
Example

Terminal target values:

- Top-down fatigue: ignore
  - Difficult to tell difference whether fatigue is top-down or bottom-up.
  - Considering all fatigue as bottom-up is somewhat more conservative
- AC only deformation: ignore
  - Difficult to tell whether rutting is whole system or just asphalt

AASHTO ME National Users Group Meeting – 12-14-16 – Design Parameters 20

Performance Targets
Project Example

Urban Principal Arterial – Flexible

Mill & Resurface

	Existing	Defaults	Chosen
Initial IRI		63	79
Terminal IRI	150	172	177
Fatigue Cracking	1%	25%	8%
Thermal Cracking	10,000	1000	10,000
Rutting	0.18"	0.75"	0.28"

AASHTO ME National Users Group Meeting – 12-14-16 – Design Parameters 21

Reliability

Current Defaults:

- **Mostly 90%**
- **AC Bottom-Up Fatigue Cracking = 50% (Flexible pavement overlays only)**
- **AC Thermal Cracking = 50% (Overlays only)**

AASHTO ME National Users Group Meeting – 12-14-16 – Design Parameters 22

Reliability

Are these defaults always appropriate?

AASHTO ME National Users Group Meeting – 12-14-16 – Design Parameters 23

Reliability
What is appropriate?

New Pavements:

- **IRI: 50%**
  - With performance specs, know what to expect
- **All other criteria: 90% is good**
  - This is our one chance to build it to last
  - More cost-effective to spend a bit more up front to save a lot more later

AASHTO ME National Users Group Meeting – 12-14-16 – Design Parameters 24

Reliability
What is appropriate?

Existing Pavements:

- **IRI: 50%**
  - With performance specs, know what to expect
- **All other criteria: 50% is good**
  - Tail wags the dog: determine how long the fix will last, not fit a fix to an expected life.
  - **Goal is to get accurate life extension, to compare to other options**

AASHTO ME National Users Group Meeting – 12-14-16 – Design Parameters 25

Reliability
Project Example

Urban Principal Arterial – Flexible

Mill & Resurface – What is life extension?

Last, similar fix lasted 15 years

- IRI Life @ 90% = 4 years
- IRI Life @ 50% = 16 years

Which is more believable?

AASHTO ME National Users Group Meeting – 12-14-16 – Design Parameters 26

Hierarchical Levels

- **Input Level 1** – Measured directly; site- or project-specific.
- **Input Level 2** – Estimated from other site specific data or parameters. May also represent measured regional values that are not project-specific.
- **Input Level 3** – "Best-estimated" or default values. Based on national or regional default values.

AASHTO ME National Users Group Meeting – 12-14-16 – Design Parameters 27

Hierarchical Levels
How are they chosen?

- Most projects: Uhhhh….whatever's readily available through our normal routine.
  - We don't have Level-1 control on many inputs
- Design-Build Projects: Design-Build team can have Level-1 control

AASHTO ME National Users Group Meeting – 12-14-16 – Design Parameters 28

Hierarchical Levels
How are they chosen?

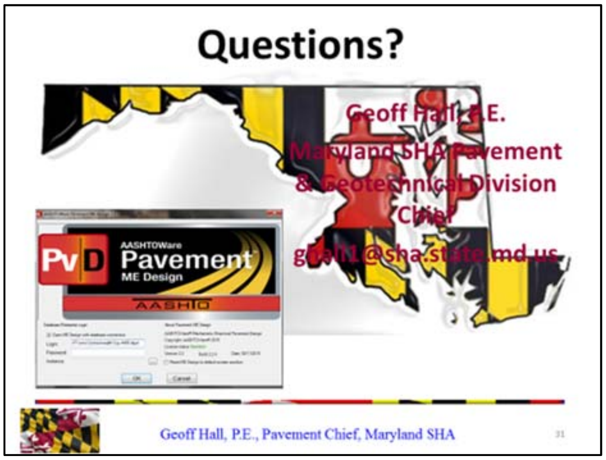
- Design-Build Projects: Design-Build team can have Level-1 control
  - DB team can make real-time adjustments to design
  - SHA can approve those adjustments…(if the DB team can prove it, of course)
  - Everybody wins!

AASHTO ME National Users Group Meeting – 12-14-16 – Design Parameters 29

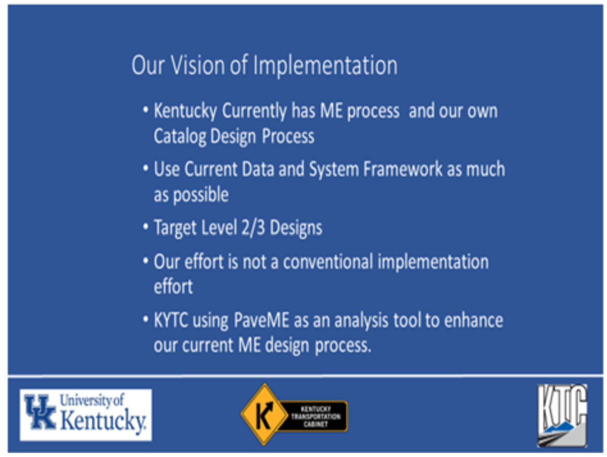
Summary

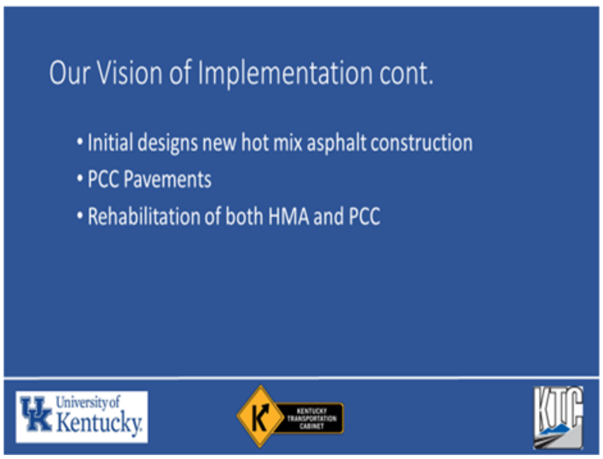
- Distress Threshold limits & Reliability
  - Do not correspond to AASHTO 93
  - Adjust for specific projects
- Hierarchical Level
  - Can effect cost savings

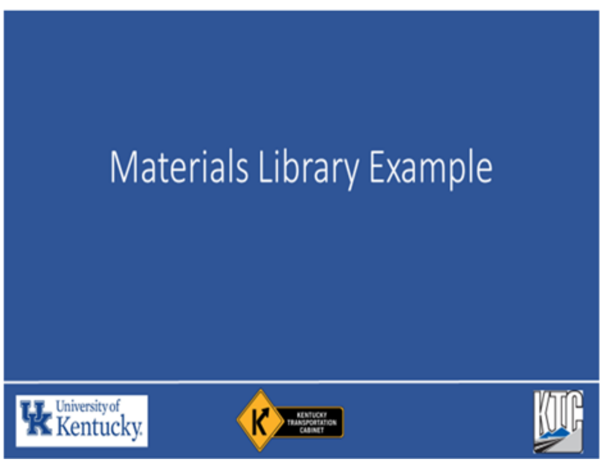
AASHTO ME National Users Group Meeting – 12-14-16 – Design Parameters 30

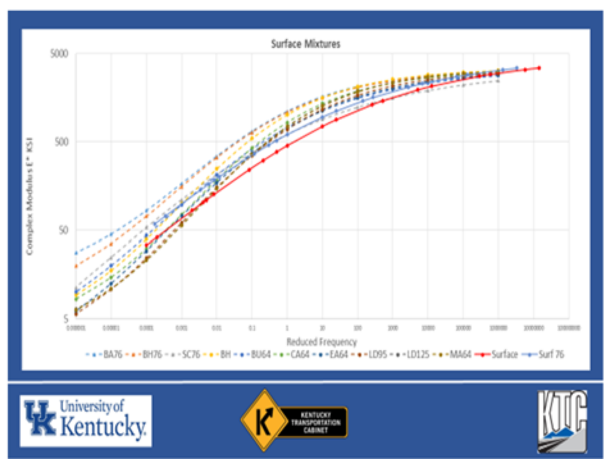

Questions?
Geoff Hall, P.E.
Maryland SHA Pavement
& Geotechnical Division
Chief
ghall1@sha.state.md.us
AASHTOWare
Pavement
ME Design
AASHTO
Geoff Hall, P.E., Pavement Chief, Maryland SHA
31

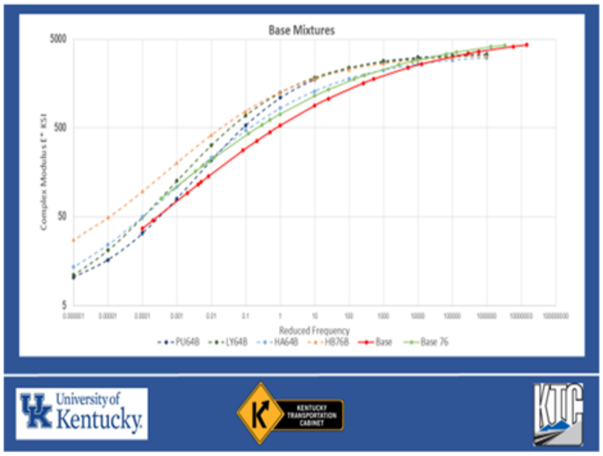
Presentation 10—Clark Graves, University of Kentucky / Joe Tucker, Kentucky Transportation Cabinet

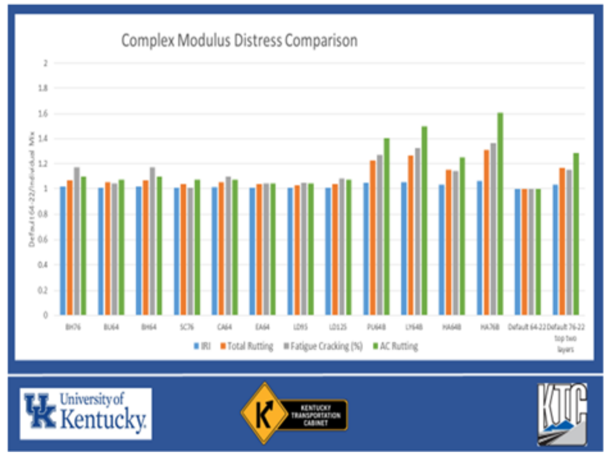




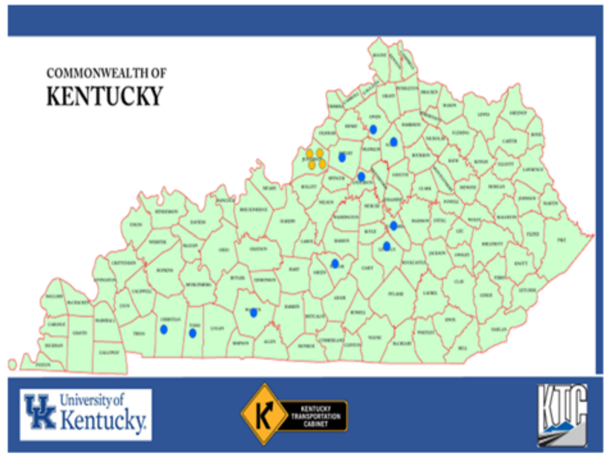


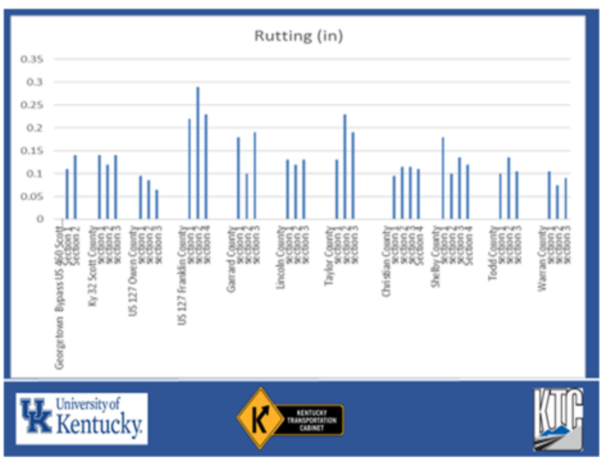


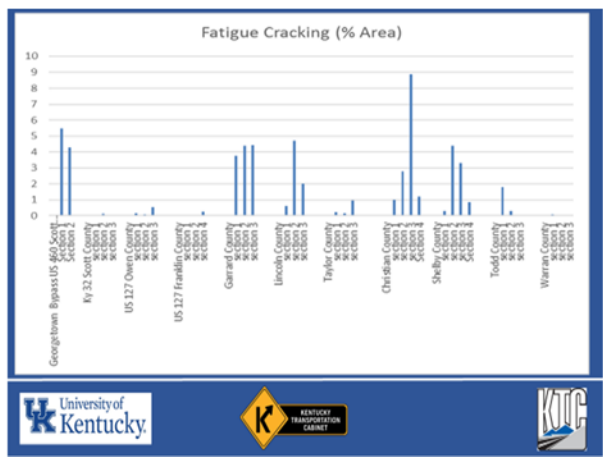

Base Mixtures
Complex Modulus E* KSI
Reduced Frequency
PU64B
LY64B
HA64B
HB76B
Base
Base 76

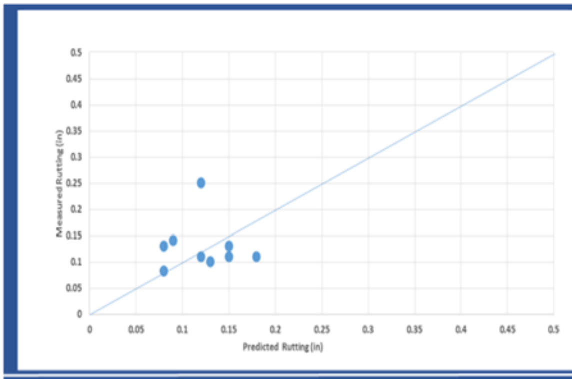

Complex Modulus Distress Comparison
IRI
Total Rutting
Fatigue Cracking (%)
AC Rutting


Calibration Sites
• Calibration Sites selected across the state
• Primary focus is on Asphalt Pavements
• 8 – 15 years old
• Constructed with Superpave Mix Design
• Various Traffic Levels


COMMONWEALTH OF
KENTUCKY


Rutting (in)
Georgetown Bypass US 460 Scott
Ky 32 Scott County
US 127 Owen County
US 127 Franklin County
Garrard County
Lincoln County
Taylor County
Christian County
Shelby County
Todd County
Warren County


Fatigue Cracking (% Area)
Georgetown Bypass US 460 Scott
Ky 32 Scott County
US 127 Owen County
US 127 Franklin County
Garrard County
Lincoln County
Taylor County
Christian County
Shelby County
Todd County
Warren County



Prepare for Tomorrows Calibration

- Calibration should be a continuous process
- Capture data at the design phase that will be needed
  - Materials
  - Traffic
  - Design changes
- Sophisticated database structure or file repository (Projectwise)

Why A Design Catalog

- Easy transition from current catalog system
- Efficiently develop pavements designs by engineers with limited PaveME experience
- Consistent cost estimation process
- State Highway Engineer looking for quick implementation
- PaveME use for specialized designs and forensic evaluations

Design Catalog Development

- Developed design space of typical designs
- Standard DGA Thickness initially 6"
- Standard HMA Mix Properties from historical designs
- Standardized unbound material properties with variable modulus
- Single Vehicle Class Distributions, default axle load spectra, AADTT from 100 – 16,000
- Variable HMA thickness 6" - 18", 343 combinations,

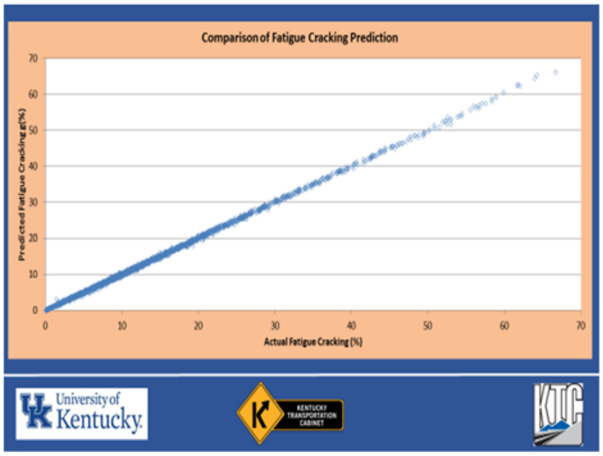
DGA Thickness (in)	6							
AC Thickness (in)		6	8	10	12	14	16	18
Subgrade Strength		6,000	7,500	9,000	10,500	12,000	13,500	15,000
Truck Traffic (AADTT)		100	500	1,000	2,000	4,000	8,000	16,000
ESALS (est)		365,000	1,825,000	3,650,000	7,300,000	14,600,000	29,200,000	58,400,000

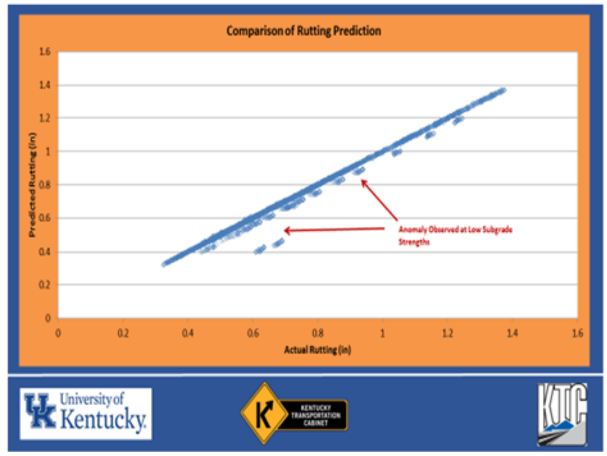
Catalog Development Cont.

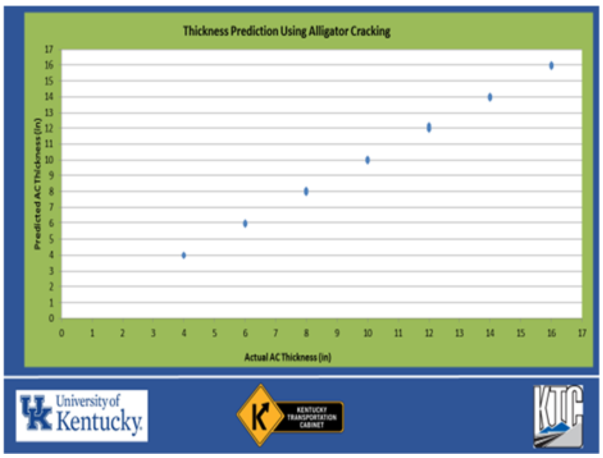
- Initial catalog based on "synthesized" calibration coefficients from surrounding states
- Refinement will be made based on local calibration sites
- Primary focus on AC rutting and fatigue cracking
- Reliability 90%

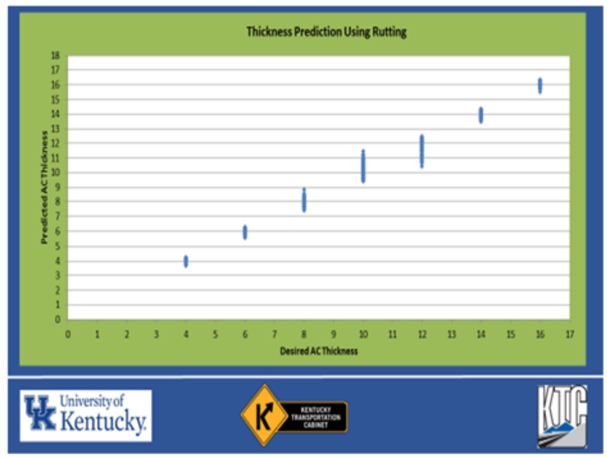
Modeling of Design Space

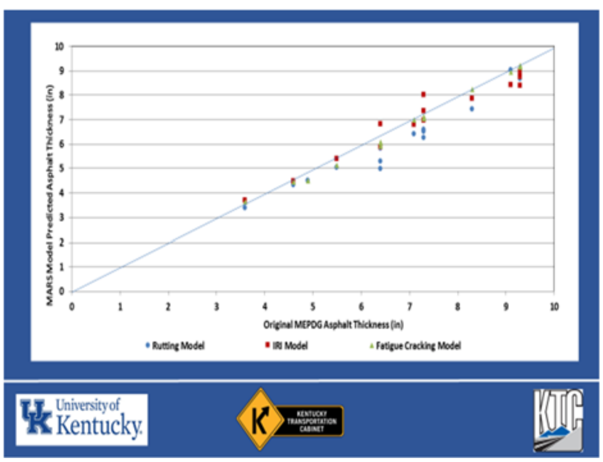
- Multiple Adaptive Regression (MARS) of design space.
- Ability to determine both forward solution and predict distress
- Backward solution to predict thickness given distress thresholds
- Accuracy within design space is very good

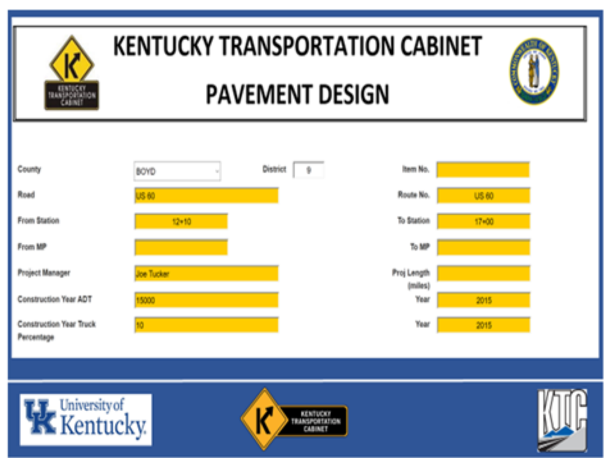

Comparison of Fatigue Cracking Prediction
Predicted Fatigue Cracking (%)
Actual Fatigue Cracking (%)
University of Kentucky
KENTUCKY TRANSPORTATION CABINET
KTC

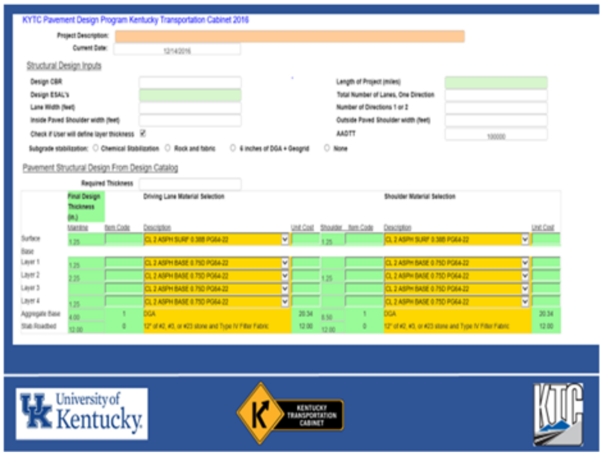

Comparison of Rutting Prediction
Predicted Rutting (in)
Actual Rutting (in)
Anomaly Observed at Low Subgrade Strengths
University of Kentucky
KENTUCKY TRANSPORTATION CABINET
KTC

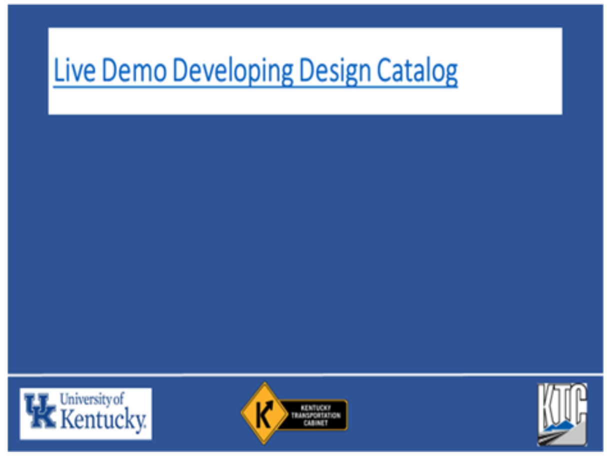

Thickness Prediction Using Alligator Cracking
Predicted AC Thickness (in)
Actual AC Thickness (in)
University of Kentucky
KENTUCKY TRANSPORTATION CABINET
KTC

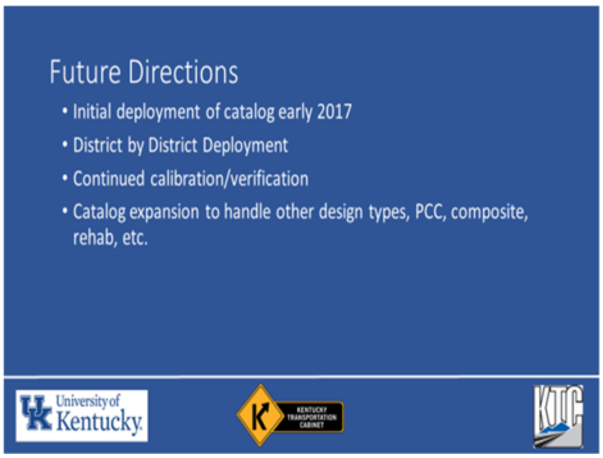

Thickness Prediction Using Rutting
Predicted AC Thickness
Desired AC Thickness
University of Kentucky
KENTUCKY TRANSPORTATION CABINET
KTC


MARS Model Predicted Asphalt Thickness (in)
Original MEPDG Asphalt Thickness (in)
Rutting Model
IRI Model
Fatigue Cracking Model
University of Kentucky
KENTUCKY TRANSPORTATION CABINET
KTC


KENTUCKY TRANSPORTATION CABINET
PAVEMENT DESIGN
County
BOYD
District
9
Item No.
Road
US 60
Route No.
US 60
From Station
12+10
To Station
17+00
From MP
To MP
Project Manager
Joe Tucker
Proj Length (miles)
Construction Year ADT
15000
Year
2015
Construction Year Truck Percentage
10
Year
2015
University of Kentucky
KENTUCKY TRANSPORTATION CABINET
KTC

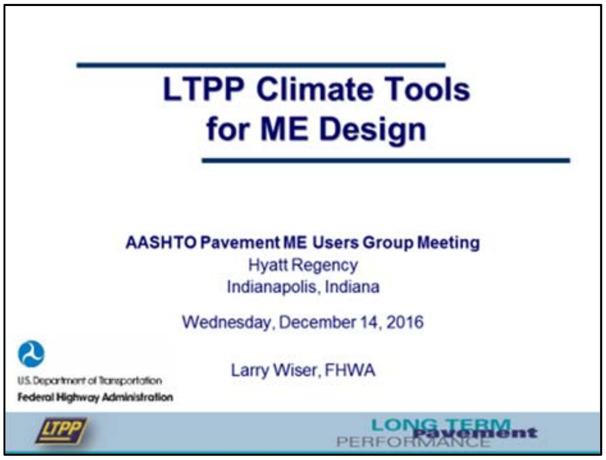

KYTC Pavement Design Program Kentucky Transportation Cabinet 2016
Project Description:
Current Date:
Structural Design Inputs
Design CBR
Design ESAL's
Lane Width (feet)
Inside Paved Shoulder width (feet)
Check if User will define layer thickness
Length of Project (miles)
Total Number of Lanes, One Direction
Number of Directions 1 or 2
Outside Paved Shoulder width (feet)
AADTT
Subgrade stabilization: Chemical Stabilization Rock and fabric 6 inches of DGA + Geogrid None
Pavement Structural Design From Design Catalog
Required Thickness
Final Design Thickness (in.)
Driving Lane Material Selection
Shoulder Material Selection
University of Kentucky
KENTUCKY TRANSPORTATION CABINET
KTC

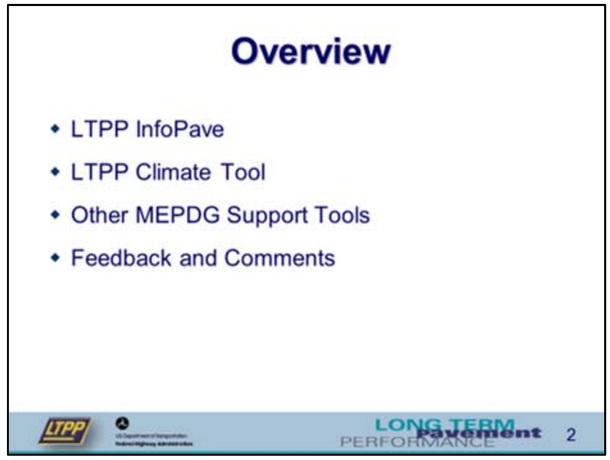

Live Demo Developing Design Catalog
University of Kentucky
KENTUCKY TRANSPORTATION CABINET
KTC

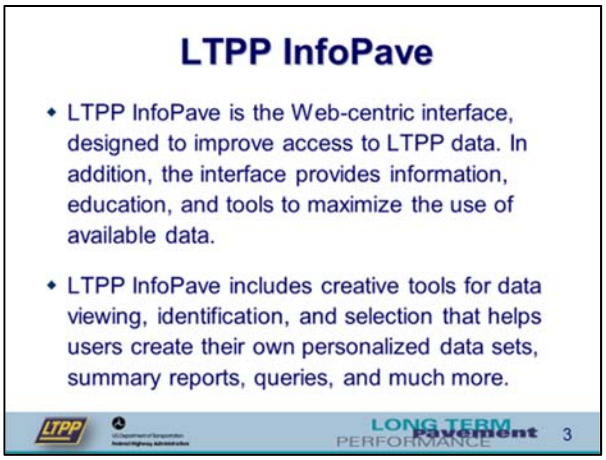

Future Directions
• Initial deployment of catalog early 2017
• District by District Deployment
• Continued calibration/verification
• Catalog expansion to handle other design types, PCC, composite, rehab, etc.
University of Kentucky
KENTUCKY TRANSPORTATION CABINET
KTC

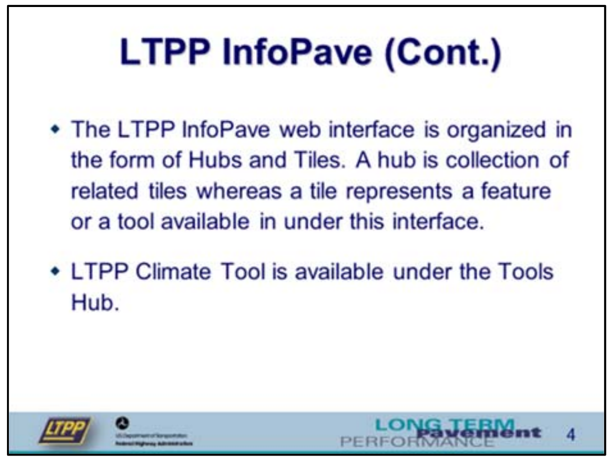

Thank You
University of Kentucky
KENTUCKY TRANSPORTATION CABINET
KTC

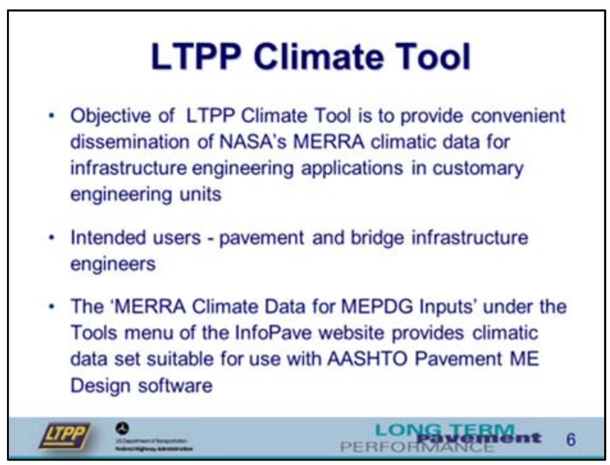
Presentation 11—Larry Wiser, FHWA





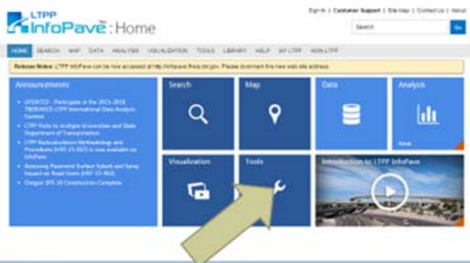






Accessing LTPP Climate Tool

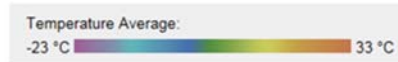
- https://infopave.fhwa.dot.gov 'Data' & 'Tools'



LTPP LONG TERM PAVEMENT PERFORMANCE 7

Available Data

- Data Attributes
  - Temperature
  - Precipitation
  - Humidity
  - Wind
  - Solar
- Data Frequency
  - Hourly
  - Daily
  - Monthly
  - Annually



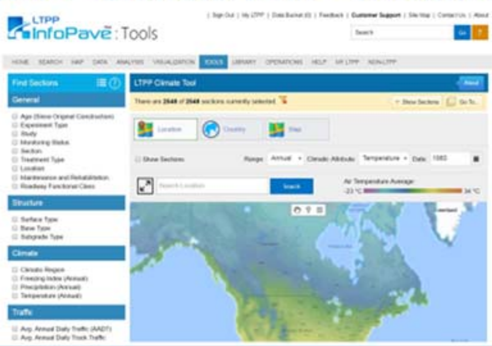
Temperature and Precipitation Elements

- Temperature
  - Temperature
  - Soil temperature layers 1 – 6
  - Soil temperature unsaturated zone
  - Soil temperature saturated zone
- Precipitation
  - Precipitation
  - Evaporation
  - Infiltration
  - Overland runoff
  - Snow Mass
  - Snow Melt
  - Snow-covered area fraction
  - Snowfall

Humidity, Wind and Solar Elements

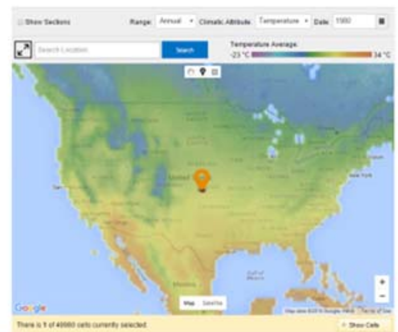
- Humidity
  - Specific humidity
  - Relative humidity
  - Air pressure
- Wind
  - North wind
  - East wind
  - Wind velocity
  - Air density
- Solar
  - Shortwave surface
  - Shortwave top of atmosphere
  - Cloud cover
  - Percent sunshine
  - Emissivity
  - Albedo

LTPP Climate Tool – Location

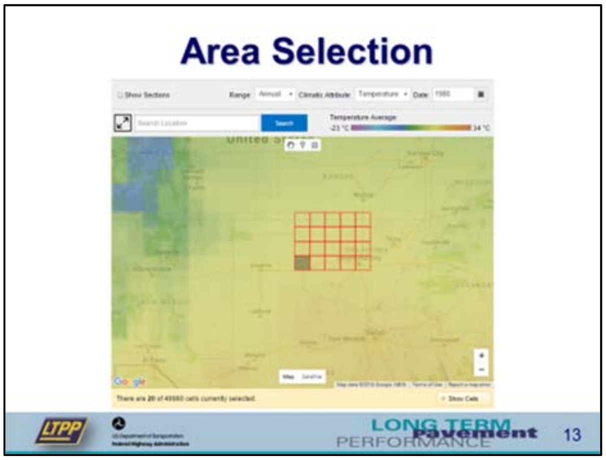


LTPP LONG TERM PAVEMENT PERFORMANCE 11

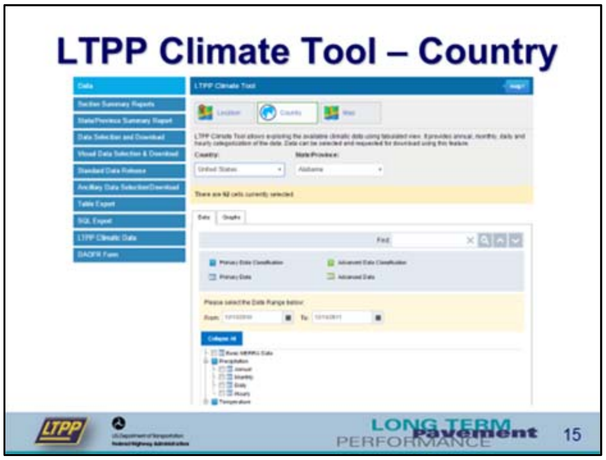
Location Selection

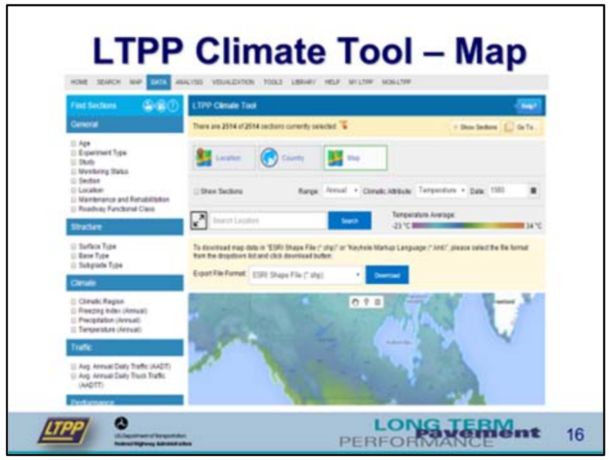


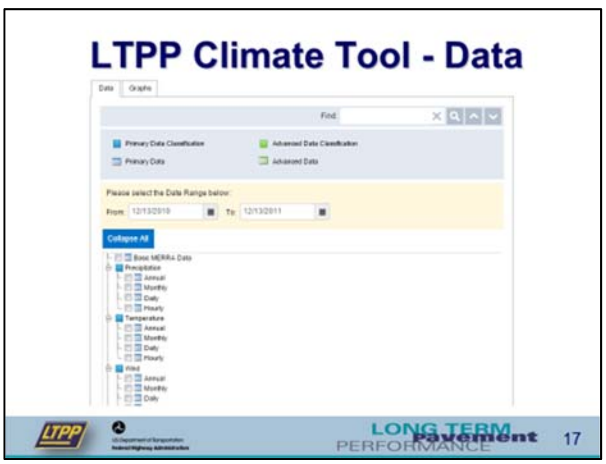
LTPP LONG TERM PAVEMENT PERFORMANCE 12

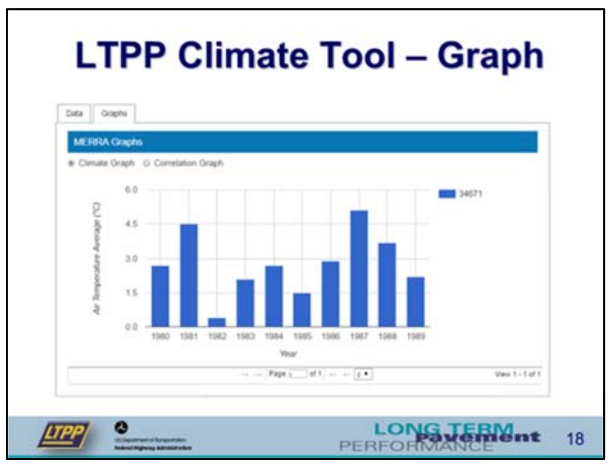

Area Selection
LTPP
LONG TERM
Pavement
PERFORMANCE
13


LTPP Section Selection
ROAD
TEST
LTPP
LONG TERM
Pavement
PERFORMANCE
14


LTPP Climate Tool – Country
LTPP
LONG TERM
Pavement
PERFORMANCE
15


LTPP Climate Tool – Map
LTPP
LONG TERM
Pavement
PERFORMANCE
16


LTPP Climate Tool - Data
LTPP
LONG TERM
Pavement
PERFORMANCE
17


LTPP Climate Tool – Graph
LTPP
LONG TERM
Pavement
PERFORMANCE
18

Data Download Formats

- **Tabulated Data** – Microsoft Excel (XLS), Microsoft Access (MDB), and Microsoft SQL Server (BAK).
- **Program Input** – Historic Climatic Data (HCD) and Integrated Climate Model (ICM) files.
- **Map** – ESRI Shape File (SHP), and Keyhole Markup Language (KML) XML files.

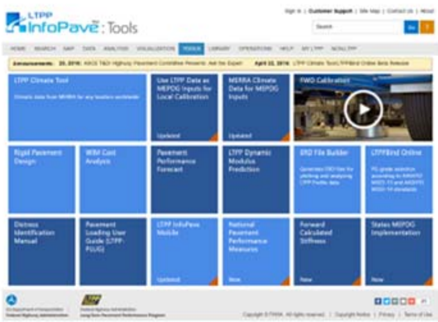
19

Other MEPDG Support Tools

- Use LTPP Data for MEPDG Inputs for Local Calibration
- MERRA Climatic Data for MEPDG Inputs

20

Tools Hub



21

MEPDG Inputs for Local Calibration

The MEPDG Inputs feature is designed to provide the performance data and inputs from the LTPP database for the AASHTOWare Pavement ME software. This allows the users to run comparisons of model predictions against the actual performance data from LTPP test sections.

22

MEPDG Inputs for Local Calibration (Cont.)

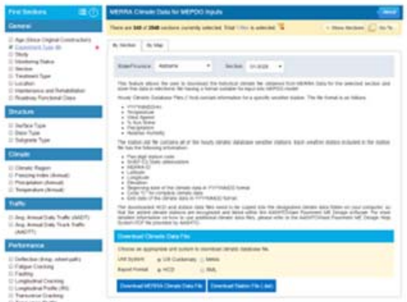
23

Climate Data for MEPDG Inputs

MERRA Climate Data for MEPDG Inputs enables users to download MERRA climate data in a format that is being used as an input for the AASHTOWare Pavement ME Design Software. This feature allows users to download the Hourly Climatic Database (.HCD) file based upon MERRA data for the selected section.

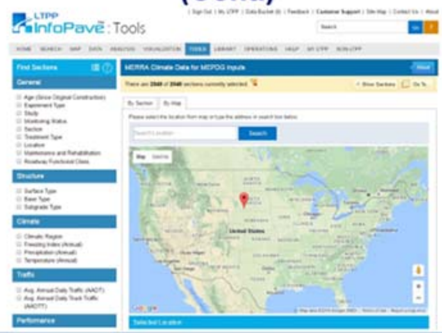
24

Climate Data for MEPDG Inputs (Cont.)



LONG TERM PERFORMANCE Pavement 25

Climate Data for MEPDG Inputs (Cont.)



LONG TERM PERFORMANCE Pavement 26

Summary

- LTPP Climate Tool provides convenient dissemination of MERRA climatic data for infrastructure engineering applications in customary engineering units
- Intended users - pavement and bridge infrastructure engineers
- 'MERRA Climate Data for MEPDG Inputs' provides climatic data set suitable for use with AASHTO Pavement ME Design software
- Use of LTPP Data for MEPDG Inputs for Local Calibration

LONG TERM PERFORMANCE Pavement 27

Feedback and Comments

Larry Wiser
Larry.Wiser@dot.gov

LONG TERM PERFORMANCE Pavement 28

Presentation 12—Nusrat Morshed, New Jersey DOT

NJDOT –STATUS OF TRAFFIC INPUT

AASHTO PAVEMENT ME NATIONAL USERS GROUP MEETING
DECEMBER 14 AND 15, 2016
INDIANAPOLIS, IN

Nusrat S. Morshed, P.E.
Senior Engineer
Pavement Design Unit, NJDOT
(609) 530 5682
Nusrat.Morshed@dot.nj.gov

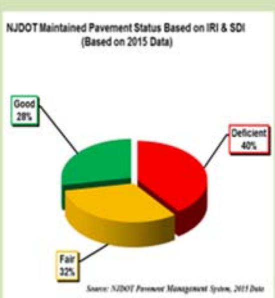
ACKNOWLEDGEMENT:

- CHRIS ZAJAC- Section Chief, Safety and Data Development, NJDOT
- PHILIP BERTUCCI- Pavement Management Administrator, Pavement & Drainage Management, NJDOT
- VIVEK JHA- Project Engineer, Advanced Infrastructure Design, Inc.
- HAO WANG, PhD - Assistant Professor, Rutgers,The State University of New Jersey

OVERVIEW

- Status of NJDOT Highway System
- Types Of Traffic Data- NJDOT
- Example Of Consultant Work Using PAVEMENT ME
- Upcoming User Manual (Traffic) for ME Design-FY-2017

STATUS OF NJDOT HIGHWAY SYSTEM



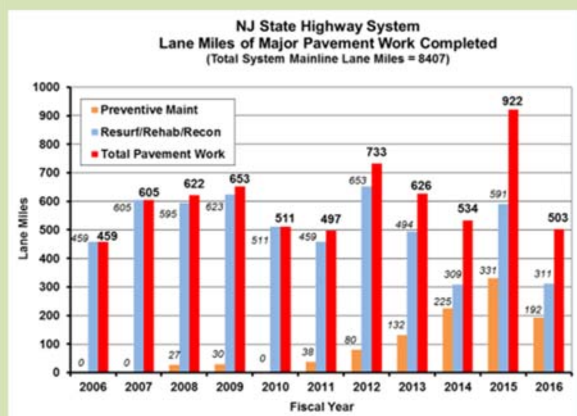
Notes:

1) IRI = International Roughness Index measured in inches per mile

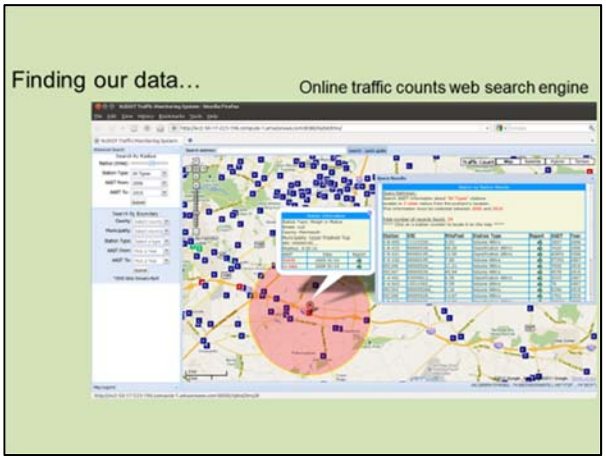
2) SDI = Surface Distress Index measured on a 0 - 5 scale (5 = distress free pavement)

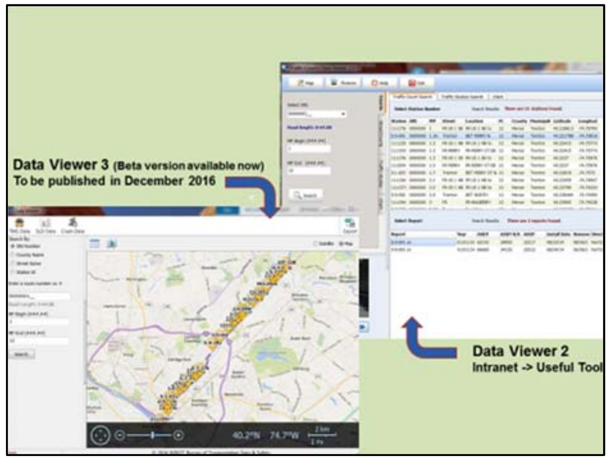
Status	Criteria	Road Miles (Two Direct'n)	Lane Miles (Two Direct'n)	% Total System Lane Miles
Deficient	IRI > 170 OR SDI < 2.4	2083.8	3411.4	40%
Fair	IRI / SDI Combinations Between Good and Deficient	1454.7	2672.1	32%
Good	IRI < 95 AND SDI > 3.5	1125.8	2321.9	28%
Total		4664.3	8405.4	100%

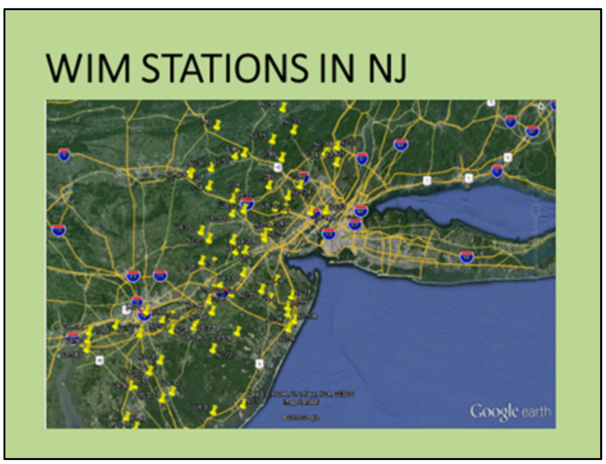
Note: Mileage in the table above represents tested mileage which is slightly less than system mileage (4664 out of 4666 and 8405 out of 8407) due to inaccessibility of some areas for testing.

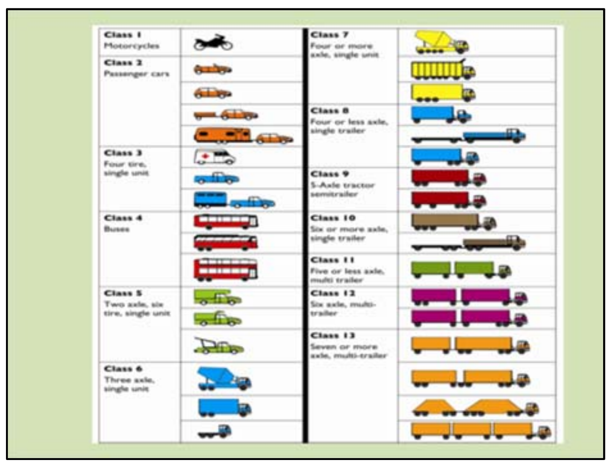


TYPES OF TRAFFIC DATA-NJDOT









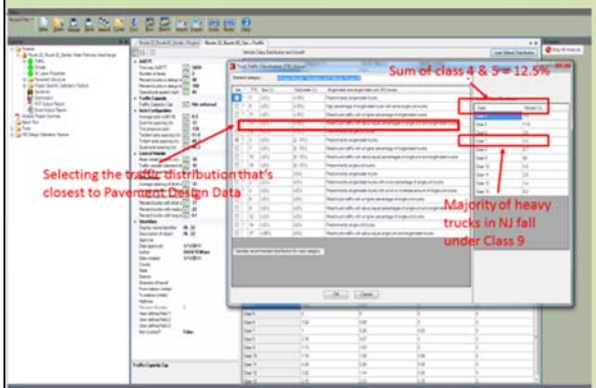
EXAMPLE OF CONSULTANT WORK USING PAVEMENT ME

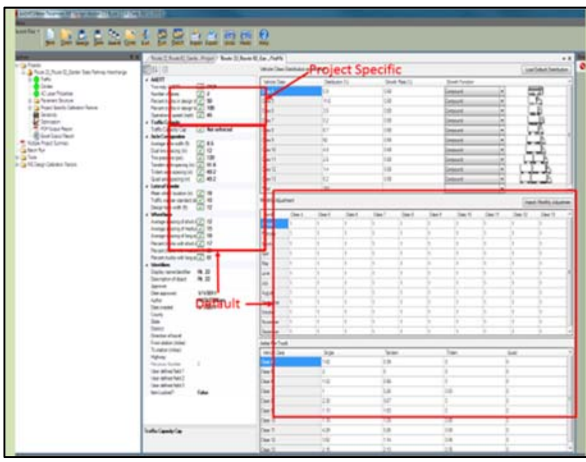
PROJECT DETAILS

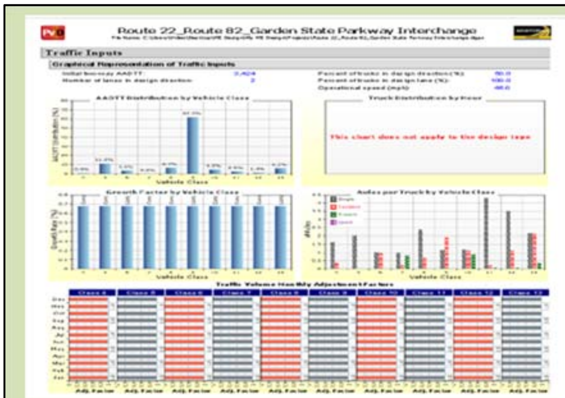
- Route 22/Route 82/Garden State Parkway Interchange Project
- Route 22: MP 55.26-56.16
- Existing Pavement
  - Route 22 EB: Primarily reinforced PCC
  - Route 22 WB: AC over reinforced PCC
- Reconstruction was considered one of the alternatives in the bare PCC section where no raise in profile was allowed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

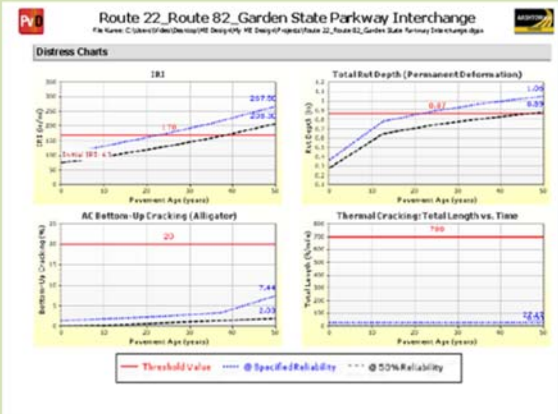
PAVEMENT DESIGN DATA

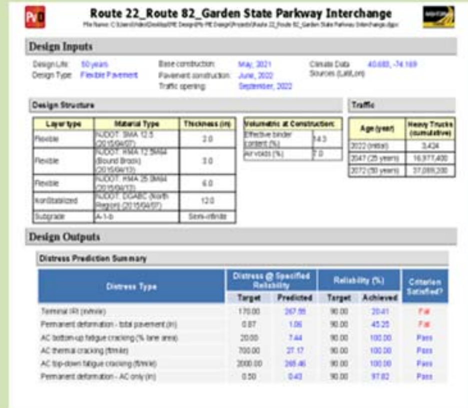
- 2016 ADT (1 Way) = 53,010 vpd
- 2022 ADT (1 Way) = 55,210 vpd
- 2032 ADT (1 Way) = 59,080 vpd
- 2042 ADT (1 Way) = 63,230 vpd
- Growth Factor = 0.68%
- Heavy (Class 6-13) Truck % in 24 hours = 2.7%
- Total (Class 4-13) Truck % in 24 hours = 3.1%
- % of Light (Class 4-5) Truck = ~13%
- % of Heavy (Class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











Route 22_Route 82_Garden State Parkway Interchange

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)	16,377,400
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

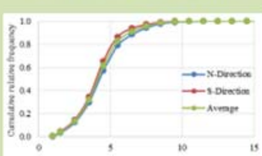
UPCOMING USER MANUAL (TRAFFIC) FOR ME DESIGN-FY-2017

TRAFFIC FAMILY ANALYSIS

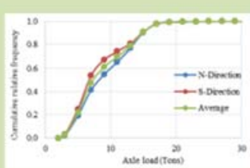
- **Analyze WIM data at New Jersey and provide level 2 (cluster average) and level 3 (statewide average) inputs used for AASHTO PAVEMENT ME**
- **Data extracted from Vehicle Travel Information System (VTRIS) operated by FHWA Office of Highway Policy Information**
- **90 Weight-in-Motion (WIM) sites in New Jersey**
- **Annual average data in 2012-2014 were used in the analysis**
- **Statistical analysis was first performed to see if there is significant variation within two directions at the same WIM site or at different years at the same WIM site**
- **Hierarchical cluster analysis was conducted to develop traffic families, respectively, for single axle load spectra, tandem axle load spectra, tridem axle load spectra, and vehicle class distribution**

DIRECTIONAL VARIATION

- **No statistical difference between traffic at different directions**



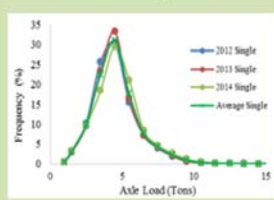
Single axle load spectra (2014)



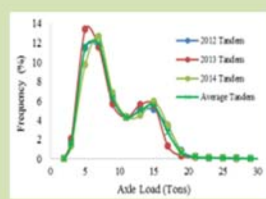
Tandem axle load spectra (2014)

TEMPORAL VARIATION

- **No statistical difference between traffic at different years**

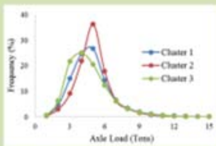


Single axle load spectra

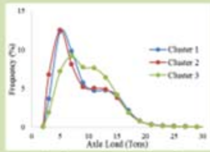


Tandem axle load spectra

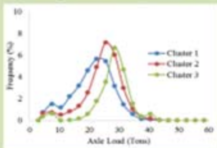
CLUSTERING ANALYSIS RESULTS



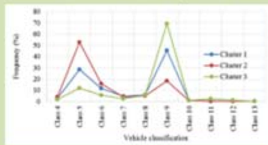
Single axle load spectra



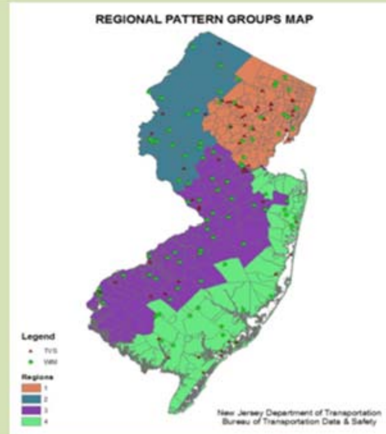
Tandem axle load spectra



Tridem axle load spectra



Vehicle class distribution



NEXT STEP

- **Develop categorization method based on traffic families for pavement design at specific sites**
- **Analyze the effect of traffic using traffic clusters, the state-averaged traffic, and the site-specific traffic**
- **Continue working on the material catalog for asphalt mixes used in NJ**

QUESTIONS?

Nusrat.Morshed@dot.nj.gov

NJDOT 1966 2016
CELEBRATING 50 YEARS OF SERVICE TO NEW JERSEY

Presentation 13—Melody Perkins, Colorado DOT

Local Calibration of Subgrade Soils

Objectives

- Define Resilient Modulus
- CDOT's Studies
- Modeling the Subgrade in M-E Design
- Where Does CDOT Go From Here?

Resilient Modulus

What is Resilient Modulus?

- Key design parameter for pavement systems.
- It allows the determination of how the pavement system will respond to traffic loadings.
- Ratio of applied deviator stress to the recoverable or "resilient" strain.

What does this mean?

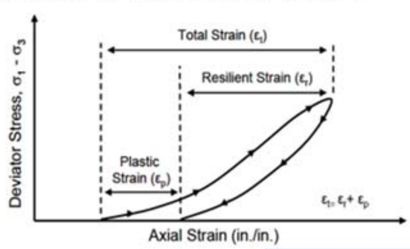
Resilient Modulus - Stress

Stress vs. Deviator Stress

- Stress - When a wheel load is applied to a pavement, locations under the load experience different levels of stress based on their depth from the surface and the distance from the applied loading.
- Deviator Stress - A specific axial or vertical stress at a point in the pavement system due to the applied load.
- Resilient modulus uses Deviator Stresses.

Resilient Modulus - Strain

- Strain - The ratio of an object's deformation to its original dimension in the same direction. A portion of the deformation may be recoverable or "resilient" while the remainder is unrecoverable or "plastic".



Resilient Modulus - Stiffness

Stiffness, not Strength

- RM is a stiffness measurement, not the strength of the materials.
- RM used to characterize pavement materials under loading conditions that will not result in "failure" of a pavement system.
- The pavement system can be designed to carry the design axle load applications during its service life by varying the layer thickness and stiffness.

Resilient Modulus

What Factors Influence Resilient Modulus?

- **Compaction**: Specimens compacted at a low density will normally have lower resilient moduli than those compacted at higher density.
- **Moisture Content**: Specimens should be prepared and tested at their optimum moisture content determined by Proctor. As a specimen moisture content increase, the resilient modulus will decrease.
- **Stress State (Bulk Stress)**: Within the pavement structure, bulk stress varies as a function of the applied traffic loading, in-situ pavement layer density, and material type. For a given loading, bulk stress decreases as the distance from the pavement surface increases.

Resilient Modulus

How is Resilient Modulus Used in Pavement Design?

- Resilient modulus provides an indication of elastic response of a given material.
- In MEPDG layered elastic analysis is utilized to determine pavement response, based on applied loading, environmental conditions, and material properties at two critical locations, which are . . . . .

Resilient Modulus

How is Resilient Modulus Used in Pavement Design?

1. Strain at the bottom of the HMA layer.
   - Excessive strain at the bottom of the HMA layer can result in a "fatigue" crack forming and continuing upwards to the pavement surface.
2. Vertical stress at the top of the subgrade.
   - Excessive vertical stress at the top of the subgrade can result in permanent or plastic deformation (i.e. rutting) in the subgrade.

Resilient Modulus

How is Resilient Modulus Measured?

- **ASTM D2844** - Standard Test Method for Resistance R-Value and Expansion Pressure of Compacted Soils.
- Also known as **AASHTO T190**
- In Colorado we use **CP-3101**, a variation of ASTM D2844

Colorado Procedure: Laboratory 3101

Differences between ASTM D2844 and CP-3101

- Utilizes a spacer below the mold
  - The spacer is not removed during the test
- Do not unlock the mold during the compaction
  - Creates straight compaction rather than 'kneeding' the soil

Why do we use CP-3101?
  - Possibly due to equipment requirements
  - And/or straight compaction creates a more conservative R-value (temperamental soils in Colorado)

2002 CDOT R-Value vs. M_r Study
(Best Fit Curves)

A-2 Soils

R^2	R-Value	LL	PI	P-4	P-10	P-40	P-200	Moisture ($M_{R(0)}$)	Density ($M_{R(0)}$)
0.830	•	•	•	•	•	•	•	•	•
0.830	•	•	•	•	•	•	•	•	
0.154	•	•	•	•	•	•	•		
0.134	•	•	•	•	•	•			
0.134	•	•	•	•	•				
0.113	•	•	•	•					
0.093	•	•	•						
0.063	•	•							
0.035	•								
0.730								•	
0.325									•
0.730	•							•	
0.815	•			•				•	
0.816		•	•	•				•	

$M_{R(0)} = 16{,}046 - 36*(LL) + 37.5*(PI) - 64.4*(P\text{-}4) - 107*(Moist(M_{R(0)}))$

AASHTO T 190 with AASHTO T 307 at various moisture contents.

Resilient Modulus R-Value Correction

CDOT uses a Hveem stabilometer to measure the strength properties of soils and bases.

- This equipment yields and index value called an R-value.
- The R-value is considered a static value
- The Mr is considered a dynamic value

Resilient Modulus R-Value Correction

Resilient Modulus in ME-Design

Differences Between CDOT and ME-Design

- ME-Design requires the resilient modulus at optimum moisture content.
  - Either by Proctor or modified Proctor testing.
- CDOT uses a Modified version of AASHTO T 190

Resilient Modulus R-Value Correction

Pre-2012 Equation

$M_R = 10^{[(S+18.72)/6.24]}$

where S = [(R-5)/11.29]+3

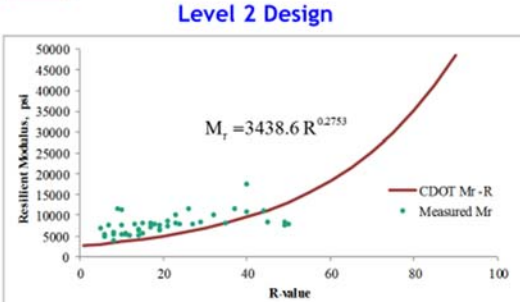
New Equation

$M_R = 3{,}438.6 * R^{0.2753}$

- Only for soils with an R-value of less than 50
- For R-values greater than 50 FWD or AASHTO T 307

Local M-E Design Calibration

Level 2 Design



FWD to Laboratory Ratios

Level 1 Design

Layer Type	Location	Mean E_R/M_r Ratio
Unbound Granular Base and Subbase Layers	Granular base/subbase between two stabilized layers (cementitious or asphalt stabilized materials).	1.43
	Granular base/subbase under a PCC layer.	1.32
	Granular base/subbase under an HMA surface or base layer.	0.62
Embankment and Subgrade Soils	Embankment or subgrade soil below a stabilized subbase layer or stabilized soil.	0.75
	Embankment or subgrade soil below a flexible or rigid pavement without a granular base/subbase layer.	0.52
	Embankment or subgrade soil below a flexible or rigid pavement with a granular base or subbase layer.	0.35

E_R – Elastic modulus backcalculated from deflection basin measurements.
M_r – Elastic modulus of the in-place materials determined from laboratory repeated load resilient modulus test.

From the Mechanistic-Empirical Pavement Design Guide Manual of Practice

National M_r Values

Level 3 Design

AASHTO Soil Classification	Resilient Modulus (M_r) at Optimum Moisture, psi	
	Flexible Pavements	Rigid Pavements
A-1-a	19,700	14,900
A-1-b	16,500	14,900
A-2-4	15,200	13,800
A-2-5	15,200	13,800
A-2-6	15,200	13,800
A-2-7	15,200	13,800
A-3	15,000	13,000
A-4	14,400	18,200
A-5	14,000	11,000
A-6	17,400	12,900
A-7-5	13,000	10,000
A-7-6	12,800	12,000

Only used for preliminary design (values tend to be higher than CDOT's)

Modeling the Subgrade in M-E

Input for New Flexible and JPCP Designs

Pavement & Design Type	Material Property	Input Hierarchy		
		Level 1	Level 2	Level 3
New Flexible and JPCP	Resilient Modulus	Not Available	CDOT Lab Testing	AASHTO Soil Class.
	Gradation	Not Available	CP 21-08	CDOT Defaults
	Atterberg Limit	Not Available	AASHTO T 195	CDOT Defaults
	Poisson's Ratio	Not Available	Software Defaults	M-E Design Software Default of 0.40
	Coefficient of Lateral Pressure	Not Available	Software Defaults	M-E Design Software Default of 0.50
	Max. Dry Density	Not Available	AASHTO T 180 or T 99	Estimate using gradation, plasticity index, and liquid limit.[2]
	Optimum Moisture Content	Not Available	AASHTO T 180 or T 99	
	Specific Gravity	Not Available	AASHTO T 100	
	Saturated Hydraulic Conductivity	Not Available	AASHTO T 215	
	Soil Water Characteristic Curve Parameters	Not Available	N/A	

Modeling the Subgrade in M-E

Inputs for HMA Overlay of Existing Flexible Pavements

Pavement & Design Type	Material Property	Input Hierarchy		
		Level 1	Level 2	Level 3
HMA Overlays of Existing Flexible Pavement	Resilient Modulus	FWD Deflection Testing and Backcalculated Resilient Modulus	CDOT Lab Testing	AASHTO Soil Classification
	Gradation	Colorado Procedure 21-08		CDOT Defaults
	Atterberg Limit	AASHTO T 195		CDOT Defaults
	Poisson's Ratio	Software Defaults		M-E Design Software Default of 0.40
	Coefficient of Lateral Pressure	Software Defaults		M-E Design Software Default of 0.50
	Max. Dry Density	AASHTO T 180 or T 99		Estimate using gradation, plasticity index, and liquid limit.[2]
	Optimum Moisture Content	AASHTO T 180 or T 99		
	Specific Gravity	AASHTO T 100		
	Saturated Hydraulic Conductivity	AASHTO T 215		
	Soil Water Characteristic Curve Parameters	N/A		

Modeling the Subgrade in M-E

Inputs for Overlays of Existing Rigid Pavements

Pavement and Design Type	Material Property	Input Hierarchy		
		Level 1	Level 2	Level 3
Overlays of Rigid Pavement	Resilient Modulus	FWD Deflection Testing and Backcalculated Dynamic k-value[3]	CDOT Lab Testing	AASHTO Soil Classification
	Gradation	CP 21-08		CDOT defaults
	Atterberg Limit	AASHTO T 195		CDOT defaults
	Poisson's Ratio	Software Defaults		M-E Design software default of 0.40
	Coefficient of Lateral Pressure	Software Defaults		M-E Design software default of 0.50
	Max. Dry Density	AASHTO T 180 or T 99		Estimate using gradation, plasticity index, and liquid limit
	Optimum Moisture Content	AASHTO T 180 or T 99		
	Specific Gravity	AASHTO T 100		
	Saturated Hydraulic Conductivity	AASHTO T 215		
	Soil Water Characteristic Curve Parameters	N/A		

Modeling the Subgrade in M-E

The top 8 feet of a pavement structure and subgrade can be divided into a maximum of 19 sublayers.

For a full-depth flexible or semi-rigid pavement placed directly on a thick embankment fill, the top 12 inches is modeled as an Aggregate Base Layer, while the remaining embankment is modeled as the Subgrade Layer 1.

Modeling the Subgrade in M-E

- Expansive Subgrade Soils

Plasticity Index	Depth of Treatment Below Normal Subgrade Elevation
10 – 20	2 feet
20 – 30	3 feet
30 – 40	4 feet
40 – 50	5 feet
More than 50	Placed in the bottom of the fills of less than 50 feet or greater than 6 feet in height, or wasted

- Stabilizing Agents
  - Lime Treated
  - Cement Treated
  - Fly Ash and Lime/Fly Ash Treated
- Geosynthetic Fabrics and Mats

Where Does CDOT Go From Here?

2017
M-E Pavement Design
Manual

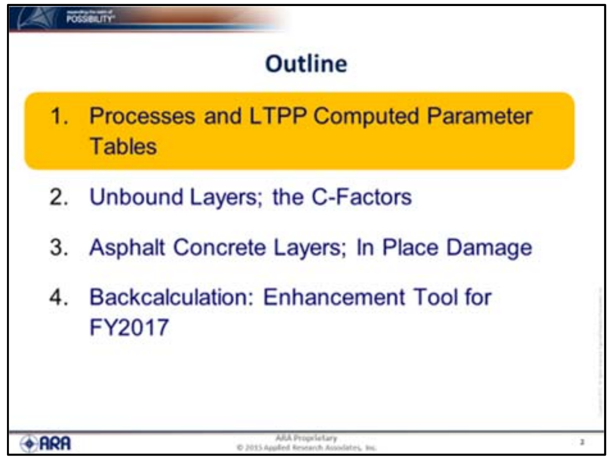
Where Does CDOT Go From Here?

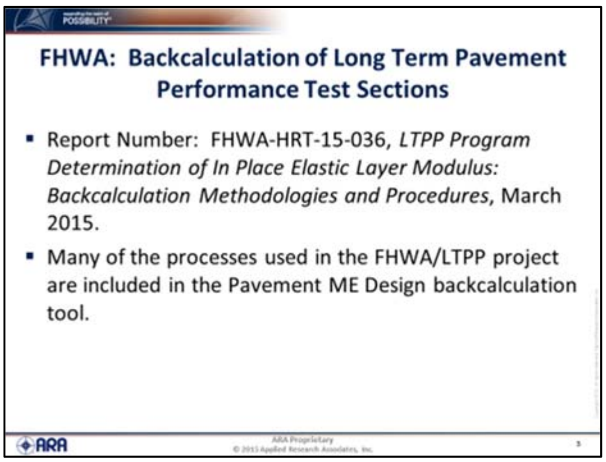
- Local calibration of M_R for soils with a R-value of greater than 50.
- Continued calibration of soils with R-value of less than 50.
- Calibration for soils unique to Colorado (i.e. volcanic tuffs).

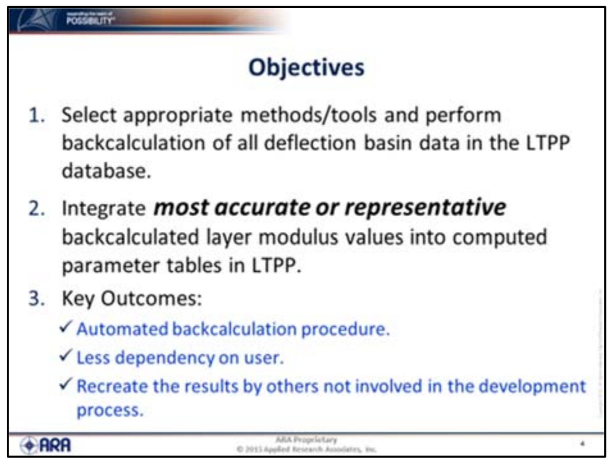
Conclusions

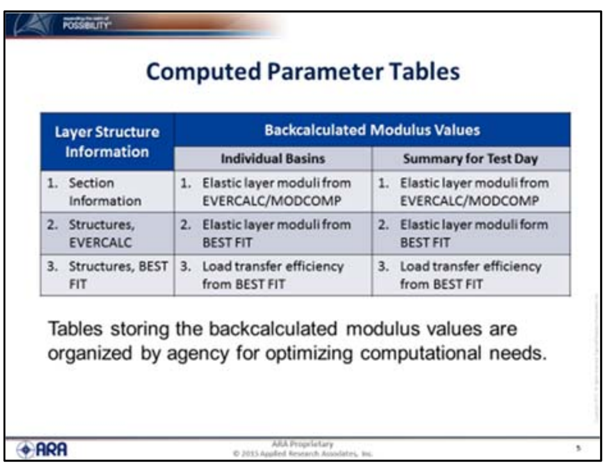
- AASHTO T 307 Standard Method of Test for Determining the Resilient Modulus of Soils should be the preferred test method.
- Old R-values should use CDOT's old equation.
- Use the Level 3 M_r values for preliminary information only. All final designs must use a Level 2 value.

Presentation 14—Harold Von Quintus, ARA

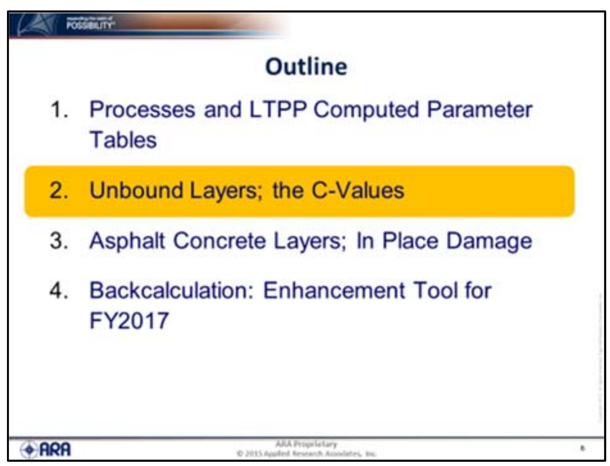








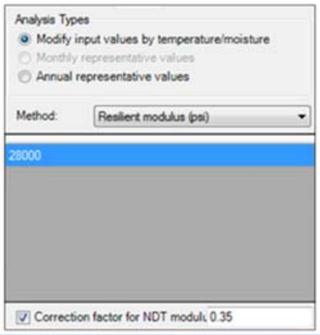
Layer Structure Information	Backcalculated Modulus Values	
	Individual Basins	Summary for Test Day
1. Section Information	1. Elastic layer moduli from EVERCALC/MODCOMP	1. Elastic layer moduli from EVERCALC/MODCOMP
2. Structures, EVERCALC	2. Elastic layer moduli from BEST FIT	2. Elastic layer moduli form BEST FIT
3. Structures, BEST FIT	3. Load transfer efficiency from BEST FIT	3. Load transfer efficiency from BEST FIT



Rehabilitation Input Level 1: Backcalculated E_{FWD}

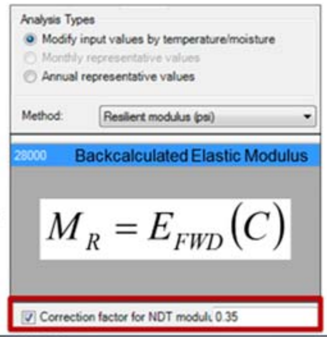
Three points:

1. Backcalculated elastic modulus versus laboratory resilient modulus.
2. Design resilient modulus from AASHTO T 307.
3. Volumetric properties for resilient modulus input.



Rehabilitation Input Level 1: Backcalculated E_{FWD}

- Input: Backcalculated elastic layer modulus, E_{FWD}.
- But, laboratory resilient modulus, M_R(Lab), used in calibration process.
- Program converts E_{FWD} to M_R(Lab) using C-value



$$M_R = E_{FWD}(C)$$

Rehabilitation Input Level 1: Backcalculated E_{FWD}

- Convert E_{FWD} to lab M_r (in situ moisture) using AASHTO C-values.

Layer Type	Location	C-Value
Aggregate Base/Subbase	Between a Stabilized & HMA Layer	1.43
	Below a PCC Layer	1.32
	Below an HMA Layer	0.62
Subgrade-Embankment	Below a Stabilized Subgrade	0.75
	Below an HMA or PCC Layer	0.52
	Below an Unbound Aggregate Base	0.35

Rehabilitation Input Level 1: C-Values

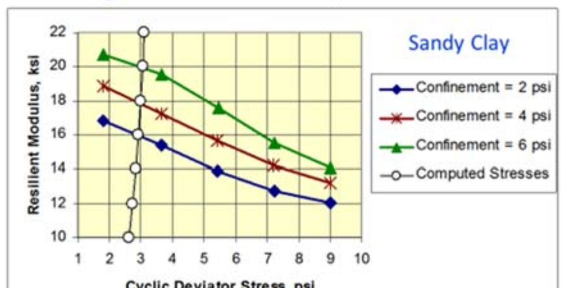
Layer Type	Location	WI	MT	GA	MS
Aggregate Base	Between a Stabilized & HMA Layer	1.43	---	---	---
	Below a PCC Layer	1.32	0.75	0.75	0.75
	Below an HMA Layer	0.62	0.60	0.60	0.60
Subgrade-Embankment	Below a Stabilized Soil	---	---	---	0.75
	Below an HMA or PCC Layer	0.52	1.00	0.50	1.00
	Below Unbound Aggregate	0.35	0.50	0.50	0.50

Laboratory Measured Value; AASHTO T-307

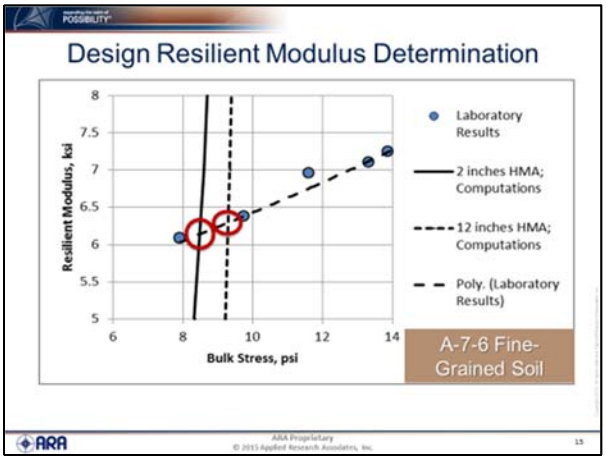
Laboratory repeated load resilient modulus tests. But, what is the input value?

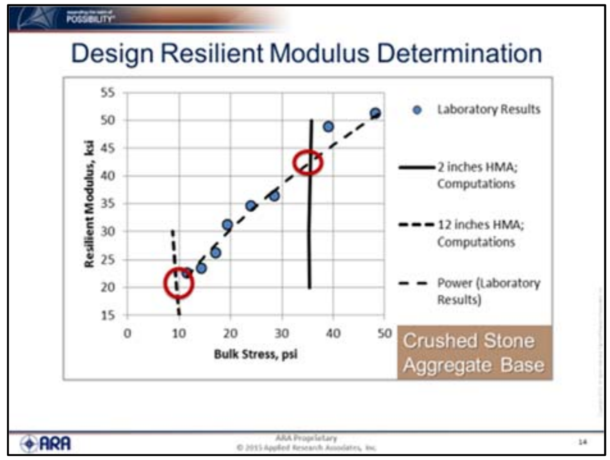
$$M_R = \frac{\sigma_d}{\varepsilon_r}$$

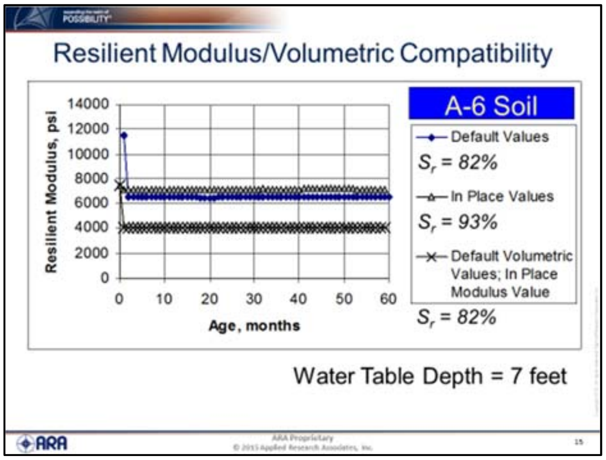
Design Resilient Modulus; AASHTO T 307

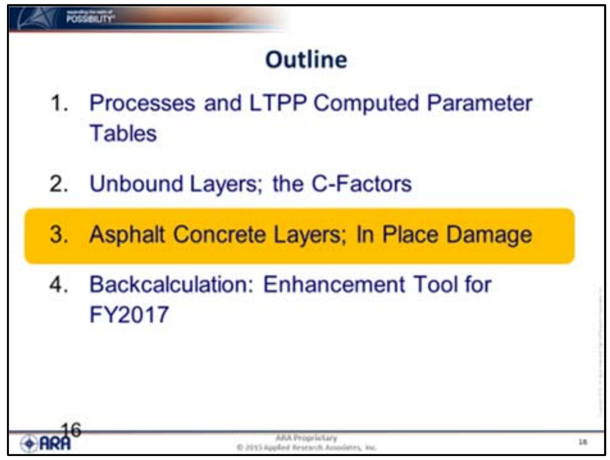


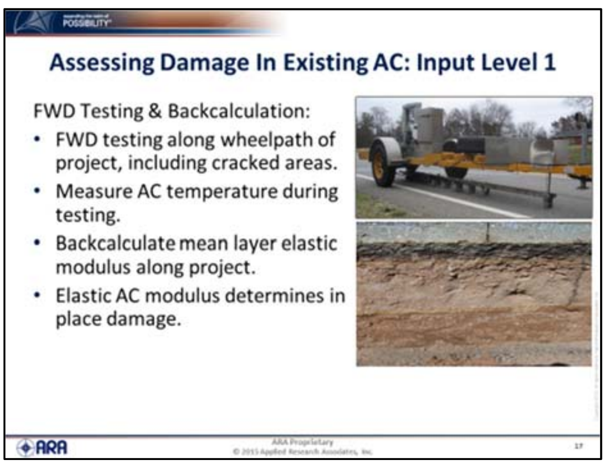
In place confining pressure determined from horizontal load stresses superimposed with lateral at-rest stresses.

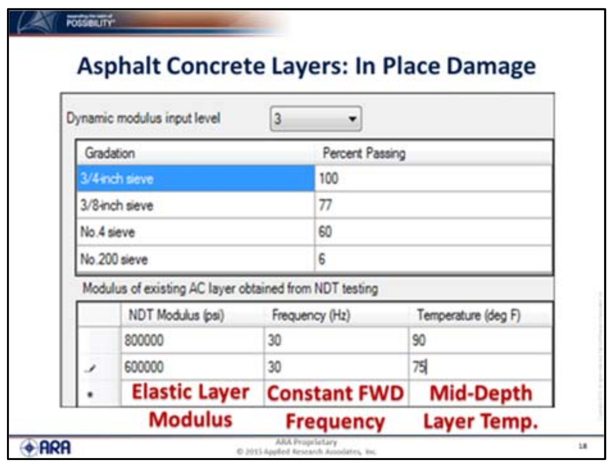

Design Resilient Modulus Determination
Resilient Modulus, ksi
Bulk Stress, psi
Laboratory Results
2 inches HMA; Computations
12 inches HMA; Computations
Poly. (Laboratory Results)
A-7-6 Fine-Grained Soil


Design Resilient Modulus Determination
Resilient Modulus, ksi
Bulk Stress, psi
Laboratory Results
2 inches HMA; Computations
12 inches HMA; Computations
Power (Laboratory Results)
Crushed Stone Aggregate Base

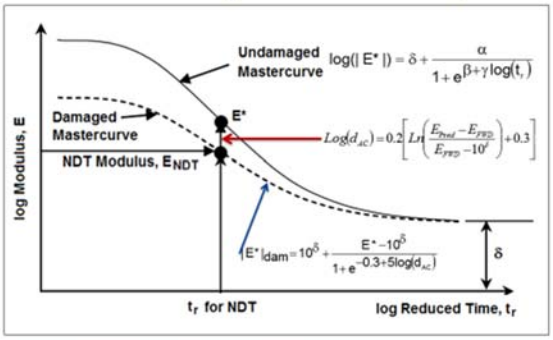

Resilient Modulus/Volumetric Compatibility
A-6 Soil
Resilient Modulus, psi
Age, months
Default Values
S_r = 82%
In Place Values
S_r = 93%
Default Volumetric Values; In Place Modulus Value
S_r = 82%
Water Table Depth = 7 feet


Outline
1. Processes and LTPP Computed Parameter Tables
2. Unbound Layers; the C-Factors
3. Asphalt Concrete Layers; In Place Damage
4. Backcalculation: Enhancement Tool for FY2017
16


Assessing Damage In Existing AC: Input Level 1
FWD Testing & Backcalculation:
• FWD testing along wheelpath of project, including cracked areas.
• Measure AC temperature during testing.
• Backcalculate mean layer elastic modulus along project.
• Elastic AC modulus determines in place damage.


Asphalt Concrete Layers: In Place Damage
Dynamic modulus input level 3
Gradation | Percent Passing
3/4-inch sieve 100
3/8-inch sieve 77
No.4 sieve 60
No.200 sieve 6
Modulus of existing AC layer obtained from NDT testing
NDT Modulus (psi) | Frequency (Hz) | Temperature (deg F)
800000 30 90
600000 30 75
Elastic Layer Modulus
Constant FWD Frequency
Mid-Depth Layer Temp.

Rehabilitation Input Level 1 for AC Layers



Rehabilitation Input Level 1 for AC Layers

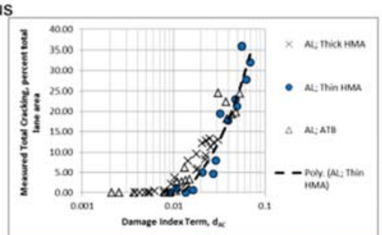
- FHWA project: *Characterizing Existing AC Damage for Rehabilitation Design using Pavement ME Design.*
- Contract Number: DTFH61-14-C-00024
- Expected publication data: Early to mid 2017.
- Objective:
  - Review, enhance, calibrate (if needed) current AASHTOWare procedure for characterizing existing HMA layer damage for rehabilitation design.

Predicted versus Measured Fatigue Cracking

Critical material properties:

1. Asphalt Content
2. Air Voids
3. Aggregate & Soil Resilient Modulus

$$FC_{Bottom} = \left(\frac{1}{60}\right)\left(\frac{C_4}{1+e^{\left(C_1C_1^*+C_2C_2^*Log(DI_{Bottom}*100)\right)}}\right)$$

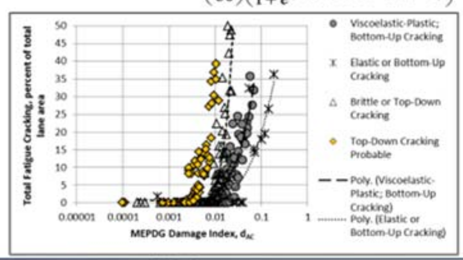


Predicted versus Measured Fatigue Cracking

Normalize for critical material properties:

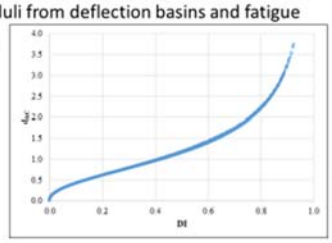
1. Asphalt Content
2. Air Voids

$$FC_{Bottom} = \left(\frac{1}{60}\right)\left(\frac{C_4}{1+e^{\left(C_1C_1^*+C_2C_2^*Log(DI_{Bottom}*100)\right)}}\right)$$



Alligator Cracking Transfer Function

Comparison of the in place damage index from FWD backcalculated elastic moduli from deflection basins and fatigue damage transfer function.

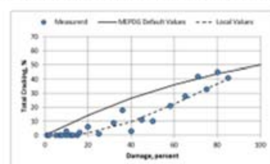


$$DI = 100\left(1-\frac{E_{FWD}}{E_{Lab}}\right)$$

$$FC_{Bottom} = \left(\frac{1}{60}\right)\left(\frac{C_4}{1+e^{\left(C_1C_1^*+C_2C_2^*Log(DI_{Bottom}*100)\right)}}\right)$$

Alligator Cracking Transfer Function

1. Calculate the in place damage index from FWD backcalculated elastic moduli from deflection basins.
2. Compare observed amount of cracking/patching to in place damage index from deflection basins.
3. Determine coefficients of transfer function.



$$DI = 100\left(1-\frac{E_{FWD}}{E_{Lab}}\right)$$

$$FC_{Bottom} = \left(\frac{1}{60}\right)\left(\frac{C_4}{1+e^{\left(C_1C_1^*+C_2C_2^*Log(DI_{Bottom}*100)\right)}}\right)$$

Outline

1. LTPP Computed Parameter Tables
2. Unbound Layers; the C-Factors
3. Asphalt Concrete Layers; In Place Damage
4. Backcalculation: Enhancement Tool for FY2017

Backcalculation

Utility tools in support of Pavement ME Design:

- ❑ Part 1—Preprocessing Deflection Data Tool for Backcalculation
- ❑ Part 2—Backcalculation of stiffness values
- ❑ Part 3—Post Processing Backcalculation Results

Backcalculation

Analysis and Post Processing Phase:

- ❑ Backcalculated elastic modulus values
- ❑ Load transfer efficiency
- ❑ Probability of voids
- ❑ Rehabilitation strategy selection guidance

Analysis and Post Processing Phase

$DI_{E-Ratio}$	Fatigue Cracking, percent total lane area						
	0	0 to 2	2 to 10	10 to 20	20 to 35	35 to 50	> 50
Negative							
0 to 0.25							
0.25 to 0.5							
0.50 to 0.75							
> 0.75							

Area with higher probability of top-down cracking, debonding near the surface, or some other near surface defect; recommendation is to use rehabilitation input level 1.

Area with higher probability of bottom-up cracking; all cracks have yet to reach the surface; or moisture damage, debonding or other lower AC layer defect; the lower the amount of cracking for the same $DI_{E-ratio}$, the greater the difference between rehabilitation input levels 1 and 2.

$$DI_{E-Ratio} = 1 - \frac{E_{FWD}}{E_{Lab}}$$

Questions

Presentation 15—Jusang Lee and Tommy Nantung, Indiana DOT

PAVEMENT ME RUTTING CALIBRATION FOR INDIANA HMA FULL-DEPTH PAVEMENTS

JUSANG LEE AND TOMMY NANTUNG
INDOT RESEARCH & DEVELOPMENT DIVISION

December 14, 2016

Outline

- Need of Pavement ME verification
- Rutting distribution in HMA full-depth pavement
- Pavement ME verification/ calibration/ validation of asphalt pavement rutting

Need of Pavement ME Verification for Indiana AC

LTPP sections used for MEPDG (asphalt): 94 sections

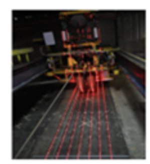
LTPP sections in Indiana's climate zone: 19 sections

LTPP sections in Indiana's soil-climate zone: 10 sections

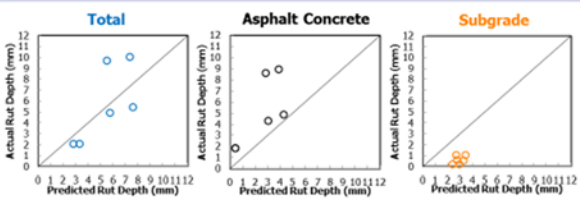
LTPP sections in Indiana's aggregate resource zone: 3 sections

LTPP full-depth asphalt section in Indiana: 0 section

RUTTING VERIFICATION USING APT



Rutting Verification (6 APTs)



Location of the Rut	Mean Measured (mm)	Mean Predicted (mm)	Bias (mm)	SSE (mm²)	S_e (mm)	R^2	Hypothesis; H0:
Total	5.75	5.37	-0.38	32.71	2.52	0.51	Accepted, p=0.829
AC Layers	5.10	2.47	-2.63	66.61	2.24	0.52	Accepted, p=0.104
Subgrade	0.64	2.90	2.26	31.46	0.42	0.19	Rejected, p=0.000

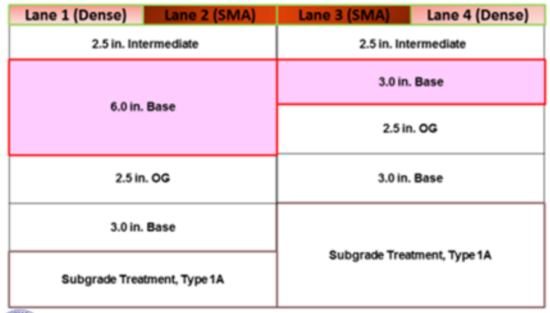
Limitation of LTPP Rutting Measurements

- LTPP measurement
  = Surface Rutting
  = "Permanent deformation (total pavement)"
  = total rutting
- Total rutting = AC rutting + Subgrade rutting
  = $\frac{\varepsilon_p}{\varepsilon_r} = K_z \beta_{r1} 10^{k_{r1}} (T)^{k_{r2}\beta_{r2}} (N)^{k_{r3}\beta_{r3}}$ + $\delta_a(N) = \beta_{s1} k_1 \varepsilon_v h (\frac{\varepsilon_0}{\varepsilon_r}) e^{-(\frac{\rho}{N})^\beta}$
  = ? + ?
- Limitation of optimization
  - β_{r1}, β_{r2}, β_{r3}, and β_{s1}

Rutting Distribution in APT HMA Full-depth Pavement

2017 TRB Annual Meeting
Event Number: 713
Presentation Number: 17-05842
Presentation Title: Development of Middepth Profile Monitoring System for Accelerated Pavement Testing

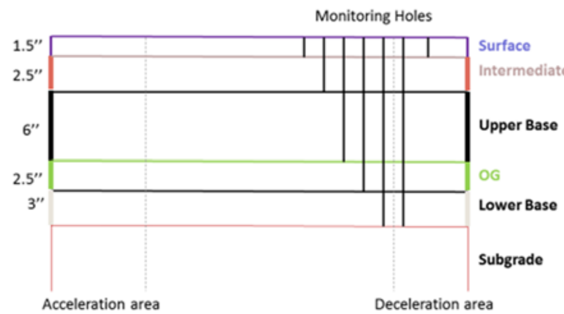
APT Test Section Design



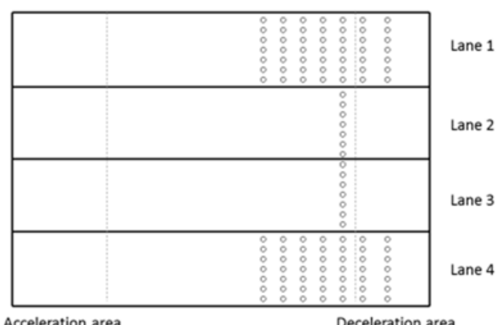
APT HMA Materials

Layer	NMAS	Binder Grade (PG)
Surface	9.5-mm Dense	70-22
	9.5-mm SMA	70-22
Intermediate	19.0-mm Dense	70-22
Upper Base	19.0-mm Dense	64-22
OG layer	19.0-mm Open Graded (OG)	76-22
Lower Base	19.0-mm Dense	64-22

APT Rutting Monitoring Hole Depth



APT Rutting Hole Locations

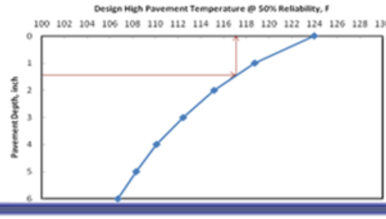


APT Testing – Laser Profile

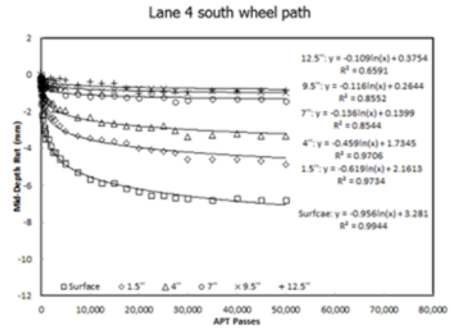
- Sampling rate: 0.16 mm/data point
- Accuracy: 0.15 mm
- Transverse profiles: 4 profiles at constant loading speed area
- Longitudinal profiles: 7 for mid-depth ruts

APT Load Application

- 9000 lbs
- 5 mph
- Pavement temp: 117 F @ 1.5"
- Target rut depth: 0.4"
- 50,000 ESALs

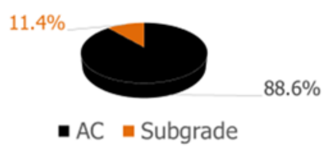


Permanent Deformation Progression



Permanent Deformation Distribution

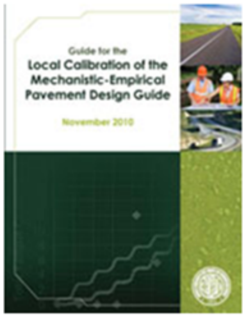
	Lane 1	Lane 2	Lane 3	Lane 4
AC	88.8%	87.2%	89.7%	88.7%
Subgrade	11.2%	12.8%	10.3%	11.3%
Total	100.0%	100.0%	100.0%	100.0%



INDOT Pavement ME Verification/ Calibration/ Validation of Asphalt Pavement Rutting

Local Calibration Procedure

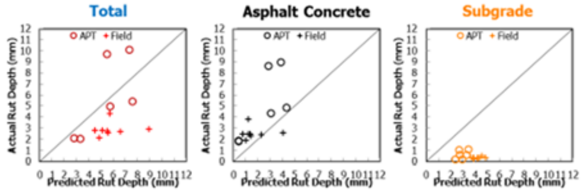
- Verification
- Calibration
- Validation



Data Collection

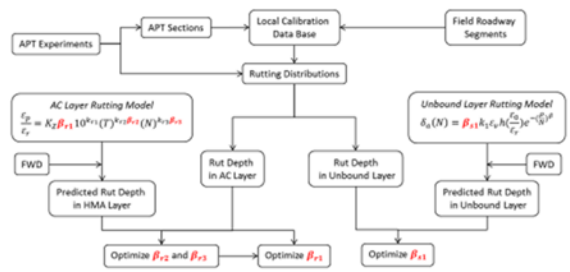
- 8 Field Roadways and 6 APT sections
- Pavement Thickness: 12.5 in. to 18.5 in.
- AADTT: 332 to 14,463
- Surface Material: Dense grade and SMA
- Pavement Age: 5 years to 7 years
- Data collection including weather station generation, traffic data configuration, material properties preparation and distress survey (PMS)

Rutting Verification

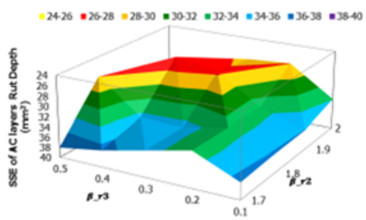


Location of the Rut	Mean Measured (mm)	Mean Predicted (mm)	Bias (mm)	SSE (mm^2)	S_e (mm)	R^2	Hypothesis; H0:
Total	4.10	5.65	1.56	119.71	2.57	0.14	Accepted, p=0.078
AC	3.64	2.01	-1.63	82.99	1.87	0.38	Rejected, p=0.035
Subgrade	0.46	3.64	3.19	153.19	0.91	0.13	Rejected, p=0.000

Calibration Flow Chart

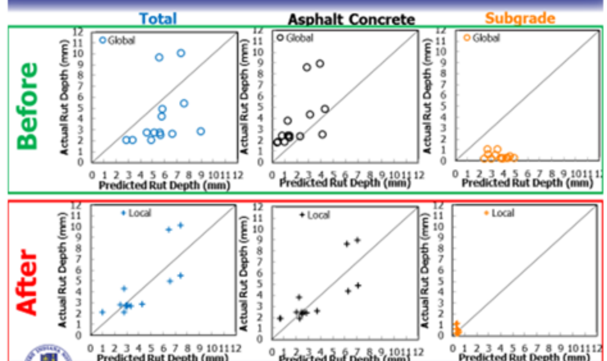


Calibration Procedure



- Number of Pavement ME runs: 20×13=260
- 15 min per run
- 65 hours running time

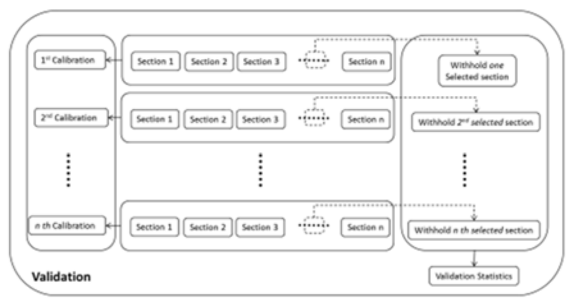
Calibration Results



Calibration Statistical Results

Layer	Model	Mean Predicted (mm)	Mean Actual (mm)	Bias (mm)	SSE (mm^2)	S_e (mm)	R^2	Hypothesis; H0:
AC	Global	2.01	3.64	-1.63	82.99	1.87	0.38	Rejected, p=0.035
	Local	3.48		-0.17	26.01	1.40	0.66	Accepted, p=0.850
SG	Global	3.64	0.46	3.19	153.19	0.91	0.13	Rejected, p=0.000
	Local	0.42		-0.04	1.51	0.34	0.13	Accepted, p=0.656
Total	Global	5.65	4.10	1.56	119.71	2.57	0.14	Accepted, p=0.078
	Local	3.89		-0.20	32.43	1.57	0.66	Accepted, p=0.828

Model Validation



Validation Results

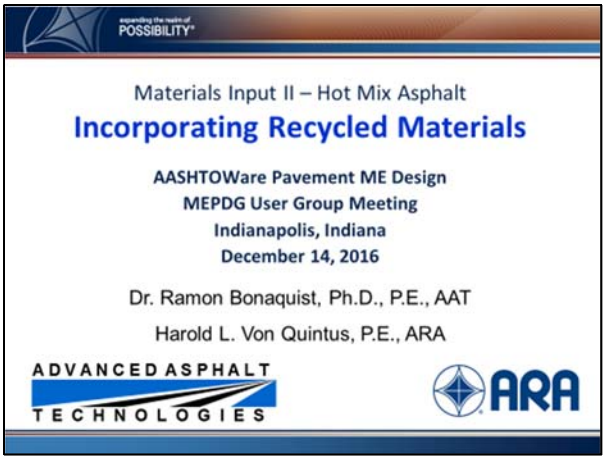
Layer	Model	Mean Predicted (mm)	Mean Actual (mm)	Bias (mm)	SSE (mm^2)	S_e	R^2	Hypothesis; H0:
AC Layer	Global	2.01	3.64	-1.63	82.99	1.87	0.38	Rejected, p=0.035
	Local	3.48		-0.17	26.01	1.40	0.66	Accepted, p=0.850
	Validation	3.54		-0.10	58.16	2.11	0.39	**Accepted, p=0.911**
SG	Global	3.64	0.46	3.19	153.19	0.91	0.13	Rejected, p=0.000
	Local	0.42		-0.04	1.51	0.34	0.13	Accepted, p=0.656
	Validation	0.42		-0.03	1.69	0.36	0.24	**Accepted, p=0.656**
Total	Global	5.65	4.10	1.56	119.71	2.57	0.14	Accepted, p=0.078
	Local	3.89		-0.20	32.43	1.57	0.66	Accepted, p=0.828
	Validation	3.96		-0.14	66.98	2.27	0.38	**Accepted, p=0.887**

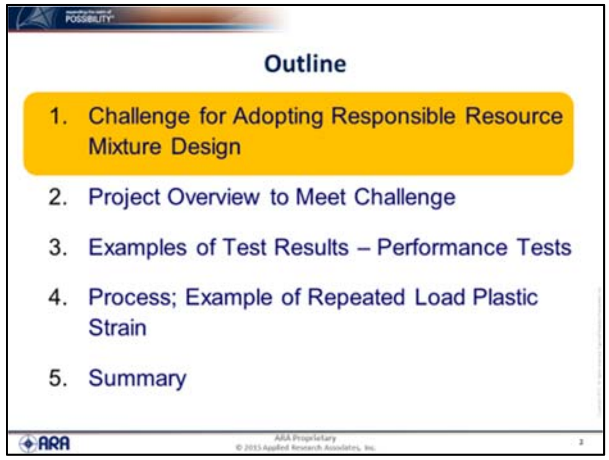
Indiana Calibration Values

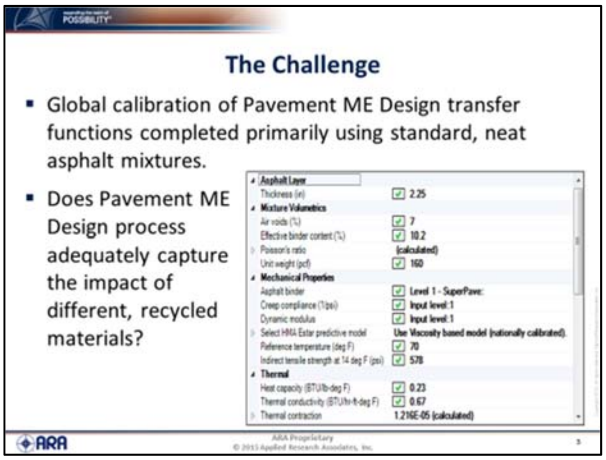
- β_{r1}:0.07
- β_{r2}:1.9
- β_{r3}:0.4
- β_{s1}:0.12

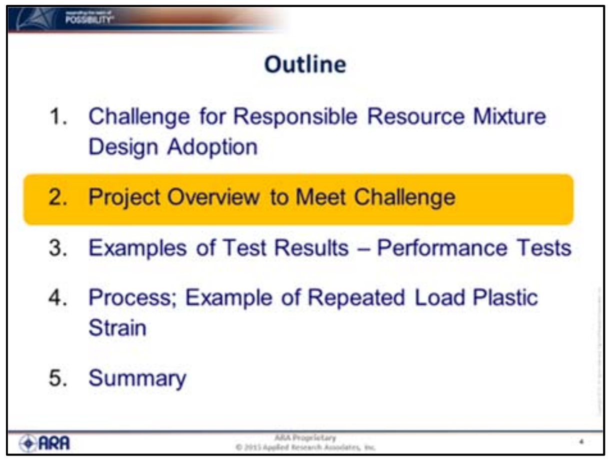
THANK YOU!!

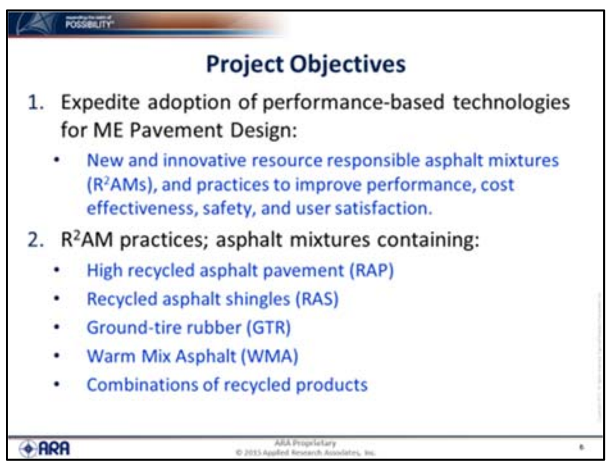
Presentation 16—Harold Von Quintus, Applied Research Associates Inc. (ARA)











Project Tasks

A. Kick Off Meeting.
B. Outreach – Technical Advisory Committee
C. Sampling and Data Collection
D. Laboratory Testing
E. Develop Practitioner's Guide on the Performance Testing of Resource Responsible Materials
F. Develop Practitioner's Guide on the use of Performance Testing of Resource Responsible Materials
G. Technical Support

Project Deliverables/Outcomes

Practitioner's Guides for:

1. **Performance testing** of R^2AMs, such as WMA, RAP, and RAS mixtures (Task E).
2. **Use of** performance testing results in Pavement ME Design software and related analysis (Task F).

Technical Advisory Committee (Task B)

Person	Affiliation
Barry Paye	Wisconsin Department of Transportation
Greg Sholar	Florida Department of Transportation
Rod Birdsall	All State Materials Group
Grant Wollenhaupt	R2R, LLC
Jeff Stempihar	Arizona Department of Transportation
Chris Robinette	Granite Construction
Dale Rand	PaveTex Engineering and Testing
Mike Santi	Idaho Department of Transportation

Asphalt Concrete Mixtures (Task C)

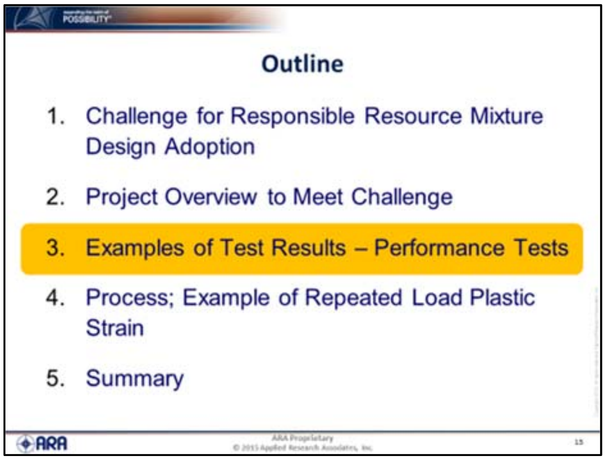
Type	Environmental Zone	Mixture
High Recycle	Wet Freeze	WI STH 73 Surface
High Recycle	Wet Freeze	WI STH 73 Base
High Recycle	Wet No Freeze	NC Surface
High Recycle	Wet No Freeze	NC Intermediate
High Recycle	Wet No Freeze	NC Base
Asphalt Rubber	Wet Freeze	PA Surface
Polymer Modified	Wet Freeze	PA Surface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

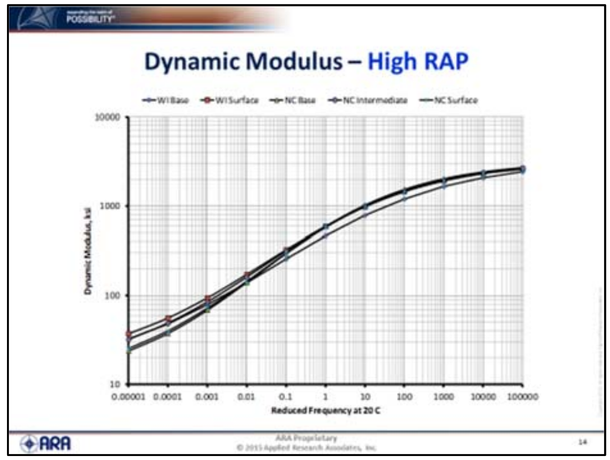
AC Mixture Tests (Task D)

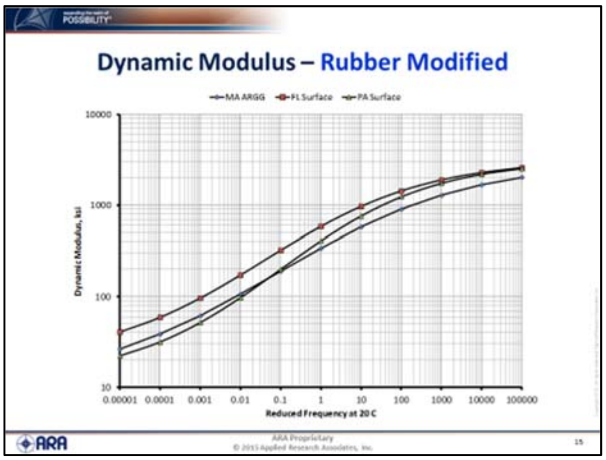
Test Type	Material Property
Level 1 Inputs	**Dynamic Modulus Master Curve**
	Binder Shear Modulus and Phase Angle
	Binder Viscosity Temperature Susceptibility
	Indirect Tensile Creep and Strength
	Repeated Load Permanent Deformation
	Effective Volumetric Binder Content
Additional Tests	**Flexural Fatigue**
	Intermediate Semi-Circular Bend
	Binder Grading
	Virgin Binder Continuous Grade
	RAP Binder Continuous Grade
	RAS Binder Continuous Grade
	Extracted Aggregate Gradation
	Extracted Coarse Aggregate Angularity
	Extracted Fine Aggregate Angularity

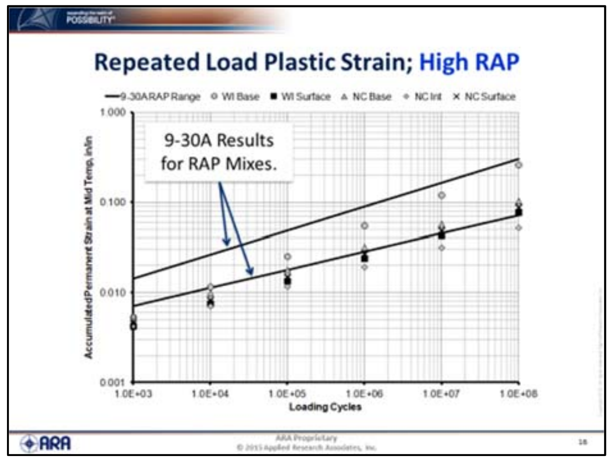
AC Mixture Tests (Task D); Temperatures

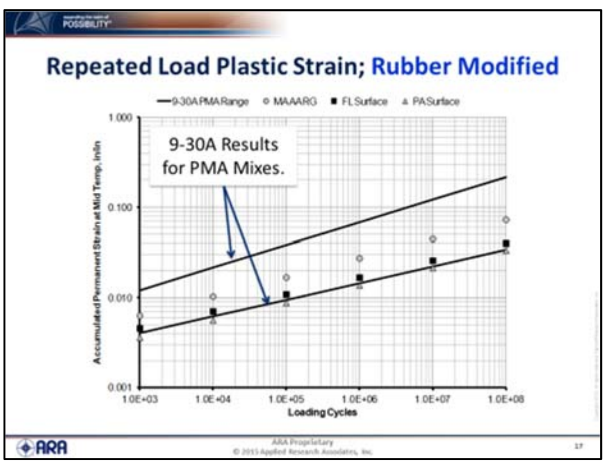
Characteristic, °C	WI	NC	MA	FL	PA
Mean Annual Air Temperature	8.4	16.7	2.4	19.5	9.7
LTPPBind 50 % High Pavement	52.6	60.8	48.0	63.0	51.6
Modulus Testing	4, 20, 45	4, 20, 45	4, 20, 40	4, 20, 45	4, 20, 45
Plastic Permanent Deformation	20, 33.8, 47.6	20, 37.6, 55.8	20, 31.5, 43.0	20, 38.0, 58.0	20, 33.3, 46.6
Flexural Fatigue	10, 20, 30	10, 20, 30	10, 20, 30	10, 20, 30	10, 20, 30
Low Temperature Creep & Strength	0, -10, -20	0, -10, -20	0, -10, -20	0, -10, -20	0, -10, -20

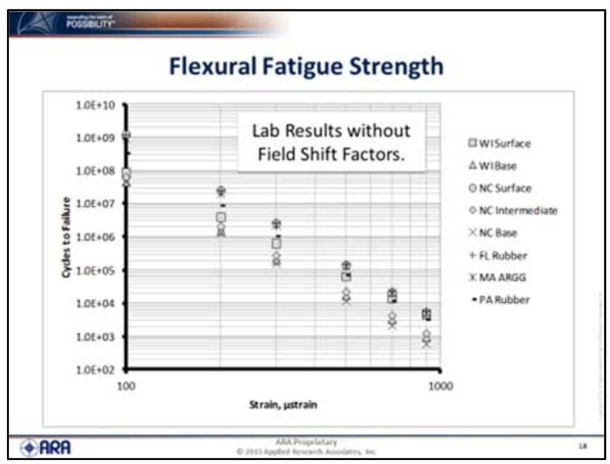

Outline
1. Challenge for Responsible Resource Mixture Design Adoption
2. Project Overview to Meet Challenge
3. Examples of Test Results – Performance Tests
4. Process; Example of Repeated Load Plastic Strain
5. Summary
ARA

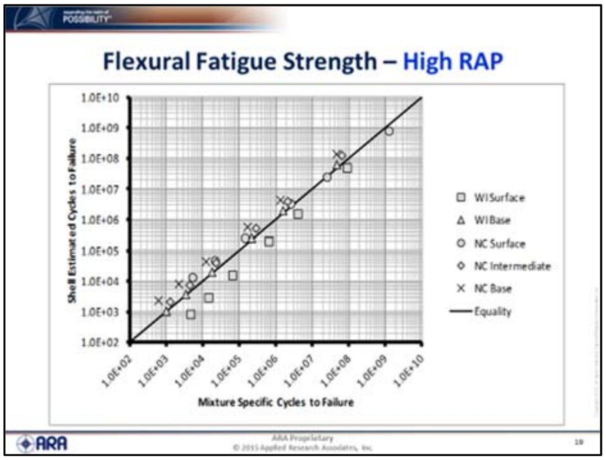

Dynamic Modulus – High RAP
WI Base
WI Surface
NC Base
NC Intermediate
NC Surface
Dynamic Modulus, ksi
Reduced Frequency at 20 C
ARA

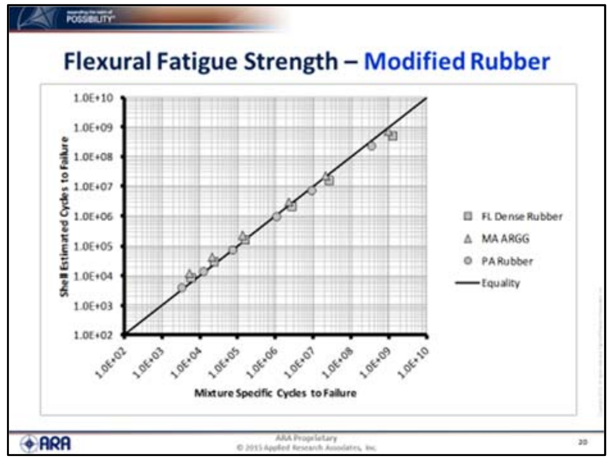

Dynamic Modulus – Rubber Modified
MA ARGG
FL Surface
PA Surface
Dynamic Modulus, ksi
Reduced Frequency at 20 C
ARA

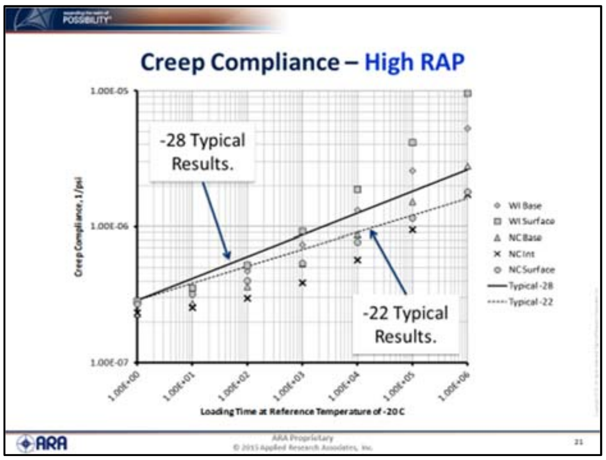

Repeated Load Plastic Strain; High RAP
9-30A RAP Range
WI Base
WI Surface
NC Base
NC Int
NC Surface
9-30A Results for RAP Mixes.
Accumulated Permanent Strain at Mid Temp, in/in
Loading Cycles
ARA

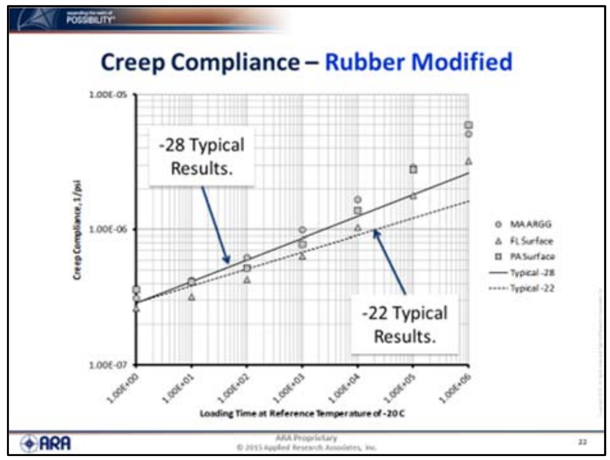

Repeated Load Plastic Strain; Rubber Modified
9-30A PMA Range
MA ARGG
FL Surface
PA Surface
9-30A Results for PMA Mixes.
Accumulated Permanent Strain at Mid Temp, in/in
Loading Cycles
ARA

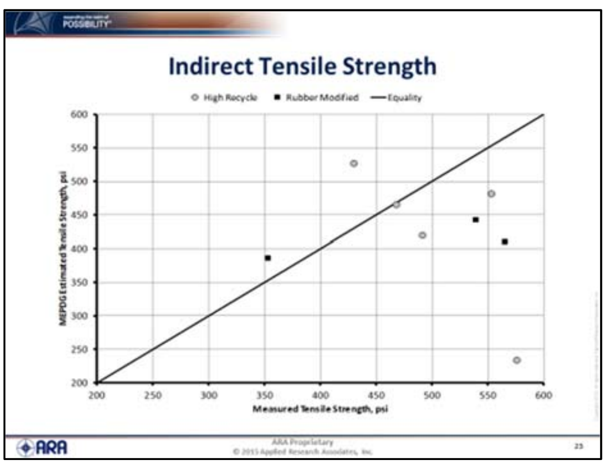

Flexural Fatigue Strength
Lab Results without Field Shift Factors.
WI Surface
WI Base
NC Surface
NC Intermediate
NC Base
FL Rubber
MA ARGG
PA Rubber
Cycles to Failure
Strain, μstrain
ARA

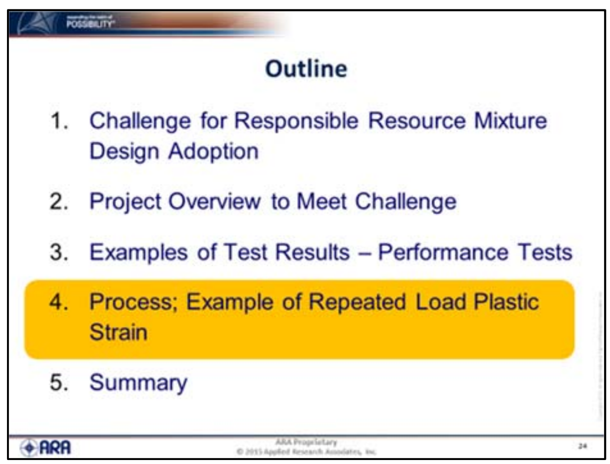

Flexural Fatigue Strength – High RAP
Shell Estimated Cycles to Failure
Mixture Specific Cycles to Failure
WI Surface
WI Base
NC Surface
NC Intermediate
NC Base
Equality
ARA


Flexural Fatigue Strength – Modified Rubber
Shell Estimated Cycles to Failure
Mixture Specific Cycles to Failure
FL Dense Rubber
MA ARGG
PA Rubber
Equality
ARA


Creep Compliance – High RAP
-28 Typical Results.
-22 Typical Results.
Creep Compliance, 1/psi
Loading Time at Reference Temperature of -20C
WI Base
WI Surface
NC Base
NC Int
NC Surface
Typical -28
Typical -22
ARA


Creep Compliance – Rubber Modified
-28 Typical Results.
-22 Typical Results.
Creep Compliance, 1/psi
Loading Time at Reference Temperature of -20C
MA ARGG
FL Surface
PA Surface
Typical -28
Typical -22
ARA


Indirect Tensile Strength
High Recycle
Rubber Modified
Equality
MEPDG Estimated Tensile Strength, psi
Measured Tensile Strength, psi
ARA


Outline
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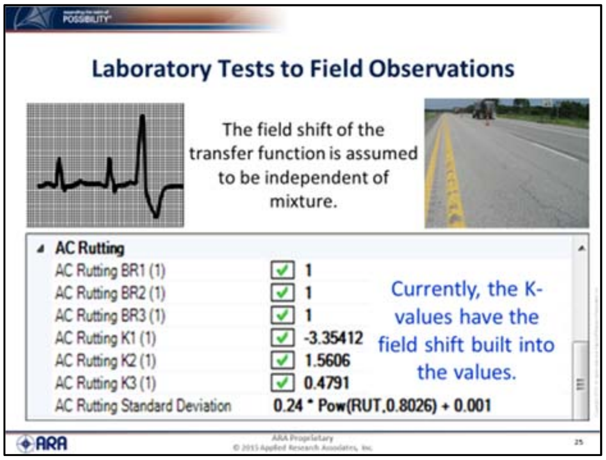
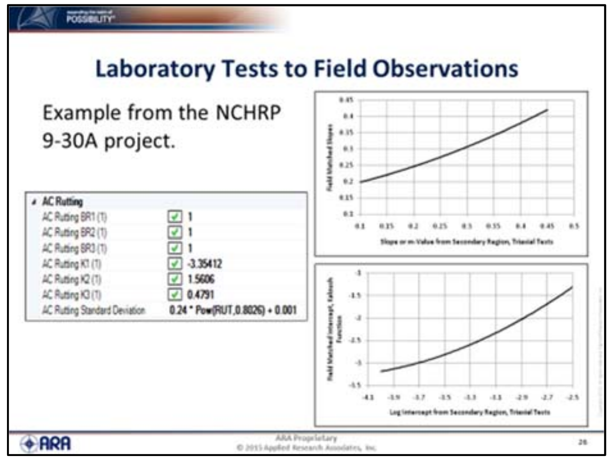
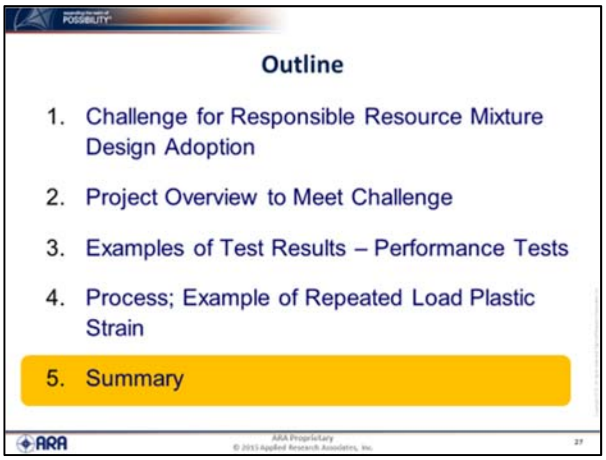
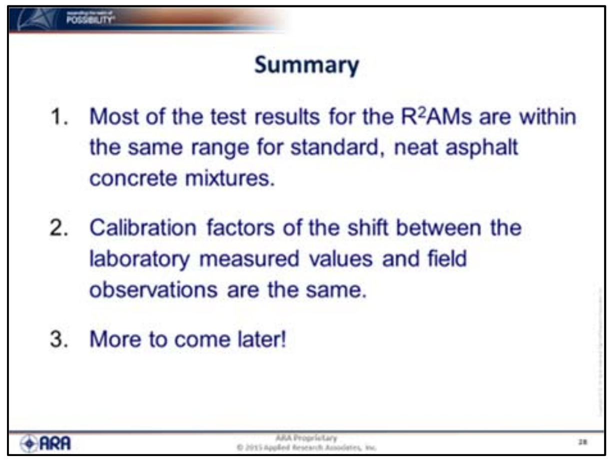
2. Project Overview to Meet Challenge
3. Examples of Test Results – Performance Tests
4. Process; Example of Repeated Load Plastic Strain
5. Summary
ARA


Laboratory Tests to Field Observations
The field shift of the transfer function is assumed to be independent of mixture.
AC Rutting
AC Rutting BR1 (1) 1
AC Rutting BR2 (1) 1
AC Rutting BR3 (1) 1
AC Rutting K1 (1) -3.35412
AC Rutting K2 (1) 1.5606
AC Rutting K3 (1) 0.4791
AC Rutting Standard Deviation 0.24 * Pow(RUT,0.8026) + 0.001
Currently, the K-values have the field shift built into the values.
ARA
25

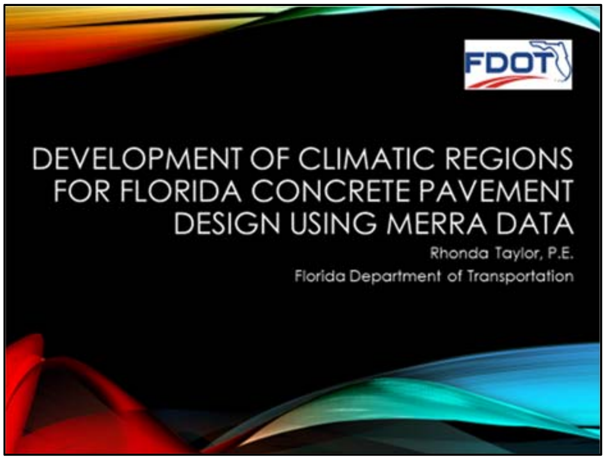

Laboratory Tests to Field Observations
Example from the NCHRP 9-30A project.
AC Rutting
AC Rutting BR1 (1) 1
AC Rutting BR2 (1) 1
AC Rutting BR3 (1) 1
AC Rutting K1 (1) -3.35412
AC Rutting K2 (1) 1.5606
AC Rutting K3 (1) 0.4791
AC Rutting Standard Deviation 0.24 * Pow(RUT,0.8026) + 0.001
ARA
26

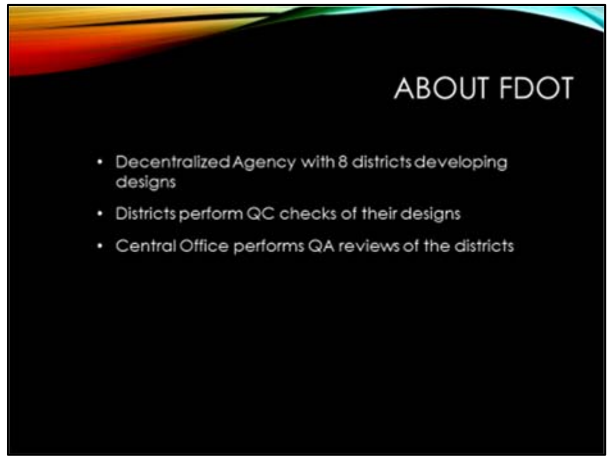

Outline
1. Challenge for Responsible Resource Mixture Design Adoption
2. Project Overview to Meet Challenge
3. Examples of Test Results – Performance Tests
4. Process; Example of Repeated Load Plastic Strain
5. Summary
ARA
27

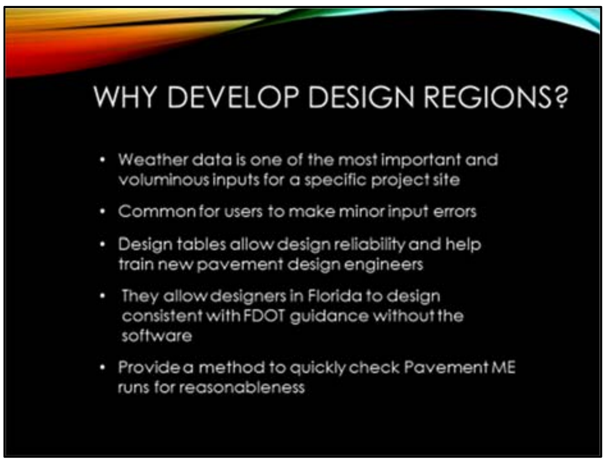

Summary
1. Most of the test results for the R2AMs are within the same range for standard, neat asphalt concrete mixtures.
2. Calibration factors of the shift between the laboratory measured values and field observations are the same.
3. More to come later!
ARA
28

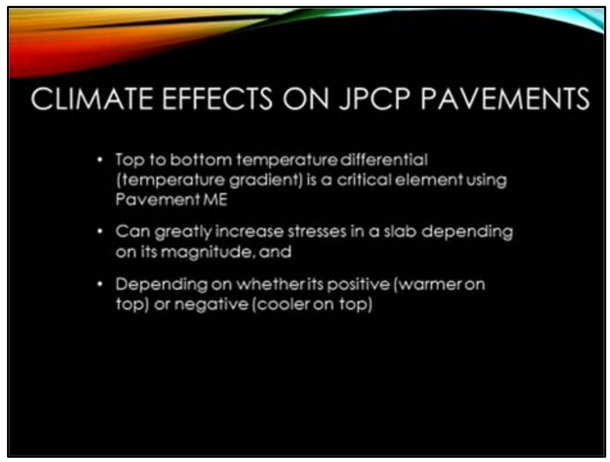

Questions
ARA
29

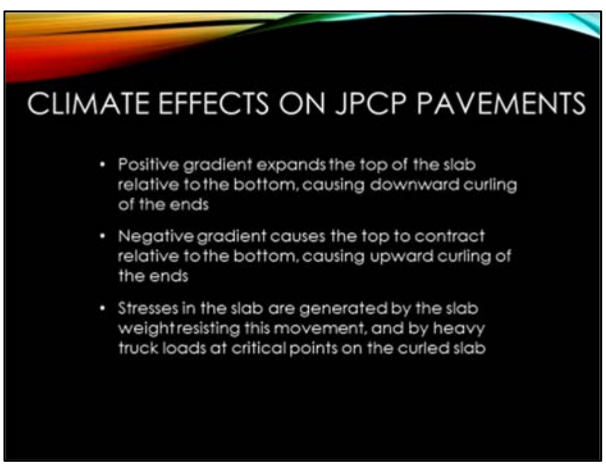
Presentation 17—Rhonda Taylor, Florida DOT

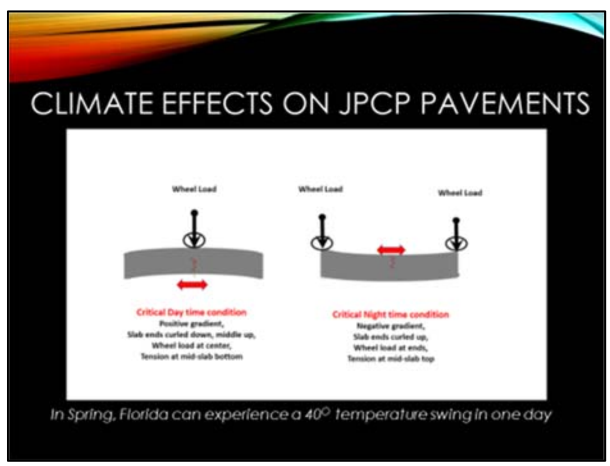












HISTORY OF CLIMATIC DESIGN REGIONS

- In previous calibration studies, FDOT developed five climatic design regions for Florida
- Determined using the then available climatic data from AASHTOWare web site
- Gaps were found in Florida's coverage
- Many weather stations had to be discarded due to poor data quality

OBTAINING NEW CLIMATE DATA

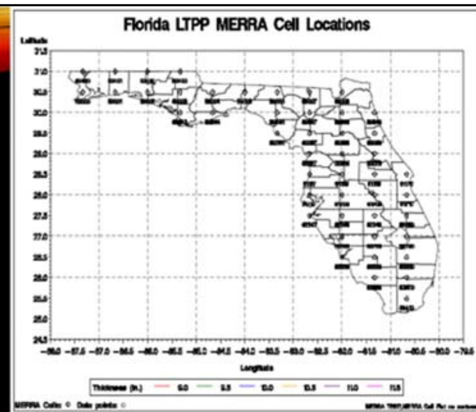
MANUAL PROCESS

- Modern-Era Retrospective Analysis for Research and Applications (MERRA)
- Satellite-based, uniformly spaced weather data
- High quality, 35 years of history (1981 to 2015)
- Obtained by download from FHWA's LTPP Infopave web site during Beta testing
- Hourly Climate Data (HCD) format
- Some cleanup was needed

PROCESSING MERRA DATA WITH PAVEMENT ME

MANUAL PROCESS

- Replace the previous weather station data with new cell-based HCD files in the correct directory
- Download station.dat directory file with cell id's and locations and replace the old station.dat file
- New data is accessed through the Climate Tab of Pavement ME
- Allows individual cell use, or virtual station creation
- Cells cover appoximately 31 by 37 miles at mid-latitudes



There are 47 MERRA cells used to cover the State of Florida

INTERPOLATION OF DESIGN REGION BOUNDARIES

MANUAL PROCESS

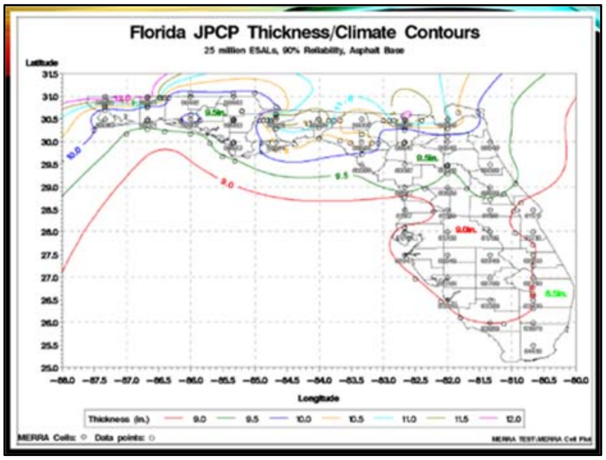
- Analyzed a standard concrete design with the same material properties, base and subgrade
- Specific region boundaries were developed using 90% R and 25M ESALs
- Trial and error runs at each cell location
- Required thickness for each cell was recorded
- Respective cracking levels and the lower thickness in 0.5 inch increments also recorded

Florida's failure level is set at 10% for mid-slab transverse cracking at 20 years

MAPPING DESIGN REGION BOUNDARIES

MANUAL PROCESS

- Imported spreadsheet data (design thickness breakpoints) to a standard statistical package (SAS)
- Uniform rectangular grid points were generated at 0.05 degree intervals
- A contour mapping procedure produced a map of Florida with color coded contours showing thickness delineations
- Due to Florida's extensive coastline, interpolation wasn't always possible so additional breakpoints had to be determined in counties on the coast



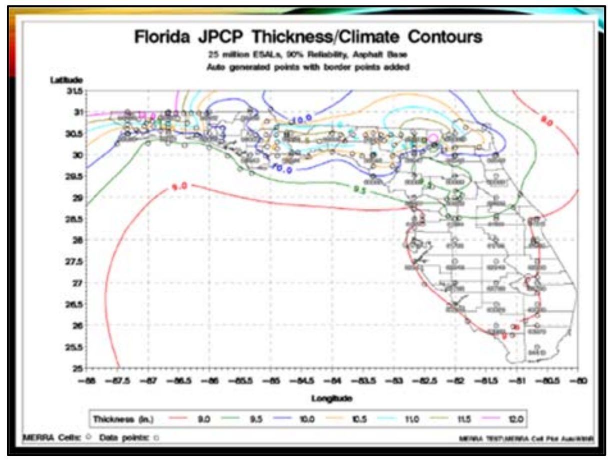
CONSIDERATIONS

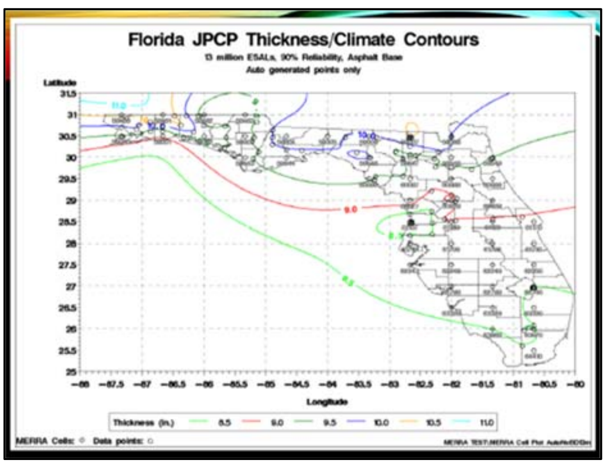
- Since historical time periods used by Pavement ME can be subset (FL uses 20 year design periods), some locations were spot checked
- Result: The time period selected can have a significant impact on the design thickness break points
- Design Reliability, %R, can have an impact on thickness boundary locations
- Because manual trial and error was tedious, it was decided to evaluate an automated interpolation process

DETERMINING DESIGN CLIMATE REGIONS

AUTOMATED PROCESS

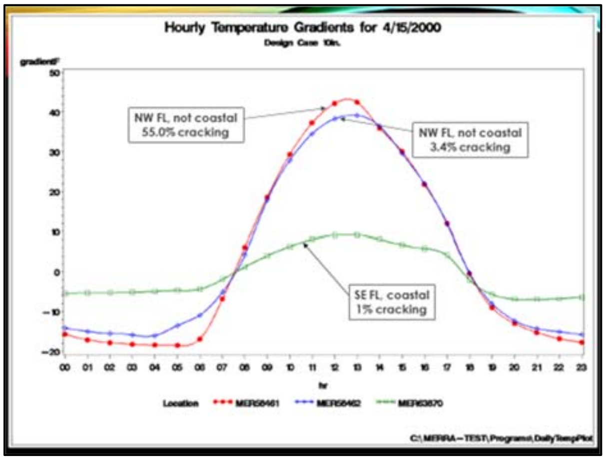
- A compute program was written to estimate where break points between adjacent cells would occur
- The program quickly estimates all the thickness break points throughout the state and generate the contour map





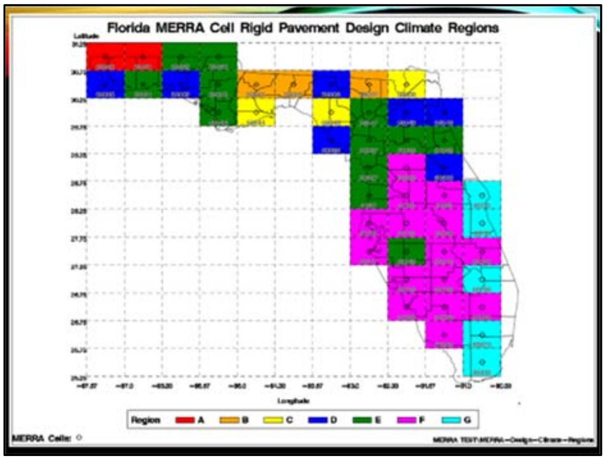
RESULTS

- Selection of different historical climate periods appears to effect where design breakpoints occur as much or more than the automated interpolation
- The automated process results look practical
- Cracking damage plots in the output files indicate that top down cracking is dominate in North Florida, but…
- Bottom up cracking is very close or exceeds top down cracking in South Florida
- Pavement ME temperature gradient files show nighttime gradients are more severe in North Florida



FUTURE EFFORTS

- 7 generalized climate regions have been established
- Design tables currently being developed showing truck design loading capacity per half inch of PCC for each region and reliability level
- Years of truck weigh-in-motion data using the software's axle load spectra categories are being reviewed by type of facility – Florida specific Truck Traffic Classifications will likely be developed
- Florida's 2.5 mi concrete test road has begun construction – will enable updating local calibration coefficients



FDOT

THANK YOU

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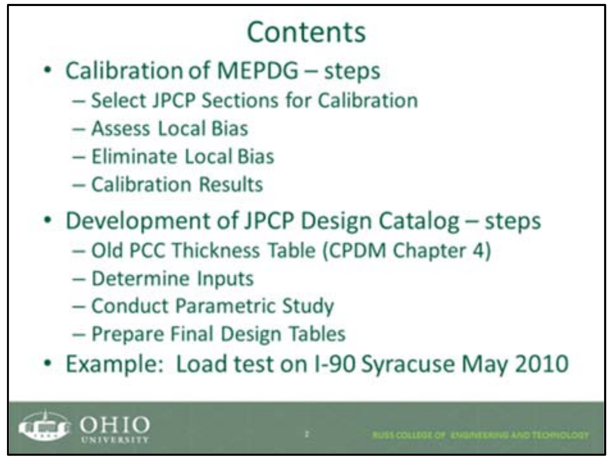
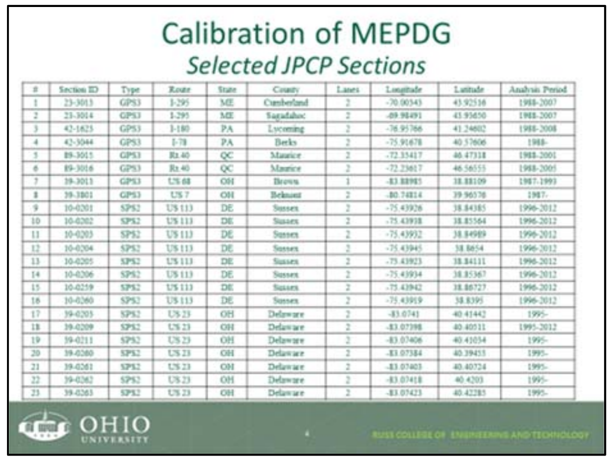
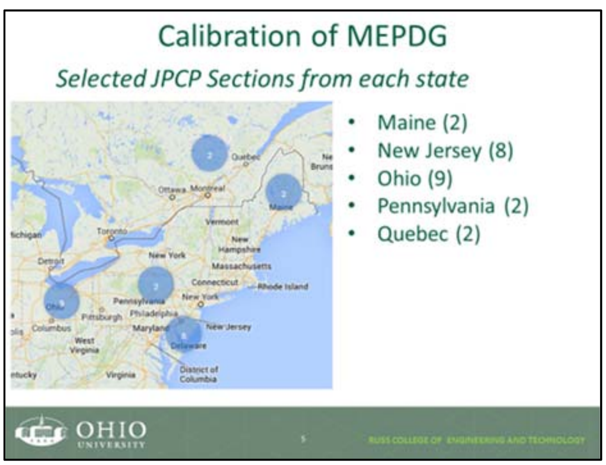
State Pavement Design Engineer
Florida Department of Transportation
Office Phone 850.414.4371
Rhonda.Taylor@dot.state.fl.us

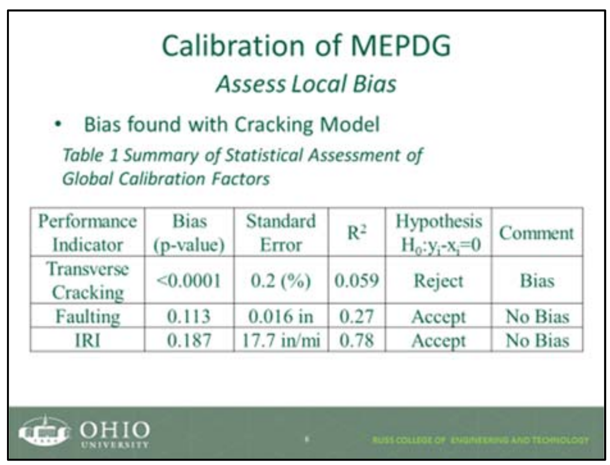
Presentation 18—Chris Brakke, Iowa DOT





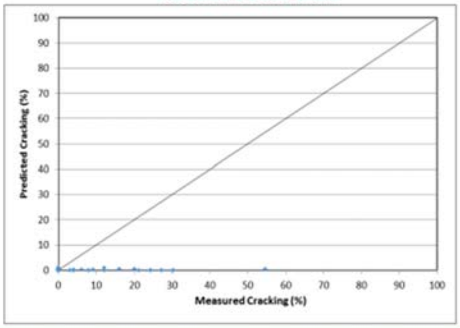
#	Section ID	Type	Route	State	County	Lanes	Longitude	Latitude	Analysis Period
1	23-3013	GPS3	I-295	ME	Cumberland	2	-70.00343	43.92516	1988-2007
2	23-3014	GPS3	I-295	ME	Sagadahoc	2	-69.98491	43.93650	1988-2007
3	42-1623	GPS3	I-180	PA	Lycoming	2	-76.95766	41.24602	1988-2008
4	42-3044	GPS3	I-78	PA	Berks	2	-75.91678	40.57606	1988-
5	89-3015	GPS3	Rt.40	QC	Maurice	2	-72.35417	46.47318	1988-2001
6	89-3016	GPS3	Rt.40	QC	Maurice	2	-72.23617	46.56555	1988-2005
7	39-3013	GPS3	US 68	OH	Brown	1	-83.88985	38.88109	1987-1993
8	39-3801	GPS3	US 7	OH	Belmont	2	-80.74814	39.96578	1987-
9	10-0201	SPS2	US 113	DE	Sussex	2	-75.43926	38.84385	1996-2012
10	10-0202	SPS2	US 113	DE	Sussex	2	-75.43938	38.85564	1996-2012
11	10-0203	SPS2	US 113	DE	Sussex	2	-75.43932	38.84989	1996-2012
12	10-0204	SPS2	US 113	DE	Sussex	2	-75.43945	38.8654	1996-2012
13	10-0205	SPS2	US 113	DE	Sussex	2	-75.43923	38.84111	1996-2012
14	10-0206	SPS2	US 113	DE	Sussex	2	-75.43934	38.85367	1996-2012
15	10-0259	SPS2	US 113	DE	Sussex	2	-75.43942	38.86727	1996-2012
16	10-0260	SPS2	US 113	DE	Sussex	2	-75.43919	38.8395	1996-2012
17	39-0205	SPS2	US 23	OH	Delaware	2	-83.0741	40.41442	1995-
18	39-0209	SPS2	US 23	OH	Delaware	2	-83.07398	40.40511	1995-2012
19	39-0211	SPS2	US 23	OH	Delaware	2	-83.07406	40.41034	1995-
20	39-0260	SPS2	US 23	OH	Delaware	2	-83.07384	40.39453	1995-
21	39-0261	SPS2	US 23	OH	Delaware	2	-83.07403	40.40724	1995-
22	39-0262	SPS2	US 23	OH	Delaware	2	-83.07418	40.4203	1995-
23	39-0263	SPS2	US 23	OH	Delaware	2	-83.07423	40.42285	1995-





Performance Indicator	Bias (p-value)	Standard Error	R^2	Hypothesis H_0:y_i-x_i=0	Comment
Transverse Cracking	<0.0001	0.2 (%)	0.059	Reject	Bias
Faulting	0.113	0.016 in	0.27	Accept	No Bias
IRI	0.187	17.7 in/mi	0.78	Accept	No Bias

Calibration of MEPDG
Assess Local Bias



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Calibration of MEPDG
Eliminate Local Bias

Table 2 Summary of Statistical Assessment of Local Calibration Factors

Performance Indicator	Bias (p-value)	Standard Error	R^2	Hypothesis H_0:y_i-x_i=0	Comment
Transverse Cracking	0.061	2.0 (%)	0.06	Accept	No Bias
Faulting	0.113	0.016 in	0.27	Accept	No Bias
IRI	0.079	17.6 in/mi	0.79	Accept	No Bias

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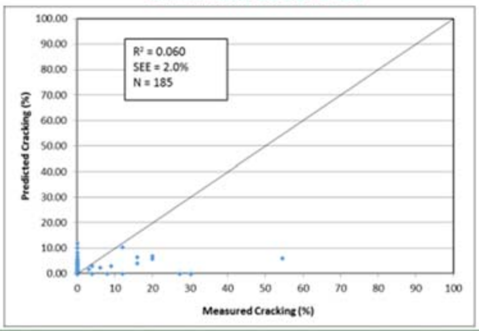
Calibration of MEPDG
Eliminate Local Bias



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Calibration of MEPDG
Calibration Results

Cracking	C1	C2	C4	C5	SSE
Global Coefficients	2	1.22	1	-1.98	8923.7
Local Coefficients	2	1.22	0.2	-1.63	8139.8
Faulting (No change)	**C1**	**C2**	**C3**	**C4**	
	1.0184	0.91656	0.0021848	0.000883739	
	C5	**C6**	**C7**	**C8**	
	250	0.4	1.83312	400	
IRI (No change)	**C1**	**C2**	**C3**	**C4**	
	0.8203	0.4417	1.4929	25.24	

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Development of Design Catalog

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Development of JPCP Design Catalog
Old PCC Thickness Table

80-kN ESALs	PCC Slab Thickness 4.2 m driving lane slab width	PCC Slab Thickness 3.6 m driving lane slab width
millions	mm	mm
ESALs ≤ 22	225	225
22 < ESALs ≤ 36	225	250
36 < ESALs ≤ 65	225	275
65 < ESALs ≤ 100	250	300
100 < ESALs ≤ 165	275	325
165 < ESALs ≤ 250	300	325[1]
250 < ESALs ≤ 400	325	325[1]

[1] For ESALs over 165 million, 3.6 m untied slabs may not be used for the right hand driving lane. Use either 3.6 m tied slabs, 4.2 m untied slabs, or 4.2 m tied slabs.

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Development of JPCP Design Catalog

Determine Inputs

- Project and JPCP Design Inputs
- Layer/Material Properties
- Traffic Inputs
- Climate Inputs
- Calibration Factors

Development of JPCP Design Catalog

Conduct Parametric Study

- Determine effects of these parameters:
  - Weather stations
  - Subgrade modulus
  - Water table depth
  - Design life
  - Traffic
  - Slab width

Development of JPCP Design Catalog

Effect of weather stations

NYSDOT Regions

Four climate zones sufficient to implement MEPDG across New York

Zone	Weather Station
1	Buffalo
2	Massena
3	Elmira/Corning
4	Farmingdale

Separate sets of design tables created for each climate zone

Development of JPCP Design Catalog

Effect of Subgrade Modulus

- Subgrade resilient modulus (M_R) generally had very little or no effect on the resulting PCC thickness when design traffic volume is small.
- When the design traffic volume is high, weak soil required significantly thicker PCC.
- Design tables generated for these values of M_R: 2000 psi (14 MPa), 4000 psi (28 MPa), 5000 psi (34 MPa), 6000 psi (41 MPa), and 9000 psi (62 MPa).
- For M_R = 2000 psi (14 MPa) or 4000 psi (28 MPa), the subgrade will be difficult to construct on and may require stabilization, depending on additional analysis.

Development of JPCP Design Catalog

Effect of Water Table Depth

- 5 ft (1.5 m) and 10 ft (3 m) water table depths were compared to examine the effect of water table depth.
- It was found that water table depth has little or no effect on the resulting PCC thickness.

Development of JPCP Design Catalog

Final Design Tables for Climate Zone 1

Subgrade M_R = 2000 psi (14 MPa)		
Initial AADTT	PCC Thickness	
	3.6 m (12 ft) width	4.2 m (14 ft) width
AADTT≤641	215.9 mm (8.5 in)	215.9 mm (8.5 in)
641<AADTT≤1049	228.6 mm (9 in)	228.6 mm (9 in)
1049<AADTT≤1895	241.3 mm (9.5in)	228.6 mm (9 in)
1895<AADTT≤2915	254 mm (10in)	241.3 mm (9.5 in)
2915<AADTT≤4809	254 mm (10in)	254 mm (10 in)
4809<AADTT≤7287	317.5 mm (12.5in)	254 mm (10 in)
7287<AADTT≤11659	> 356 mm (14 in)	266.7 mm (10.5 in)

Development of JPCP Design Catalog

Final Design Tables for Climate Zone 1

Subgrade M_R = 4000 psi (28 MPa)		
Initial AADTT	PCC Thickness	
	3.6 m (12 ft) width	4.2 m (14 ft) width
AADTT≤641	228.6 mm (9 in)	215.9 mm (8.5 in)
641<AADTT≤1049	228.6 mm(9 in)	215.9 mm (8.5 in)
1049<AADTT≤1895	241.3 mm (9.5 in)	228.6 mm (9 in)
1895<AADTT≤2915	254 mm (10 in)	241.3 mm (9.5 in)
2915<AADTT≤4809	266.7 mm (10.5 in)	254 mm (10 in)
4809<AADTT≤7287	279.4 mm (11 in)	266.7 mm (10.5 in)
7287<AADTT≤11659	292 mm (11.5 in)	266.7 mm (10.5 in)

Development of JPCP Design Catalog

Final Design Tables for Climate Zone 1

Subgrade M_R = 5000 psi (34 MPa)		
Initial AADTT	PCC Thickness	
	3.6 m (12 ft) width	4.2 m (14 ft) width
AADTT<=641	228.6 mm (9 in)	215.9 mm (8.5 in)
641<AADTT<=1049	228.6 mm (9 in)	215.9 mm (8.5 in)
1049<AADTT<=1895	241.3 mm (9.5 in)	228.6 mm (9 in)
1895<AADTT<=2915	254 mm (10 in)	241.3 mm (9.5 in)
2915<AADTT<=4809	266.7 mm (10.5 in)	254 mm (10 in)
4809<AADTT<=7287	279.4 mm (11 in)	266.7 mm (10.5 in)
7287<AADTT<=11659	292 mm (11.5 in)	279.4 mm (11 in)

Development of JPCP Design Catalog

Final Design Tables for Climate Zone 1

Subgrade M_R = 6000 psi (41 MPa)		
Initial AADTT	PCC Thickness	
	3.6 m (12 ft) width	4.2 m (14 ft) width
AADTT<=641	228.6 mm (9 in)	215.9 mm (8.5 in)
641<AADTT<=1049	228.6 mm (9 in)	215.9 mm (8.5 in)
1049<AADTT<=1895	254 mm (10 in)	241.3 mm (9.5 in)
1895<AADTT<=2915	254 mm (10 in)	241.3 mm (9.5 in)
2915<AADTT<=4809	266.7 mm (10.5 in)	254 mm (10 in)
4809<AADTT<=7287	279.4 mm (11 in)	266.7 mm (10.5 in)
7287<AADTT<=11659	292 mm (11.5 in)	279.4 mm (11 in)

Development of JPCP Design Catalog

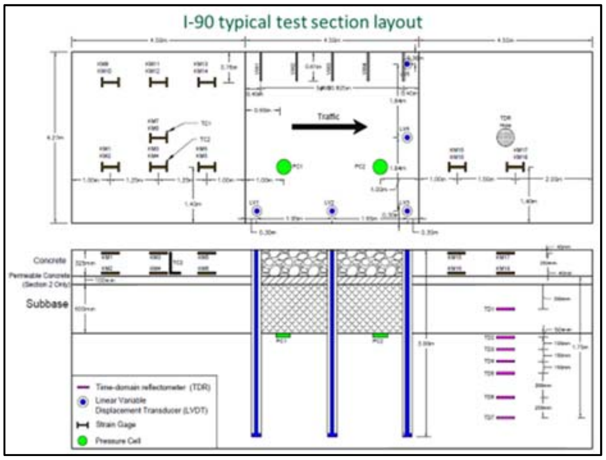
Final Design Tables for Climate Zone 1

Subgrade M_R = 9000 psi (62 MPa)		
Initial AADTT	PCC Thickness	
	3.6 m (12 ft) width	4.2 m (14 ft) width
AADTT<=641	228.6 mm (9 in)	215.9 mm (8.5 in)
641<AADTT<=1049	241.3 mm (9.5 in)	228.6 mm (9 in)
1049<AADTT<=1895	254 mm (10 in)	241.3 mm (9.5 in)
1895<AADTT<=2915	266.7 mm (10.5 in)	254 mm (10 in)
2915<AADTT<=4809	279.4 mm (11 in)	266.7 mm (10.5in)
4809<AADTT<=7287	292 mm (11.5 in)	279.4 mm (11 in)
7287<AADTT<=11659	304.8 mm (12 in)	292 mm (11.5 in)

Example: Truck load testing on I-90 Syracuse May 2010

I-90 Syracuse

- Section of I-90 at Weedsport, near Syracuse
- Full-depth reconstruction in October 2009 with new PCC, pavement, base, and subbase
- AADT 34,320 vehicles
- 50 year design
- Comparison of two base types
  - Cement Treated Permeable Base (CTPB)
  - Dense Graded Aggregate Base (DGAB)
- Test sections were fully instrumented with strain gauges in PCC (KM) and on tie bars (VW), LVDTs (LV), pressure cells (PC), thermocouples (TC), and TDR cables (TD)


I-90 typical test section layout
Traffic
Concrete
Permeable Concrete (Section 2 Only)
Subbase
Time-domain reflectometer (TDR)
Linear Variable Displacement Transducer (LVDT)
Strain Gage
Pressure Cell


Spring 2010 Truck Test on I-90 Syracuse
Truck load test performed in late May 2010
Two truck loads used for test
– 16-kip rear axle (Light)
– 20-kip real axle (Heavy)
Tested at 4 speeds
– 5, 25, 35, 45 MPH
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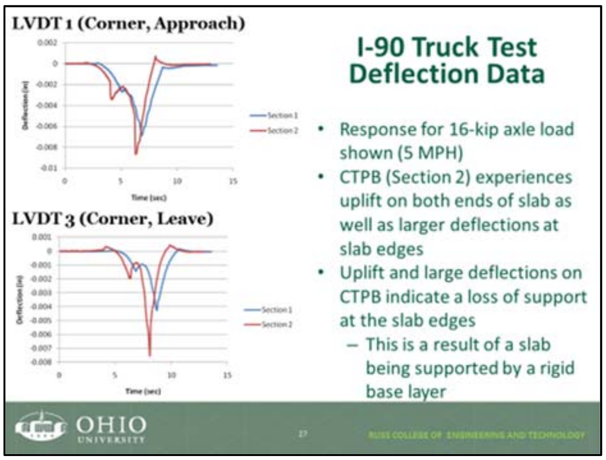
LVDT 1 (Corner, Approach)
LVDT 3 (Corner, Leave)
Deflection (in)
Time (sec)
Section 1
Section 2
I-90 Truck Test Deflection Data
Response for 16-kip axle load shown (5 MPH)
CTPB (Section 2) experiences uplift on both ends of slab as well as larger deflections at slab edges
Uplift and large deflections on CTPB indicate a loss of support at the slab edges
– This is a result of a slab being supported by a rigid base layer
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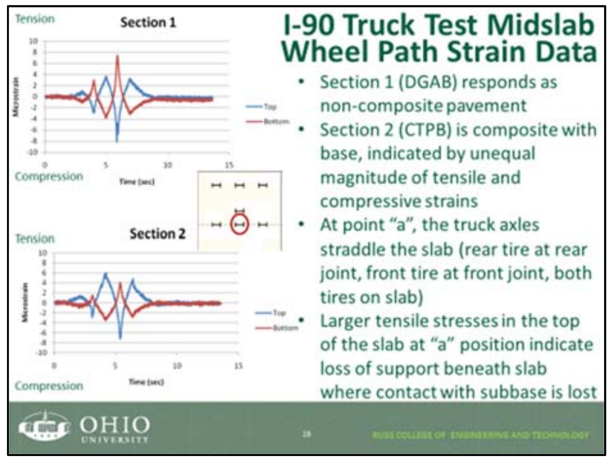
Tension
Section 1
Compression
Section 2
Microstrain
Time (sec)
Top
Bottom
I-90 Truck Test Midslab Wheel Path Strain Data
Section 1 (DGAB) responds as non-composite pavement
Section 2 (CTPB) is composite with base, indicated by unequal magnitude of tensile and compressive strains
At point "a", the truck axles straddle the slab (rear tire at rear joint, front tire at front joint, both tires on slab)
Larger tensile stresses in the top of the slab at "a" position indicate loss of support beneath slab where contact with subbase is lost
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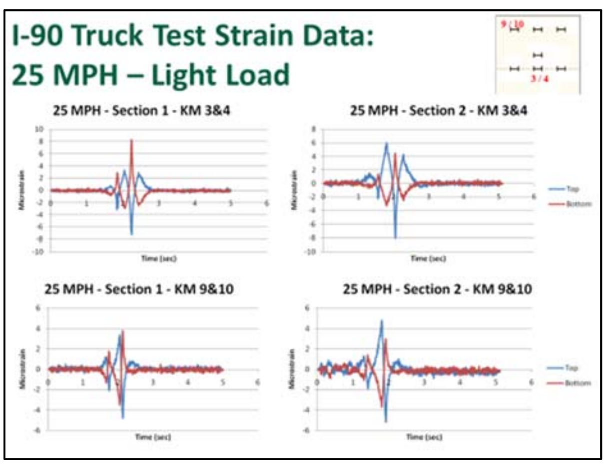
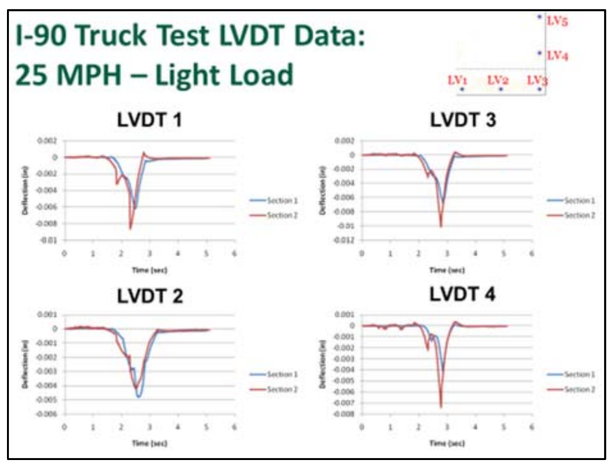
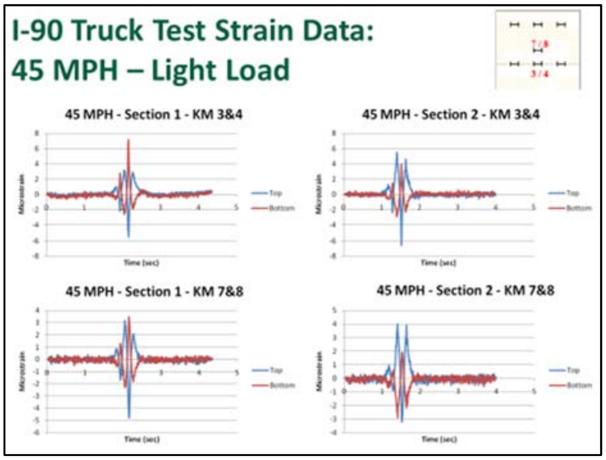
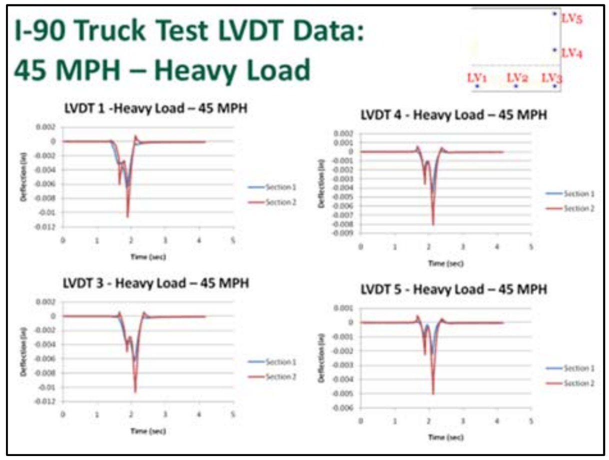

I-90 Truck Test Strain Data:
25 MPH – Light Load
25 MPH - Section 1 - KM 3&4
25 MPH - Section 2 - KM 3&4
25 MPH - Section 1 - KM 9&10
25 MPH - Section 2 - KM 9&10
Microstrain
Time (sec)
Top
Bottom


I-90 Truck Test LVDT Data:
25 MPH – Light Load
LV1
LV2
LV3
LV4
LV5
LVDT 1
LVDT 3
LVDT 2
LVDT 4
Deflection (in)
Time (sec)
Section 1
Section 2


I-90 Truck Test Strain Data:
45 MPH – Light Load
45 MPH - Section 1 - KM 3&4
45 MPH - Section 2 - KM 3&4
45 MPH - Section 1 - KM 7&8
45 MPH - Section 2 - KM 7&8


I-90 Truck Test LVDT Data:
45 MPH – Heavy Load
LVDT 1 -Heavy Load – 45 MPH
LVDT 4 - Heavy Load – 45 MPH
LVDT 3 - Heavy Load – 45 MPH
LVDT 5 - Heavy Load – 45 MPH


Thank you!
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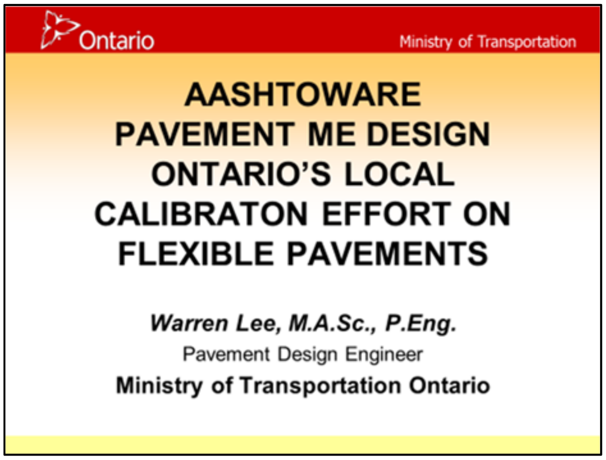
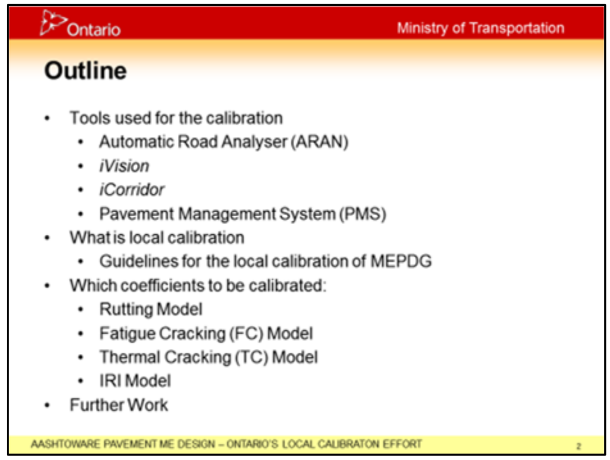
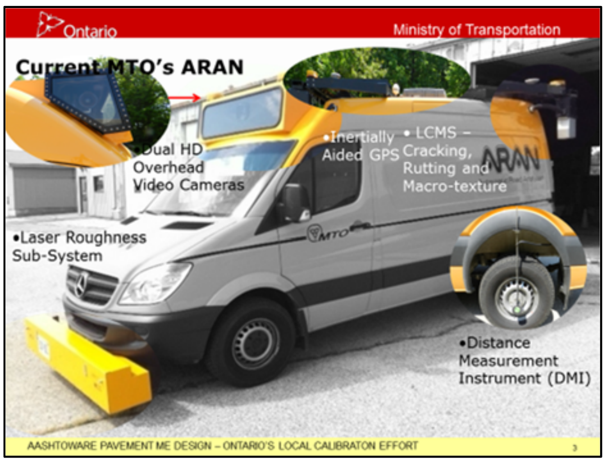
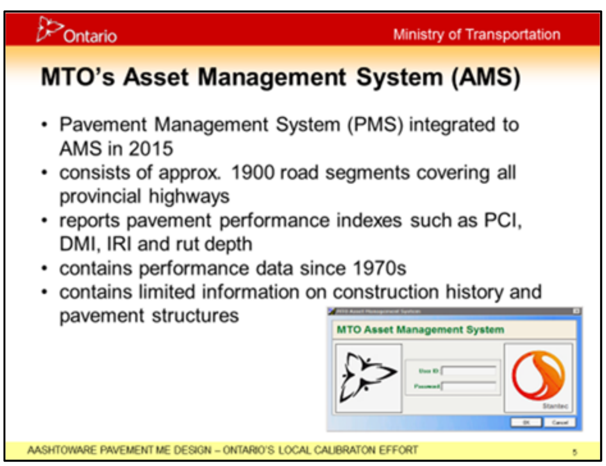
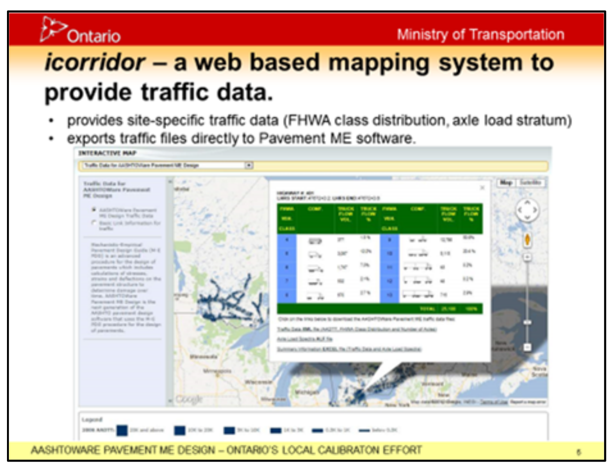
Presentation 19—Warren Lee, Ministry of Transportation Ontario











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What is Local Calibration

To develop a non-bias and precise performance prediction model:

1) Eliminating Bias

$$\text{Bias} = \sum_{i=1}^{n} (D_{observe} - D_{predict})$$

- $D_{observe}$= Observed pavement performance on the roadways
- $D_{predict}$= Predicted pavement performance from Pavement ME software
- N = number of pavement segments used for the calibration

2) Minimizing sum of squared error (SSE) or standard error of the estimate (Se)

$$SSE = \sum_{i=1}^{n} (D_{observe} - D_{predict})^2 \qquad S_e = \sqrt{\frac{SSE}{n-2}}$$

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Guide for the Local Calibration of MEPDG

Traditional Approach – Split Sample

- A portion of the data (typically half or more) is used for calibrating the coefficients while the remainder is used to validate accuracy.

Minimum roadway segments suggested in the Guide:

- Distortion (Total Rutting) – 20 (*64)
- Load-Related Cracking - 30 (*46)
- Non-Load-Related Cracking - 26 (*59)
- IRI (*48)

* Number used in this calibration

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Factorial for the Selected Pavement Sections

	64 pavement sections from PMS (for rutting calibration)			
Highway Classification	Freeway (26)		Arterial / Collector (38)	
Surface HMA Mix Type	SMA 12.5 (19)	SP12.5 (10)	SP12.5FC1 (8)	SP12.5 (27)
Construction Type	New (11)	Rehabilitation (53)		
Calibration vs. Validation	Calibration (46)			Validation (18)

- Select sections with normal performance from PMS, i.e. good trend of increasing rutting and IRI
- Involves 20 Highways (6 hwys. from Southern; 14 hwys. from Northern)
- Age: 2 to 17 yrs.; Median = 7.5 yrs.; Mode = 9 yrs.

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Rutting Model

Five calibration coefficients in three equations to be determined:

1. **Asphalt Concrete (AC) Equation**

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{AC} 10^{k_1} T^{k_2 \beta_T} N^{k_3 \beta_N}$$

β_{AC} = AC scale factor
β_T = Temperature exponent
β_N = Traffic exponent

2. **Granular Base / Sub-base Equation**

$$\delta_a(N) = \beta_{GB} k_1 \varepsilon_v h \left(\frac{\varepsilon_o}{\varepsilon_r}\right) e^{-\left(\frac{\rho}{N}\right)^{\beta}}$$

β_{GB} = Granular material scale factor

3. **Subgrade Equation**

$$\delta_a(N) = \beta_{SG} k_1 \varepsilon_v h \left(\frac{\varepsilon_o}{\varepsilon_r}\right) e^{-\left(\frac{\rho}{N}\right)^{\beta}}$$

β_{SG} = Subgrade scale factor

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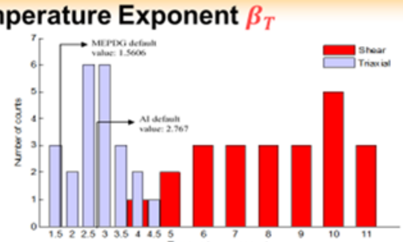
Temperature Exponent β_T



- Histogram of temperature exponents obtained from triaxle and shear tests (Data source: Tables 24 and 25 of NCHRP Report 719 of Project 9-30A)
- Project 9-30A involves a recalibration of AC rutting model using 60 field sections and 46 laboratory specimens.
- Temperature exponent largely dependent upon material testing methods
- Triaxle results are systematically smaller than those from shear tests.
- Follows MEPDG default k_2 = 1.5606 ➔ β_T = 1.0

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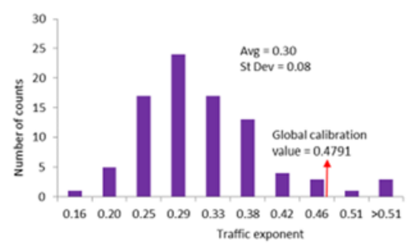
Traffic Exponent β_N



- Histogram of the field- and laboratory test-derived traffic exponents of various road sections (Data source: Tables 8, 9, 25 and 26 of NCHRP Report 719)
- Use average traffic exponent: k_3 = 0.30 ➔ β_N = 0.6262

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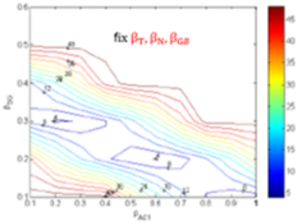
Three Scale Factors: β_{AC}, β_{GB}, β_{SG}

Predicted rut depth $= \beta_{AC} D_{AC} + \beta_{GB} D_{GB} + \beta_{SG} D_{SG}$

- Indeterminacy of the transfer functions
- Multiple Local Optima Issue
- Example of trial run: SSE contours against β_{AC} and β_{SG} showing multiple local minima
- Use rational engineering judgement to select the appropriate solution



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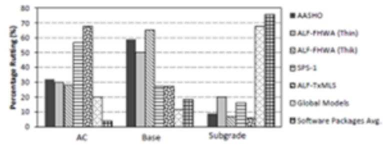
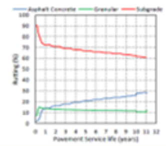
Layer Contribution to Rutting

- Trench Study
  - expensive and hard to repair at highways
  - need experience and expertise for field measurement and analysis
- From Previous Study (literature review)
  - mixed results
  - not realistic to use one layer contribution to represent the entire network
- Follow Pavement ME Results
  - Use the same layer proportion from Pavement ME
  - Compare total rut from ME and surface rut on pavement





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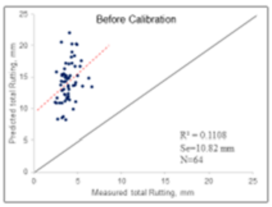
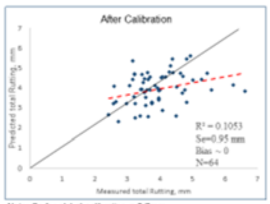
Rutting Calibration - Results





Note: Se for global calibration = 2.7mm

Calibration Coefficient	Global Model	Local Calibration - Ontario	Local Calibration- Layer Contribution
β_{AC}	1	2.3570	23%
β_{GB}	1	0.1254	11%
β_{SG}	1	0.2482	66 %

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Local calibration and performance criteria

- Review the performance criteria after local calibration
- Use the same reference, i.e. PMS

Performance Criteria	MEPDG Default Target Values
Permanent deformation - total pavement (mm)	19
Permanent deformation - AC only (mm)	6

Performance Criteria	Ontario Target Values
Permanent deformation - total pavement (mm)	Freeway: 10 Arterial: 13 Collector/Local: 17
Permanent deformation - AC only (mm)	ignore

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Alligator Cracking – N_f constants β_{f1}, β_{f2}, β_{f3}

Allowable number of axle-load application:

$$N_f = \beta_{f1} C_V C_H k_1 \varepsilon_t^{-\beta_{f2} k_2} E_{AC}^{-\beta_{f3} k_3}$$

where β_{f1}, β_{f2}, β_{f3} is local or mixture specific field calibration constants.

- These constants have very limited impact on the biases and residuals.
- Pavement ME does not allow independent change of these constants between the alligator and longitudinal cracking analyses.
- β_{f1}, β_{f2}, β_{f3} are kept to the default value of 1.0.

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Alligator Cracking – FC constants C_1, C_2, C_4

% of alligator cracking for total lane area:

$$FC_{bottom} = \frac{C_4}{1 + e^{(C_1 * C_1' + C_2 * C_2'' * \ln(100D))}} * \frac{1}{60}$$

where C_1, C_2, C_4 is the transfer function regression constants

- C_4 = 6000 is fixed as it represents the lane area, i.e. 500 ft. x 12 ft
- C_1, C_2 are the local calibration constants
- Transforms the above transfer equation to a linear regression equation to calibrate C_1, C_2

$$\ln\left(\frac{100}{FC_{bottom}} - 1\right) \times \frac{1}{C_2'} = -2C_1 + C_2 \ln(D \times 100)$$

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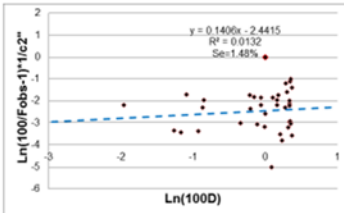
Alligator Cracking – Results



	Local	Global
C_1	1.2208	1
C_2	0.1406	1

Note: Se for global calibration = 5.01%

- Very low predicted distresses from software – alligator cracking is seldom the governed criterion for the current design
- Consider those cracks on wheelpath and midlane, exclude edge cracks
- Avoid section with reflective cracks
- Select sections with high age and more cracks.
- Clustering analysis and cleaning up the data to enhance the correlation

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Longitudinal Cracking – FC constants C_1, C_2, C_4

Length of top-down longitudinal crack in ft/mi

$$FC_{top} = \frac{C_4}{1+\exp(C_1 C_1' - C_2 C_2' \ln(D))} \times 10.56$$

where C_1, C_2, C_4 is the transfer function regression constants

- C_4= 1000 is fixed as it represents the maximum linear cracking length (500 ft. x 2)
- C_1, C_2 are the local calibration constants
- Transforms the above transfer equation to a linear regression equation to calibrate C_1, C_2

$$\ln\left(\frac{10560}{FC_{top}} - 1\right) = C_1 - C_2 \ln(D)$$

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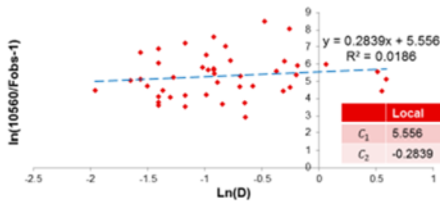
Longitudinal Cracking – Results



	Local	Global
C_1	5.556	7.0
C_2	-0.2839	3.5

- Follow the M of P that longitudinal cracking is top-down crack.
- Very scattered data and correlation is low.
- Consider longitudinal cracks along wheelpath, excluding centre-line cracks
- Clustering analysis and cleaning up the data to enhance the correlation

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Thermal Cracking – Paris Law constant k_t

Fracture parameters for the HMA mixture:

$$\log_{10} A = k_t \beta_t \{4.389 - 2.52 \log_{10}(E_{AC} \sigma_t m)\}$$

where

k_t =1.5 for Level 1; 0.5 for Level 2; 1.5 for Level 3

Observed amount of thermal cracking, ft/mi:

$$TC = \beta_{t1} N\left(\frac{1}{\sigma_d} \log_{10}\left(\frac{C_d}{h_{AC}}\right)\right)$$

where

N = standard normal distribution evaluated at [z]

β_{t1} = 400 = the upper bound of the thermal cracking in ft/mi

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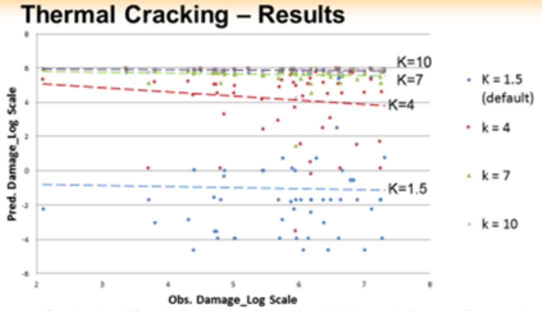
Thermal Cracking – Results



- Conduct Level 3 analysis only; Level 1 requires lab data on indirect tensile strength and creep compliance.
- Correlation is low. (low sensitivity for level 3 study)
- K = 7 provides the minimum bias.

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IRI Calibration

$$IRI = IRI_0 + C_1(RD) + C_2(FC_{Total}) + C_3(TC) + C_4(SF)$$

where

IRI = Predicted IRI, in/mi

IRI_0 =Initial IRI after construction, in/mi

FC_{Total} = Area of fatigue cracking (Combined alligator, longitudinal, and reflection cracking in the wheel path), percent of total lane area

TC =Length of transverse cracking, feet/mile

RD = Average rut depth, inches

SF =Site factor

C_1, C_2, C_3, C_4 =IRI model calibration factor for rut depth, fatigue cracking, transverse cracking and site factor, the global values are equal to 40, 0.4, 0.008, 0.015 respectively

- Best estimate of initial IRI from historical data in PMS
- Reflective cracking uses the default values of Pavement ME, i.e. Level 3 with 'fair' existing pavement condition
- Note: plug-in the distress quantity in imperial unit to the formula and convert IRI to SI unit (m/km) for the correlation

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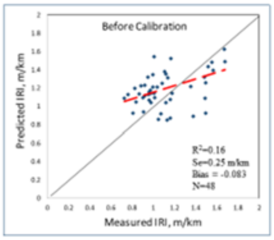
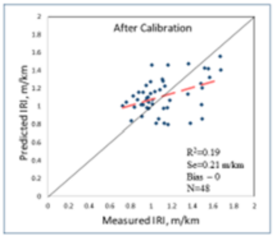
IRI Calibration - Results





Calibration Coefficient	Global Model	Local Calibration - Ontario
C_1	40	5.927
C_2	0.4	0.4
C_3	0.008	0.008
C_4	0.015	0.018

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Further Work

- Clustering analysis and clean-up on dataset to improve the correlation on FC_{top} and FC_{bottom} models.
- Conduct Levels 1 & 2 calibration on TC model.
- Complete the reflection crack calibration (integrated in C_2 and C_3 coefficients of IRI model)
- Review the performance criteria for various distresses.

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Thank You

QUESTIONS?

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Presentation 20—Ryan Barrett, Kansas DOT

The KDOT Experience - Pavement ME Calibration and Validation

Kansas Department of Transportation
December 15, 2016

Kansas Department of Transportation

Outline

- Why Local Calibrate Pavement ME
- Typical Distresses in Kansas
- Local Calibration & Validation Overview
- Lessons Learned
- What are the next steps?

Why Pavement ME and Why Perform Local Calibration?

- Theory on overdesigned pavement thickness with AASHTO '93
- More thickness → More $$
- With many needs and shrinking budgets, Pavement ME → provide required design period thickness to save $$ (initial and life cycle)

Typical Distresses In Kansas Pavements Portland Cement Concrete (PCC)

I-35 Franklin County

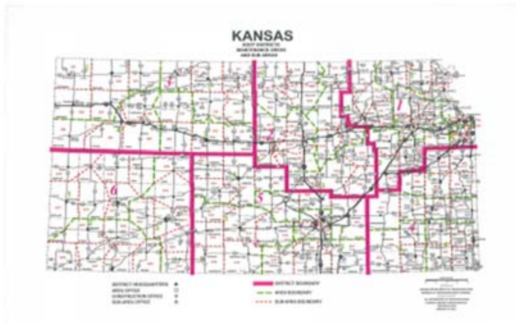
Typical Distresses in Kansas Pavements Hot Mix Asphalt (HMA)

I-435 Johnson County (Kansas City Metro Area)

Local Calibration Goals

- Reduce or eliminate bias to prevent under or over designed pavement
- Increase precision to prevent premature failures
- Implement new Pavement ME software to optimize pavement designs and replace DARWin software

Kansas – District Breakdown



Local Calibration Overview

- Selected 27 flexible pavement projects statewide
  - 21 projects for calibration
  - 6 projects for validation
- Selected 22 rigid pavement projects statewide
  - 17 projects for calibration
  - 5 projects for validation
- Compared Pavement ME predicted distresses for flexible and rigid pavements with distresses measured by KDOT's Pavement Management Information System (PMIS) and Network Optimization System (NOS)
- Adjusted coefficients of distress models to obtain a match between data sets

Validation Overview

- Used local calibration inputs for both pavement types
- Ran pavement designs with different climate, soil type, and heavy truck traffic
- Compared Pavement ME design thickness output with the following parameters:
  - Known historical performance
  - Service life
  - Design thickness
  - Traffic loading

Results

- PCC Pavements:
  - No measured data for transverse cracking
  - Model over predicted roughness (IRI)
  - Lower/mid-range traffic routes: JPCP design pavement thickness consistent with expectations
  - Higher truck traffic routes: JPCP design pavement thickness greater than expected
- HMA Pavements:
  - No measured bottom up fatigue cracking data
  - Inconsistent thickness results for all route classes
- More testing and research needed to refine key inputs

Lessons Learned

- Sample project size for calibration and validation needed to be increased
- Sample projects did not consider all statewide surfacing possibilities
- Cracking, faulting, and rutting data collection format needed refinement to be easier to input
- More Resilient Modulus (M_R) data needed
  - AASHTO Subgrade Soil Types
  - Chemically Stabilized Soils
  - Granular Base Layers
  - HMA Base Layers
  - CTB/ATB Layers
- Construct Long Term Pavement Performance (LTPP) test sections using Pavement ME output to monitor performance over time statewide

Future Refinement of Local Calibration

- Continue materials testing to better characterize Resilient Modulus (M_R) values in the following layers:
  - soil types (un-stabilized/untreated soil)
  - chemically stabilized soils
  - aggregate base materials
  - HMA base mixtures
  - PCTB/ACTB
- Model JPCP (PCC pavement) projects constructed over granular base
- Develop proper calibration for blended HMA binders that include Recycled Asphalt Pavement (RAP) & Recycled Asphalt Shingles (RAS)
- Complete creep compliance and indirect tensile strength tests for SR Superpave mixtures
- Divide state into Areas/Districts based on severity of thermal cracking and improve inputs for low temperature cracking model
- Identify bottom up fatigue cracking by coring HMA pavements that exhibit fatigue cracking distresses
- Increase number of projects statewide for calibration and validation

Questions?

- Contact Information:

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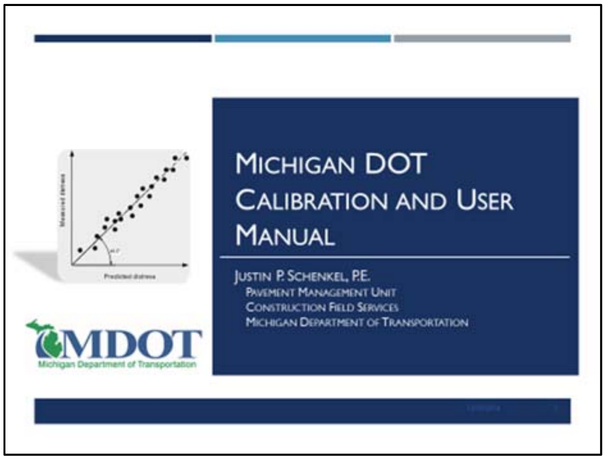
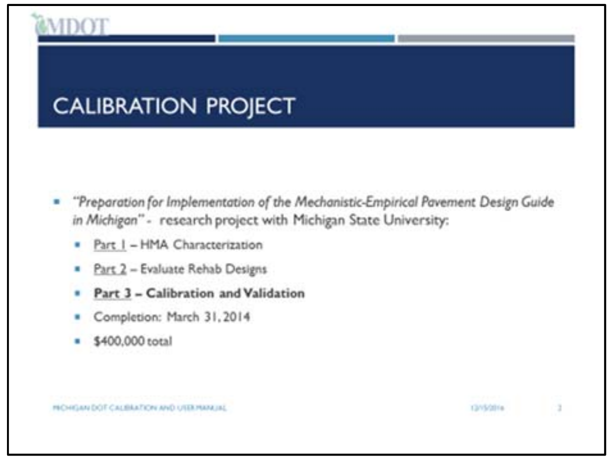
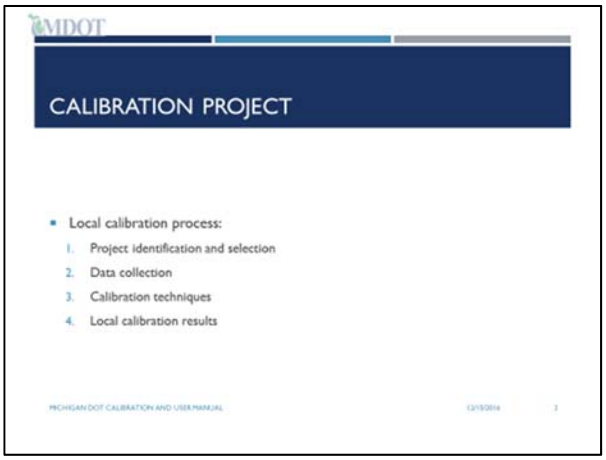
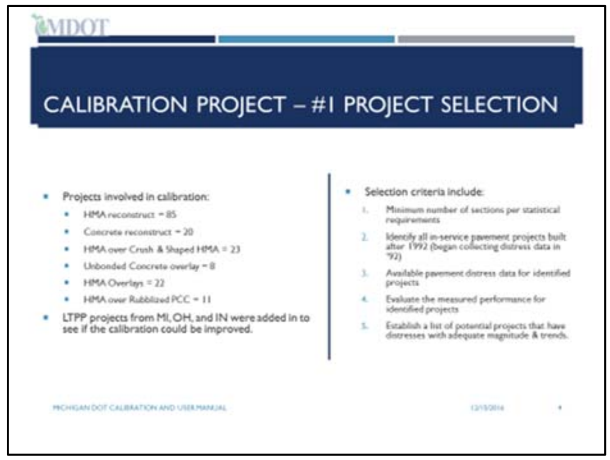
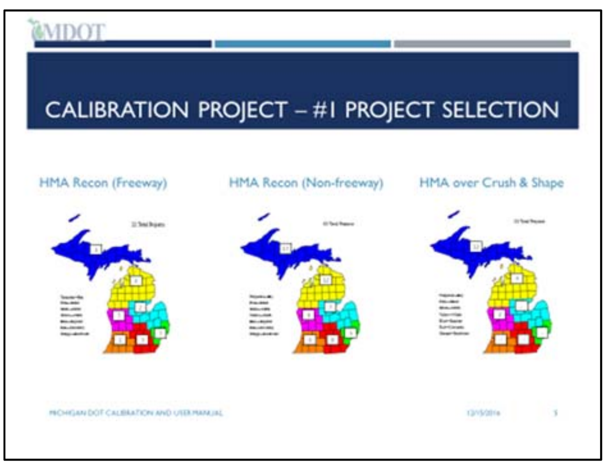
Presentation 21—Justin Schenkel, Michigan DOT

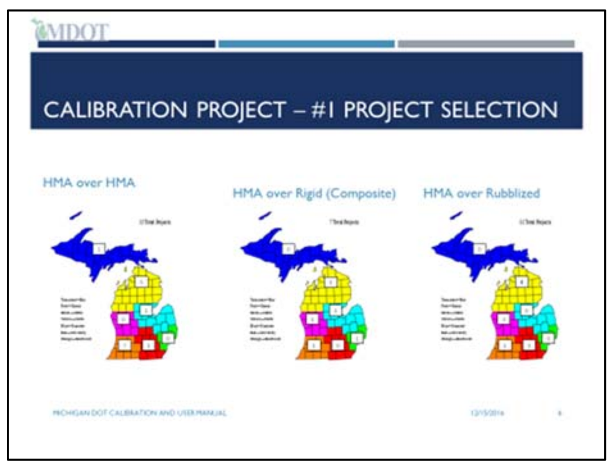












MDOT

CALIBRATION PROJECT – #1 PROJECT SELECTION

JPCP Reconstruction

Unbonded Rigid Overlay

MICHIGAN DOT CALIBRATION AND USER MANUAL 12/13/2016 7

MDOT

CALIBRATION PROJECT – #1 PROJECT SELECTION

Reconstruct Pavement Types	Age Group <10	10-15	>15	Total
Crush & Shape	0	6	17	23
HMA Reconstruct (Freeway)	2	15	5	22
HMA Reconstruct (Non-Freeway)	12	36	15	63
JPCP Reconstruct	3	11	6	20
Total	17	68	43	128

Rehab Pavement Types	Age Group <10	10-20	>20	Total
Composite overlay	0	3	4	7
HMA over HMA	2	5	8	15
Rubblized overlay	0	7	4	11
Unbonded overlay	1	7	0	8
Total	3	22	16	41

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CALIBRATION PROJECT – #2 DATA COLLECTION

- Process:
  - Observed data: MDOT pavement asset condition records
    - Conversion & some assumption needed for ME format.
  - Material inputs: historical construction projects records & MDOT studies
    - Missing some data & some assumption needed for ME input.
  - Predicted distresses from the ME results & compared to observed data

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CALIBRATION PROJECT – #2 DATA COLLECTION

MDOT Distress Data to ME Conversions:

Flexible pavement distresses	MDOT units	Pavement-ME units	Conversion needed?
IRI	in/mile	in/mile	No
Top-down cracking	miles	ft./mile	Yes
Bottom-up cracking	miles	% area	Yes
Thermal cracking	No. of occurrences	ft./mile	Yes
Rutting	in	in	No
Reflective cracking	None	% area	N/A

Rigid pavement distresses	MDOT units	Pavement-ME units	Conversion needed?
IRI	in/mile	in/mile	No
Faulting	in	in	Yes
Transverse cracking	No. of occurrences	% slabs cracked	Yes

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CALIBRATION PROJECT – #2 DATA COLLECTION

Performance measure	Acceptable pavement sections	Total number of available sections
Flexible pavements		
Alligator cracking	121	129
Longitudinal cracking	128 (37)	129 (40)
Rutting	129 (33)	129 (40)
IRI	127 (40)	129 (40)
Rigid pavements		
Transverse cracking	18 (13)	18 (13)
Joint faulting	33 (16)	33 (16)
IRI	29 (15)	29 (15)

Note:
- The values in parenthesis represent number of rehabilitated pavement sections.
- Number of sections may not match number of projects because divided freeways were treated as separate sections.

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CALIBRATION PROJECT – #2 DATA COLLECTION

MDOT Input Summary:

[illegible]

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CALIBRATION PROJECT – #3 CALIB. TECHNIQUES

- Dataset Options:
  - Option 1: MDOT reconstruct sections only
  - Option 2: MDOT reconstruct and rehabilitation sections
  - Option 3: MDOT reconstruct, rehabilitation, and LTPP sections (Rigid Pavements only)
  - Option 4: MDOT rehabilitation sections only

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CALIBRATION PROJECT – #3 CALIB. TECHNIQUES

- Statistical methods:
  - Full data set – no sampling
  - Traditional split sampling – 70% calibration/30% validation
  - Repeated split sampling – split sampling repeated 1000 times
  - Bootstrapping – random sampling of full dataset with replacement, validated with 80% calibration/20% validation.

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CALIBRATION PROJECT – #3 CALIB. TECHNIQUES

Bootstrapping Flowchart:

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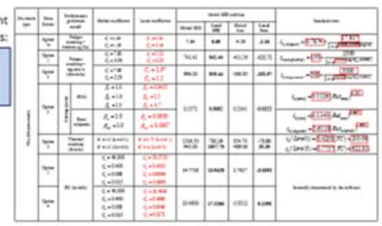
CALIBRATION PROJECT – #4 CALIBRATION RESULTS

Flexible Pavement Results:

Data Subset Options:
1a = MDOT recon sections (TD & BU combined)
1b = MDOT recon sections (BU only)
2 = MDOT recon/rehab sections
3 = MDOT recon/MDOT rehab/LTPP sections (rigid only)
4 = MDOT rehab sections



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CALIBRATION PROJECT – #4 CALIBRATION RESULTS

- Flexible Calibration Determination
  - Bottom-Up (BU) Cracking:
    - Option 1a provided most realistic ("best") model - More pavement sections could be used (due to the way MDOT identifies crack types)
    - Option 1b is not recommended - Few pavement sections identified BU Cracking based on the distresses in the MDOT database (MDOT to ME conversion issue)
  - Top-Down (TD) Cracking:
    - Option 1 had best results for new/reconstruct
      - NOTE: Using Option 1a for BU Cracking means that TD model should not be used because cracking is already included in Option 1a
    - Option 2 had best results for rehabilitation
  - Rutting:
    - Individual layer calibration provided the best results – used estimated rutting contribution for each layer
    - Option 2 gave the most realistic results for rutting model
  - Thermal Cracking:
    - Option 2 had best results for Level 1 & 3 calibration coefficients
  - IRI:
    - Option 1 had best results for new/reconstruct
    - Option 4 was best results for rehabilitation

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CALIBRATION PROJECT – #4 CALIBRATION RESULTS

New Flexible Coefficient Comparison

Model	Coefficients	Global	MI	AZ	CO	MO	OR	AR	NH	WA	MT	NC	OH	TX
Bottom-up Cracking	C1	1	0.50	1	0.07	1	0.56	0.688	0.625	1.071	1	1	1	1
	C2	1	0.56	4.5	2.35	1	0.225	0.294	0.25	1	1	1	1	1
	C3	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000
Thermal cracking	Level 1	1.5	0.75	1.5	7.5	0.625	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	Level 2	0.5	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	Level 3	1.5	4.00	1.5	1.5	1.5	1.5	1.5	1.5	1.5	0.25	1.5	1.5	1.5
Rutting HMA	Br1	1	0.9453	0.69	1.34	1	1.48	1.2	1.1	1.05	1	13.1	0.51	2.39
	Br2	1	1.3	1	1	1	1	1	1.1	1.109	1	0.4	1	1
	Br3	1	0.7	1	1	1	0.9	0.8	0.8	1.1	1	1.4	1	0.856
Rutting base	Bs1	1	0.0985	0.37	0.84	0.4375	1	1	0.8	-	1	0.303	0.32	1
Rutting subgrade	Bsg1	1	0.0367	0.14	0.4	0.01	1	0.5	1.2	0	1	1.102	0.33	0.5
IRI	C1	40	50.372	1.2281	35	17.7	40	40	0.015	40	40	40	17.6	40
	C2	0.4	0.4102	0.1175	0.3	0.975	0.4	0.4	0.4	0.4	0.4	0.4	0.01	0.4
	C3	0.008	0.0066	0.008	0.02	0.008	0.008	0.008	0.008	0.008	0.008	0.008	1.37	0.008
	C4	0.015	0.0271	0.028	0.019	0.01	0.015	0.015	0.015	0.015	0.015	0.015	0.066	0.015

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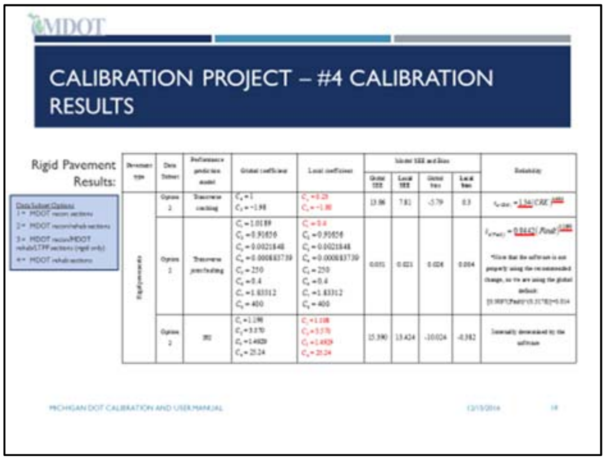
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CALIBRATION PROJECT – #4 CALIBRATION RESULTS
Rigid Pavement Results:
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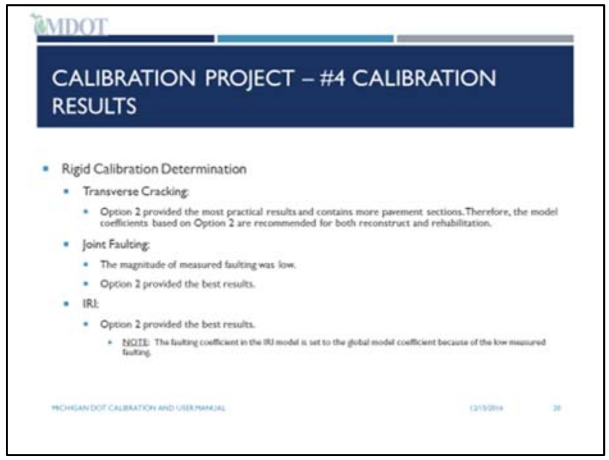
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CALIBRATION PROJECT – #4 CALIBRATION RESULTS
Rigid Calibration Determination
Transverse Cracking:
Option 2 provided the most practical results and contains more pavement sections. Therefore, the model coefficients based on Option 2 are recommended for both reconstruct and rehabilitation.
Joint Faulting:
The magnitude of measured faulting was low.
Option 2 provided the best results.
IRI:
Option 2 provided the best results.
NOTE: The faulting coefficient in the IRI model is set to the global model coefficient because of the low measured faulting.
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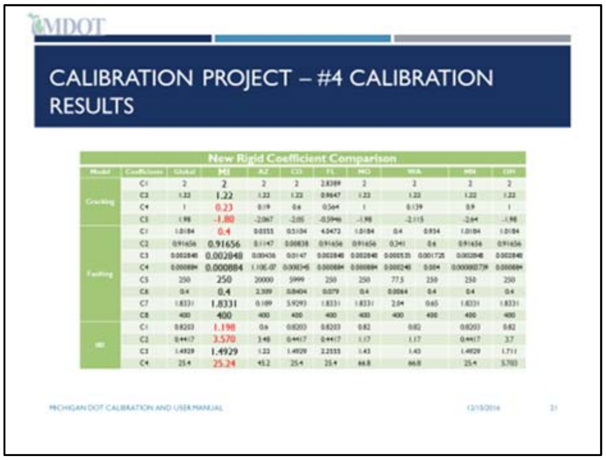
MDOT
CALIBRATION PROJECT – #4 CALIBRATION RESULTS
New Rigid Coefficient Comparison
MI
2
1.22
0.23
-1.80
0.4
0.91656
0.002848
0.000884
250
0.4
1.8331
400
1.198
3.570
1.4929
25.24
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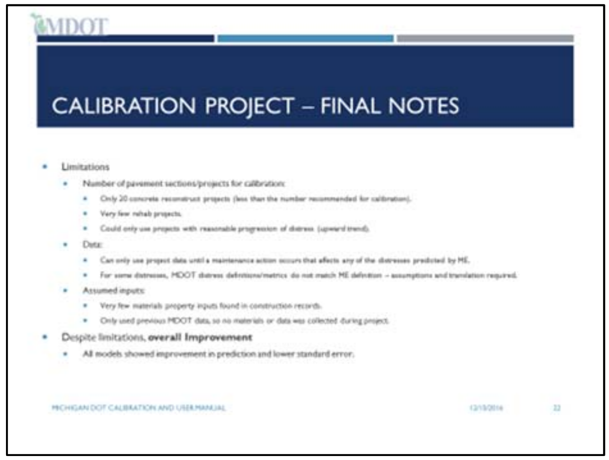
MDOT
CALIBRATION PROJECT – FINAL NOTES
Limitations
Number of pavement sections/projects for calibration:
Only 20 concrete reconstruct projects (less than the number recommended for calibration).
Very few rehab projects.
Could only use projects with reasonable progression of distress (upward trend).
Data:
Can only use project data until a maintenance action occurs that affects any of the distresses predicted by ME.
For some distresses, MDOT distress definitions/metrics do not match ME definition – assumptions and translation required.
Assumed inputs:
Very few materials property inputs found in construction records.
Only used previous MDOT data, so no materials or data was collected during project.
Despite limitations, overall Improvement
All models showed improvement in prediction and lower standard error.
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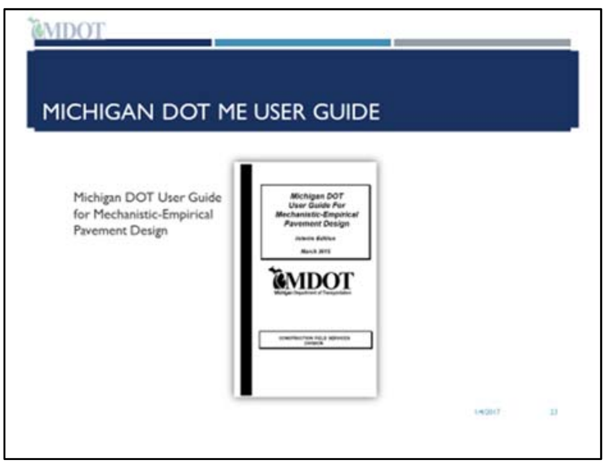
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MICHIGAN DOT ME USER GUIDE
Michigan DOT User Guide for Mechanistic-Empirical Pavement Design
Michigan DOT User Guide For Mechanistic-Empirical Pavement Design
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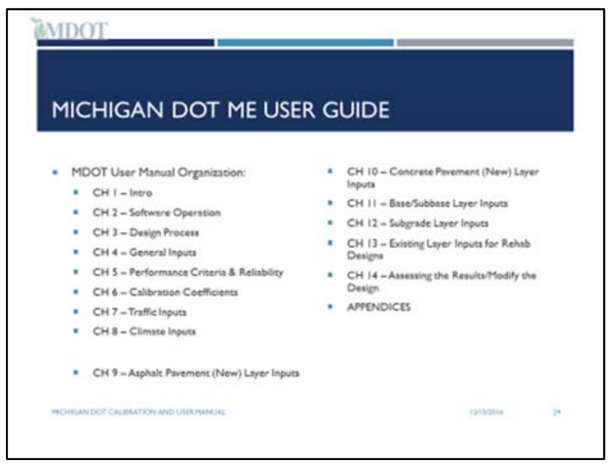
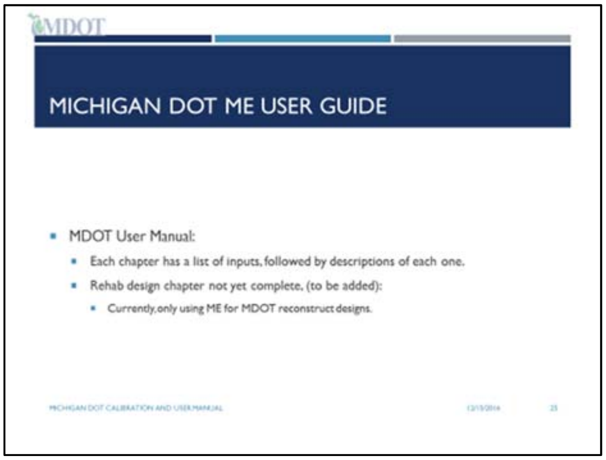

MDOT
MICHIGAN DOT ME USER GUIDE
MDOT User Manual Organization:
CH 1 – Intro
CH 2 – Software Operation
CH 3 – Design Process
CH 4 – General Inputs
CH 5 – Performance Criteria & Reliability
CH 6 – Calibration Coefficients
CH 7 – Traffic Inputs
CH 8 – Climate Inputs
CH 9 – Asphalt Pavement (New) Layer Inputs
CH 10 – Concrete Pavement (New) Layer Inputs
CH 11 – Base/Subbase Layer Inputs
CH 12 – Subgrade Layer Inputs
CH 13 – Existing Layer Inputs for Rehab Designs
CH 14 – Assessing the Results/Modify the Design
APPENDICES
MICHIGAN DOT CALIBRATION AND USER MANUAL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MICHIGAN DOT ME USER GUIDE
MDOT User Manual:
Each chapter has a list of inputs, followed by descriptions of each one.
Rehab design chapter not yet complete, (to be added):
Currently, only using ME for MDOT reconstruct designs.
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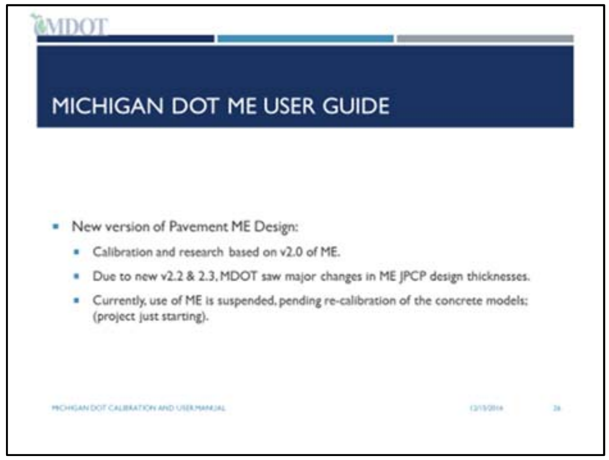
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MICHIGAN DOT ME USER GUIDE
New version of Pavement ME Design:
Calibration and research based on v2.0 of ME.
Due to new v2.2 & 2.3, MDOT saw major changes in ME JPCP design thicknesses.
Currently, use of ME is suspended, pending re-calibration of the concrete models; (project just starting).
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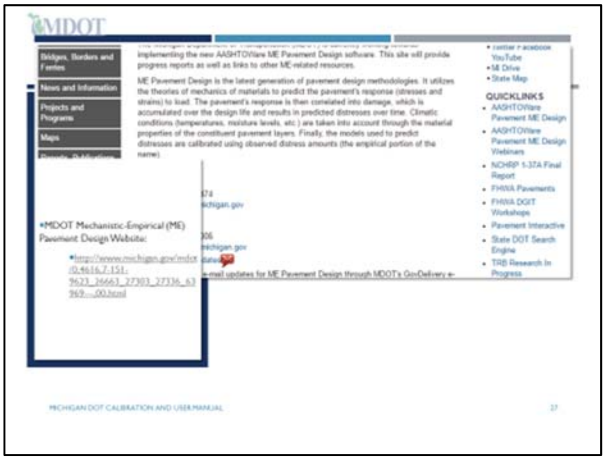
MDOT
Bridges, Borders and Ferries
News and Information
Projects and Programs
Maps
implementing the new AASHTOWare ME Pavement Design software. This site will provide progress reports as well as links to other ME-related resources.
ME Pavement Design is the latest generation of pavement design methodologies. It utilizes the theories of mechanics of materials to predict the pavement's response (stresses and strains) to load. The pavement's response is then correlated into damage, which is accumulated over the design life and results in predicted distresses over time. Climatic conditions (temperatures, moisture levels, etc.) are taken into account through the material properties of the constituent pavement layers. Finally, the models used to predict distresses are calibrated using observed distress amounts (the empirical portion of the name).
YouTube
MI Drive
State Map
QUICKLINKS
AASHTOWare Pavement ME Design
AASHTOWare Pavement ME Design Webinars
NCHRP 1-37A Final Report
FHWA Pavements
FHWA DGIT Workshops
Pavement Interactive
State DOT Search Engine
TRB Research In Progress
MDOT Mechanistic-Empirical (ME) Pavement Design Website:
http://www.michigan.gov/mdot/0,4616,7-151-9623_26663_27303_27336_63969---,00.html
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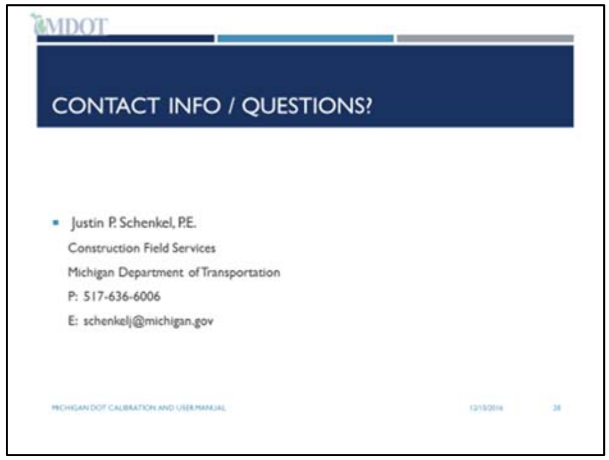
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MICHIGAN DOT CALIBRATION AND USER MANUAL

Presentation 22—Hari Nair and Affan Habib, Virginia DOT

VTRC
Virginia Transportation Research Council

We bring innovation to transportation.

AASHTOWare M-E

VDOT Local Calibration for Flexible and Rigid Pavement Design

Hari Nair, Ph.D., P.E
Affan Habib, P.E

VDOT M-E Implementation

- Developed Implementation plan in 2007
- Several Research projects completed
  - Traffic inputs (VTRC 10-R19)
  - Asphalt Material Inputs (VTRC 12-R16)
  - Unbound materials inputs (VTRC 11-R16)
  - Subgrade Inputs (VCTIR 15-R12)
  - Drainage layer and Cement treated aggregate layer
  - Concrete material properties from past projects
- Developed User Manual for Pavement ME design

1/5/2017

VDOT ME Local Calibration/Validation

- Review of both asphalt and concrete distress prediction models
  Asphalt pavement: Permanent deformation, Cracking, IRI
  Concrete Pavement (CRCP): Punchouts, IRI
- Preliminary values for performance targets, reliability and design life
- Measured values from VDOT Pavement Management System (PMS)
- Local Calibration was performed to remove bias and assess standard error of distress models (Followed AASHTO guide for local calibration)

1/5/2017

Asphalt Calibration Sites

- 53 sites from 8 VDOT districts; locations and pavement structure information provided by districts
- Mostly paved in early 2000s; range from 1992 to 2008
- Asphalt thickness typically 10”, ranges from 5.5 to 15.5
- 16 sites with CTA layer; 20 with drainage layer

1/5/2017

VDOT PMS Distress Data

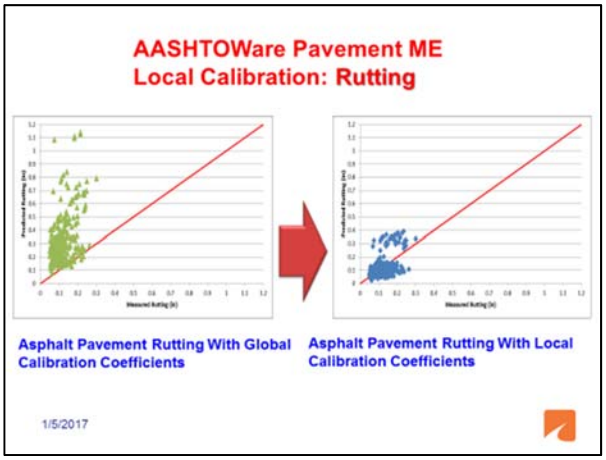
- VDOT Uses Automated distress data collection (from 2007 Onwards)
- Distress values averaged for all segments within project limits to get average value each year.
- Fatigue cracking- labelled as alligator cracking in PMS (Square feet, Three severity levels).
- Sum of severity levels (level 2 and 3) of alligator cracking divided by lane area (12’ wide X length) for % fatigue cracking. Level 1 severity were assumed to be longitudinal cracks

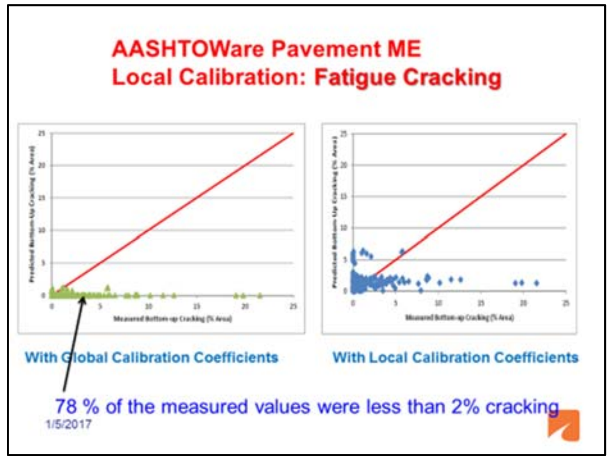
1/5/2017

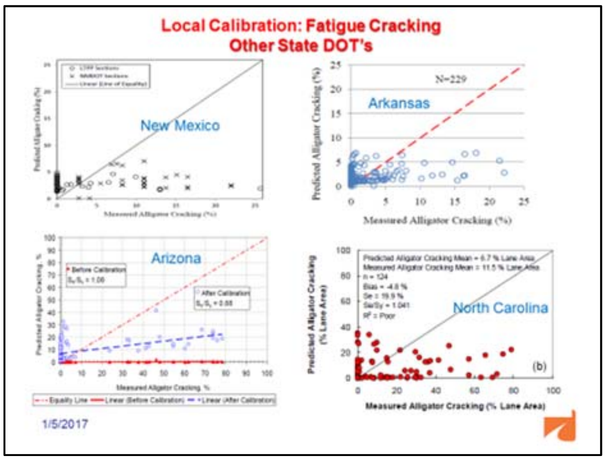
Calibration procedure

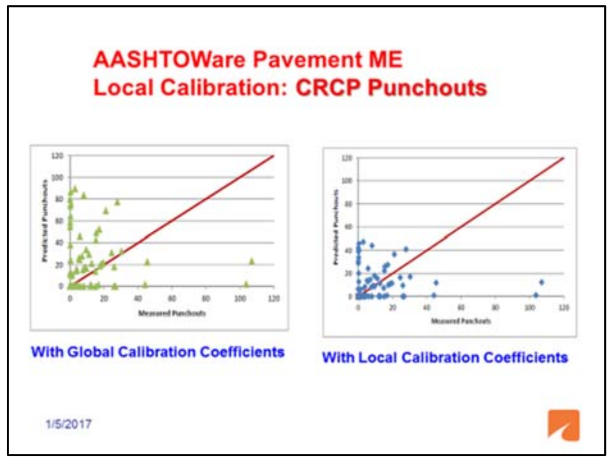
- Compare measured distress against predicted distress for each year.
- Measured IRI values that decreased greater than 10% in a given year was taken to be that the pavement had been resurfaced and data beyond the decrease would not be considered.
- Also compared year of last rehab from PMS records to remove data points on sites that had been resurfaced
- Removed ME distress predictions that were erroneous and missing measured distress points.
- Sites split into calibration/validation sets based on district

1/5/2017





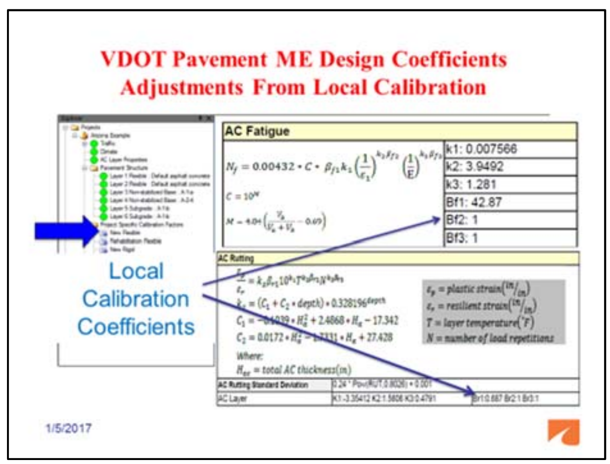




VDOT Pavement ME Design Coefficients Adjustments From Local Calibration

Model	β_{r1}	β_{s1} (fine subgrade)	β_{s1} (granular subgrade)	β_{f1}	C_1	C_2	C_3
Asphalt pavement permanent deformation	0.687	0.153	0.153				
Asphalt pavement bottom-up cracking				42.87	0.3190	0.3190	
CRCP punchouts							114.76

1/5/2017



Development of Suggested Values for Design Requirements

- National guidelines
- Previous VDOT design standards
- Data from end-of-service pavements in Virginia
- Relationships between distress in serviceability used in PMS
- Values in local calibration site data
- Experience of VDOT district and field personnel.

1/5/2017
1/5/2017

Reliability Level, Design Life, and Performance Target Recommendations for VDOT's Use With Pavement ME Design

Pavement ME Design Requirement Parameter	Design Life (years)	Highway Classification			
		Interstate	Divided Primary	Undivided Primary	Secondary
Reliability Level		95	90	90	85
Performance Measure					
Asphalt pavement—Total permanent deformation (in)	15	0.26	0.26	0.26	0.26
Asphalt pavement—Bottom-up fatigue cracking (%)	30	6	6	6	6
Asphalt and concrete pavement—IRI (in/mi)	15	140	140	140	140
CRCP punchouts (count/mile)	30	6	6	6	6

1/5/2017

Summary

Developed a set of local calibration factors applicable for the entire state.

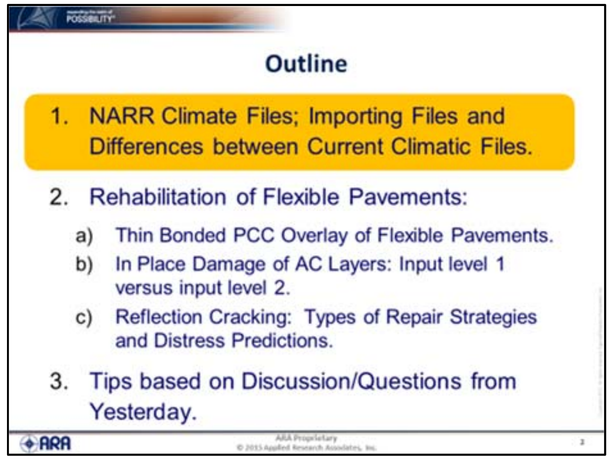
Further refinement of the calibration coefficients might be necessary beyond initial implementation.

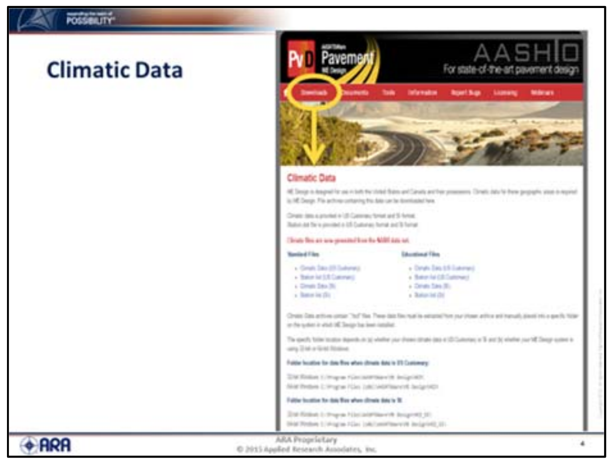
Expanding the pool of project sites used for calibration can help provide more robust calibration coefficients.

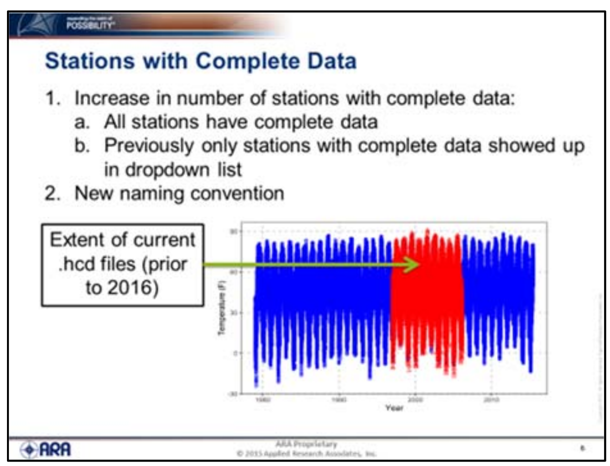
Local Calibration research report:
http://www.virginiadot.org/vtrc/main/online_reports/pdf/16-r1.pdf

1/5/2017

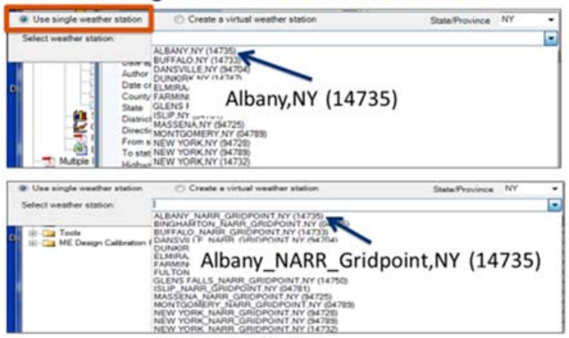
Presentation 23—Harold Von Quintus and Chad Becker, ARA



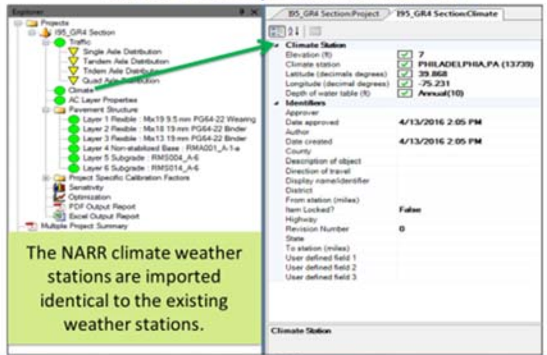




Naming Convention: Old versus New

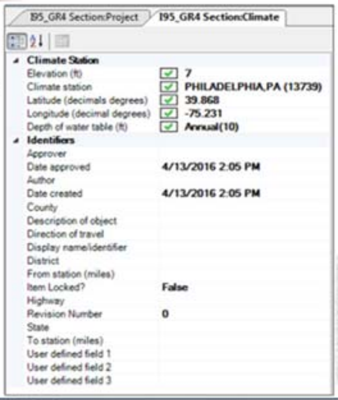


NARR Climate/Weather Stations



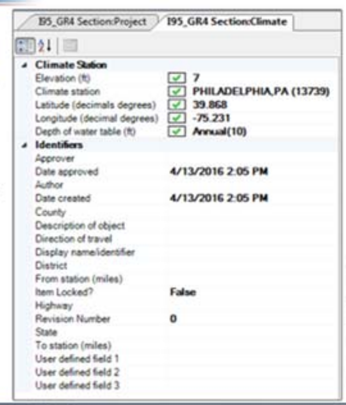
Getting weather data for design:

1. Select weather station for a project.
2. Select starting date for project.



Select Weather Station for Project

1. Enter depth to water tables (annual or seasonal values).
2. Enter latitude, longitude & elevation of project.
3. Select one or more climate stations.



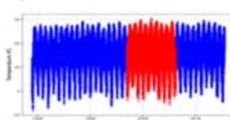
Select Weather Station for Project

Some stations have multiple grid points (i.e.; 94015a, 94015b, 94015c, 94015d)

a. Multiple grid points added to show multiple elevations
b. Selected station should have elevation ± 500 ft. of project elevation.
c. Use virtual climate station for areas with significant elevation differences.

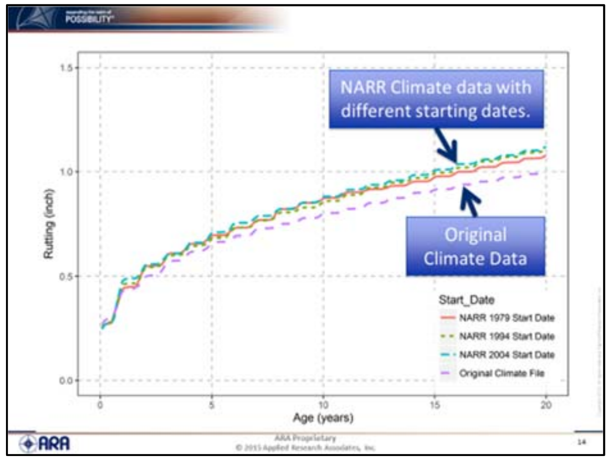
Select Starting Date or Year

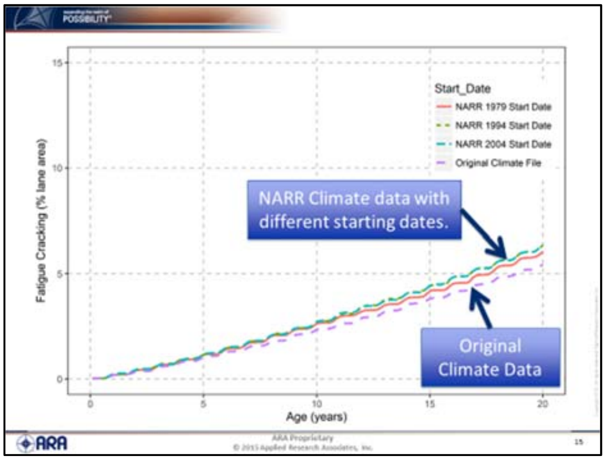
1. Prior to 2016, most stations contained less than 10 years of hourly climate data. The software repeated the climate data for the length of design period.
2. Start date was the beginning of the climate data
3. New files have 37 years of continuous data
   a. Default starting date is 1/1/1979.
   b. Manual starting dates; manually delete data in the .hcd file.

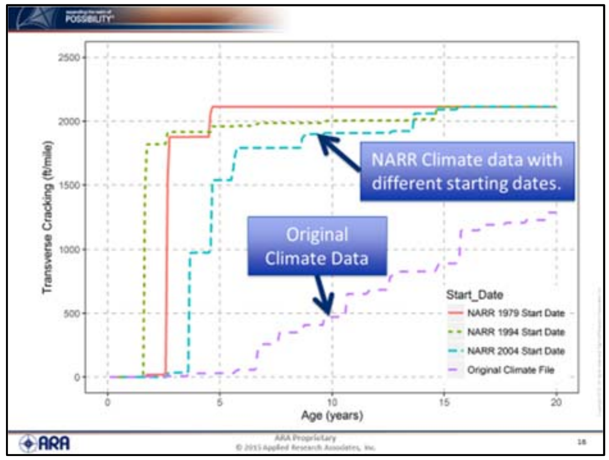


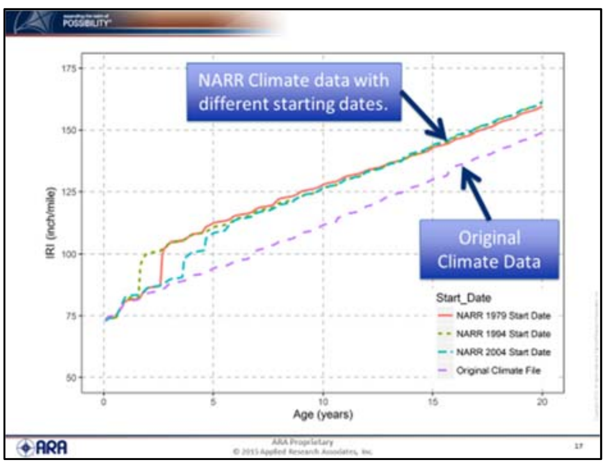
Questions

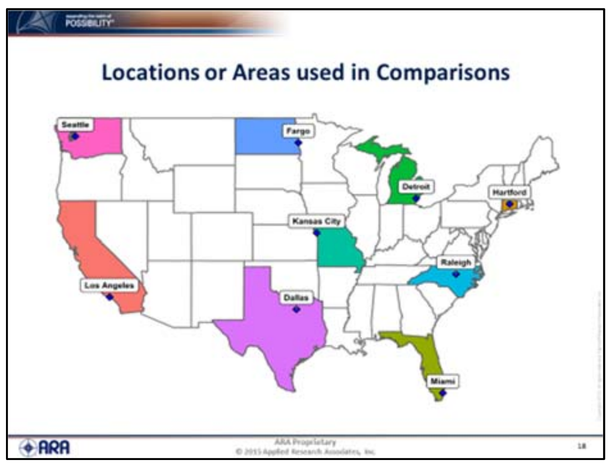
- Do different starting dates make a difference?
- Is there a difference between use of the NARR and original climate data; and what about MERRA?

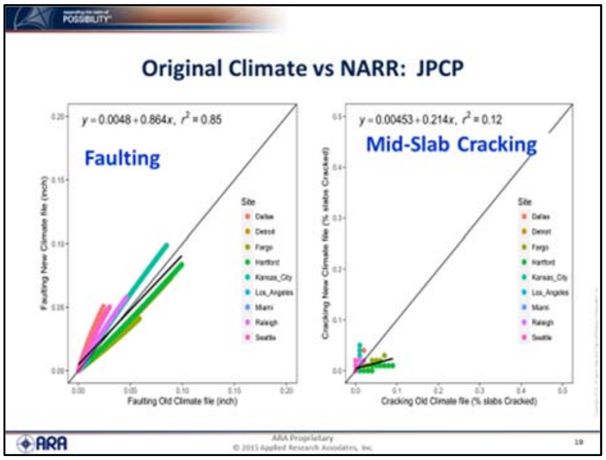


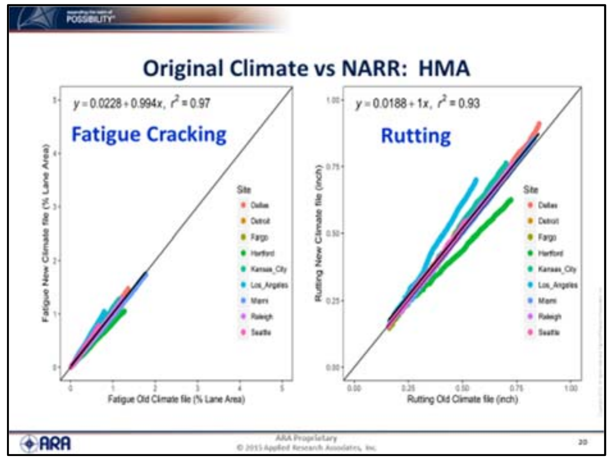


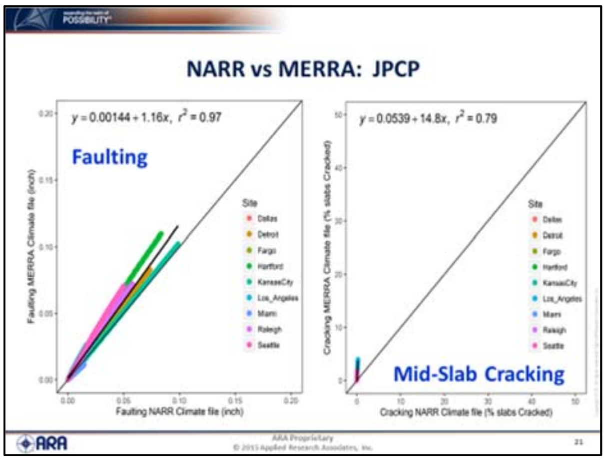


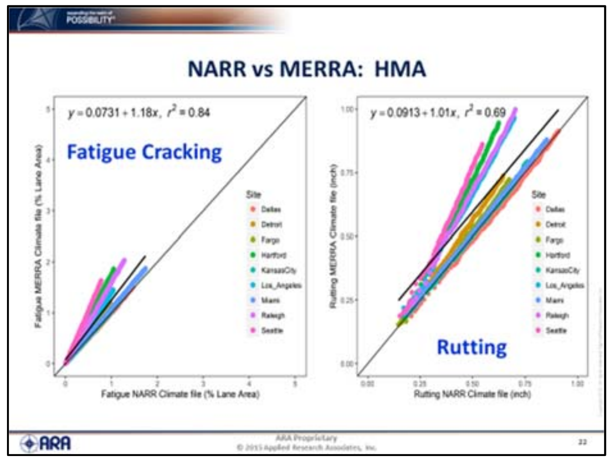










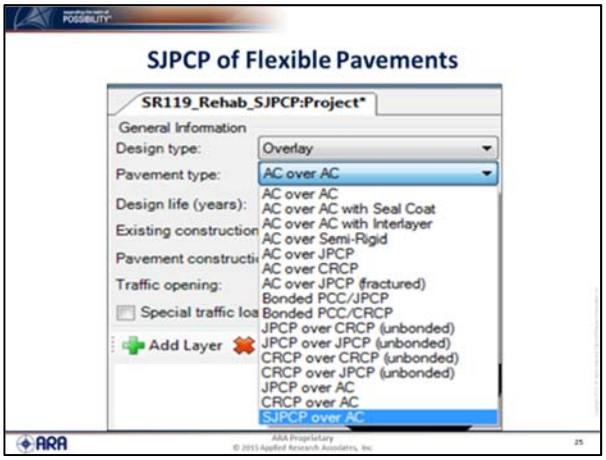


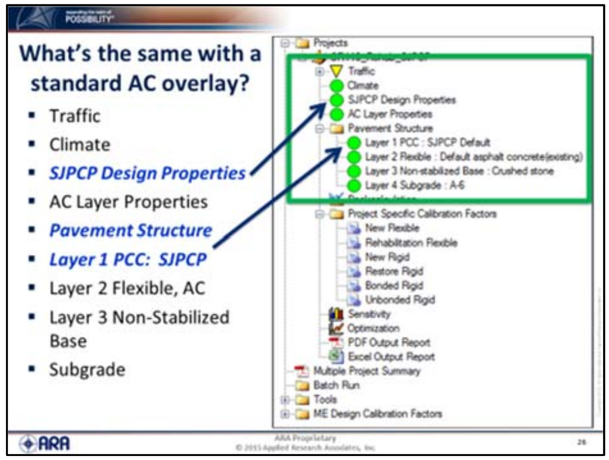
Why the Difference?

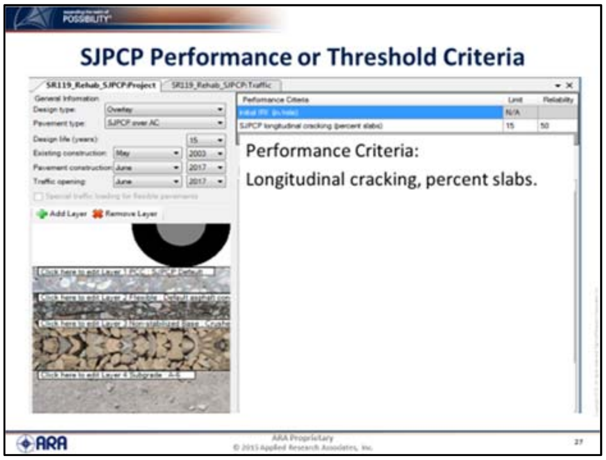
- NARR versus Current Climate Data:
  - Differences observed at an individual site.
  - No bias between two data sets across many different climates.
- NARR versus MERRA:
  - Percent cloud cover is different between NARR and MERRA.
  - Can have more than 100 percent humidity in MERRA database; ICM will not run for that case.

Outline

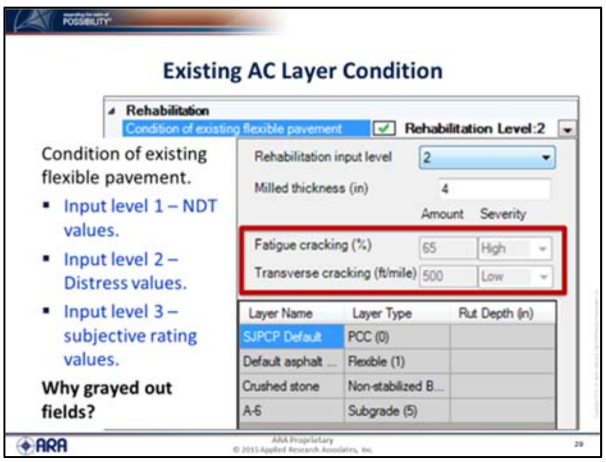
1. NARR Climate Files; Importing Files and Differences between Current Climatic Files.
2. Rehabilitation of Flexible Pavements:
   a) SJPCP of Flexible Pavements.
   b) In Place Damage of AC Layers: Input level 1 versus input level 2.
   c) Reflection Cracking: Types of Repair Strategies and Distress Predictions.
3. Tips based on Discussion/Questions from Yesterday.

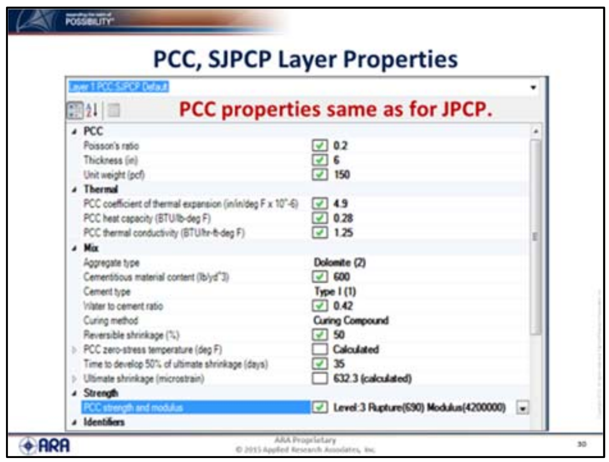

SJPCP of Flexible Pavements
SR119_Rehab_SJPCP:Project*
General Information
Design type:
Overlay
Pavement type:
AC over AC
Design life (years):
Existing construction
Pavement constructi
Traffic opening:
Special traffic loa
Add Layer
AC over AC
AC over AC with Seal Coat
AC over AC with Interlayer
AC over Semi-Rigid
AC over JPCP
AC over CRCP
AC over JPCP (fractured)
Bonded PCC/JPCP
Bonded PCC/CRCP
JPCP over CRCP (unbonded)
JPCP over JPCP (unbonded)
CRCP over CRCP (unbonded)
CRCP over JPCP (unbonded)
JPCP over AC
CRCP over AC
SJPCP over AC
ARA

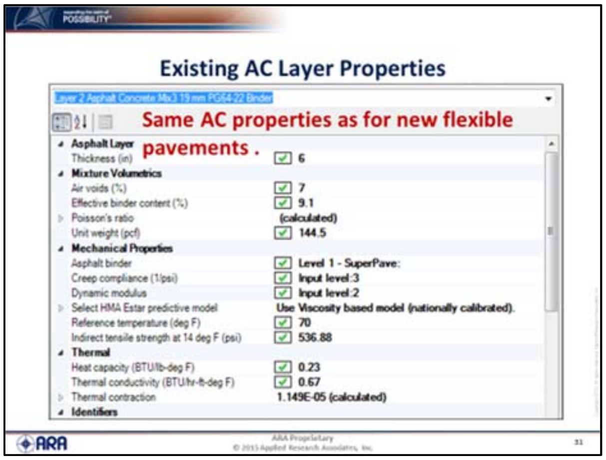

What's the same with a standard AC overlay?
Traffic
Climate
SJPCP Design Properties
AC Layer Properties
Pavement Structure
Layer 1 PCC: SJPCP
Layer 2 Flexible, AC
Layer 3 Non-Stabilized Base
Subgrade
Projects
Traffic
Climate
SJPCP Design Properties
AC Layer Properties
Pavement Structure
Layer 1 PCC : SJPCP Default
Layer 2 Flexible : Default asphalt concrete(existing)
Layer 3 Non-stabilized Base : Crushed stone
Layer 4 Subgrade : A-6
Project Specific Calibration Factors
New Flexible
Rehabilitation Flexible
New Rigid
Restore Rigid
Bonded Rigid
Unbonded Rigid
Sensitivity
Optimization
PDF Output Report
Excel Output Report
Multiple Project Summary
Batch Run
Tools
ME Design Calibration Factors
ARA

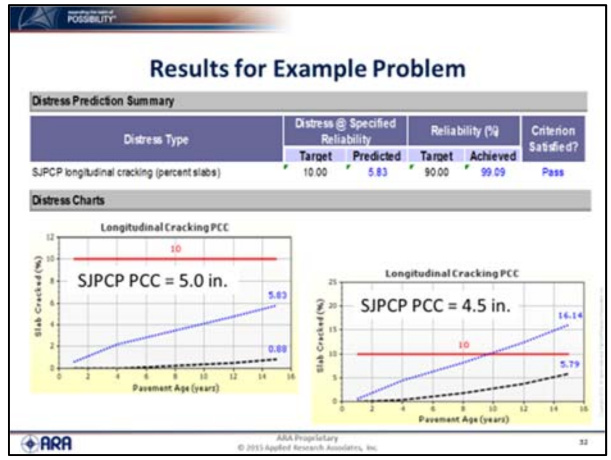

SJPCP Performance or Threshold Criteria
Performance Criteria:
Longitudinal cracking, percent slabs.
ARA

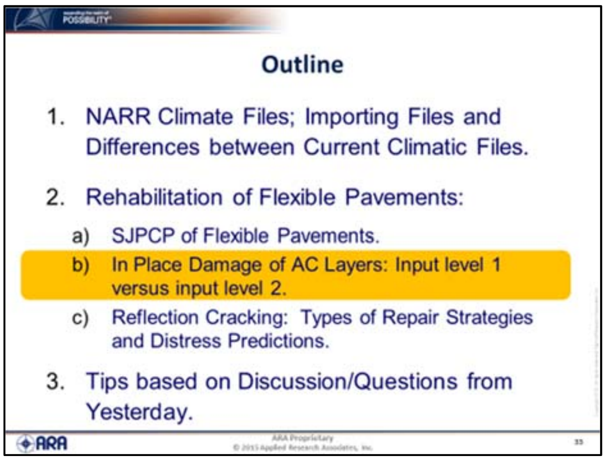

SJPCP Design Properties
PCC surface shortwave absorptivity
PCC joint spacing (ft. square slab)
Sealant type
Tied shoulders
Permanent curl/warp effective temp. difference
Transverse joint LTE
ARA

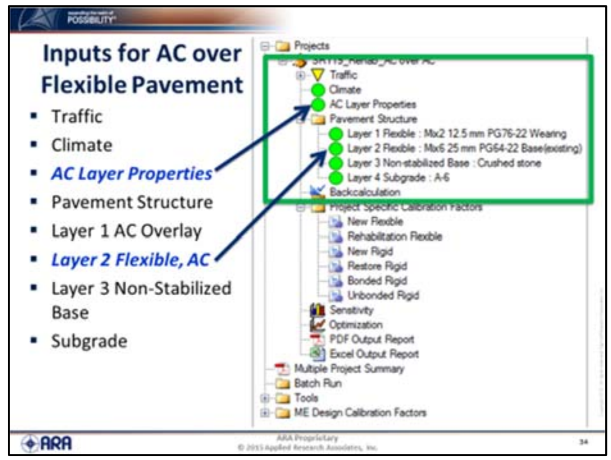

Existing AC Layer Condition
Rehabilitation
Condition of existing flexible pavement
Rehabilitation Level:2
Condition of existing flexible pavement.
Input level 1 – NDT values.
Input level 2 – Distress values.
Input level 3 – subjective rating values.
Why grayed out fields?
Rehabilitation input level
2
Milled thickness (in)
4
Amount
Severity
Fatigue cracking (%)
65
High
Transverse cracking (ft/mile)
500
Low
Layer Name
Layer Type
Rut Depth (in)
SJPCP Default
PCC (0)
Default asphalt ...
Flexible (1)
Crushed stone
Non-stabilized B...
A-6
Subgrade (5)
ARA

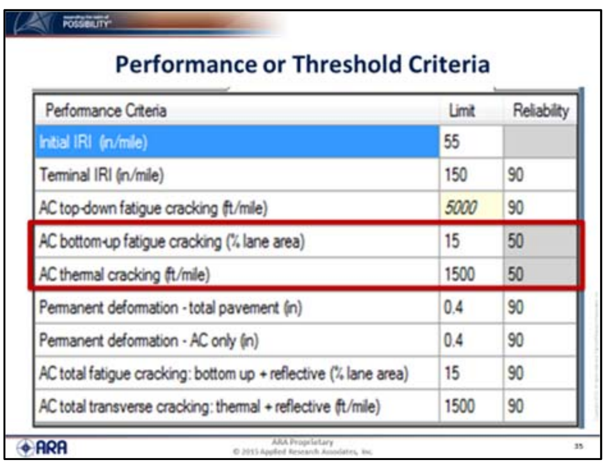

PCC, SJPCP Layer Properties
PCC properties same as for JPCP.
PCC
Poisson's ratio
0.2
Thickness (in)
6
Unit weight (pcf)
150
Thermal
4.9
0.28
1.25
Mix
Aggregate type
Dolomite (2)
600
Type I (1)
0.42
Curing Compound
50
Calculated
35
632.3 (calculated)
Strength
Level:3 Rupture(690) Modulus(4200000)
Identifiers
ARA

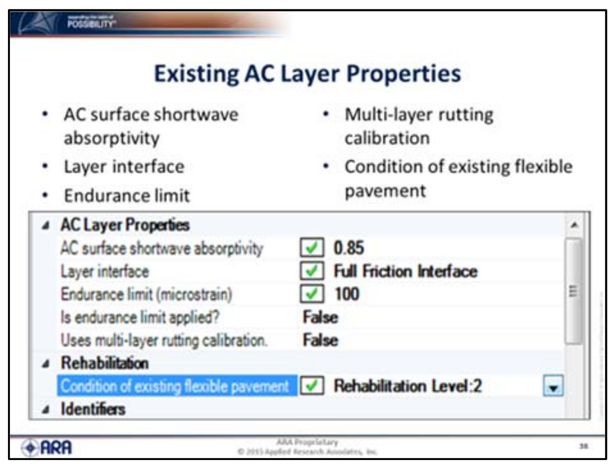

Existing AC Layer Properties
Same AC properties as for new flexible pavements .
Asphalt Layer
Thickness (in)
6
Mixture Volumetrics
Air voids (%)
7
Effective binder content (%)
9.1
Poisson's ratio
(calculated)
Unit weight (pcf)
144.5
Mechanical Properties
Asphalt binder
Level 1 - SuperPave:
Creep compliance (1/psi)
Input level:3
Dynamic modulus
Input level:2
Select HMA Estar predictive model
Use Viscosity based model (nationally calibrated).
Reference temperature (deg F)
70
Indirect tensile strength at 14 deg F (psi)
536.88
Thermal
Heat capacity (BTU/lb-deg F)
0.23
Thermal conductivity (BTU/hr-ft-deg F)
0.67
Thermal contraction
1.149E-05 (calculated)
Identifiers

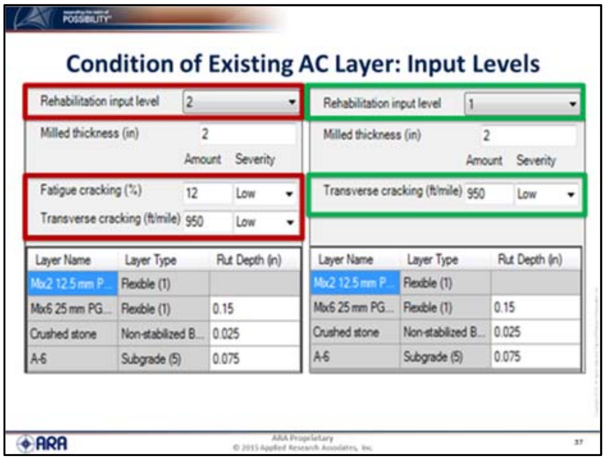

Results for Example Problem
Distress Prediction Summary
Distress Type
Distress @ Specified Reliability
Reliability (%)
Criterion Satisfied?
Target
Predicted
Target
Achieved
SJPCP longitudinal cracking (percent slabs)
10.00
5.83
90.00
99.09
Pass
Distress Charts
Longitudinal Cracking PCC
SJPCP PCC = 5.0 in.
SJPCP PCC = 4.5 in.
Slab Cracked (%)
Pavement Age (years)

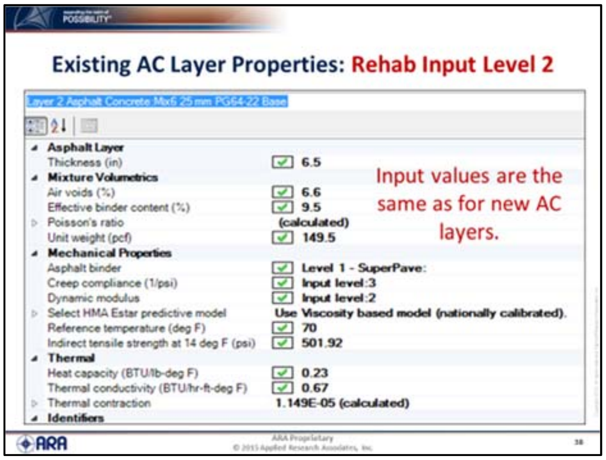

Outline
1. NARR Climate Files; Importing Files and Differences between Current Climatic Files.
2. Rehabilitation of Flexible Pavements:
a) SJPCP of Flexible Pavements.
b) In Place Damage of AC Layers: Input level 1 versus input level 2.
c) Reflection Cracking: Types of Repair Strategies and Distress Predictions.
3. Tips based on Discussion/Questions from Yesterday.

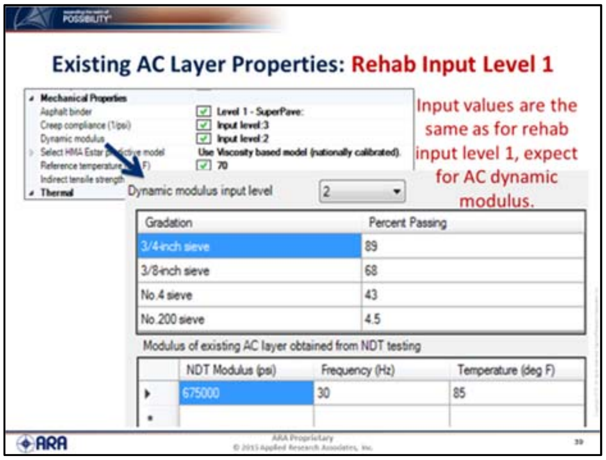

Inputs for AC over Flexible Pavement
Traffic
Climate
AC Layer Properties
Pavement Structure
Layer 1 AC Overlay
Layer 2 Flexible, AC
Layer 3 Non-Stabilized Base
Subgrade
Projects
Traffic
Climate
AC Layer Properties
Pavement Structure
Layer 1 Flexible : Mx2 12.5 mm PG76-22 Wearing
Layer 2 Flexible : Mx6 25 mm PG64-22 Base(existing)
Layer 3 Non-stabilized Base : Crushed stone
Layer 4 Subgrade : A-6
Backcalculation
New Flexible
Rehabilitation Flexible
New Rigid
Restore Rigid
Bonded Rigid
Unbonded Rigid
Sensitivity
Optimization
PDF Output Report
Excel Output Report
Multiple Project Summary
Batch Run
Tools
ME Design Calibration Factors

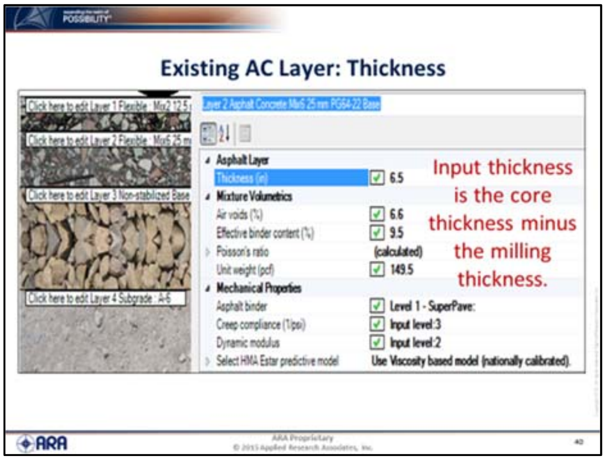

Performance or Threshold Criteria
Performance Criteria | Limit | Reliability
Initial IRI (in/mile) | 55
Terminal IRI (in/mile) | 150 | 90
AC top-down fatigue cracking (ft/mile) | 5000 | 90
AC bottom-up fatigue cracking (% lane area) | 15 | 50
AC thermal cracking (ft/mile) | 1500 | 50
Permanent deformation - total pavement (in) | 0.4 | 90
Permanent deformation - AC only (in) | 0.4 | 90
AC total fatigue cracking: bottom up + reflective (% lane area) | 15 | 90
AC total transverse cracking: thermal + reflective (ft/mile) | 1500 | 90

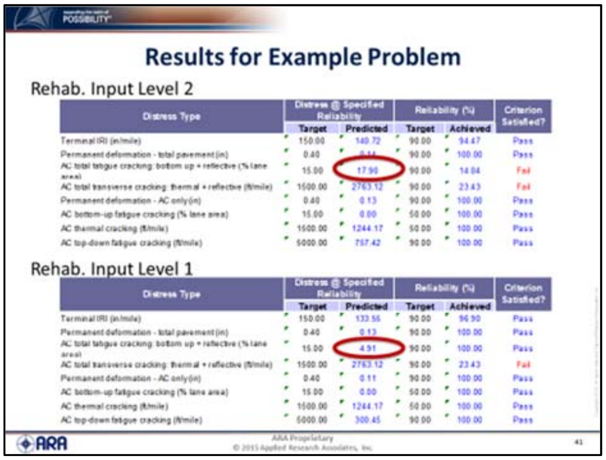

Existing AC Layer Properties
AC surface shortwave absorptivity
Layer interface
Endurance limit
Multi-layer rutting calibration
Condition of existing flexible pavement
AC Layer Properties
AC surface shortwave absorptivity
0.85
Layer interface
Full Friction Interface
Endurance limit (microstrain)
100
Is endurance limit applied?
False
Uses multi-layer rutting calibration.
False
Rehabilitation
Condition of existing flexible pavement
Rehabilitation Level:2
Identifiers


Condition of Existing AC Layer: Input Levels
Rehabilitation input level 2
Milled thickness (in) 2
Amount Severity
Fatigue cracking (%) 12 Low
Transverse cracking (ft/mile) 950 Low
Rehabilitation input level 1
Milled thickness (in) 2
Transverse cracking (ft/mile) 950 Low
Layer Name Layer Type Rut Depth (in)
Mx2 12.5 mm P... Flexible (1)
Mx6 25 mm PG... Flexible (1) 0.15
Crushed stone Non-stabilized B... 0.025
A-6 Subgrade (5) 0.075
ARA


Existing AC Layer Properties: Rehab Input Level 2
Layer 2 Asphalt Concrete Mx6 25 mm PG64-22 Base
Asphalt Layer
Thickness (in) 6.5
Mixture Volumetrics
Air voids (%) 6.6
Effective binder content (%) 9.5
Poisson's ratio (calculated)
Unit weight (pcf) 149.5
Mechanical Properties
Asphalt binder Level 1 - SuperPave:
Creep compliance (1/psi) Input level:3
Dynamic modulus Input level:2
Select HMA Estar predictive model Use Viscosity based model (nationally calibrated).
Reference temperature (deg F) 70
Indirect tensile strength at 14 deg F (psi) 501.92
Thermal
Heat capacity (BTU/lb-deg F) 0.23
Thermal conductivity (BTU/hr-ft-deg F) 0.67
Thermal contraction 1.149E-05 (calculated)
Identifiers
Input values are the same as for new AC layers.
ARA


Existing AC Layer Properties: Rehab Input Level 1
Mechanical Properties
Asphalt binder Level 1 - SuperPave:
Creep compliance (1/psi) Input level:3
Dynamic modulus Input level:2
Use Viscosity based model (nationally calibrated).
70
Thermal
Input values are the same as for rehab input level 1, expect for AC dynamic modulus.
Dynamic modulus input level 2
Gradation Percent Passing
3/4-inch sieve 89
3/8-inch sieve 68
No.4 sieve 43
No.200 sieve 4.5
Modulus of existing AC layer obtained from NDT testing
NDT Modulus (psi) Frequency (Hz) Temperature (deg F)
675000 30 85
ARA


Existing AC Layer: Thickness
Layer 2 Asphalt Concrete Mx6 25 mm PG64-22 Base
Asphalt Layer
Thickness (in) 6.5
Mixture Volumetrics
Air voids (%) 6.6
Effective binder content (%) 9.5
Poisson's ratio (calculated)
Unit weight (pcf) 149.5
Mechanical Properties
Asphalt binder Level 1 - SuperPave:
Creep compliance (1/psi) Input level:3
Dynamic modulus Input level:2
Select HMA Estar predictive model Use Viscosity based model (nationally calibrated).
Input thickness is the core thickness minus the milling thickness.
ARA


Results for Example Problem
Rehab. Input Level 2
Distress Type | Distress @ Specified Reliability: Target, Predicted | Reliability (%): Target, Achieved | Criterion Satisfied?
Terminal IRI (in/mile) 150.00 140.72 90.00 94.47 Pass
Permanent deformation - total pavement (in) 0.40 90.00 100.00 Pass
AC total fatigue cracking: bottom up + reflective (% lane area) 15.00 17.90 90.00 14.04 Fail
AC total transverse cracking: thermal + reflective (ft/mile) 1500.00 2763.12 90.00 23.43 Fail
Permanent deformation - AC only (in) 0.40 0.13 90.00 100.00 Pass
AC bottom-up fatigue cracking (% lane area) 15.00 0.00 50.00 100.00 Pass
AC thermal cracking (ft/mile) 1500.00 1244.17 50.00 100.00 Pass
AC top-down fatigue cracking (ft/mile) 5000.00 757.42 90.00 100.00 Pass
Rehab. Input Level 1
Terminal IRI (in/mile) 150.00 133.56 90.00 96.90 Pass
Permanent deformation - total pavement (in) 0.40 0.13 90.00 100.00 Pass
AC total fatigue cracking: bottom up + reflective (% lane area) 15.00 4.91 90.00 100.00 Pass
AC total transverse cracking: thermal + reflective (ft/mile) 1500.00 2763.12 90.00 23.43 Fail
Permanent deformation - AC only (in) 0.40 0.11 90.00 100.00 Pass
AC bottom-up fatigue cracking (% lane area) 15.00 0.00 50.00 100.00 Pass
AC thermal cracking (ft/mile) 1500.00 1244.17 50.00 100.00 Pass
AC top-down fatigue cracking (ft/mile) 5000.00 300.45 90.00 100.00 Pass
ARA
ARA Proprietary
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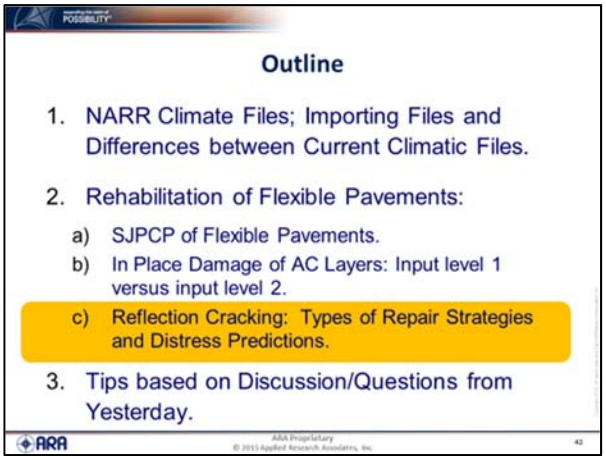
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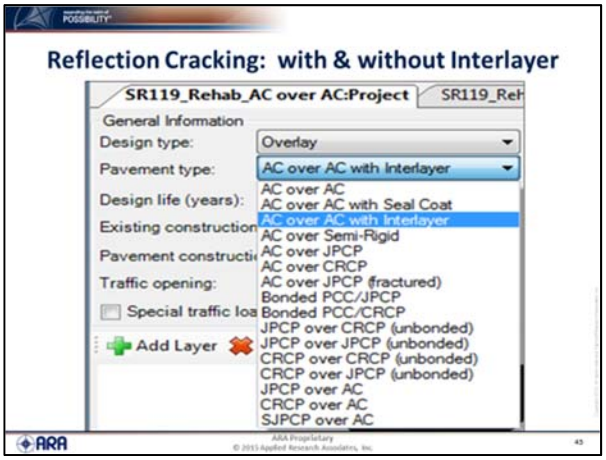
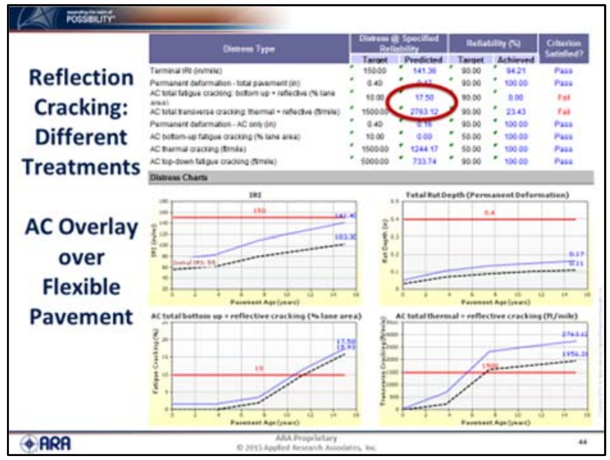
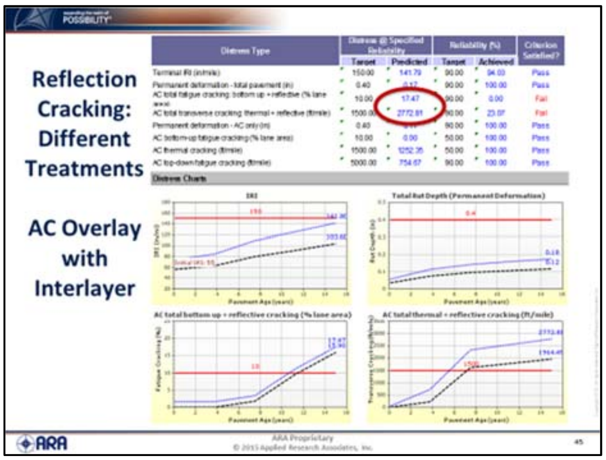
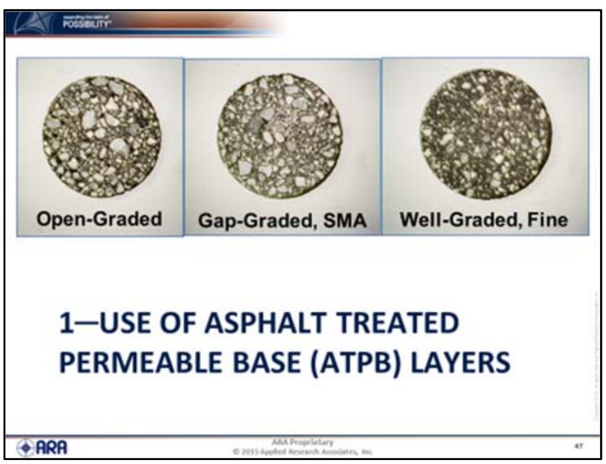
ARA


Reflection Cracking: with & without Interlayer
SR119_Rehab_AC over AC:Project
SR119_Reh
General Information
Design type:
Overlay
Pavement type:
AC over AC with Interlayer
Design life (years):
Existing construction
Pavement constructi
Traffic opening:
Special traffic loa
Add Layer
AC over AC
AC over AC with Seal Coat
AC over AC with Interlayer
AC over Semi-Rigid
AC over JPCP
AC over CRCP
AC over JPCP (fractured)
Bonded PCC/JPCP
Bonded PCC/CRCP
JPCP over CRCP (unbonded)
JPCP over JPCP (unbonded)
CRCP over CRCP (unbonded)
CRCP over JPCP (unbonded)
JPCP over AC
CRCP over AC
SJPCP over AC


Reflection Cracking: Different Treatments
AC Overlay over Flexible Pavement
Distress Type
Distress Charts

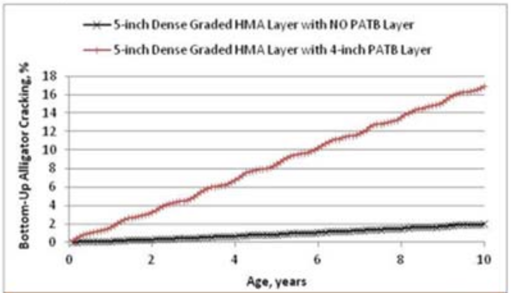

Reflection Cracking: Different Treatments
AC Overlay with Interlayer
Distress Type
Distress Charts


What You Need to Know – Topics
1. Asphalt Treated Permeable Base Layers
2. Global Plastic Deformation Constants
3. Polymer Modified Asphalt Mixtures – accounting for the benefit.


Open-Graded
Gap-Graded, SMA
Well-Graded, Fine
1—USE OF ASPHALT TREATED PERMEABLE BASE (ATPB) LAYERS


Asphalt Treated Permeable Base Mixtures
Open-Graded
Well-Graded, Fine
5-inch Dense Graded HMA Mixture
4-inch PATB Mixture; 20% Air Voids
12-inch Crushed Stone Base Layer; Good Quality
Subgrade Soil; A-2-4 Classification

Asphalt Treated Permeable Base Mixtures

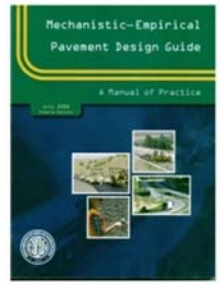


Excessive thickness resulting from high air voids & low asphalt content in lower bit. layer.

Asphalt Treated Permeable Base Mixtures

MEPDG Manual of Practice, Section 3.5 – Design Features & Factors not Included within the MEPDG Process, Page 24:

…the ATPB may be treated as a high-quality aggregate base… The resilient modulus appropriate for this simulation is 65 ksi but should be verified through local calibration…



2—GLOBAL PLASTIC DEFORMATION CONSTANTS: HMA MIXTURES UNBOUND MATERIALS/SOILS

Global Plastic Deformation Constants

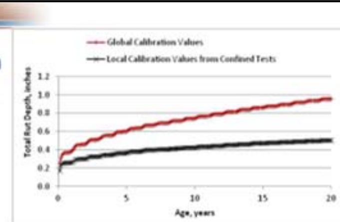
Global calibration values determined from LTPP sections with lower traffic levels.

Plastic Deformation Constants

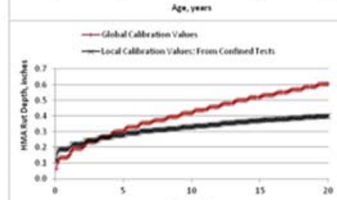
Layer	Calibration Value	
	Global	Local
HMA Layers		
Kr1; Intercept	-3.354	-2.30
Kr3; N-Exponent	**0.479**	**0.27**
Kr2; Temp. Exponent	1.5606	1.5606
Unbound Layers		
Coarse-Grained	1.0	0.3
Fine-Grained	1.0	0.3

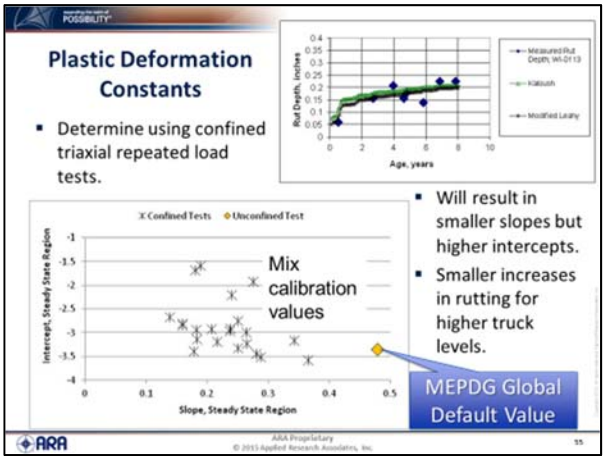
Climate – Missouri Area

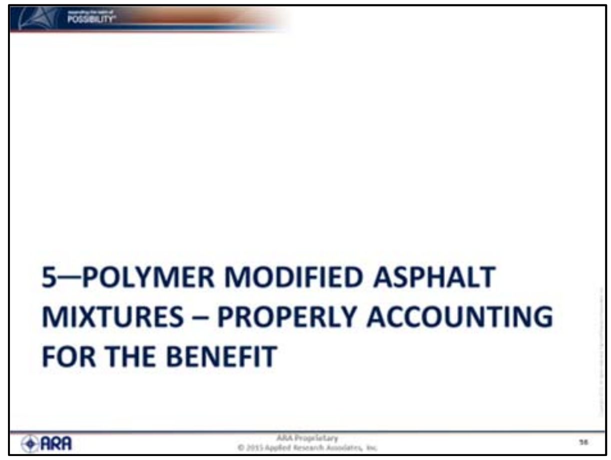
Plastic Deformation Constants; HMA & Unbound Layers

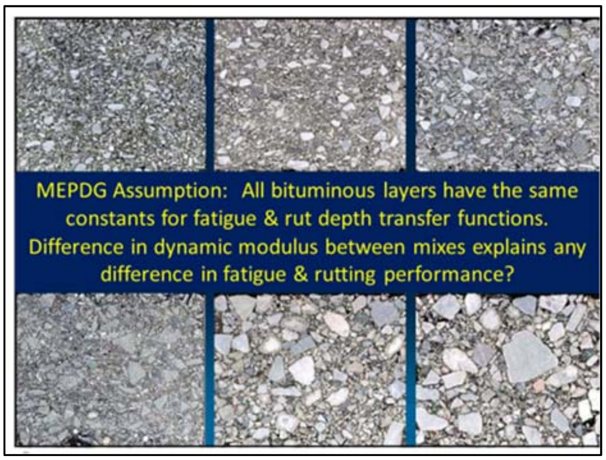


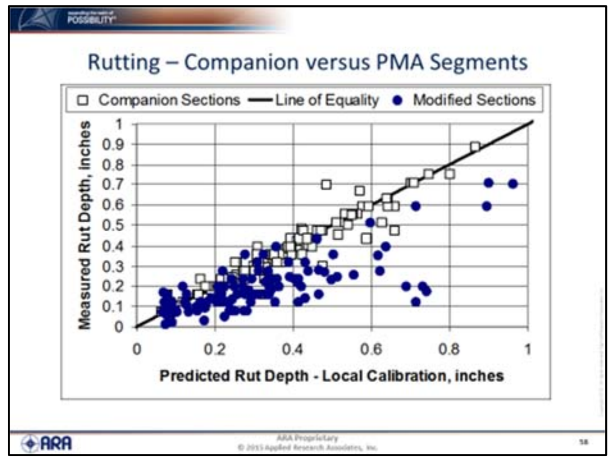
The high slope (Kr2 or exponent of N-term results in higher incremental rut depths with time for high truck traffic.

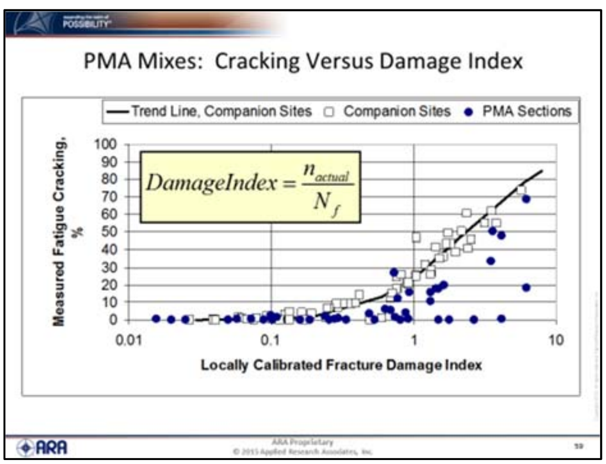


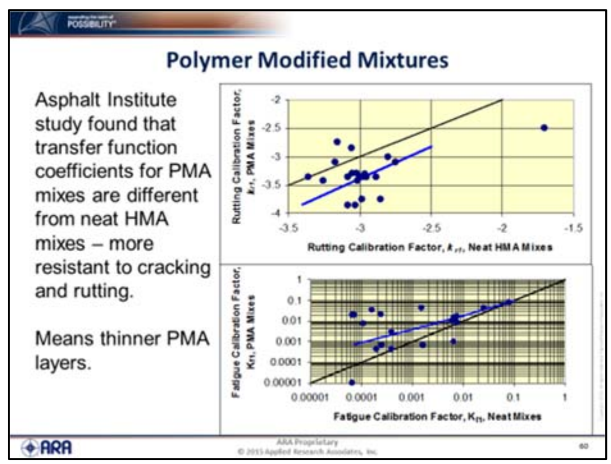

Plastic Deformation Constants
Determine using confined triaxial repeated load tests.
Mix calibration values
Will result in smaller slopes but higher intercepts.
Smaller increases in rutting for higher truck levels.
MEPDG Global Default Value
Rut Depth, inches
Age, years
Confined Tests
Unconfined Test
Intercept, Steady State Region
Slope, Steady State Region
ARA

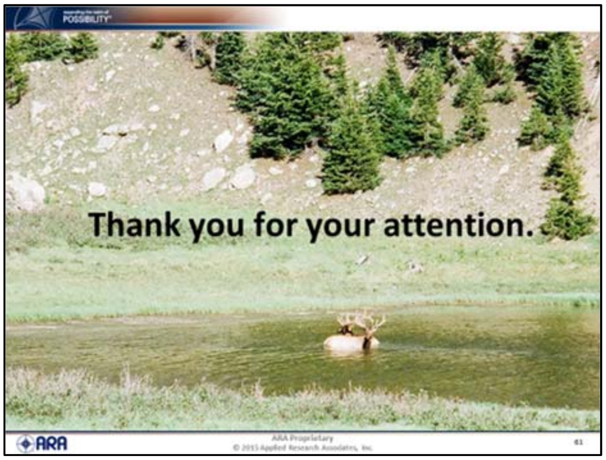

5—POLYMER MODIFIED ASPHALT MIXTURES – PROPERLY ACCOUNTING FOR THE BENEFIT
ARA


MEPDG Assumption: All bituminous layers have the same constants for fatigue & rut depth transfer functions. Difference in dynamic modulus between mixes explains any difference in fatigue & rutting performance?


Rutting – Companion versus PMA Segments
Companion Sections
Line of Equality
Modified Sections
Measured Rut Depth, inches
Predicted Rut Depth - Local Calibration, inches
ARA


PMA Mixes: Cracking Versus Damage Index
Trend Line, Companion Sites
Companion Sites
PMA Sections
$DamageIndex = \frac{n_{actual}}{N_f}$
Measured Fatigue Cracking, %
Locally Calibrated Fracture Damage Index
ARA


Polymer Modified Mixtures
Asphalt Institute study found that transfer function coefficients for PMA mixes are different from neat HMA mixes – more resistant to cracking and rutting.
Means thinner PMA layers.
Rutting Calibration Factor, k_{r1}, Neat HMA Mixes
Fatigue Calibration Factor, K_{f1}, Neat Mixes
ARA


POSSIBILITY
Thank you for your attention.
ARA
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Presentation 24—Prashant Ram, Applied Pavement Technology, Inc. (APTech)

AASHTO Pavement ME National Users Group Meeting

Clearing-House of MEPDG Research and Implementation Efforts

Prashant Ram
Applied Pavement Technology, Inc.

Indianapolis, Indiana
December 15, 2016

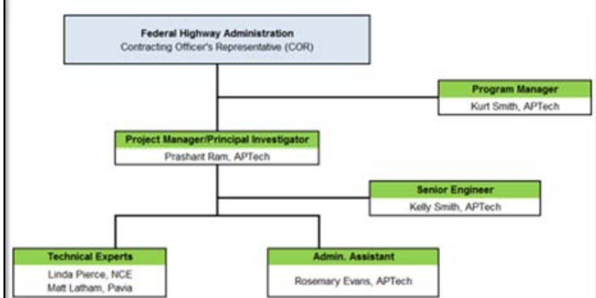
Project Background

- Numerous research and implementation efforts related to MEPDG completed and underway
  - Information from these studies of great interest to agencies using or implementing AASHTO Pavement ME Design
  - Creation of a central repository of this information would be valuable to agencies

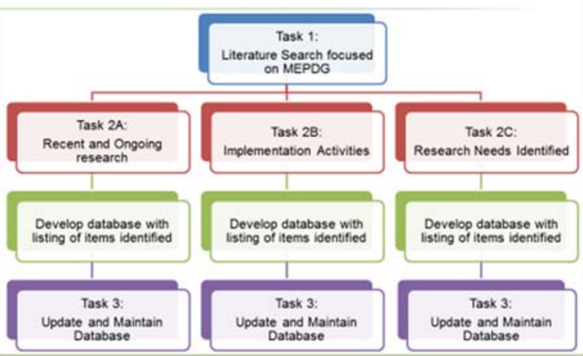
FHWA Clearing-house Project

- Initiated March 2016
- Objectives:
  - Gather current information on on-going and recently completed research and implementation efforts related to MEPDG
  - Develop a database of resources identified and host it on a dedicated FHWA website
  - Continuous monitoring of information that is relevant and useful for inclusion in the clearing-house

Project Team

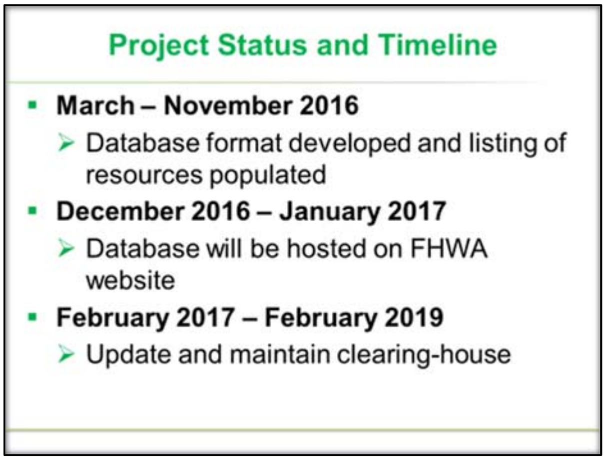


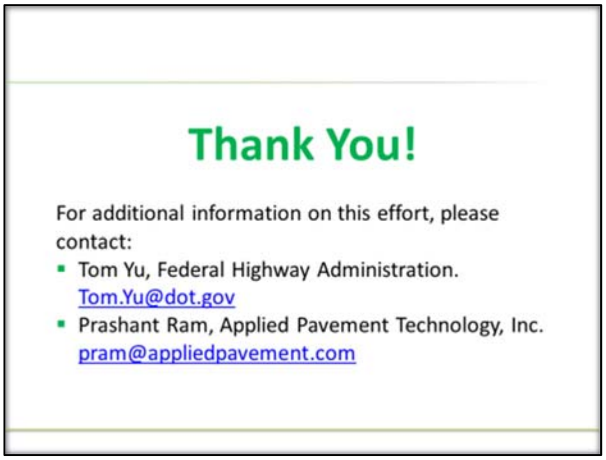
Clearing-House Development Framework



Information Housed in Database

- Project title
- Sponsoring agency and Contractor
- Type of work (e.g., NCHRP, state-sponsored, pooled-fund etc.)
- Principal Investigator
- Project status, cost and duration
- Project data (if available)
- Links to project summaries and reports


Project Status and Timeline
March – November 2016
Database format developed and listing of resources populated
December 2016 – January 2017
Database will be hosted on FHWA website
February 2017 – February 2019
Update and maintain clearing-house


Thank You!
For additional information on this effort, please contact:
Tom Yu, Federal Highway Administration. Tom.Yu@dot.gov
Prashant Ram, Applied Pavement Technology, Inc. pram@appliedpavement.com