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
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 Yes	blackburnl@dot.state.al.us shugartr@dot.state.al.us
Scott Weinland Ashek Rana	Arizona DOT	Yes No	Yes No	No No	sweinland@azdot.gov arana@azdot.gov
Mehdi Parvini	California DOT	Yes	Yes	No	Mehdi_parvini@dot.ca.gov
Jay Goldbaum Laura Conroy Melody Perkins	Colorado DOT	Yes Yes No	Yes Yes No	Yes No No	jay.goldbaum@dot.state.co.us laura.conroy@dot.state.co.us melody.perkins@dot.state.co.us
Patrick Overton	Florida DOT	Yes	Yes	No	patrick.overton@dot.state.fl.us
Nat Valesquez	Kansas DOT	No	No	No	nat.velasquez@ks.gov
Sunil Saha Joe Tucker	Kentucky TC	Yes Yes	Yes Yes	No No	sunil.saha@ky.gov joseph.tucker@ky.gov
Alauddin Ahammed William Tang	Manitoba Transportation	Yes No	Yes No	No No	alauddin.ahammed@gov.mb.ca William.Tang@gov.mb.ca
Praveen Desaraju	Maryland SHA	No	No	No	PDesaraju@mdot.state.md.us
Justin Schenkel Adnan Iftikhar	Michigan DOT	Yes No	Yes No	No No	schenkelj@michigan.gov iftikhara@michigan.gov
John Donahue Jason Blomberg Jeff Kroner	Missouri DOT	Yes Yes No	No Yes No	Yes No No	john.donahue@modot.mo.gov Jason.Blomberg@modot.mo.gov jeffery.kroner@modot.mo.gov
Yathi Yatheepan Nathan Morian	Nevada DOT	Yes No	Yes No	No No	yyatheepan@dot.state.nv.us NMorian@dot.state.nv.us
Clark Morrison Shihai Zhang	North Carolina DOT	Yes No	Yes No	Yes No	cmorrison@ncdot.gov szhang2@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	Yes No	Yes No	No No	susanne.chan@ontario.ca warren.lee@ontario.ca
Josh Freeman Lydia Peddicord	Pennsylvania DOT	Yes Yes	Yes Yes	No No	josfreeman@pa.gov lpeddicord@pa.gov
Eric Carroll Jesse Thompson	South Carolina DOT	Yes Yes	Yes Yes	No No	CarrollE@scdot.org thompsonju@scdot.org
Hari Nair Affan Habib Girum Merine	Virginia DOT	Yes Yes No	Yes Yes No	No No No	harikrishnan.nair@vdot.virginia.gov affan.habib@vdot.virginia.gov girum.merine@vdot.virginia.gov
Laura Fenley	Wisconsin DOT	Yes	Yes	No	Laura.Fenley@dot.wi.gov

Non-TAC / Non-Pooled Fund Member Participation

Name	Agency	Pvt ME Design TF Member	Email Address
Kelly Smith	APTech	No	klsmith@appliedpavement.com
Linda Pierce	NCE	No	lpierce@ncenet.com
Chadwick Becker Harold Von Quintus Shreenath Rao	ARA	No No	cbecker@ara.com hvonquintus@ara.com srao@ara.com
Nadarajah Sivaneswaran	FHWA	No	Nadarajah.Sivaneswaran@dot.gov
Mike Voth	FHWA Federal Lands	No	michael.voth@dot.gov
Bruce Dietrich	Pavement Analytics LLC	No	bdietrich@pavementanalytics.com
Clark Graves	University of Kentucky	No	clark.graves@uky.edu
Marta Juhasz	Alberta Transportation	Yes	marta.juhasz@gov.ab.ca
Ian Rish	Georgia DOT	No	irish@dot.ga.gov
LaDonna Rowden Charles Wienrank	Illinois DOT	No	LaDonna.Rowden@illinois.gov charles.wienrank@illinois.gov
Jusang Lee	Indiana DOT	No	jlee@indot.in.gov
Casey Nash	Maine DOT	No	casey.b.nash@maine.gov
Narinder Kohli	New Jersey DOT	No	Narinder.Kohli@dot.nj.gov
Naomi Gaede	New Mexico DOT	No	Naomi.Gaede@state.nm.us
Enad Mahmoud	Texas DOT	No	Enad.Mahmoud@txdot.gov
David Holmgren	Utah DOT	No	dholmgren@utah.gov
Jianhua Li	Washington State DOT	No	lijia@wsdot.wa.gov

Academia/Consultant/Industry Representative Participation

Name	Agency	Pvt ME Design TF Member	Email Address
Halil Ceylan	Iowa State University	No	hceylan@iastate.edu
Richard Kim	North Carolina State University	No	kim@ncsu.edu
Joshua Li	Oklahoma State University	No	qiang.li@okstate.edu
Fouad Bayomy Ahmed Muftah Emad Kassem	University of Idaho	No No No	bayomy@uidaho.edu muftah@uidaho.edu ekassem@uidaho.edu
Pan Lu	North Dakota State University	No	pan.lu@ndsu.edu; lupan79@hotmail.com
Hao Wang	Rutgers University	No	hw261@soe.rutgers.edu
Jesse Kwilosz	Transtec	No	jesseks@thetranstecgroup.com
Scot Schwandt	Kiewit Engineering Group	No	Scot.Schwandt@Kiewit.com
Angela Folkestad	ACPA-CO/WY Chapter	No	afolkestad@pavement.com
Mike Skinner	Colorado Asphalt Association	No	mikeskinner@co-asphalt.com
Feng Mu	CEMEX	No	feng.mu@cemex.com

APPENDIX B. MEETING AGENDA

Wednesday, October 11

Time	Topic
8:00–8:45 AM	WELCOME AND INTRODUCTIONS Welcome | Chris Wagner (FHWA). Introduction and Remarks | John Donahue (Missouri DOT, AASHTO Subcommittee on Materials and Pavements Executive Committee, and Chair of AASHTOWare Pavement ME Design Taskforce) Remarks on Canadian efforts | Marta Juhasz (Alberta Transportation) Review of agenda and meeting goals | Linda Pierce (NCE) and Kelly Smith (APTech)
8:45–9:45 AM	AGENCY IMPLEMENTATION STATUS Implementation map updates and agency reports on implementation plans, timelines, and progress | Linda Pierce (NCE) and Kelly Smith (APTech)
9:45–10:00 AM	BREAK
10:00–11:00 AM	AASHTOWARE PAVEMENT ME DESIGN SOFTWARE UPDATE Announcements and news regarding latest software and purchasing/licensing | John Donahue Software enhancements/updates, including new features/capabilities | Chad Becker (ARA) Backcalculation Module | Harold Von Quintus (ARA)
11:00 AM–NOON	AGENCY IMPLEMENTATION EXPERIENCES ME Design Implementation | Lydia Peddicord (Pennsylvania DOT) ME Design Implementation | Joe Tucker (Kentucky Transportation Cabinet)
NOON–1:15 PM	LUNCH (ON YOUR OWN)
1:15–2:15 PM	AGENCY IMPLEMENTATION EXPERIENCES (continued) Modeling Stabilized Materials | Affan Habib (Virginia DOT) Multi-Agency Effort to Prepare Data for Pavement ME Design | Joshua Li (Oklahoma State U.)
2:15–2:45 PM	REHABILITATION DESIGN Concrete Overlays | Halil Ceylan (Iowa State U.)
2:45–3:00 PM	BREAK
3:00–3:30 PM	REHABILITATION DESIGN (continued) Dynamic Modulus of Cold In-Place Recycling | Jay Goldbaum (Colorado DOT)
3:30–4:45 PM	ME RESEARCH FHWA Research Summary | Tom Yu (FHWA) NCHRP Research Summary | Linda Pierce (NCE) Top-Down Cracking Model (NCHRP 1-52) | Linda Pierce (NCE) Unbound Materials (NCHRP 1-53) | Linda Pierce (NCE)
4:45–5:00 PM	DAY ONE KEY TAKE-AWAYS Discuss key takeaways of day one | All

Thursday, October 12

Time	Topic
8:00–8:45 AM	PERFORMANCE CRITERIA Rational Basis for Establishing Performance Criteria Thresholds | Tom Yu (FHWA) State Perspectives on Selection of Thresholds | State Agency Panel Discussion
8:45–10:00 AM	LOCAL CALIBRATION EXPERIENCES Calibration of Pavement ME Design Software for Idaho | Fouad Bayomy (U. of Idaho) MEPDG Design Parameters for Ontario and Canada | Warren Lee and Susanne Chan (Ontario Ministry of Transportation) Automated Calibration Process | John Donahue
10:00–10:15 AM	BREAK
10:15 AM–NOON	SOFTWARE TRAINING Live demonstration-based training on new software features and example applications | Harold Von Quintus and Chad Becker (ARA)
NOON–1:15 PM	LUNCH (ON YOUR OWN)
1:15–3:00 PM	SOFTWARE TRAINING (Continued) Live demonstration-based training on new software features and example applications | Harold Von Quintus and Chad Becker (ARA)
3:00–3:15 PM	BREAK
3:15–4:00 PM	RESEARCH AND TRAINING NEEDS Future of ME Design (narrated presentation) | Kevin Hall (U. of Arkansas) Additional training, software, and research needs, including future pavement ME design enhancements, additional web-based training | All agencies
4:00–4:30 PM	CHALLENGES/ISSUES/ROADBLOCKS Common challenges/issues/roadblocks that can be resolved at the regional level rather than by each SHA
4:30–4:45 PM	DAY TWO KEY TAKE-AWAYS Discuss key takeaways of day two | All Concluding remarks

APPENDIX C. MEETING PRESENTATIONS

Presentation 1—John Donahue, Missouri DOT 60
Presentation 2—Marta Juhasz, Alberta Transportation 61
Presentation 3—Kelly Smith, APTech 62
Presentation 4—John Donahue, Missouri DOT 65
Presentation 5—Chad Becker, Applied Research Associates Inc. (ARA) 68
Presentation 6—Harold Von Quintus, ARA 73
Presentation 7—Lydia Peddicord, Pennsylvania DOT 77
Presentation 8—Joe Tucker, Kentucky Transportation Cabinet 83
Presentation 9—Affan Habib, Virginia DOT 89
Presentation 10—Joshua Li, Oklahoma State University 94
Presentation 11—Halil Ceylan, Iowa State University 100
Presentation 12—Jay Goldbaum, Colorado DOT 110
Presentation 13—Linda Pierce, NCE 114
Presentation 14—Linda Pierce, NCE 115
Presentation 15—Linda Pierce, NCE 118
Presentation 16—Tom Yu, FHWA 120
Presentation 17—Fouad Bayomy, University of Idaho 123
Presentation 18—Warren Lee and Susanne Chan, Ministry of Transportation Ontario 131
Presentation 19—John Donahue, Missouri DOT 136
Presentation 20—Harold Von Quintus and Chad Becker, ARA 140
Presentation 21—Kevin Hall, University of Arkansas 155

Presentation 1—John Donahue, Missouri DOT

AASHTO Pavement ME National Users Group Meeting Updates

Denver, CO
10/11/201
7

John Donahue

Pavement ME Design Updates

- Version 2.4
  - July 2017 rollout
  - Backcalculation Tool (BcT)
- Version 2.5
  - January 2018
  - Global recalibration of flexible and semi-rigid models
  - MERRA weather data
  - MOP integration

COMP

- AASHTO JTCOP and SOM merged into new Committee on Materials and Pavements (COMP)
- Membership expanded to allow pavement design engineer reps from each State.
  - DAMS supporters allowed two ‘scholarships’ for travel expenses

COMP

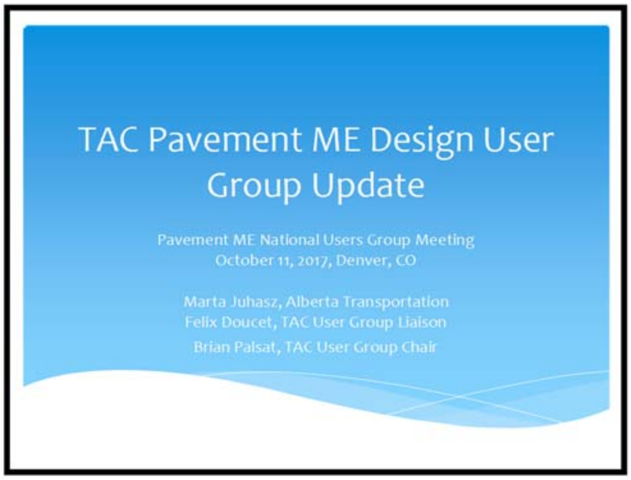
- New Tech Section 5d for Pavement Design will be created
  - Manual of Practice (MOP)
  - Local Calibration Guide
  - Pavement Handbook

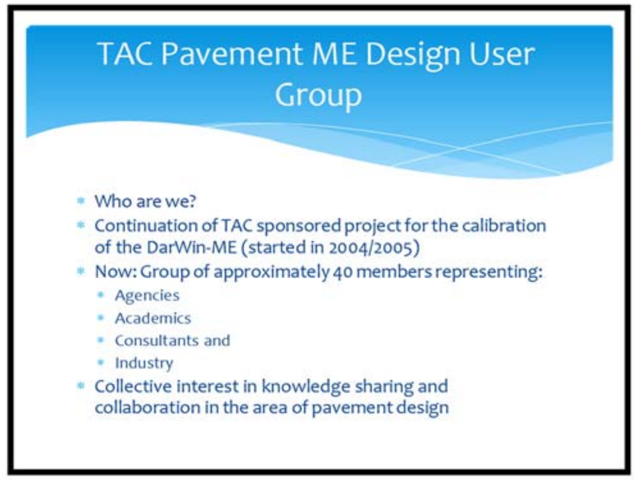
Future Enhancements ~ FY 19

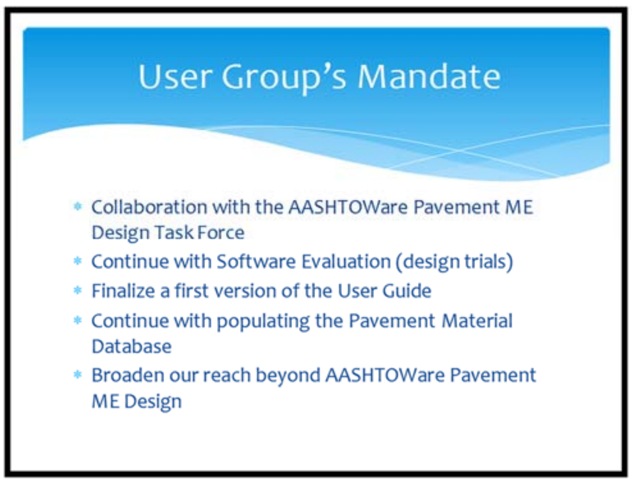
- Integrating Geosynthetics (1-50)
- Top Down Cracking Model and Transfer Function (1-52)
- Slab / Underlying Layer Interaction (1-51)
- Automated Local Calibration

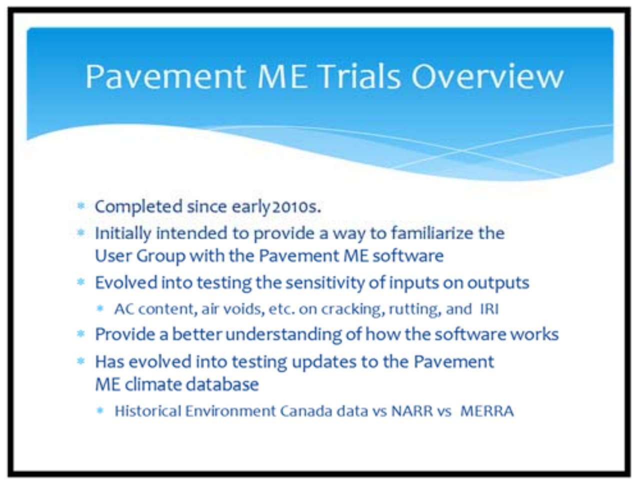
Possible RIPI funding

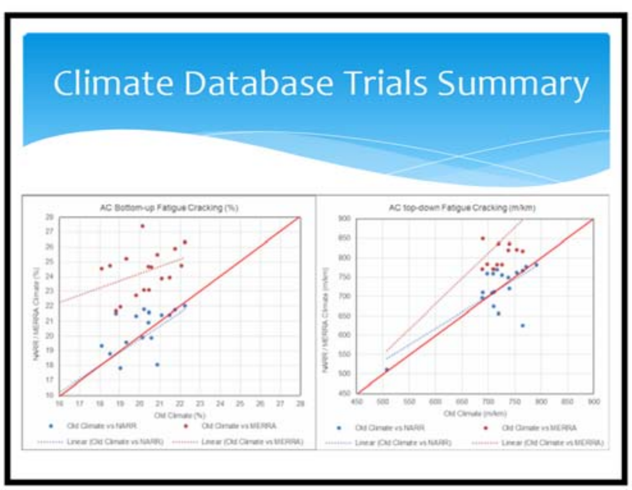
Presentation 2—Marta Juhasz, Alberta Transportation

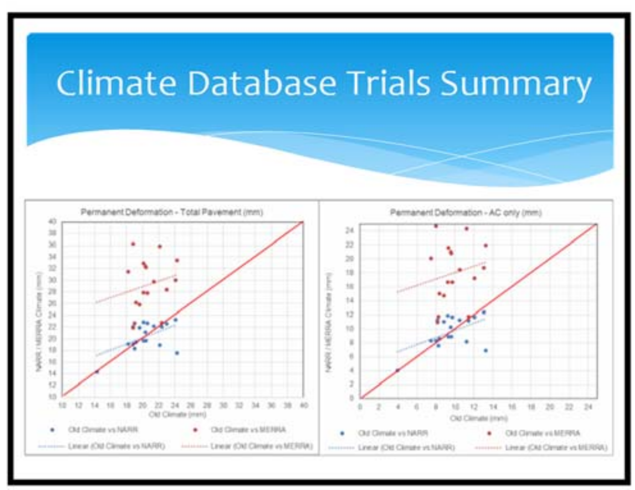




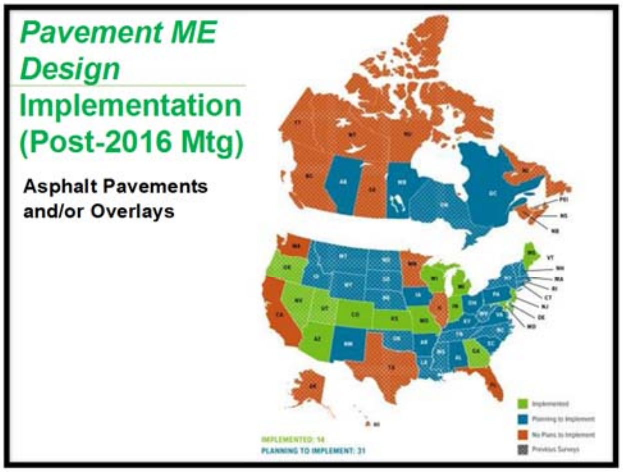


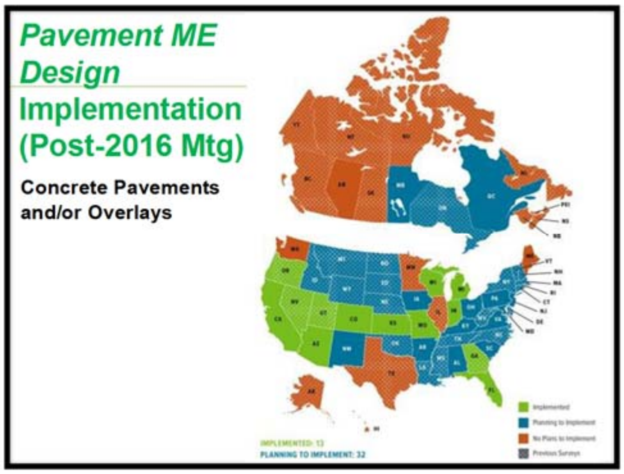


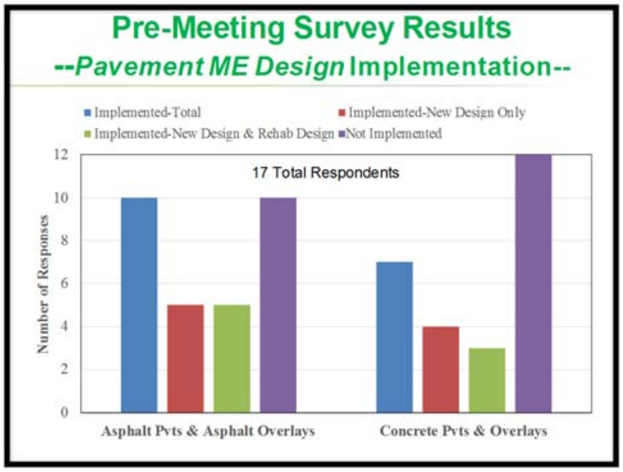


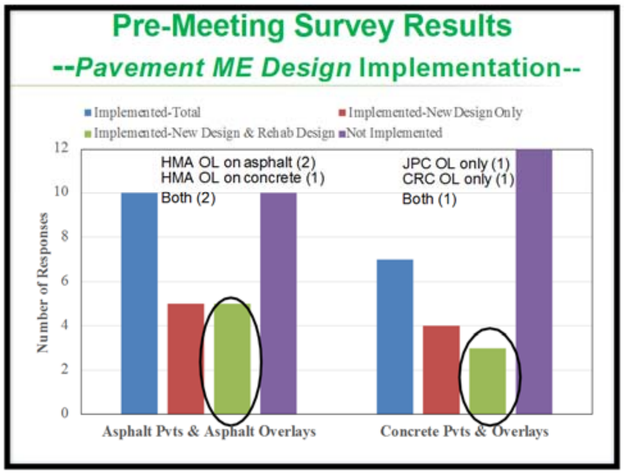


Presentation 3—Kelly Smith, APTech





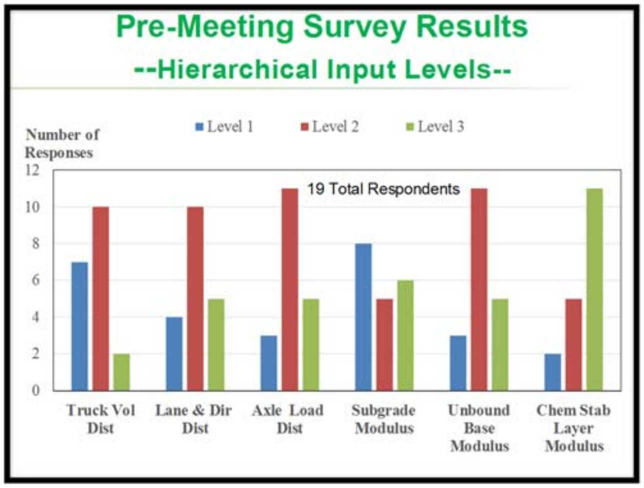


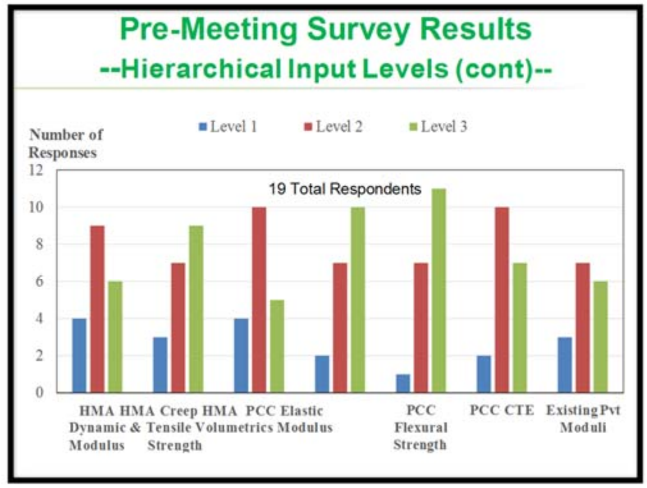


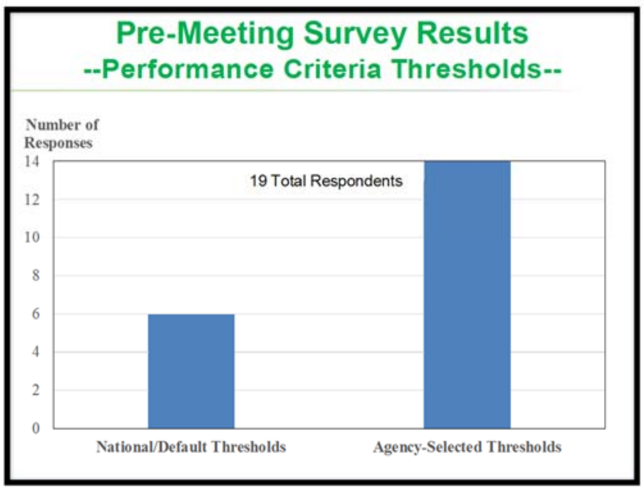
Pre-Meeting Survey Results

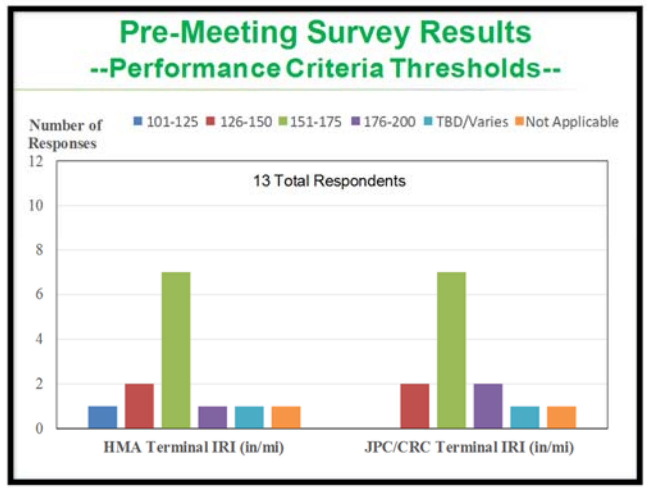
--Top Implementation Challenges--

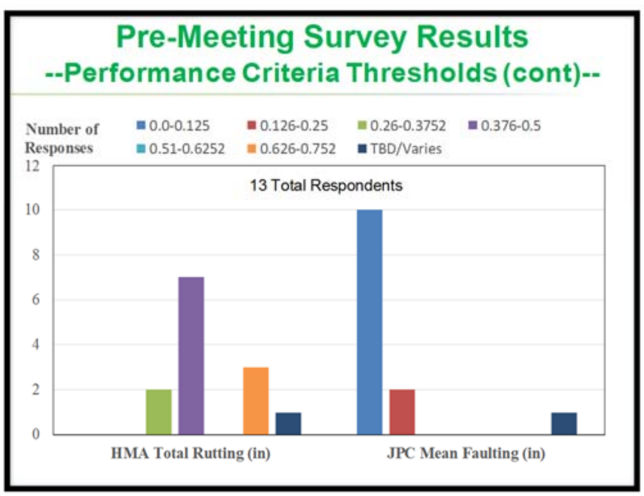
- Local calibration/verification of performance model coefficients (7)
- Designing pavements with features not included in ME or that have not been calibrated (5)
- Characterization of HMA properties (4)
- Availability of performance data to adequately perform local calibration/verification (4)
- Characterization of existing pavement and subgrade via backcalculation analysis (2)
- Characterization of traffic (2), PCC properties (2)

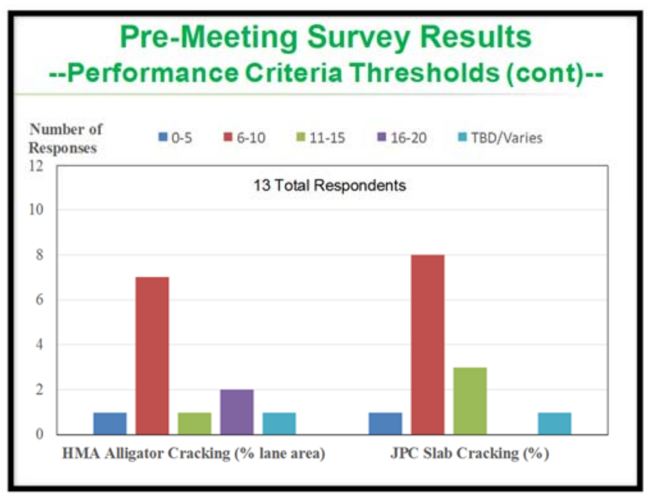

Pre-Meeting Survey Results
--Hierarchical Input Levels--
Number of Responses
Level 1
Level 2
Level 3
19 Total Respondents
Truck Vol Dist
Lane & Dir Dist
Axle Load Dist
Subgrade Modulus
Unbound Base Modulus
Chem Stab Layer Modulus


Pre-Meeting Survey Results
--Hierarchical Input Levels (cont)--
Number of Responses
Level 1
Level 2
Level 3
19 Total Respondents
HMA Dynamic Modulus
HMA Creep & Tensile Strength
HMA Volumetrics
PCC Elastic Modulus
PCC Flexural Strength
PCC CTE
Existing Pvt Moduli


Pre-Meeting Survey Results
--Performance Criteria Thresholds--
Number of Responses
19 Total Respondents
National/Default Thresholds
Agency-Selected Thresholds


Pre-Meeting Survey Results
--Performance Criteria Thresholds--
Number of Responses
101-125
126-150
151-175
176-200
TBD/Varies
Not Applicable
13 Total Respondents
HMA Terminal IRI (in/mi)
JPC/CRC Terminal IRI (in/mi)


Pre-Meeting Survey Results
--Performance Criteria Thresholds (cont)--
Number of Responses
0.0-0.125
0.126-0.25
0.26-0.3752
0.376-0.5
0.51-0.6252
0.626-0.752
TBD/Varies
13 Total Respondents
HMA Total Rutting (in)
JPC Mean Faulting (in)


Pre-Meeting Survey Results
--Performance Criteria Thresholds (cont)--
Number of Responses
0-5
6-10
11-15
16-20
TBD/Varies
13 Total Respondents
HMA Alligator Cracking (% lane area)
JPC Slab Cracking (%)

Pavement ME Design Implementation

- Has your agency implemented PMED for asphalt pavements/overlays? For concrete pavements/ overlays?
  - If not, does it plan to? When?
- What key issues has your agency experienced during implementation?
  - What was done to address the issues?
- Local calibration(s) performed? Calibrated models being used?
- PMED officially being used? Parallel with DARWin?

3 MINUTE TIME LIMIT

Pre-Meeting Survey Results
--Suggested Software Improvements--

- Sensitivity to unbound layer stiffness/thickness and subgrade stiffness
- Add "streamline" calibration tool or application
- Include module for stabilized full-depth recycling
- Add option for selecting new models or old models
- More user-friendly interface
- Ability to customize report to reflect only distresses considered by agency
- Reduce frequency of software version releases to just critical ones
- Interactive app/function to show significance of inputs

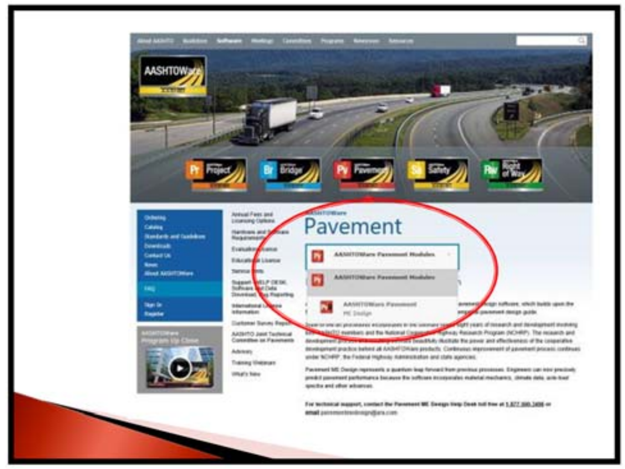
Pre-Meeting Survey Results
--Research Needs Requests--

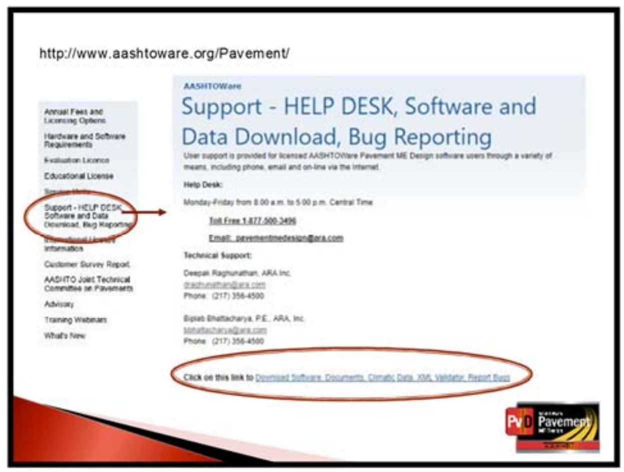
- Frost and swelling issues in performance prediction
- Improved HMA top-down and bottom-up cracking models
- Re-calibrated PCC faulting and widened slab models
- CTE and how it affects faulting
- Ability to model SMA, UBWC, and open-graded seal coat
- ME Design for chip seal over flexible base
- Detailed manual on updates performed since NCHRP 1-37A
- Calibration info and clarified sequence of steps
- Characterization of CIR, CCPR, and FDR
- Improved characterization of SMA (marginal benefit)
- Review and recalibration of semi-rigid model

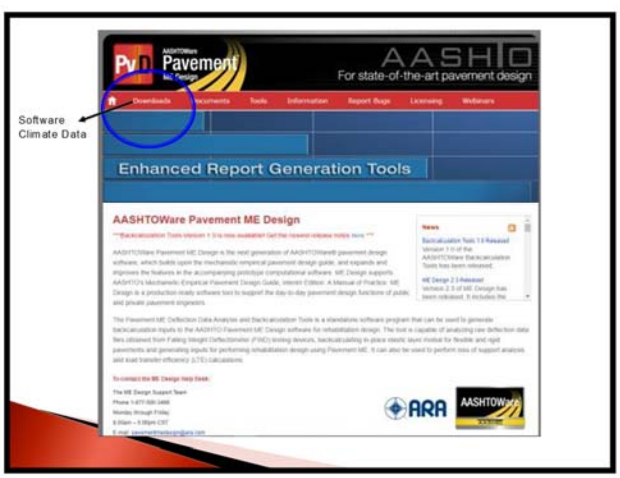
Pre-Meeting Survey Results
--Training Needs--

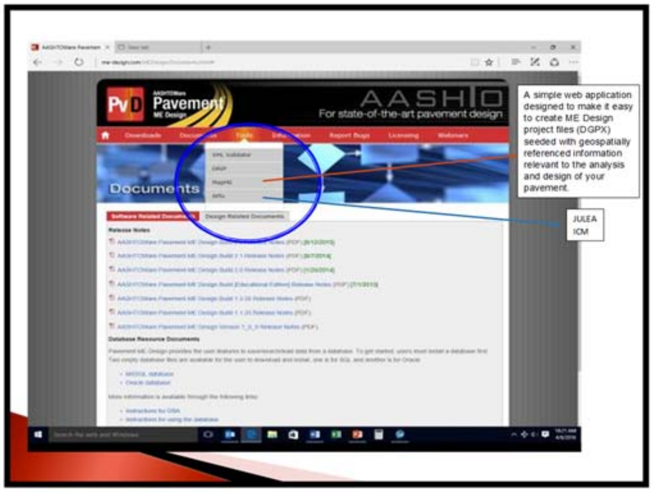
- How to qualify and quantify existing pavement characteristics for ME design
- In-depth training by developers
- For implementing agencies, fundamental training in modeling, material characterization, and calibration.

Presentation 4—John Donahue, Missouri DOT

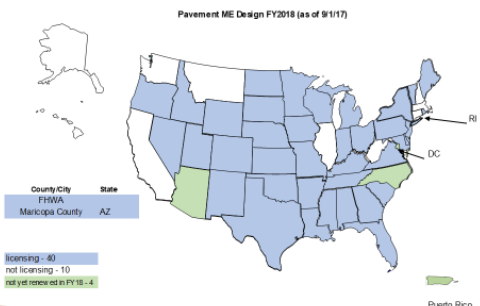








AASHTOWare Pavement ME Design Licensee Map – United States



AASHTOWare Pavement ME Design Licensee Map – Canada

Additional License Types as of 9/1/17

	2017	2018
No Cost Educational	51	39
Private Sector	73	67
Universities	17	9
Local Agencies	1	1
30-Day Evaluation	2	2
International	14	

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

Enhancements for Next Release

The next release, v2.5, is scheduled for January 1, 2018 and will include

1. Integrated MEDPDG Manual of Practice (MOP)
2. Recalibration Plan for Flexible and Semi-Rigid Pavements: Both New and Rehabilitated Pavements
3. Technical Audit Corrections, Recalibration and LTPP MERRA Data.

SHRP2 R23

The rePave scoping tool from the SHRP2 R23 project is an interactive web-based pavement design scoping tool that provides guidance for deciding where and under what conditions to use existing pavement as part of roadway renewal projects.

After discussions with and at FHWA's request, AASHTO submitted technical and cost proposals for ARA and webhosting provider Pavia Systems' to transition the rePave tool to AASHTOWare per FHWA's Work Order Amendment request.

It is intended that the rePave tool be included in the Pavement ME Design tool box.

AASHTOWare Pavement ME Design Product Task Force

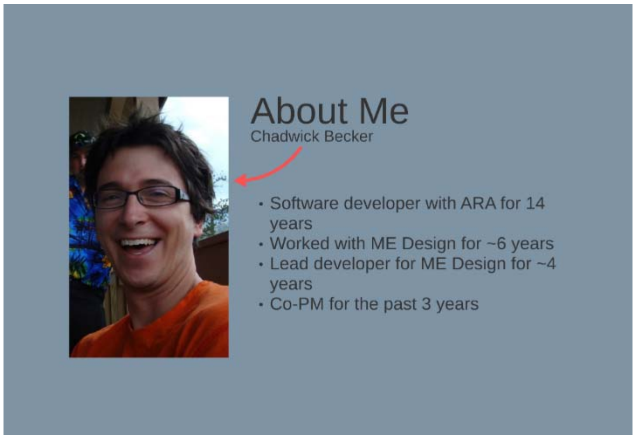
John Donahue, Chair, Missouri DOT
Jay Goldbaum, Colorado DOT
Marta Juhasz, Alberta Transportation
Clark Morrison, North Carolina DOT
Robert Shugart, Alabama DOT
Patrick Bierl, Ohio DOT

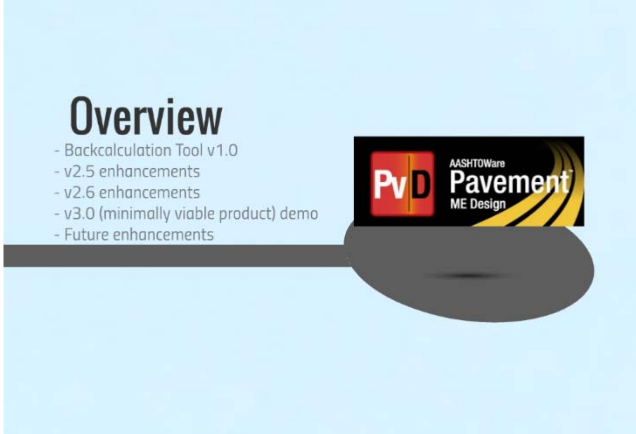
Liaisons:
Tom Yu, FHWA
Felix Doucet, Ministère des Transports du Québec - TAC
Jack Dartman, Montana DOT - TAA
Shane Marshall, Utah DOT - SCOA

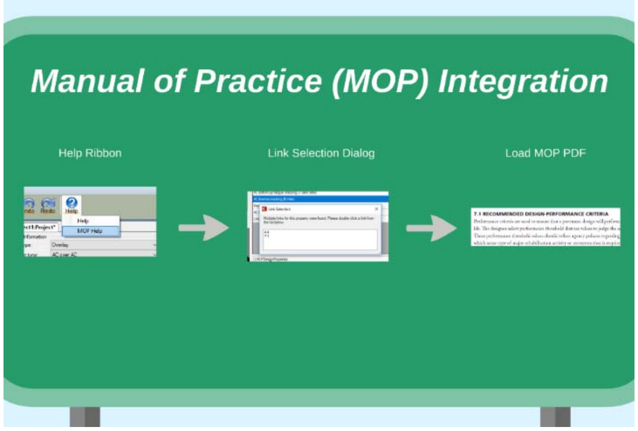
For Additional Information:

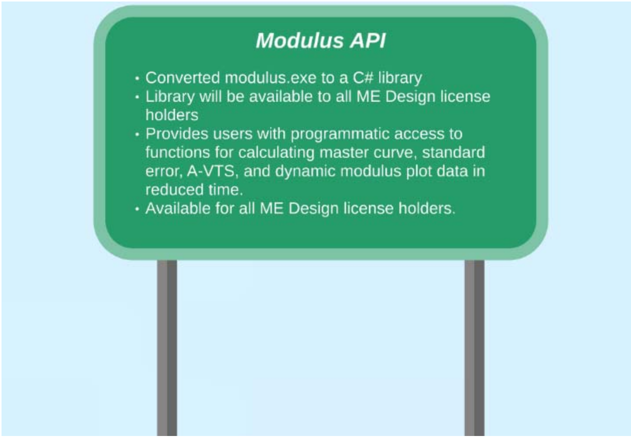
Vicki Schofield
AASHTO Project Manager
vschofield@aashto.org
(202) 624-3640

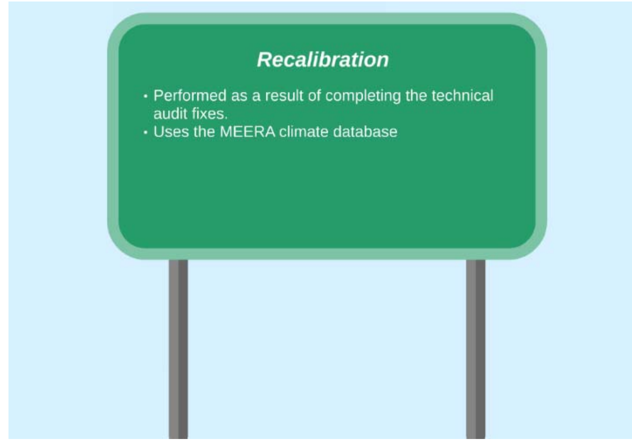
Presentation 5—Chad Becker, Applied Research Associates Inc. (ARA)





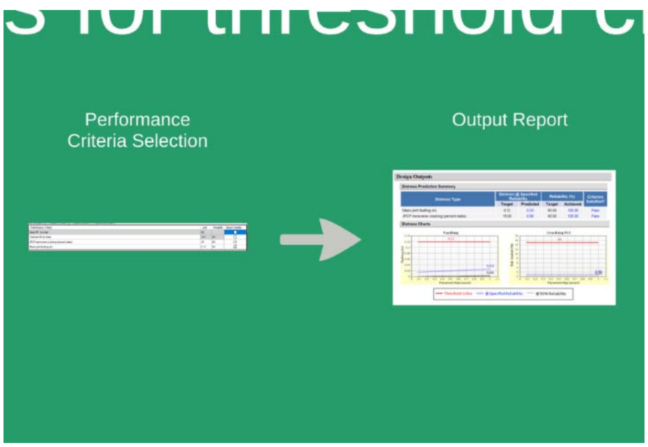


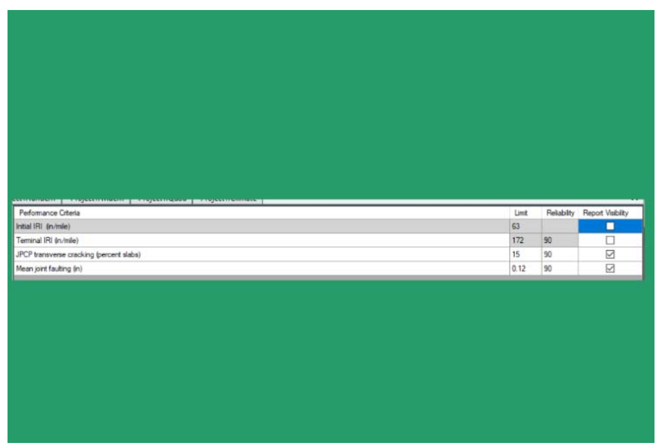

Modulus API
• Converted modulus.exe to a C# library
• Library will be available to all ME Design license holders
• Provides users with programmatic access to functions for calculating master curve, standard error, A-VTS, and dynamic modulus plot data in reduced time.
• Available for all ME Design license holders.

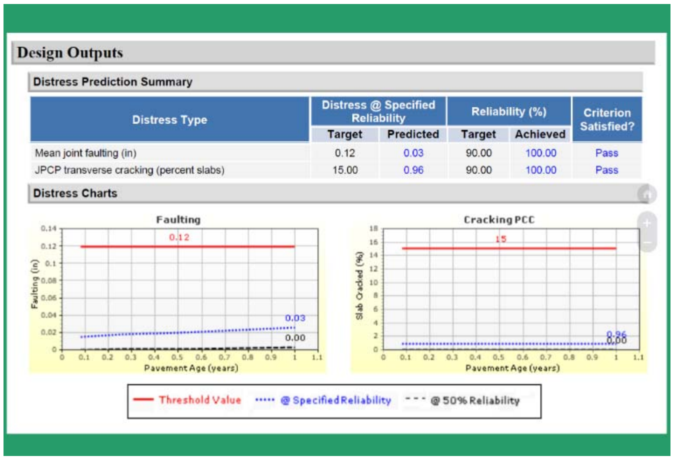

Recalibration
• Performed as a result of completing the technical audit fixes.
• Uses the MEERA climate database

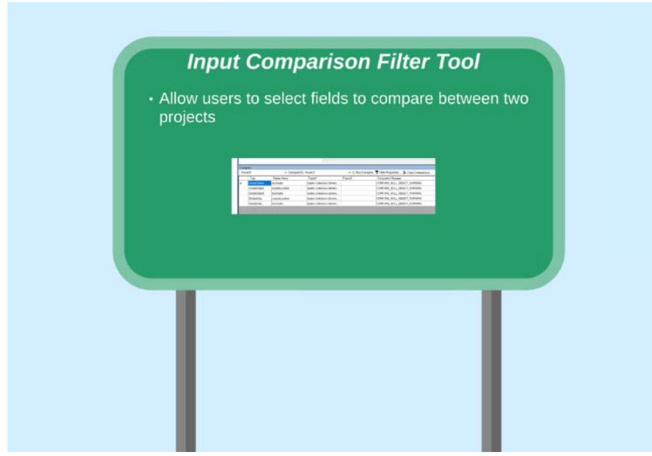

v2.6
Jul 2018
Features
• Report Customization
• Input Comparison Filter Tool
• Maintenance Strategy Module
• Level 1 Tensile Strength

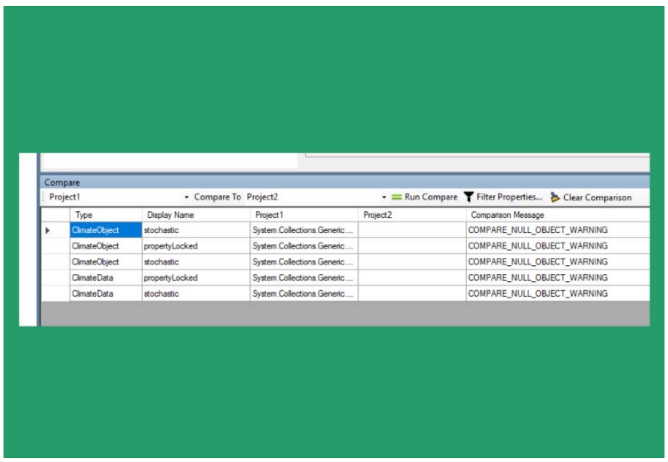

Report Customization
• Allows selection of specific performance criteria for report visualization (PDF and Excel)
• Performance criteria not selected will not be visible in the output report, nor considered during optimization or sensitivity runs for threshold checks.


Performance
Criteria Selection
Output Report


Performance Criteria
Limit
Reliability
Report Visibility
Initial IRI (in/mile)
63
Terminal IRI (in/mile)
172
90
JPCP transverse cracking (percent slabs)
15
90
Mean joint faulting (in)
0.12
90

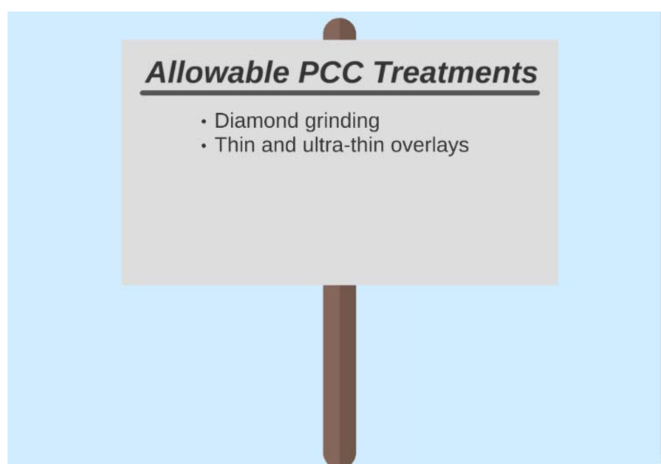

Design Outputs
Distress Prediction Summary
Distress Type
Distress @ Specified Reliability
Target
Predicted
Reliability (%)
Target
Achieved
Criterion Satisfied?
Mean joint faulting (in) 0.12 0.03 90.00 100.00 Pass
JPCP transverse cracking (percent slabs) 15.00 0.96 90.00 100.00 Pass
Distress Charts
Faulting
Faulting (in)
Pavement Age (years)
Cracking PCC
Slab Cracked (%)
Pavement Age (years)
Threshold Value
@ Specified Reliability
@ 50% Reliability


Input Comparison Filter Tool
• Allow users to select fields to compare between two projects


Compare
Project1
Compare To Project2
Run Compare
Filter Properties...
Clear Comparison
Type
Display Name
Project1
Project2
Comparison Message
ClimateObject stochastic System.Collections.Generic... COMPARE_NULL_OBJECT_WARNING
ClimateObject propertyLocked System.Collections.Generic... COMPARE_NULL_OBJECT_WARNING
ClimateObject stochastic System.Collections.Generic... COMPARE_NULL_OBJECT_WARNING
ClimateData propertyLocked System.Collections.Generic... COMPARE_NULL_OBJECT_WARNING
ClimateData stochastic System.Collections.Generic... COMPARE_NULL_OBJECT_WARNING


Maintenance Strategy Module
• Allow users to consider pavement preservation or preventative maintenance activities during the design period by resetting the performance parameters of the pavement
• Based around NCHRP Report #810 and Project 01-48
• Addendum to MOP will describe rules for applying specific maintenance types


Allowable AC Treatments
• Cold milling with other treatments
• Scratch layer with other treatments
• Micro-surfacing
• Thin and ultra-thin overlays
• Hot in place recycling with seal coat

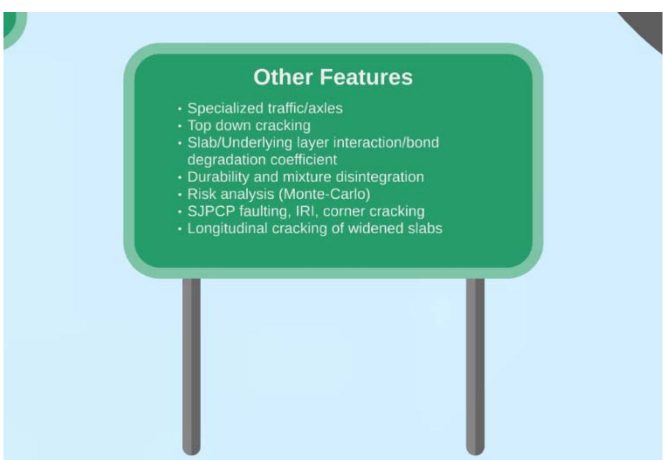

Allowable PCC Treatments
• Diamond grinding
• Thin and ultra-thin overlays

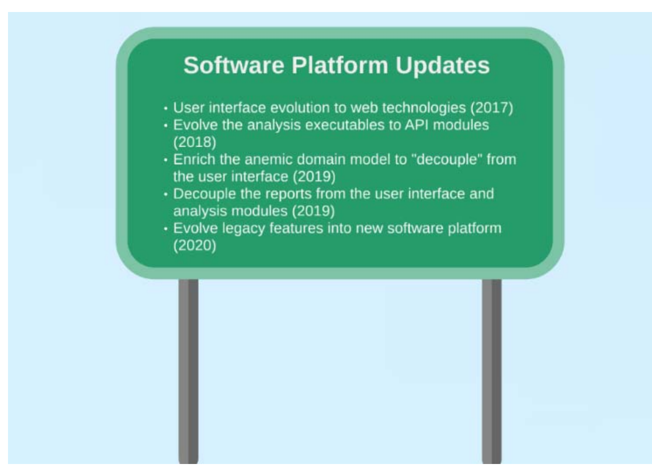

Level 1 and 2 Tensile Strength
• Input level 2 (changes): Include the normalized Molenaar indirect tensile strength versus temperature relationship for prediction of transverse cracks.
• Input level 1 (new): Allow input for three tensile strengths measured at different test temperatures 14 ºF, 30 ºF, and 40 ºF. The temperatures will be modified to select the "best" test temperatures for adjusting Molenaar's normalized relationship to fit the input level 1 strength data.


v3.0 Demo
Web technology application - MVP


Future Enhancements
• ME Design v3.x
• ME Design v2.7+
1

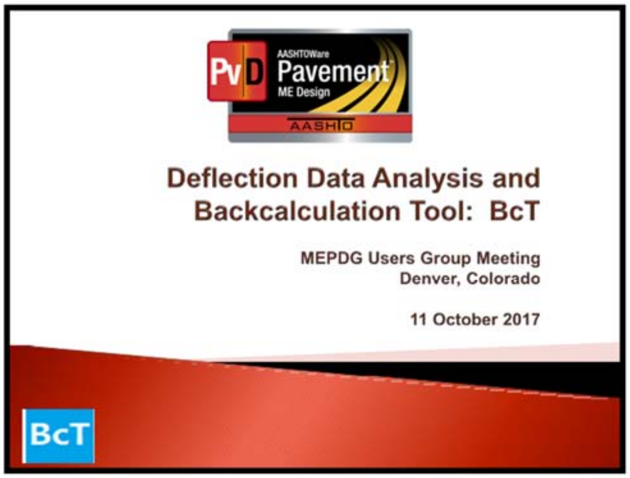

New Design Strategies
New Design Strategies
• New Composite Pavements
• Geosynthetics

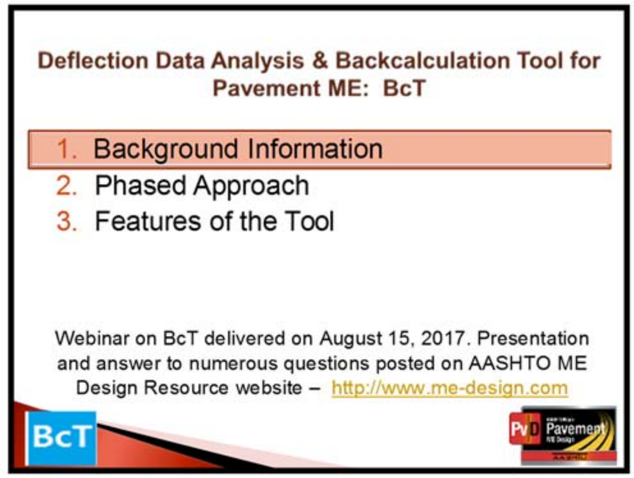

Other Features
• Specialized traffic/axles
• Top down cracking
• Slab/Underlying layer interaction/bond degradation coefficient
• Durability and mixture disintegration
• Risk analysis (Monte-Carlo)
• SJPCP faulting, IRI, corner cracking
• Longitudinal cracking of widened slabs

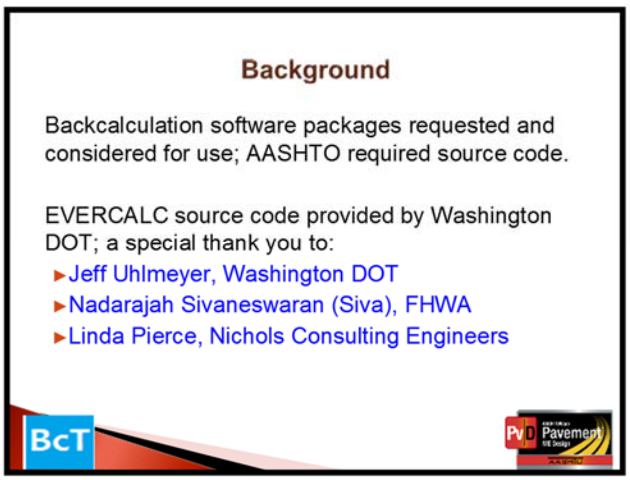

Software Platform Updates
• User interface evolution to web technologies (2017)
• Evolve the analysis executables to API modules (2018)
• Enrich the anemic domain model to "decouple" from the user interface (2019)
• Decouple the reports from the user interface and analysis modules (2019)
• Evolve legacy features into new software platform (2020)

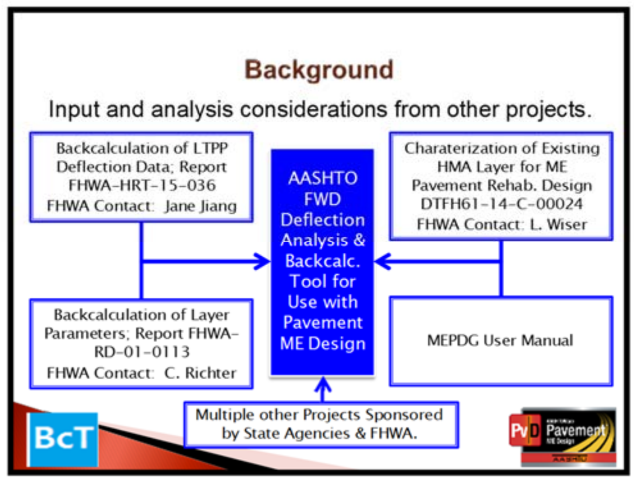

AASHTOWare Pavement ME Design
Enhancements and Future Outlook

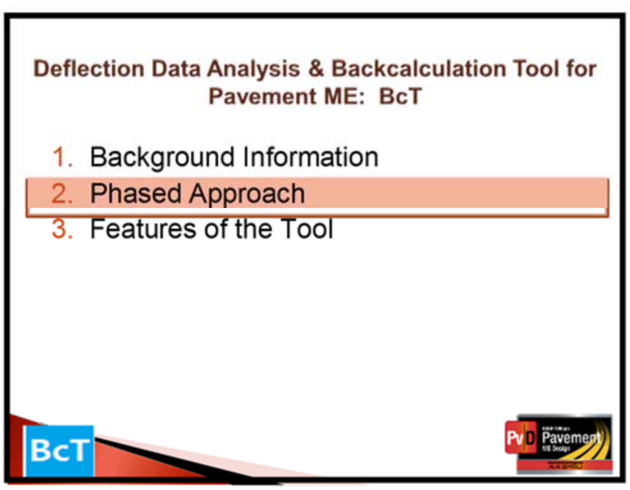
Presentation 6—Harold Von Quintus, ARA

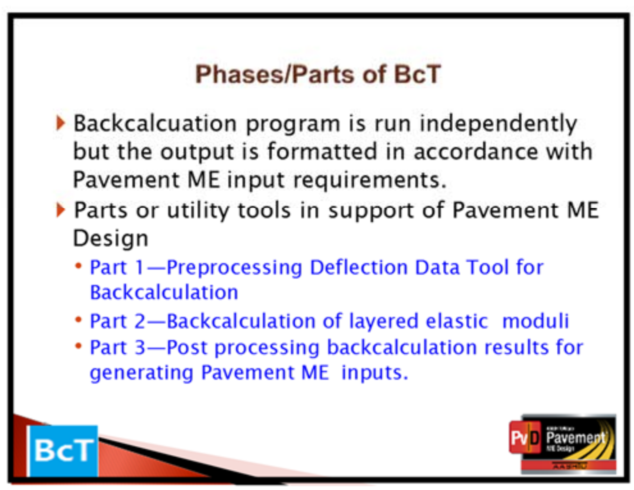


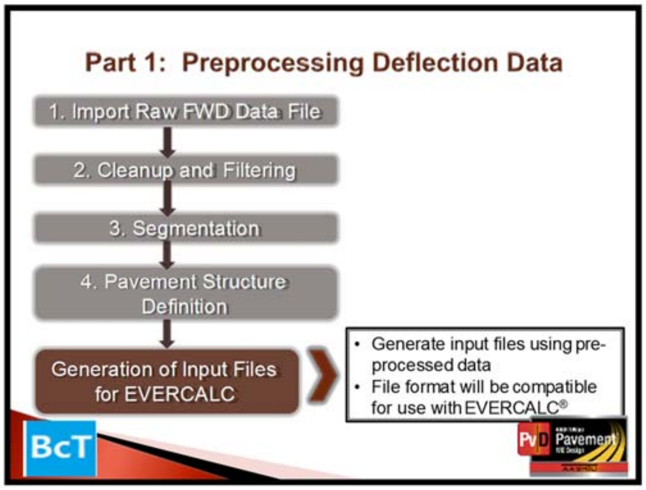


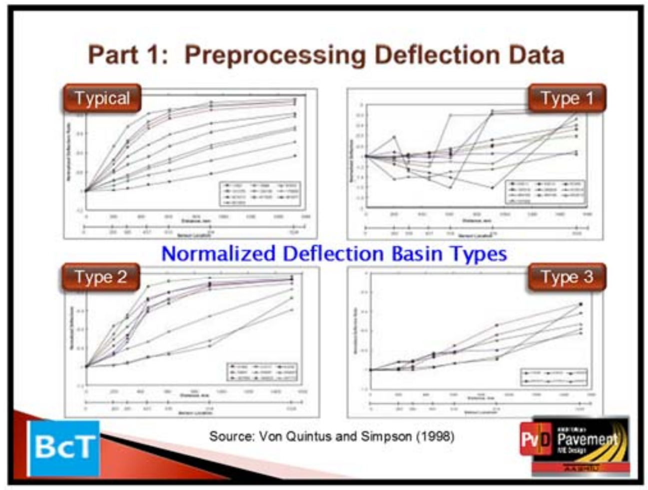


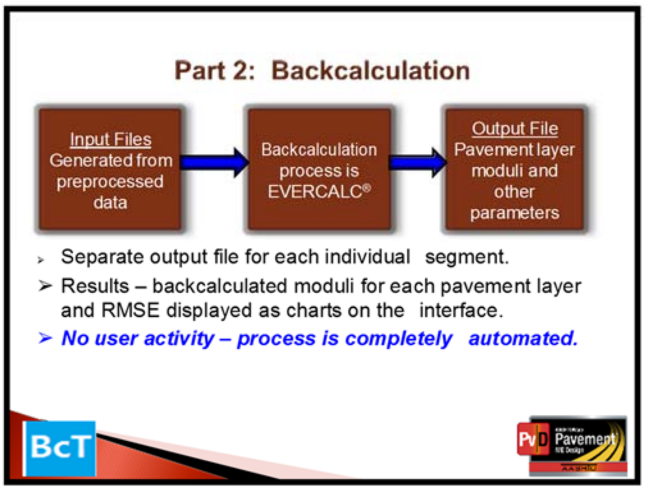


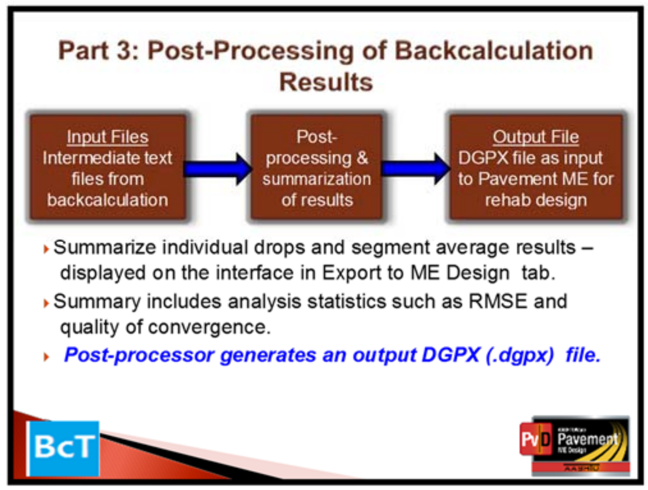


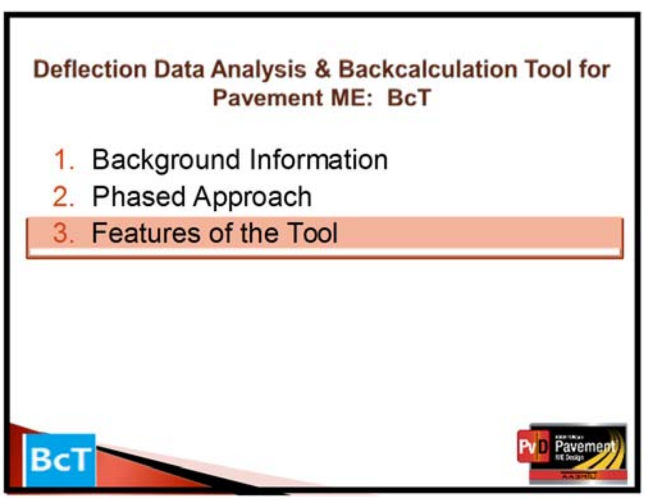


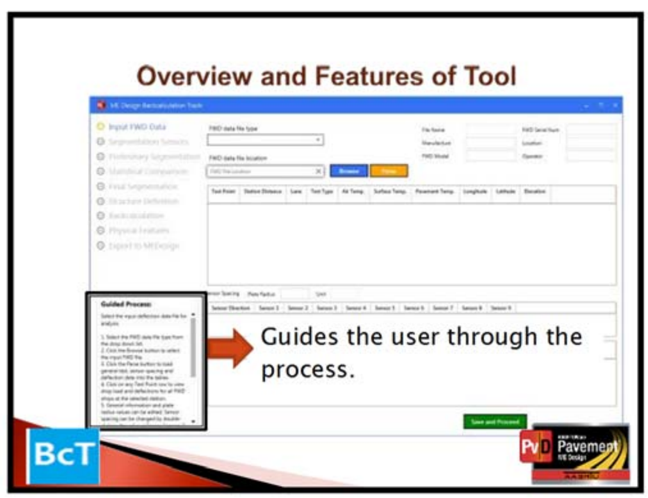

Part 1: Preprocessing Deflection Data
1. Import Raw FWD Data File
2. Cleanup and Filtering
3. Segmentation
4. Pavement Structure Definition
Generation of Input Files for EVERCALC
• Generate input files using pre-processed data
• File format will be compatible for use with EVERCALC®
BcT

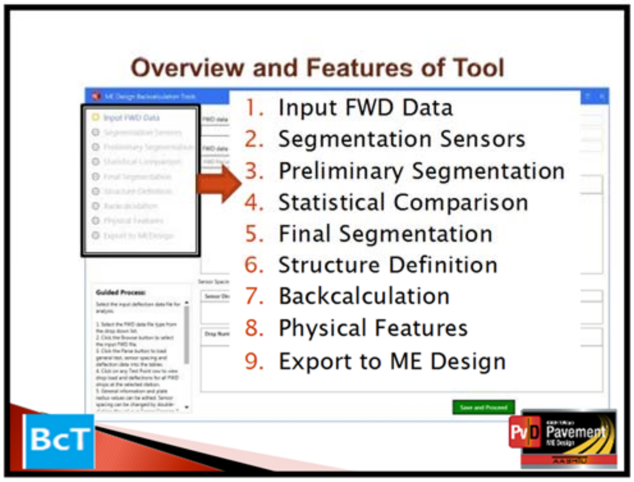

Part 1: Preprocessing Deflection Data
Typical
Type 1
Normalized Deflection Basin Types
Type 2
Type 3
Source: Von Quintus and Simpson (1998)
BcT

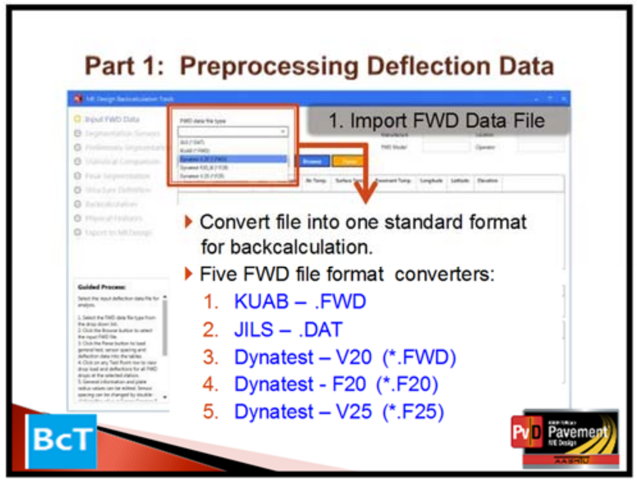

Part 2: Backcalculation
Input Files Generated from preprocessed data
Backcalculation process is EVERCALC®
Output File Pavement layer moduli and other parameters
Separate output file for each individual segment.
Results – backcalculated moduli for each pavement layer and RMSE displayed as charts on the interface.
No user activity – process is completely automated.
BcT

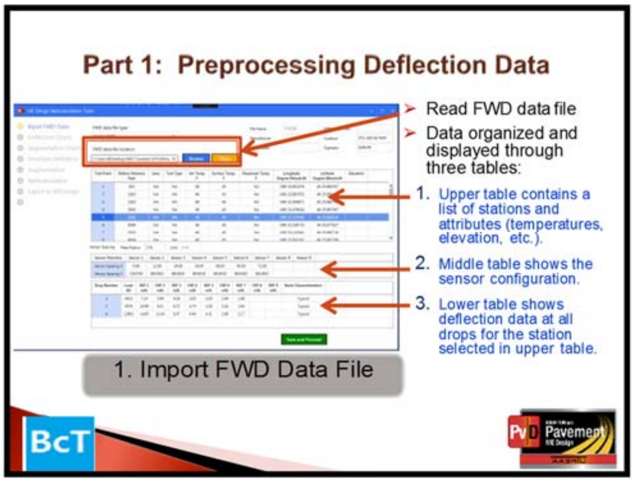

Part 3: Post-Processing of Backcalculation Results
Input Files Intermediate text files from backcalculation
Post-processing & summarization of results
Output File DGPX file as input to Pavement ME for rehab design
Summarize individual drops and segment average results – displayed on the interface in Export to ME Design tab.
Summary includes analysis statistics such as RMSE and quality of convergence.
Post-processor generates an output DGPX (.dgpx) file.
BcT

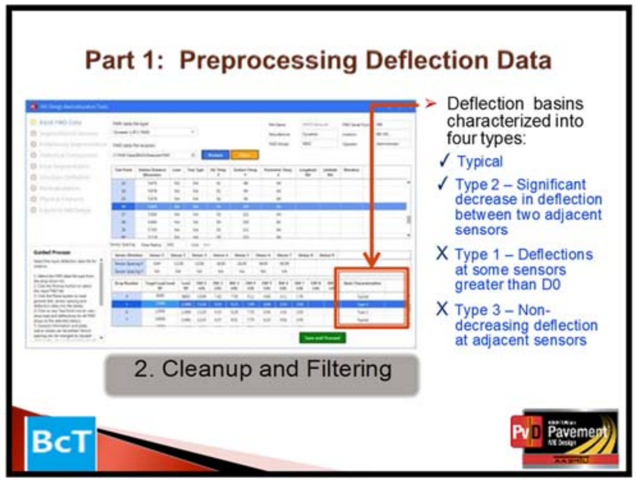

Deflection Data Analysis & Backcalculation Tool for Pavement ME: BcT
1. Background Information
2. Phased Approach
3. Features of the Tool
BcT

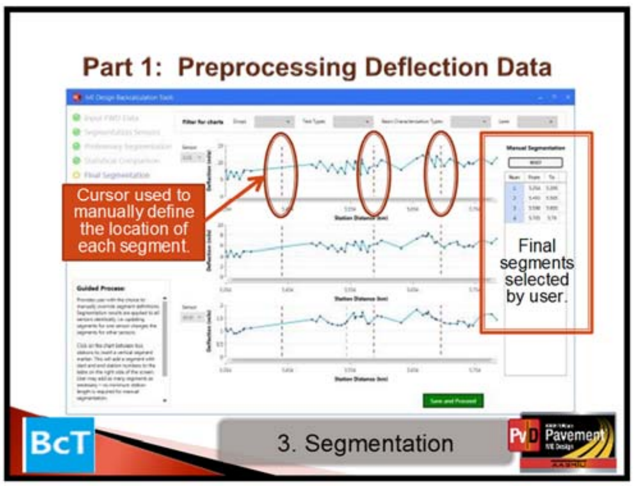

Overview and Features of Tool
Guides the user through the process.
BcT

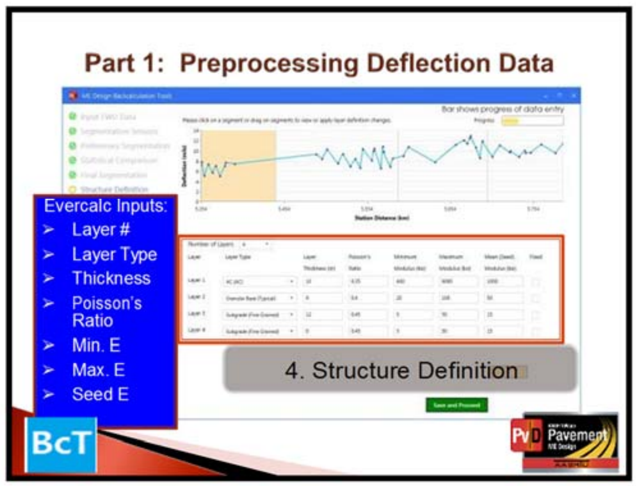

Overview and Features of Tool
1. Input FWD Data
2. Segmentation Sensors
3. Preliminary Segmentation
4. Statistical Comparison
5. Final Segmentation
6. Structure Definition
7. Backcalculation
8. Physical Features
9. Export to ME Design
BcT

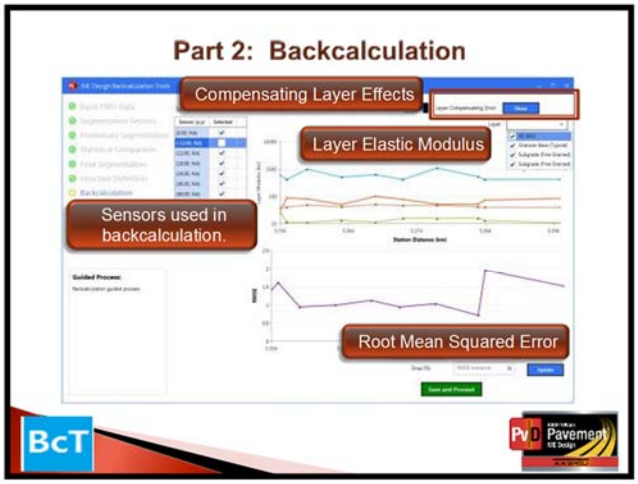

Part 1: Preprocessing Deflection Data
1. Import FWD Data File
Convert file into one standard format for backcalculation.
Five FWD file format converters:
1. KUAB – .FWD
2. JILS – .DAT
3. Dynatest – V20 (*.FWD)
4. Dynatest - F20 (*.F20)
5. Dynatest – V25 (*.F25)
BcT

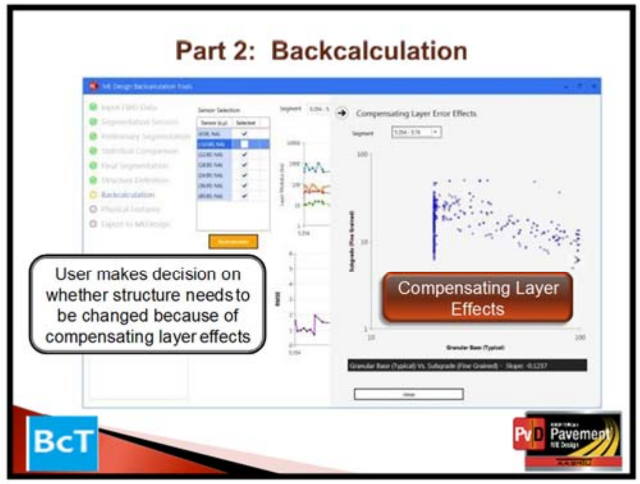

Part 1: Preprocessing Deflection Data
Read FWD data file
Data organized and displayed through three tables:
1. Upper table contains a list of stations and attributes (temperatures, elevation, etc.).
2. Middle table shows the sensor configuration.
3. Lower table shows deflection data at all drops for the station selected in upper table.
1. Import FWD Data File
BcT

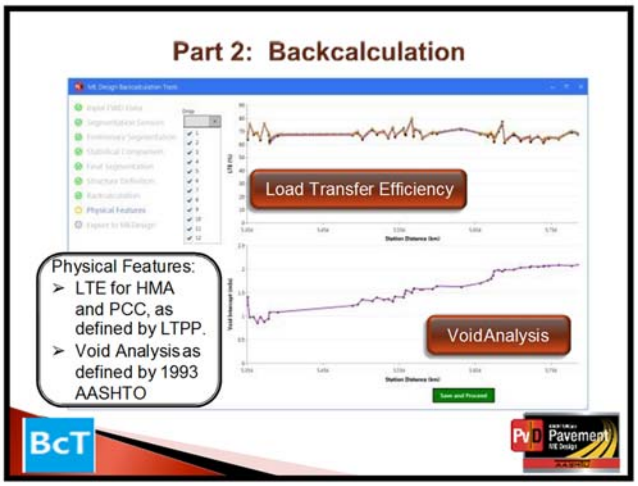

Part 1: Preprocessing Deflection Data
Deflection basins characterized into four types:
✓ Typical
✓ Type 2 – Significant decrease in deflection between two adjacent sensors
X Type 1 – Deflections at some sensors greater than D0
X Type 3 – Non-decreasing deflection at adjacent sensors
2. Cleanup and Filtering
BcT

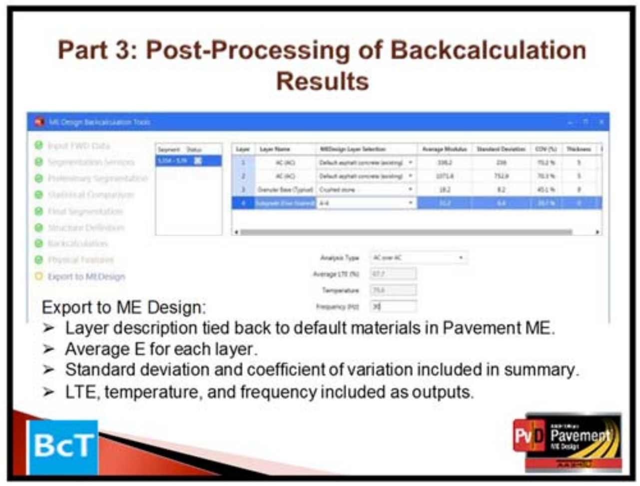

Part 1: Preprocessing Deflection Data
Cursor used to manually define the location of each segment.
Final segments selected by user.
3. Segmentation
BcT


Part 1: Preprocessing Deflection Data
Evercalc Inputs:
Layer #
Layer Type
Thickness
Poisson's Ratio
Min. E
Max. E
Seed E
4. Structure Definition
BcT


Part 2: Backcalculation
Compensating Layer Effects
Layer Elastic Modulus
Sensors used in backcalculation.
Root Mean Squared Error


Part 2: Backcalculation
User makes decision on whether structure needs to be changed because of compensating layer effects
Compensating Layer Effects


Part 2: Backcalculation
Load Transfer Efficiency
Physical Features:
➢ LTE for HMA and PCC, as defined by LTPP.
➢ Void Analysis as defined by 1993 AASHTO
Void Analysis


Part 3: Post-Processing of Backcalculation Results
Export to ME Design:
➢ Layer description tied back to default materials in Pavement ME.
➢ Average E for each layer.
➢ Standard deviation and coefficient of variation included in summary.
➢ LTE, temperature, and frequency included as outputs.


QUESTIONS?

Presentation 7—Lydia Peddicord, Pennsylvania DOT

PennDOT's MEPDG Implementation Plan Second Annual AASHTO Pavement ME National User Group Meeting
October 11-12, 2017

Lydia E. Peddicord, P.E.
Chief, Pavement Design and Analysis
Unit Bureau of Project Delivery
(717) 787-4246, lpeddicord@pa.gov

Pavement ME Design

- Performing parallel designs on a limited basis since July 1, 2014 with no local calibration
- Started verification project with ARA May 2015.

Libraries

- Asphalt Mixes
  - 19 from active projects
  - 22 SISSI mixes
  - 1 Asphalt rich bottom base from PA Turnpike
- Concrete Mixes
  - 17 from active projects
  - 6 from prior research
  - (17 LTPP sites)

Pavement ME Design

- 6 subbase 2A (unbound aggregate) samples
- 19 soil samples
- Time for Districts to collect from active projects

HMA Materials

Asphalt Concrete:		
6 AC wearing course mixes (from construction sites with volumetrics data available; select mixes covering typical PennDOT aggregates & binders)	Dynamic modulus Creep compliance Indirect tensile strength at low temperature (14°F)	AASHTO T 79 AASHTO T 322 AASHTO T 322
6 AC intermediate course mixes (from construction sites with volumetrics data available; select mixes covering typical PennDOT aggregates & binders)	Dynamic modulus Repeated load plastic deformation	AASHTO T 79 NCHRP Report #719 (modification of AASHTO T79)
6 AC base course mixes (from construction sites with volumetrics data available; select mixes covering typical PennDOT aggregates & binders)	Dynamic modulus Repeated load plastic deformation Indirect tensile strength at mid temperature (68°F)	AASHTO T 79 NCHRP Report #719 (modification of AASHTO T79) ASTM D6931. In addition to the standard test procedure, obtain Load vs. Horizontal Displacement data.

HMA/WMA Materials

Test Type	No. of Material	No. of Test Specimen per Material	Test Performed by
Dynamic modulus (AASHTO T 79)	10	3	PennDOT
	8	3	ARA/AAT
Creep compliance (AASHTO T 322)	6 (surface mix only)	3 specimen each @ 3 temp (-4°F, 14°F, 32°F)	ARA/AAT
Low temperature (14°F) indirect tensile strength (AASHTO T 322)	6 (surface mix only)	3	ARA/AAT
Mid temperature (68°F) indirect tensile strength (ASTM D6931). In addition to the standard test procedure, obtain Load vs. Horizontal Displacement data.	6 (base mix only)	3	ARA/AAT
Repeated load plastic deformation (NCHRP Report #719: modification of AASHTO T79)	12 (base and intermediate mixes)	3	PennDOT
Dynamic shear rheometer (DSR) (AASHTO T 315)	18 (Minimum 4 binder type: PG 76-22, PG 64-28, PG 64-22, and PG 58-28)		Data will be obtained from quality assurance records. MEPDG requires binder G* data at 3 different temperature levels. More information will be obtained from the supplier.
Unit weight, air voids, and binder content	18		Data will be obtained from quality assurance records.

PCC Materials

Test Type	No. of Material	No. of Test Specimen per Material	Test Performed by
28-day compressive strength (AASHTO T22)	12	3	PennDOT
28-elastic modulus (ASTM C469)	12	3	PennDOT
Coefficient of Thermal Expansion (AASHTO T336)	12	3	PennDOT
Unit weight, Poission's ratio and other PCC material properties	12		Data will be obtained from construction records.

Aggregate Base Materials

Test Type	No. of Material	No. of Test Specimen per Material	Test Performed by
Resilient Modulus (AASHTO T 307)	6	3	ARA/ Boudreau Engineering
	4	3	PennDOT (In the future)
Moisture-Density (PTM 106- Method B)	6	1	ARA/ Novarro & Wright
	4	1	PennDOT (In the future)
Gradations (ASTM D 422)	6	1	ARA/ Novarro & Wright
	4	1	PennDOT (In the future)
Atterberg limits (ASTM D 4318)	6	1	ARA/ Novarro & Wright
	4	1	PennDOT (In the future)

Soils

Test Type	No. of Material	No. of Test Specimen per Material	Test Performed by
Resilient Modulus (AASHTO T 307)	18	3	ARA/ Boudreau Engineering
	57	3	PennDOT (In the future)
Moisture-Density (PTM 106- Method B)	18	1	ARA/ Novarro & Wright
	57	1	PennDOT (In the future)
Gradations (ASTM D 422)	18	1	ARA/ Novarro & Wright
	57	1	PennDOT (In the future)
Atterberg limits (ASTM D 4318)	18	1	ARA/ Novarro & Wright
	57	1	PennDOT (In the future)
Unconfined compressive strength (AASHTO T 208)	18	3	ARA/ Novarro & Wright
	57	3	PennDOT (In the future)

Soils

Detailed Criteria for Selection of Soil Samples for setting Mr Default Values for MEPDG*

AASHTO Classification	Minimum Number Mr Tests**	Material Properties: PI Range	Minus 200 Range	1994-2014 CAMMS Count	Approx Percent of PA Subgrade Materials	Relative risk as a subgrade material***
A-1-a	5	0 - 3	8 - 12	664	6.90	5.00
A-1-b	5	1 - 4	18 - 22	1678	17.44	4.00
A-2-4	5	0 - 2	25 - 30			
A-2-4	5	3 - 5	25 - 30	2340	24.32	2.00
A-2-4	5	6 - 9	25 - 30			
A-2-6	5	11 - 14	25 - 30	98	1.02	3.00
A-4	5	0 - 2	45 - 55			
A-4	5	3 - 5	45 - 55			
A-4	5	6 - 9	45 - 55	3784	39.33	1.00
A-4	5	0 - 2	65 - 75			
A-4	5	3 - 5	65 - 75			
A-4	5	6 - 9	65 - 75			
A-6	5	12.5-15.5	55 - 65	780	8.11	3.00
A-6	5	12.5-15.5	75 - 85			
A-7-6	5	20 - 25	65 - 85	182	1.89	3.00
A-3	0	N/A	N/A			
A-2-5	0	N/A	N/A	96	1.00	5.00
A-5	0	N/A	N/A			
A-2-7	0	N/A	N/A			
A-7-5	0	N/A	N/A			
Totals	75			9621	100.00	

* Table prepared by loooking at frequency of AASHTO classifications occuring in PA based upon CAMMS soil test database, property ranges of AASHTO materials classifications, and relative risk of material group based upon expected performance of material class as a subgrade.

** Note: While 3 test would be the minimum for a stastitical basis and would reduce the total number od required tests to 45, five tests for each material classification/property set (total 75 tests) would be expected to nearly double the reliability of the default values

*** Relative risk based on combination of typical performance of material as subgrade, and relative frequency of encountering material as subgrade. Scale of 1 to 5 (highest risk = 1)

Soils

Soil Tests Performed by the Private Lab			
AASHTO Classification	Minimum Number Mr Tests**	PI Range	Minus 200 Range
A-2-4	2	0 - 2	25 - 30
A-2-4	2	3 - 5	25 - 30
A-2-4	2	6 - 9	25 - 30
A-4	2	0 - 2	45 - 55
A-4	2	3 - 5	45 - 55
A-4	2	6 - 9	45 - 55
A-4	2	0 - 2	65 - 75
A-4	2	3 - 5	65 - 75
A-4	2	6 - 9	65 - 75
Totals	18		

Table 9.15—Resilient Modulus Level 1 Values Derived for Selected Subgrade Soils in Pennsylvania

Soils

Table 9.15—Resilient Modulus Level 1 Values Derived for Selected Subgrade Soils in Pennsylvania

Type of Material or Soil: ID	Location or County	District	USCS	AASHTO Class	Optimum Water Content, %	Maximum Dry Density, pcf	Laboratory Resilient Modulus, psi	Unconfined Compressive Strength, psi
RMS001	Union	3	SC	A-4	14.5	114.5	13,545	230
RMS002	Franklin	8		A-1-a	10.4	125.1	14,456	
RMS003	Clinton	2	SM	A-2-4	13.6	113.6	14,940	
RMS004	Clinton	2	CL	A-6	14.0	117.0	11,017	320
RMS005	Potter	2	SC-SM	A-2-4	9.5	127.6	23,007	
RMS006	Potter	2		A-1-a	11.6	122.3	12,343	
RMS007	Fayette	12	SM	A-2-4	14.1	115.8	14,318	260
RMS008		12	SM	A-2-7	21.3	100.3	8,036	170
RMS009	Fayette	12	SC	A-2-4	12.6	119.3	16,592	
RMS010	Washington	12		A-1-a	14.8	114	12,425	
RMS011	Lycoming	3		A-1-a	12.6	119.6	12,577	
RMSComb*	**			A-4	15.1	114.4	12,430	40
RMS013	Northampton	5	ML	A-7-6	17.3	109.4	11,150	150
RMS014	Schuylkill	5	SM	A-6	22.5	97	6,201	230
RMS017	Berks	5	SC-SM	A-2-4	13.5	117.8	11,033	
RMS018			GC-GM	A-1-b	10	124.3	11,478	
RMS019			SC-SM	A-4	12.9	118.5	19,790	340
RMS025			SC-SM	A-2-4	10.5	124.3	20,402	260

Note A: The optimum water content and maximum dry density listed in this table were determined using PTM 106-Method B, Modified Proctor compaction effort.
Note B: Optimum water content must be entered into the Pavement ME under "Optimum gravimetric water content" input. Similar entry for maximum dry density under "Maximum dry unit weight (pcf)".
*RMSComb is a combination of RMS-012, RMS-015 and RMS-016.
**Location: RMS-012: Northampton; RMS-015: Schuylkill; RMS-016: Berks

Pavement ME Design

- Asphalt Test Sections
  - 8 SISSI sites
  - 9 LTPP sites
- Concrete JPCP Test Sections
  - 4 LTPP sites
  - 18 RMS sites

pennsylvania DEPARTMENT OF TRANSPORTATION www.dot.state.pa.us

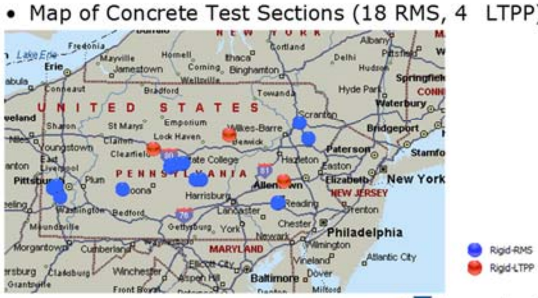
Pavement ME Design

- Map of Asphalt Test Sections (8 SISSI, 9 LTPP)

pennsylvania DEPARTMENT OF TRANSPORTATION www.dot.state.pa.us

Pavement ME Design

- Map of Concrete Test Sections (18 RMS, 4 LTPP)



pennsylvania DEPARTMENT OF TRANSPORTATION www.dot.state.pa.us

Pavement ME Design

- March 31, 2017 local calibration coefficients with limited number of test sections

pennsylvania DEPARTMENT OF TRANSPORTATION www.dot.state.pa.us

Pavement ME Design

- Design life
  - Asphalt
    - 35 years for bottom-up cracking
    - 15 years for IRI, Rutting, Thermal cracking
    - Ave. 4.5 inches thinner than 20-yr Darwin (18 designs) (range from 10 inches thinner to 2 inches thicker)
    - Ave. 20-yr Darwin life through Pavement ME analysis: 24.5 years (range from 10 to 36 years)

pennsylvania DEPARTMENT OF TRANSPORTATION www.dot.state.pa.us

Pavement ME Design

- Design life
  - Asphalt
    - 35 years for bottom-up cracking
    - 20 years for IRI, Rutting, Thermal cracking
    - Ave. 2.4 inches thinner than 20-yr Darwin (18 designs) (range from 9 inches thinner to 6.5 inches thicker)

pennsylvania DEPARTMENT OF TRANSPORTATION www.dot.state.pa.us

Pavement ME Design

- Design life
  - Concrete
    - 35 years for cracking and faulting
    - 20 years for IRI
    - Ave. 3.1 inches thinner than 20-yr Darwin (9 designs) (range 1.5 to 4.5 inches thinner)
    - Ave. 20-yr Darwin life through Pavement ME analysis: 37.1 years (range 22 to 55 years)

pennsylvania DEPARTMENT OF TRANSPORTATION www.dot.state.pa.us

Pavement ME Design

- Pavement ME graphs show how modest additional pavement thickness could significantly extend pavement life
  - Additional inch of concrete may result in an additional 10 years of predicted life.
- Potential to create issues with LCCA analysis

pennsylvania DEPARTMENT OF TRANSPORTATION www.dot.state.pa.us

Pavement ME Design

- Potential CTE issues
  - Wide range in PA (3.87 to 6.11)
  - Collecting more data
  - ASR and skid issues

pennsylvania DEPARTMENT OF TRANSPORTATION www.dot.state.pa.us

Pavement ME Design

Higher CTE (6.05) with
lower compressive strength (4,825 psi)
Elastic Modulus 3,932,166 psi
resulting in 20 inches of JPCP to
resolve faulting at 20 years.

- Mix with CTE (5.0) and compressive (5,580 psi), elastic modulus (4,200,000 psi)
- resulted in 10.5 inches of JPCP
- Should CTE affect faulting?
- Both had 1.5 inch dowels and 15-foot joint spacing

pennsylvania DEPARTMENT OF TRANSPORTATION www.dot.state.pa.us

Pavement ME Design

- 13-ft Widened lane resulted in 10.5 inches of JPCP (CTE 6.05)
  - Should a widened lane reduce faulting so dramatically?
- TRB 2524 – Calibration of National Rigid Pavement Performance Models for the Pavement Mechanistic-Empirical Design Guide – 2015
  - Possible changes to the faulting model ?

pennsylvania DEPARTMENT OF TRANSPORTATION www.dot.state.pa.us

Pavement ME Design

- Update Pavement Policy Manual to design with Pavement ME for full-depth asphalt and concrete pavements on roads with 500 ADTT or greater as of XX XX, 2018
- All Pavement ME designs to be submitted to Central Office for approval
- Need to develop policy for rehabilitation and overlay projects

pennsylvania DEPARTMENT OF TRANSPORTATION www.dot.state.pa.us

PvD

Project Name: Snyder SR 15-088 CSVT (Mainline) local calibration asphalt 8inch base
Project Location: C:\Users\lpeddicord\Documents\My ME Design\Projects\Snyder SR 15-088 CSVT (Mainline) local calibration asphalt 8inch base

Design Inputs

Design Life: 45 years
Design Type: FLEXIBLE
Base construction: May, 2019
Pavement construction: June, 2019
Traffic opening: September, 2019
Climate Data Sources (Lat/Lon): 40.821, -76.864; 41.243, -76.922

Design Structure

Layer type	Material Type	Thickness (in)
Flexible	Perry 12.5 mm PG76-22 Wearing	1.5
Flexible	Mix4 19 mm PG76-22 Binder	2.5
Flexible	ARB_Mix1_JMF2016_D02	8.0
NonStabilized	RMA005_A-1-a	8.0
Subgrade	RMS001_A-4	10.0
Subgrade	RMS001_A-4	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	7.9
Air voids (%)	6.4

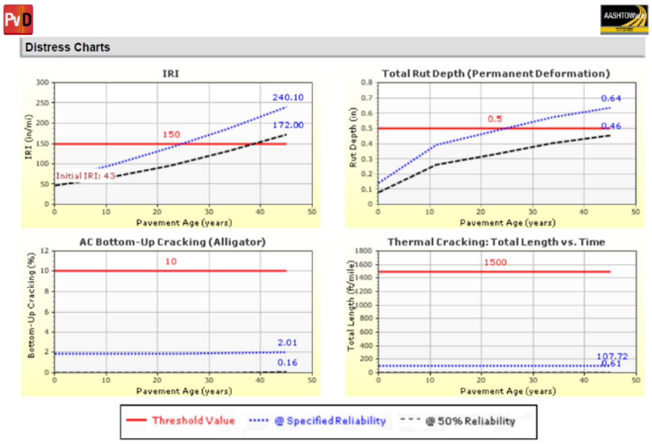
Traffic

Age (year)	Heavy Trucks (cumulative)
2019 (initial)	5,614
2041 (22 years)	34,829,300
2064 (45 years)	102,844,000

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	150.00	240.07	95.00	29.79	Fail
Permanent deformation - total pavement (in)	0.50	0.64	95.00	64.96	Fail
AC bottom-up fatigue cracking (% lane area)	10.00	2.01	95.00	100.00	Pass
AC thermal cracking (ft/mile)	1500.00	107.72	95.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	5000.00	394.05	95.00	100.00	Pass
Permanent deformation - AC only (in)	0.50	0.46	95.00	97.89	Pass



PvD

Project Name: Snyder SR 15-088 CSVT (Mainline) local calibration asphalt 10inch base
Project Location: C:\Users\lpeddicord\Documents\My ME Design\Projects\Snyder SR 15-088 CSVT (Mainline) local calibration asphalt 10inch base

Design Inputs

Design Life: 45 years
Design Type: FLEXIBLE
Base construction: May, 2019
Pavement construction: June, 2019
Traffic opening: September, 2019
Climate Data Sources (Lat/Lon): 40.821, -76.864; 41.243, -76.922

Design Structure

Layer type	Material Type	Thickness (in)
Flexible	Perry 12.5 mm PG76-22 Wearing	1.5
Flexible	Mix4 19 mm PG76-22 Binder	2.5
Flexible	ARB_Mix1_JMF2016_D02	10.0
NonStabilized	RMA005_A-1-a	8.0
Subgrade	RMS001_A-4	10.0
Subgrade	RMS001_A-4	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	7.9
Air voids (%)	6.4

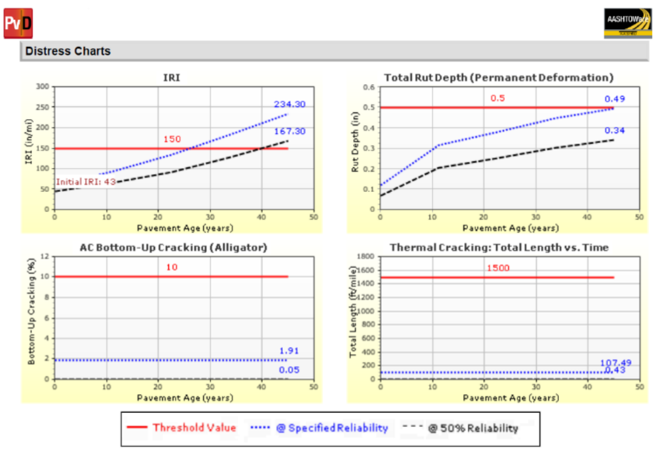
Traffic

Age (year)	Heavy Trucks (cumulative)
2019 (initial)	5,614
2041 (22 years)	34,829,300
2064 (45 years)	102,844,000

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	150.00	234.29	95.00	33.57	Fail
Permanent deformation - total pavement (in)	0.50	0.49	95.00	95.66	Pass
AC bottom-up fatigue cracking (% lane area)	10.00	1.91	95.00	100.00	Pass
AC thermal cracking (ft/mile)	1500.00	107.49	95.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	5000.00	374.09	95.00	100.00	Pass
Permanent deformation - AC only (in)	0.50	0.33	95.00	99.98	Pass



PvD

Project Name: Snyder SR 15-088 CSVT (Mainline) local calibration asphalt 11inch base
Project Location: C:\Users\lpeddicord\Documents\My ME Design\Projects\Snyder SR 15-088 CSVT (Mainline) local calibration asphalt 11inch base

Design Inputs

Design Life: 45 years
Design Type: FLEXIBLE
Base construction: May, 2019
Pavement construction: June, 2019
Traffic opening: September, 2019
Climate Data Sources (Lat/Lon): 40.821, -76.864; 41.243, -76.922

Design Structure

Layer type	Material Type	Thickness (in)
Flexible	Perry 12.5 mm PG76-22 Wearing	1.5
Flexible	Mix4 19 mm PG76-22 Binder	2.5
Flexible	ARB_Mix1_JMF2016_D02	11.0
NonStabilized	RMA005_A-1-a	8.0
Subgrade	RMS001_A-4	10.0
Subgrade	RMS001_A-4	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	7.9
Air voids (%)	6.4

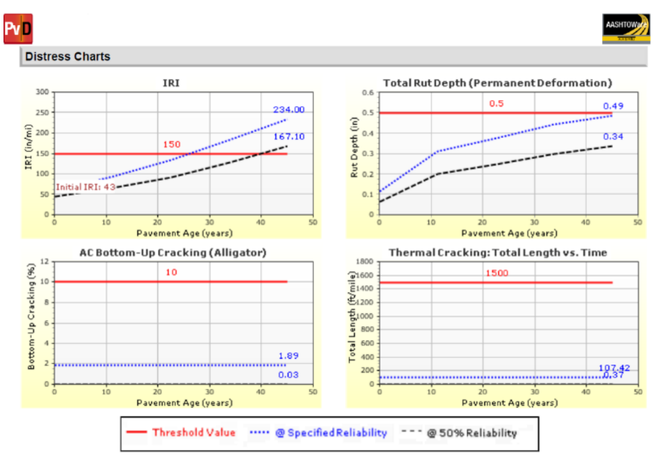
Traffic

Age (year)	Heavy Trucks (cumulative)
2019 (initial)	5,614
2041 (22 years)	34,829,300
2064 (45 years)	102,844,000

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	150.00	234.04	95.00	33.74	Fail
Permanent deformation - total pavement (in)	0.50	0.49	95.00	96.07	Pass
AC bottom-up fatigue cracking (% lane area)	10.00	1.89	95.00	100.00	Pass
AC thermal cracking (ft/mile)	1500.00	107.42	95.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	5000.00	337.08	95.00	100.00	Pass
Permanent deformation - AC only (in)	0.50	0.34	95.00	99.97	Pass



Project Name: Snyder SR 15-088 CSVT (Mainline) Concrete LLCP 9inches
Project Location: C:\Users\lpeddicord\Documents\My ME Design\Projects\Snyder SR 15-088 CSVT (Mainline) Concrete LLCP 9inches

Design Inputs

Design Life: 45 years
Design Type: JPCP
Existing construction: -
Pavement construction: April, 2019
Traffic opening: September, 2019
Climate Data Sources (Lat/Lon): 40.821, -76.864; 41.243, -76.922

Design Structure

Layer type	Material Type	Thickness (in)
PCC	LCCP	9.0
Flexible	Asphalt Treated Permeable Base Course	4.0
NonStabilized	RMA005_A-1-a	4.0
Subgrade	RMS001_A-4	10.0
Subgrade	RMS001_A-4	Semi-infinite

Joint Design:	
Joint spacing (ft)	15.0
Dowel diameter (in)	1.50
Slab width (ft)	13.0 (w)

Traffic

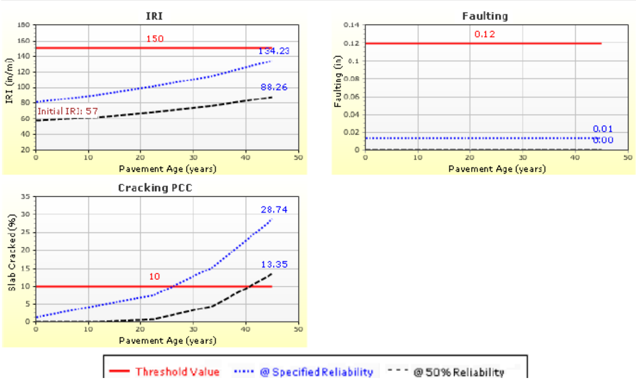
Age (year)	Heavy Trucks (cumulative)
2019 (initial)	5,614
2041 (22 years)	34,829,300
2064 (45 years)	102,844,000

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability: Target	Predicted	Reliability (%): Target	Achieved	Criterion Satisfied?
Terminal IRI (in/mile)	150.00	134.23	95.00	98.64	Pass
Mean joint faulting (in)	0.12	0.01	95.00	100.00	Pass
JPCP transverse cracking (percent slabs)	10.00	28.74	95.00	36.02	Fail

Distress Charts



Project Name: Snyder SR 15-088 CSVT (Mainline) Concrete LLCP 10inches
Project Location: C:\Users\lpeddicord\Documents\My ME Design\Projects\Snyder SR 15-088 CSVT (Mainline) Concrete LLCP 10inches

Design Inputs

Design Life: 45 years
Design Type: JPCP
Existing construction: -
Pavement construction: April, 2019
Traffic opening: September, 2019
Climate Data Sources (Lat/Lon): 40.821, -76.864; 41.243, -76.922

Design Structure

Layer type	Material Type	Thickness (in)
PCC	LCCP	10.0
Flexible	Asphalt Treated Permeable Base Course	4.0
NonStabilized	RMA005_A-1-a	4.0
Subgrade	RMS001_A-4	10.0
Subgrade	RMS001_A-4	Semi-infinite

Joint Design:	
Joint spacing (ft)	15.0
Dowel diameter (in)	1.50
Slab width (ft)	13.0 (w)

Traffic

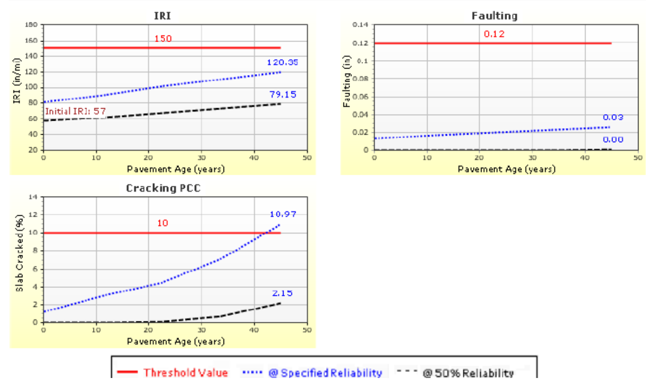
Age (year)	Heavy Trucks (cumulative)
2019 (initial)	5,614
2041 (22 years)	34,829,300
2064 (45 years)	102,844,000

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability: Target	Predicted	Reliability (%): Target	Achieved	Criterion Satisfied?
Terminal IRI (in/mile)	150.00	120.35	95.00	99.77	Pass
Mean joint faulting (in)	0.12	0.03	95.00	100.00	Pass
JPCP transverse cracking (percent slabs)	10.00	10.97	95.00	92.83	Fail

Distress Charts



Project Name: Snyder SR 15-088 CSVT (Mainline) Concrete LLCP 10.5inches
Project Location: C:\Users\lpeddicord\Documents\My ME Design\Projects\Snyder SR 15-088 CSVT (Mainline) Concrete LLCP 10.5inches

Design Inputs

Design Life: 45 years
Design Type: JPCP
Existing construction: -
Pavement construction: April, 2019
Traffic opening: September, 2019
Climate Data Sources (Lat/Lon): 40.821, -76.864; 41.243, -76.922

Design Structure

Layer type	Material Type	Thickness (in)
PCC	LCCP	10.5
Flexible	Asphalt Treated Permeable Base Course	4.0
NonStabilized	RMA005_A-1-a	4.0
Subgrade	RMS001_A-4	10.0
Subgrade	RMS001_A-4	Semi-infinite

Joint Design:	
Joint spacing (ft)	15.0
Dowel diameter (in)	1.50
Slab width (ft)	13.0 (w)

Traffic

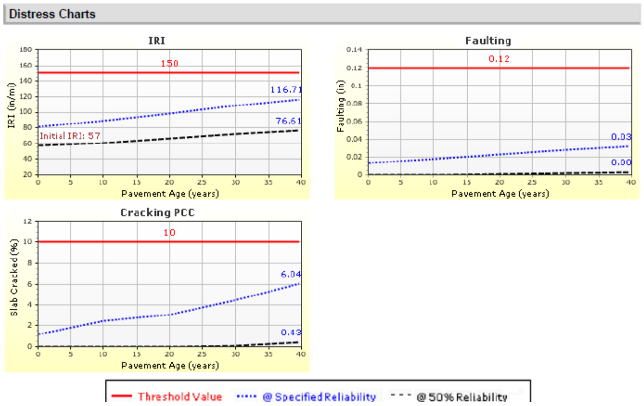
Age (year)	Heavy Trucks (cumulative)
2019 (initial)	5,614
2041 (22 years)	34,829,300
2064 (45 years)	102,844,000

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability: Target	Predicted	Reliability (%): Target	Achieved	Criterion Satisfied?
Terminal IRI (in/mile)	150.00	116.88	95.00	99.87	Pass
Mean joint faulting (in)	0.12	0.03	95.00	100.00	Pass
JPCP transverse cracking (percent slabs)	10.00	7.11	95.00	99.15	Pass

Distress Charts



Project Name: Snyder SR 15-088 CSVT (Mainline) Concrete LLCP 12inches
Project Location: C:\Users\lpeddicord\Documents\My ME Design\Projects\Snyder SR 15-088 CSVT (Mainline) Concrete LLCP 12inches

Design Inputs

Design Life: 45 years
Design Type: JPCP
Existing construction: -
Pavement construction: April, 2019
Traffic opening: September, 2019
Climate Data Sources (Lat/Lon): 40.821, -76.864; 41.243, -76.922

Design Structure

Layer type	Material Type	Thickness (in)
PCC	LCCP	12.0
Flexible	Asphalt Treated Permeable Base Course	4.0
NonStabilized	RMA005_A-1-a	4.0
Subgrade	RMS001_A-4	10.0
Subgrade	RMS001_A-4	Semi-infinite

Joint Design:	
Joint spacing (ft)	15.0
Dowel diameter (in)	1.50
Slab width (ft)	13.0 (w)

Traffic

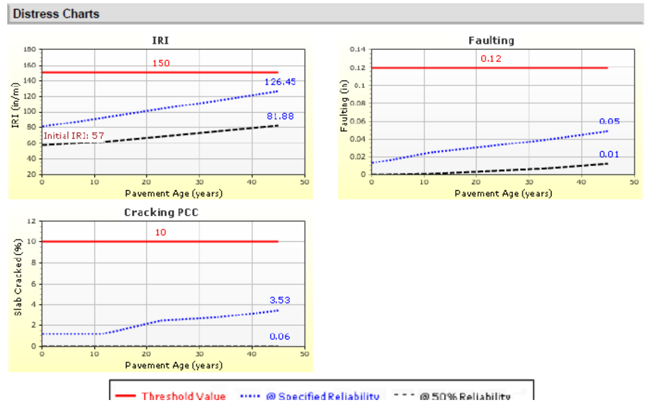
Age (year)	Heavy Trucks (cumulative)
2019 (initial)	5,614
2041 (22 years)	34,829,300
2064 (45 years)	102,844,000

Design Outputs

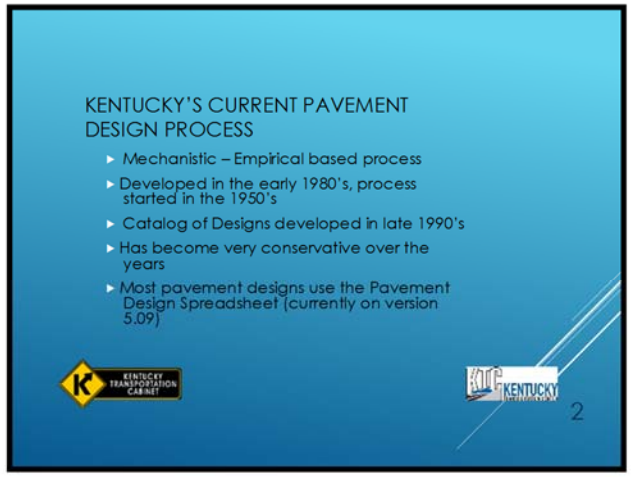
Distress Prediction Summary

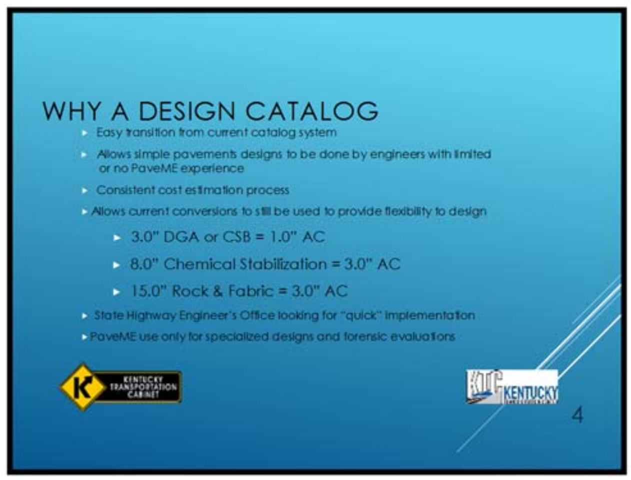
Distress Type	Distress @ Specified Reliability: Target	Predicted	Reliability (%): Target	Achieved	Criterion Satisfied?
Terminal IRI (in/mile)	150.00	126.45	95.00	99.40	Pass
Mean joint faulting (in)	0.12	0.05	95.00	100.00	Pass
JPCP transverse cracking (percent slabs)	10.00	3.53	95.00	100.00	Pass

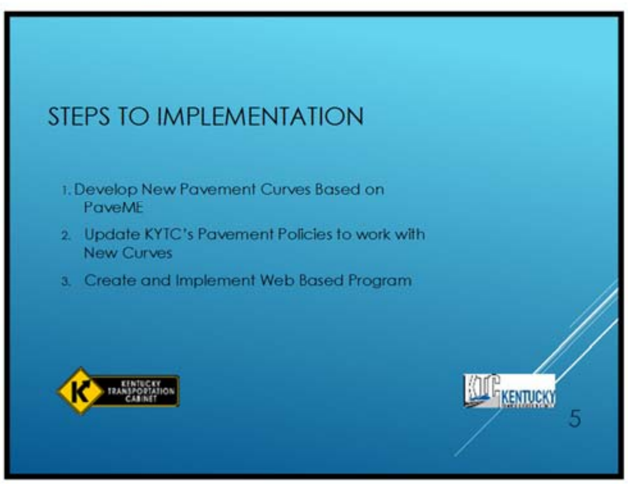
Distress Charts



Presentation 8—Joe Tucker, Kentucky Transportation Cabinet







Default Asphalt Parameters

NMAS	Unit Weight	% Eff AC by Vol	Average % Solid	Air voids (%)	% Pass. 3/4"	% Pass. 3/8"	% Pass. #4	Pass. #200
PG64-22								
0.38	148.9	11.34	92.8	7.2	100.00	95.00	66.42	5.55
0.50	148.4	10.64	93.3	6.7	99.99	88.38	58.46	5.28
0.75	150.2	9.38	93.1	6.9	95.80	68.48	42.10	4.89
1.00	151.8	8.81	93.3	6.7	88.71	61.41	37.88	4.70
1.50	151.8	7.95	93.2	6.8	78.49	56.52	32.93	4.50
PG76-22								
0.38	148.8	11.48	92.7	7.3	99.93	94.63	64.89	5.46
0.5	148.5	10.79	92.9	7.1	100.00	84.60	56.40	4.80
0.75	150.1	9.40	92.9	7.1	96.29	73.54	44.54	4.66
1.00	151.4	8.61	93.3	6.7	85.72	61.37	36.19	4.60

7

Default Soil Parameters

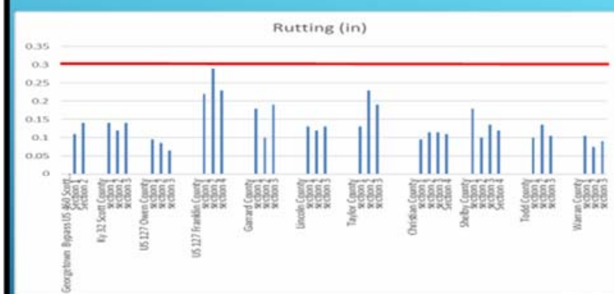
AASHTO Class	Soil Property	Average		Sieve Size	Average % passing
A-7-6	Water Content (%)	23.41		#200	87.38
	Liquid Limit (%)	52.65		#40	94.09
	Plastic Limit (%)	21.74		#10	97.27
	Plasticity Index (%)	30.89		#4	98.63
	Max Dry Density (pcf)	100.27		3/8 in.	99.39
	Opt. Moisture Content (%)	21.20		3/4 in.	99.85
	Specific Gravity	2.706		1 in.	99.93
	KY CBR	3.81		2 in.	100.00
	AASHTO CBR	3.17		3 in.	100.00

8

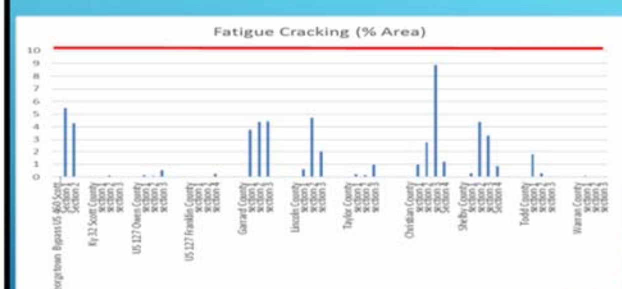
Calibration Sites

- Used for verification of initial design curves
- Calibration Sites selected across the state
  - 15 Different Test Site Locations with 45 different sections
- Primary focus is on Asphalt Pavements
- 8 – 15 years old
- Constructed with Superpave Mix Design
- Various Traffic Levels

9



10



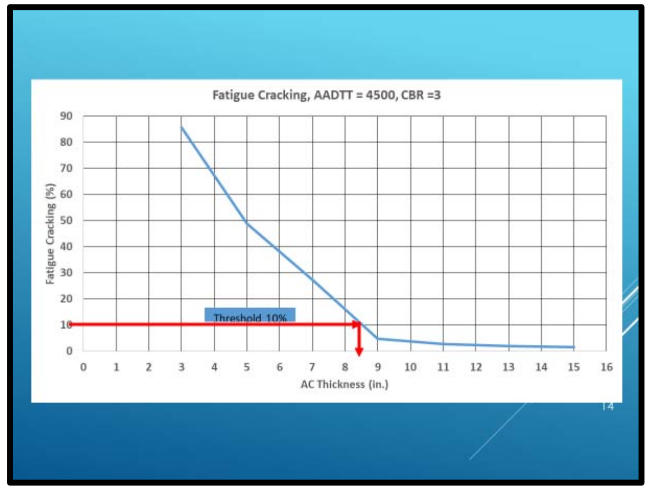
11

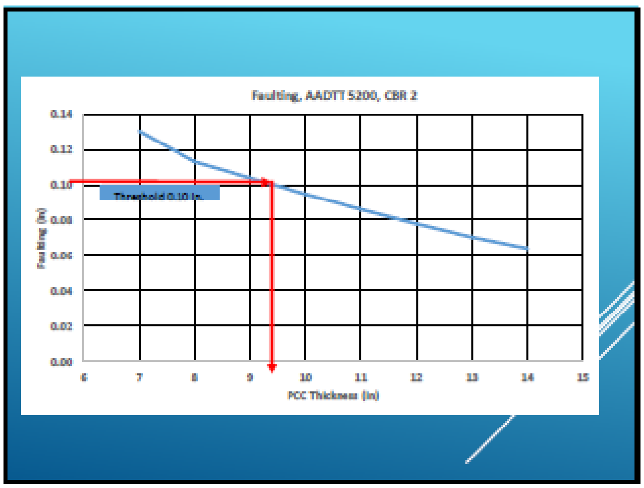
DESIGN CATALOG DEVELOPMENT

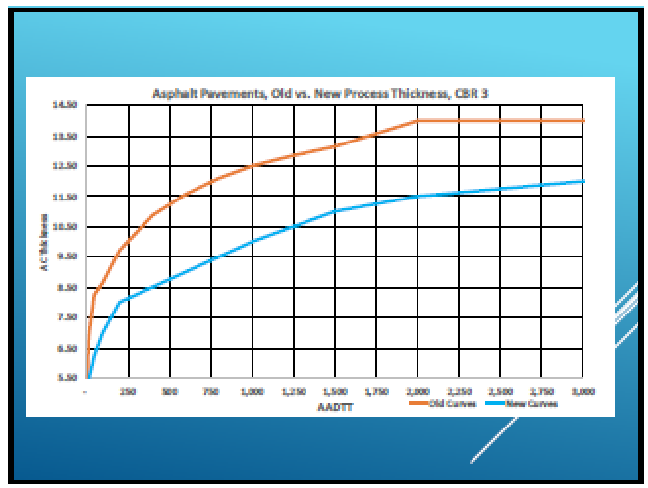
- Initial catalog based on a synthesis of the surrounding states calibration coefficients
  - Verification done with our local calibration sites
  - Coefficients will be refined regularly based on local calibration sites
- Reliability set at 95%
- Developed an Initial Set of Asphalt depths
  - Based Initial curves on a 6" DGA thickness
  - 1.5" Asphalt Surface
- 5.5" Minimum Asphalt Depth (4" AB + 1.5" AS) on 6" DGA
- 14" Maximum Asphalt Depth on 6" DGA
- 8" Minimum Concrete. 13" Maximum Concrete Depth on 6" DGA

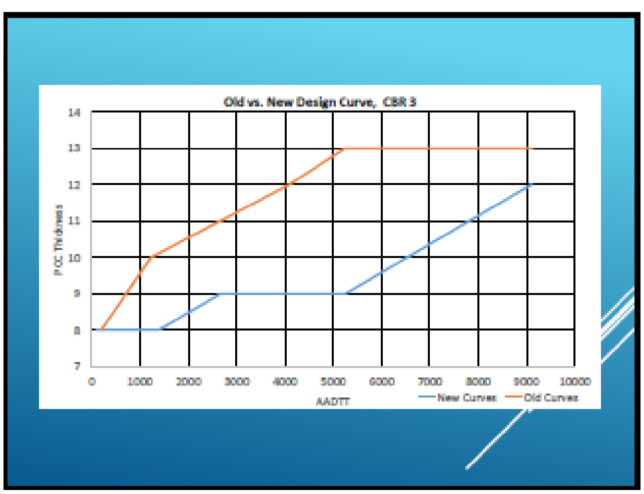
12

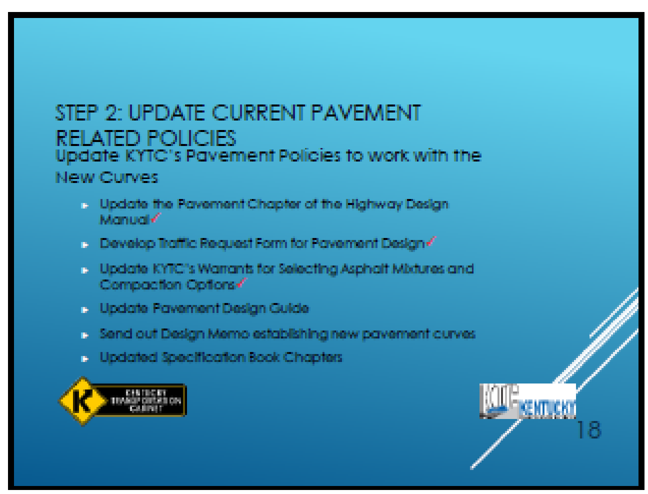

DESIGN CATALOG THRESHOLDS
Asphalt Pavement distress focused on AC rutting and fatigue cracking
Threshold for Rutting Set at 0.30"
Threshold for Fatigue Cracking Set at 10%
Also looked at an IRI threshold of 160 and top down cracking
Concrete Pavement Distress focused on PCC faulting and Cracked Slabs
Threshold for Faulting 0.10"
Threshold for Cracked Slabs 10%
Also looked at an IRI threshold of 160
KENTUCKY TRANSPORTATION CABINET
KTC KENTUCKY
13

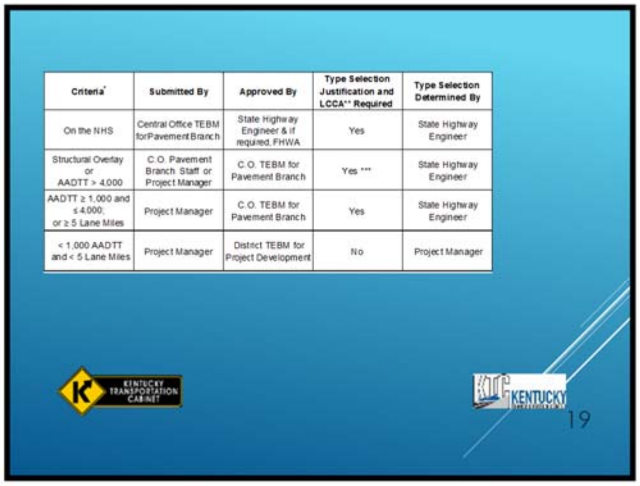

Fatigue Cracking, AADTT = 4500, CBR =3
Fatigue Cracking (%)
Threshold 10%
AC Thickness (in.)


Faulting, AADTT 5200, CBR 2
Faulting (in)
Threshold 0.10 in.
PCC Thickness (in)

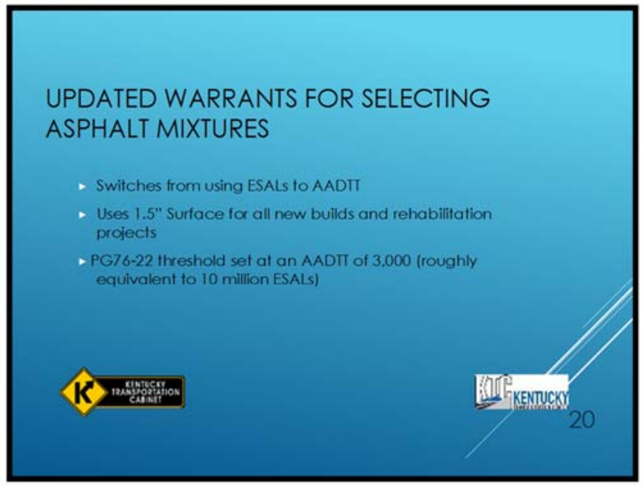

Asphalt Pavements, Old vs. New Process Thickness, CBR 3
AC Thickness
AADTT
Old Curves
New Curves

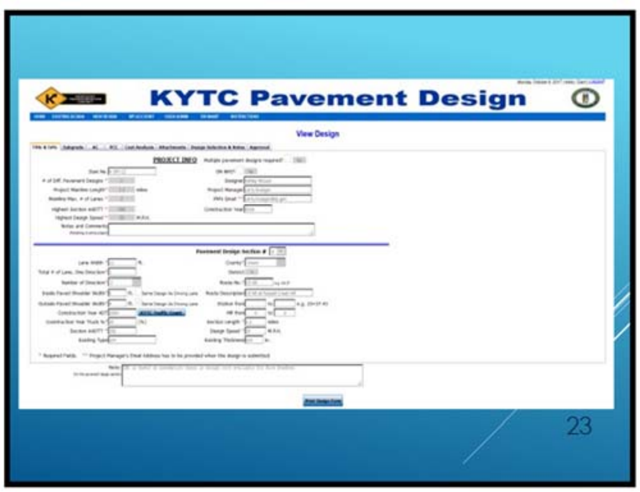

Old vs. New Design Curve, CBR 3
PCC Thickness
AADTT
New Curves
Old Curves

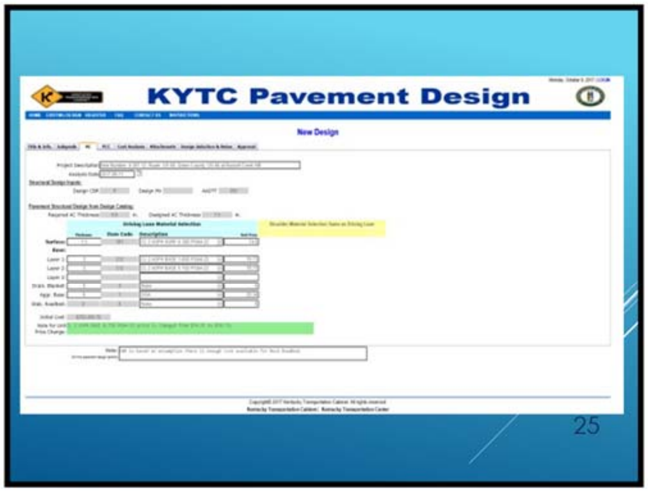

STEP 2: UPDATE CURRENT PAVEMENT RELATED POLICIES
Update KYTC's Pavement Policies to work with the New Curves
Update the Pavement Chapter of the Highway Design Manual
Develop Traffic Request Form for Pavement Design
Update KYTC's Warrants for Selecting Asphalt Mixtures and Compaction Options
Update Pavement Design Guide
Send out Design Memo establishing new pavement curves
Updated Specification Book Chapters
18

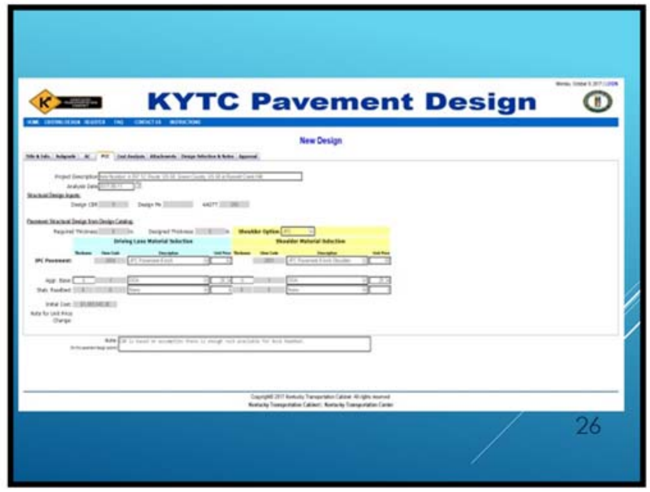


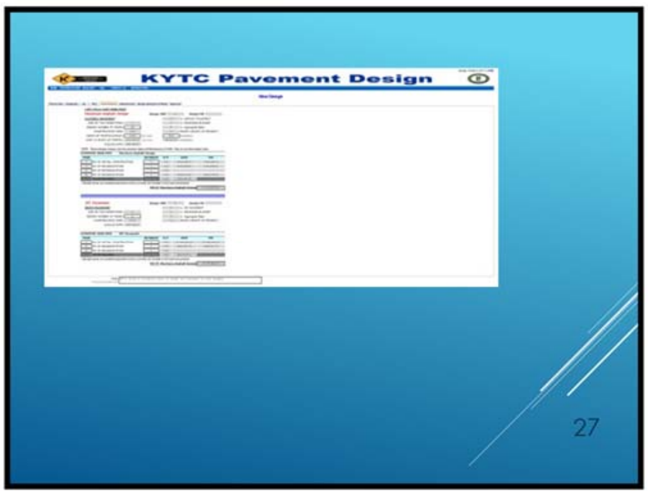
Criteria*	Submitted By	Approved By	Type Selection Justification and LCCA** Required	Type Selection Determined By
On the NHS	Central Office TEBM forPavement Branch	State Highway Engineer & if required, FHWA	Yes	State Highway Engineer
Structural Overlay or AADTT > 4,000	C.O. Pavement Branch Staff or Project Manager	C.O. TEBM for Pavement Branch	Yes ***	State Highway Engineer
AADTT ≥ 1,000 and ≤ 4,000; or ≥ 5 Lane Miles	Project Manager	C.O. TEBM for Pavement Branch	Yes	State Highway Engineer
< 1,000 AADTT and < 5 Lane Miles	Project Manager	District TEBM for Project Development	No	Project Manager





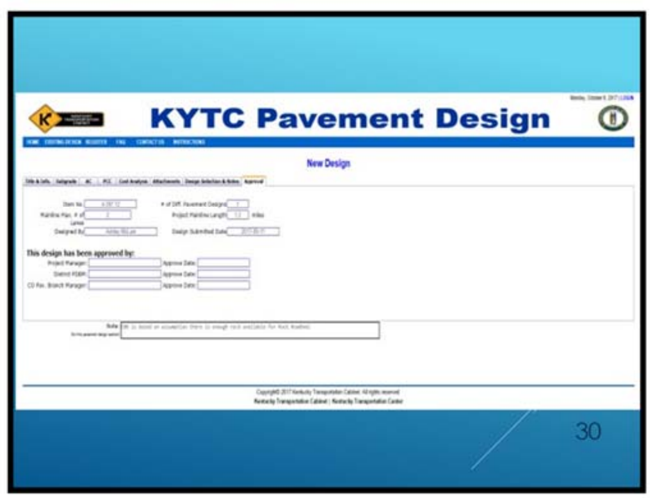

KYTC Pavement Design
New Design
25

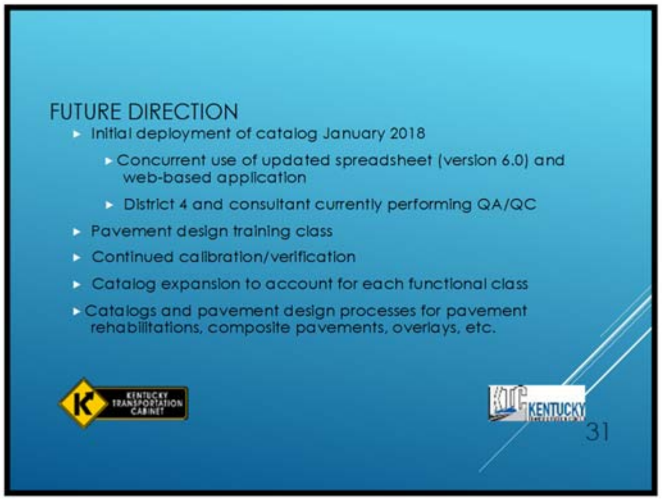

KYTC Pavement Design
New Design
26


KYTC Pavement Design
27


KYTC Pavement Design
New Design
Currently there are not any attachments for this pavement design now.
28


KYTC Pavement Design
New Design
29


KYTC Pavement Design
New Design
This design has been approved by:
30


FUTURE DIRECTION
Initial deployment of catalog January 2018
Concurrent use of updated spreadsheet (version 6.0) and web-based application
District 4 and consultant currently performing QA/QC
Pavement design training class
Continued calibration/verification
Catalog expansion to account for each functional class
Catalogs and pavement design processes for pavement rehabilitations, composite pavements, overlays, etc.
KENTUCKY TRANSPORTATION CABINET
KENTUCKY
31


THANK YOU
KENTUCKY TRANSPORTATION CABINET
KENTUCKY

Presentation 9—Affan Habib, Virginia DOT

VDOT Virginia Department of Transportation

MODELLING OF STABILIZED MATERIALS IN PAVEMENT ME

October 11, 2017 – Denver, CO

Affan Habib, PE
Pavement Program Manager

VDOT Materials Division

Presentation Outline

- ❑ Overview of stabilized materials
- ❑ Characterization of stabilized materials in Pavement ME
- ❑ Challenges in modelling of chemically stabilized materials in Pavement ME
- ❑ VDOT's Interim strategy in modelling of stabilized materials

OVERVIEW OF STABILIZED MATERIALS

Overview of Stabilized Materials

- **Commonly used stabilized materials:**
  - ✓ Cement Treated Aggregate Base
  - ✓ Lime/Cement stabilized soils
  - ✓ Asphalt/Cement treated drainage layers
- **Higher structural capacity compared to unstabilized layers.**
- **Material properties are less sensitive to seasonal variation of moisture.**

Overview of Stabilized Materials

- **To have a better performing pavement.**
- **Higher erodibility levels over unstabilized materials.**
- **Can be used to improve weak subgrade material to create stable working platform.**

Commonly used Stabilized Materials in Virginia

- **Cement Treated Aggregate (CTA) Base**
  - ✓ Contains 4% cement by weight
  - ✓ Typically 6" thickness
  - ✓ Recommended for high volume traffic facilities
- **Cement Treated Full Depth Reclamation (FDR)**
  - ✓ Used in reconstruction and major rehabs
  - ✓ 10-12" thickness
- **Soil Cement**
  - ✓ Subgrade stabilization

VDOT

CHARACTERIZATION OF STABILIZED MATERIALS IN PAVEMENT ME

7

VDOT

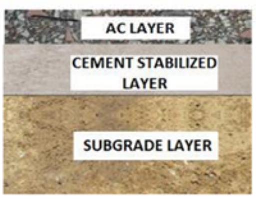
Characterization of Chemically Stabilized Materials

- **Pre version 2.2**
  - No semi rigid modeling option
  - Modelled as flexible pavement
  - Can select chemically stabilized layers under AC layers
- **Post version 2.2**
  - Semi rigid modelling option
  - Can no longer select chemically stabilized layers under 'flexible' pavement

VDOT

Characterization of Chemically Stabilized Materials

- **Chemically stabilized materials modelled as semi-rigid pavement (v. 2.2 & above)**



9

VDOT

Characterization ofChemically Stabilized Materials

Type of pavement	Inputs required	
Flexible pavement (Semi rigid)	General	Layer thickness (in), Unit weight (pcf), Poisson's ratio
	Strength	Elastic modulus (psi) Modulus of rupture (psi) Minimum elastic modulus (psi)
	Cracking	Chemically stabilized base crack spacing (ft) Chemically stabilized base crack Load Transfer Efficiency (LTE) (%) Chemically stabilized base crack fatigue LTE (%)
	Thermal	Thermal conductivity (BTU/hr-ft-degree F) Heat capacity (BTU/lb- deg F)

10

VDOT

Characterization ofChemically Stabilized Materials

Type of pavement	Inputs required	
Rigid pavement (CRCP, JPCP)	General	Layer thickness (in), Unit weight (pcf), Poisson's ratio
	Strength	Elastic modulus (psi)
	Thermal	Thermal conductivity (BTU/hr-ft-degree F) Heat capacity (BTU/lb- deg F)

11

VDOT

Characterization of Stabilized Materials in Pavement ME

- **Asphalt Treated Permeable Base**
  - ✓ **Under Flexible (AC) Layer**
    - Modelled as high quality aggregate with constant resilient modulus.
    - Manual of Practice recommends ~ 65,000 psi.
  - ✓ **Under Rigid Layer**
    - Modelled as flexible layer similar to HMA material.

12

VDOT

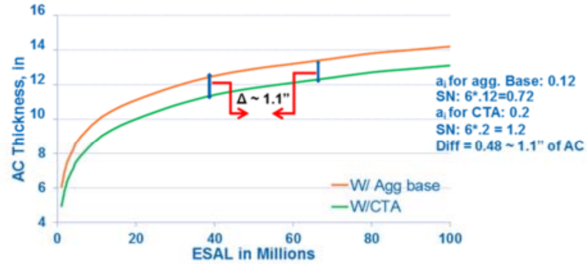
CHALLENGES IN MODELLING OF CHEMICALLY STABILIZED MATERIALS

13

VDOT

Challenges in Modelling of Stabilized Materials

- Everything was linear with 1993 method



- ME broke this "linearity"

14

VDOT

Challenges in Modelling of Stabilized Materials in AC Pavements

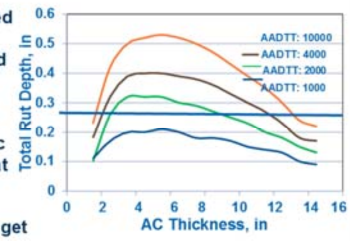
- VDOT initially planned to use the semi-rigid option in Pavement ME.
- Virginia local calibration sites have some CTA sections.
- VDOT is considering Rutting and AC Bottom-up Fatigue as a threshold criteria at this time.
  - Same as flexible pavement
  - Does it need to be same?

15

VDOT

General Observations with Semi Rigid Option

- CTA reduces the predicted AC bottom-up fatigue compared to unstabilized layer.
- Rutting governs design
- Rutting may not be high enough up to some traffic
- At lower traffic, somewhat thinner compared to unstabilized base
- At higher traffic, may not get benefit compared to unstabilized base



16

VDOT

Sensitivity of the Semi Rigid Option

✓ Insensitiveness of predicted distress:

- To variation of CTA thickness
- To variation of CTA elastic modulus
- To variation of CTA Modulus of Rupture (MOR).

17

VDOT

Sensitivity from CTA thickness

Distress Type	Target	CTA Modulus (1,000,000 psi), Crack spacing (25 feet)			
		CTA thickness			
		4 inch	6 inch	8 inch	10 inch
Terminal IRI (in/mile)	140		149.4	147.7	149.3
Permanent deformation - total pavement (in)	**0.26**	**0.27**	**0.27**	**0.27**	**0.27**
AC total fatigue cracking: bottom up + reflective (% lane area)	25	4.89	4.12	3.67	3.38
AC total transverse cracking: thermal + reflective (ft/mile)	2500	2414.9	2414.4	2415.4	2417.2
AC bottom-up fatigue cracking (% lane area)	**6**	**1.56**	**1.07**	**0.80**	**0.65**
AC thermal cracking (ft/mile)	1000	1	1	1	1
AC top-down fatigue cracking (ft/mile)	2000	332.5	346.7	359.1	336.9
Chemically stabilized layer - fatigue fracture (% lane area)	25	0.03	0.03	0.03	0.03

18

VDOT

Sensitivity from CTA Modulus

Distress Type	Target	CTA Elastic Modulus (psi)				
		200000	500000	1000000	1500000	2000000
Terminal IRI (in/mile)	140	150.6	149.6	149	149.2	148.8
Permanent deformation - total pavement (in)	**0.26**	**0.27**	**0.27**	**0.27**	**0.27**	**0.27**
AC total fatigue cracking: bottom up + reflective (% lane area)	25	7.09	5.44	4.12	3.49	3.09
AC total transverse cracking: thermal + reflective (ft/mile)	2500	2414.4	2414.4	2414.4	2414.4	2414.4
AC bottom-up fatigue cracking (% lane area)	**6**	**3.08**	**1.92**	**1.07**	**0.71**	**0.51**
AC thermal cracking (ft/mile)	1000	1	1	1	1	1
AC top-down fatigue cracking (ft/mile)	2000	329.9	333.6	346.7	329.2	329.2
Chemically stabilized layer - fatigue fracture (% lane area)	25	0.13	0.06	0.03	0.02	0.01

19

VDOT

Sensitivity from CTA Modulus of Rupture

Distress Type	CTA Modulus (1,000,000 psi)				
	Target	CTA Modulus of rupture (psi)			
		50	100	200	300
Terminal IRI (in/mile)	140	148.8	149.4	149.1	149.4
Permanent deformation - total pavement (in)	**0.26**	**0.27**	**0.27**	**0.27**	**0.27**
AC total fatigue cracking: bottom up + reflective (% lane area)	25	4.02	4.1	4.54	5.1
AC total transverse cracking: thermal + reflective (ft/mile)	2500	2414.4	2414.4	2414.4	2414.4
AC bottom-up fatigue cracking (% lane area)	**6**	**1.02**	**1.06**	**1.3**	**1.64**
AC thermal cracking (ft/mile)	1000	1	1	1	1
AC top-down fatigue cracking (ft/mile)	2000	347.8	346.9	343.6	341.5
Chemically stabilized layer - fatigue fracture (% lane area)	25	0	0.02	0.07	0.12

20

VDOT

VDOT's INTERIM STRATEGY IN MODELLING OF STABILIED MATERIALS

21

VDOT

VDOT's Interim Strategy in Modelling of Stabilized Materials

- CTA and FDR
  - ✓ Until the revised semi-rigid model released – not to use semi-rigid option in Pavement ME.
  - ✓ Will be modelled as non-stabilize base with constant resilient modulus value.
  - ✓ Resilient modulus ~ 80,000 psi.

22

VDOT

VDOT's Interim Strategy in Modelling of Stabilized Materials

- Soil-Cement
  - ✓ Modelled as a subgrade soil with constant resilient modulus value.
  - ✓ Resilient modulus ~ 40,000 psi.

23

VDOT

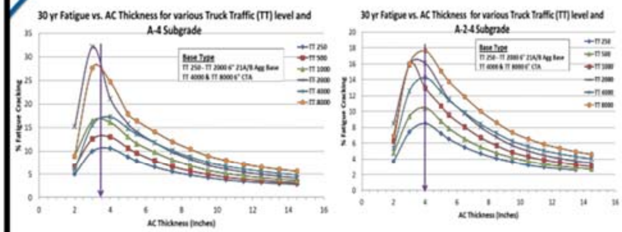
VDOT's Interim Strategy in Modelling of Stabilized Materials

- **For rigid pavement**
  - ✓ **CTA to be used as CTA chemically stabilized layer**
  - ✓ **OGDL is generally used on top of CTA**
  - ✓ **Cracking less sensitive to CTA thickness**

24

VDOT

Minimum AC Thickness



- Minimum AC thickness set at 4"
- One layer AC may be used on top of FDR for TT<200

25

VDOT

QUESTIONS TO PARTICIPANTS

- How other State DOTs model chemically stabilized materials in Pavement ME?
- What kind of distresses are considered to be critical & need to be considered as threshold criteria?
- Upon release of the version 2.4, how to assess the semi rigid option?

26

VDOT

Thank You
Any Questions?

Affan Habib
(affan.habib@vdot.virginia.gov
)

27

Presentation 10—Joshua Li, Oklahoma State University

MULTI-AGENCY EFFORT TO PREPARE DATA FOR PAVEMENT ME DESIGN

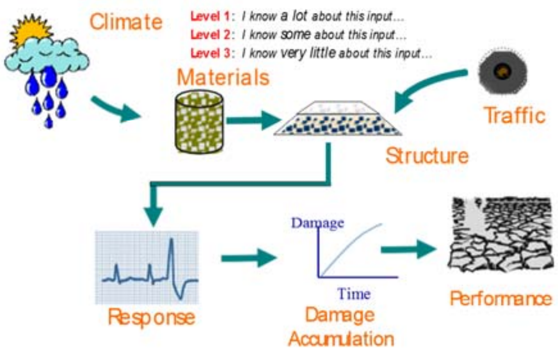
Joshua Q. Li
Oklahoma State University
qiang.li@okstate.edu

Oct 11 & 12, 2017 — 2017 AASHTO Pavement ME National Users Group Meeting

Acknowledgement

- AHTD (initially developed in 2008)
- TPF-5(242) lead agency: Louisiana Transportation Research Center (LTRC)
- Participating states: HI, KY, LA, MD, MI, NC, NH, WI, NV
- Relevant support/ Funding: OK
- FHWA: Chris Wagner, and many others
- Several other DOTs: demonstrations, conference calls, etc.

Pavement ME Design



Problem Statement

- Extensive amount of data inputs (many are new to designers)
  - Traffic: axle loading spectra instead of ESALs
  - Climate: hourly climatic data
  - Materials: dynamic modulus (E*), coefficient thermal expansion (CTE)
- Challenges of data availability, quality & process
  - Availability: either not available or stored somewhere
  - Quality & process: Weigh-In-Motion (WIM) data huge in size but poor in quality; selection of limited WIM data for design at any location
- Local calibration of performance models required
  - Integration of design with PMS
  - Data quality: fair IRI & rutting data, poor cracking data
  - Sophisticated 11-step procedure with statistical analysis (AASHTO 2014)

Goals of Prep-ME

- Assist DOTs with data preparation for ME implementation and local calibration
- Improve management and workflow of input data for Pavement ME Design in a production environment
- Provide high quality input data sets that can be directly imported to ME in required XML format

Prep-ME Memory Lane

- Initial development: AHTD 2006 to 2008
- TPF-5(242) Phase II: Traffic and Data Preparation for AASHTO DARWin-ME Analysis and Design, 2011 to 2014
- TPF-5(242) Phase III: Training and implementation

Prep-ME Interface

Overview of Software Capabilities

- Traffic Module
- Climate Module
- Material Module
- Tools
- Local Calibration Module: under development

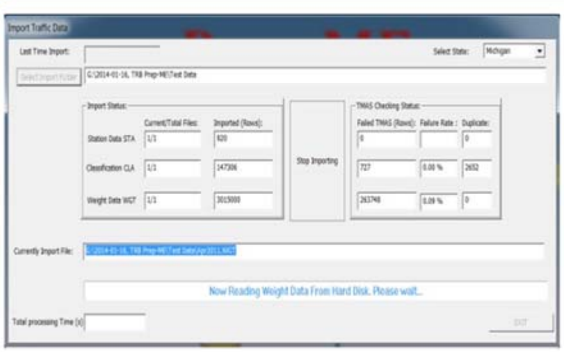
Traffic Module of Prep-ME

- Import & process raw WIM data (both 2001 & 2013 TMG format) into SQL DB: advanced parallel computing & DB techniques (GB in size in txt format)
- Implement algorithms and check WIM data quality: rigorous & flexible to meet various needs
- Generate loading spectra inputs for ME Design at any location using available WIM data: cluster analysis; 3 levels of input

Traffic Data Import

- Import traffic data based on file format defined in the FHWA's Traffic Monitoring Guide (TMG): both 2001 and 2013 versions
- Conduct Travel Monitoring Analysis System (TMAS 2.0) data check for each record
- Generate TMAS error reports for sensor diagnostics
- Process the raw data for Pavement ME Design & save data in the Prep- ME database tables

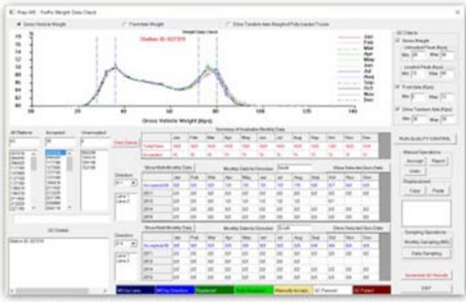
Traffic Data Import



Traffic Data Check

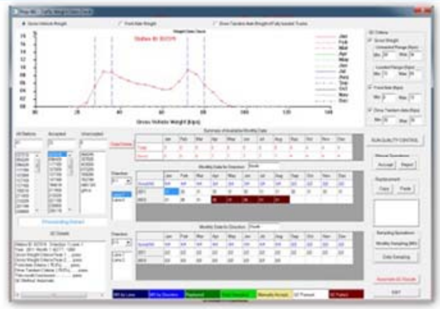
- Conduct automatic QC for classification & weight data by direction and lane: default data check algorithms from the 2001 TMG, while allow users make adjustments
- Provide interfaces to review monthly, weekly and daily traffic data and perform various comparisons
- Provide various manual, replacement, and sampling operations to analyze and utilize incomplete or failed data if possible
- Provide alternatives to investigate sites with low truck volume

Traffic Data Check



Auto & manual operations: by station, by direction, by lane (for various checks and comparisons)

Traffic Data Check



Review lanes for each month

Traffic Data Check

Look for pattern change – by day & week

Traffic QC Data Management

- TMG QC – automatically check data quality in batch mode (QC criteria customizable)
- Daily Sampling – select good days when a month has some invalid data
- Monthly Sampling – used when focusing on a particular time period
- Copy & Paste – borrow data from one month to represent a missing month
- Manual Accept/ Reject – available if the standard QC is not suitable for a station

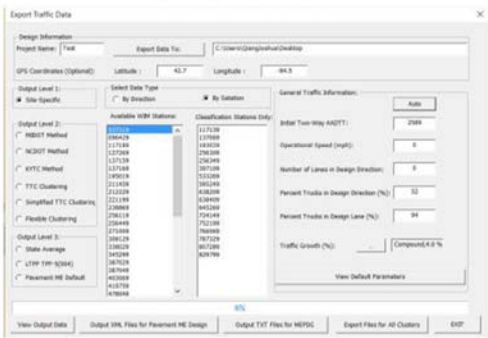
Load Spectra Export

- Provide 3 levels of outputs (can be mixed)
- Level 2 clustering methods
  - Michigan DOT method
  - NCDOT method
  - Kentucky method
  - Nevada method
  - TTC method
  - Simplified TTC method: low volume road
  - Flexible method: manual clusters
  - Modified TPF-5(004) method

Load Spectra Export

- Fully implemented C++ Ward-based hierarchical clustering algorithm
  - Allow users to evaluate existing clusters and define new clusters if necessary (such as with new data sets)
- Allow mixed three levels of traffic outputs
- Generate traffic input files for MEPDG (11 text files) and Pavement ME Design software (2 xml files)

Load Spectra Export – Level 1



Michigan Method – Level 2

Statistics based discriminant equations: based on freight data & traffic clusters

NCDOT Method – Level 2

Project specific VCD; Decision-tree based method: designer selects ALDF

Setup Clusters

Compare new data and new stations to research groups and identify new patterns

Traffic Module Summary

- High efficient data import: 2001 & 2013 TMG format; TMAS check
- Targeted QC – evaluates weight measures that are relatively consistent
- Manage Data – able to select the data used to generate statistics
- Clustering – able to cluster data to identify patterns for each input with multiple methodologies

Other Capability: Climate

- Import climate data
  - Any climate data that comply with Pavement ME Design Hourly Climate Data (HCD) format
  - Conduct preliminary data checks
- Interpolate ICM file for MEPDG and XML file for Pavement MEDesign

Other Capability: Materials

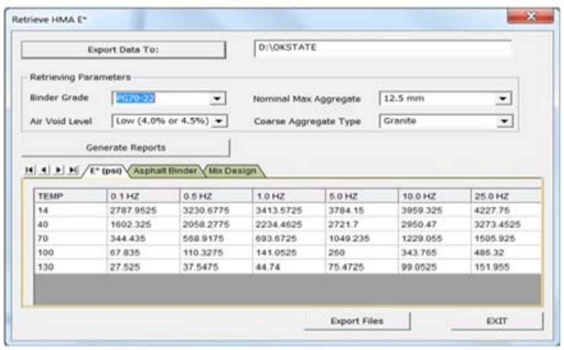
- Retrieve dynamic modulus (E*) data for HMA materials from statewide material library
- Retrieve Coefficient of Thermal Expansion (CTE) data for PCC materials from statewide material library
- Retrieve resilient modulus (M_R) from subgrade soil map data

Other Capability: Materials

- Dynamic modulus (E*)
  - 3 nominal max agg sizes
  - 3 binder grades
  - 4 agg types
  - 2 gradations
  - 4 temperatures
  - 5 loading frequencies
- Catalog of E* data for "Level 1" design

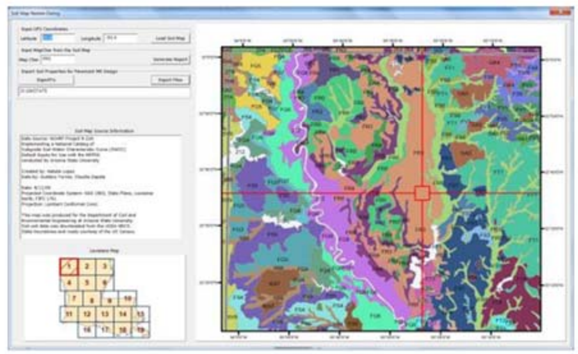
(Hall, 2007)

Other Capability: Materials

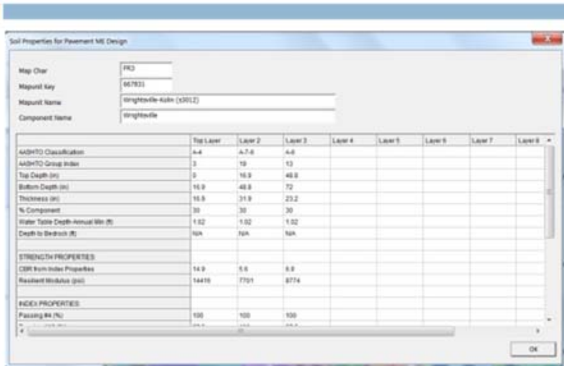


TEMP	0.1 HZ	0.5 HZ	1.0 HZ	5.0 HZ	10.0 HZ	25.0 HZ
14	2787.9525	3230.6775	3413.5725	3784.15	3959.325	4227.75
40	1602.325	2058.2775	2234.4625	2721.7	2950.47	3273.4525
70	344.435	568.9175	693.6725	1049.235	1229.055	1505.925
100	67.835	110.3275	141.0525	260	343.765	486.32
130	27.525	37.5475	44.74	75.4725	99.0525	151.955

Other Capability: Materials



Other Capability: Materials



	Top Layer	Layer 2	Layer 3	Layer 4	Layer 5	Layer 6	Layer 7	Layer 8
AASHTO Classification	A-4	A-7-6	A-6					
AASHTO Group Index	3	19	13					
Top Depth (in)	0	16.9	48.8					
Bottom Depth (in)	16.9	48.8	72					
Thickness (in)	16.9	31.9	23.2					
% Component	30	30	30					
Water Table Depth-Annual Min (ft)	1.02	1.02	1.02					
Depth to Bedrock (ft)	N/A	N/A	N/A					
STRENGTH PROPERTIES								
CBR from Index Properties	14.9	5.6	6.8					
Resilient Modulus (psi)	14416	7701	8774					
INDEX PROPERTIES								
Passing #4 (%)	100	100	100					

Other Capability: FWD

- Import raw FWD data (such as F25 format) into Prep-ME database
- Output summary report for back-calculation software
- Generate FWD XML file for Pavement ME Design

Other Capability: Tools

- Up-to-date Google Map v3.22 API
- Traffic file name change: those don't comply with the TMG name convention
- AADTT and VCD factors calculator: based on 24-h or 48-h short term count data
- State material library data import
- ALD to XML loading spectra converter

Other Capability: Tools

Prep-ME Future Development

- Assist state agencies implementing Prep-ME
  - Customization and feature improvements
  - Technical support

Prep-ME Future Development

- New module for **automated/assisted local calibration**: under development
  - Develop import functions to read ME analysis files into Prep-ME DB tables
  - Develop functions to import required performance data from state PMS, and LTPP database
  - Automate most of the AASHTO local calibration steps, especially Step 7, 8, 9, 10, 11, which involve extensive computing analyses and repeating research efforts when with additional and/or better data sets

How Prep-ME Can Be Used

- Traffic data collection engineers
  - To conduct effective traffic data QA/QC for various applications
- Pavement design engineers
  - To analyze axle loading data and select the best spectra among WIMs, national, and local defaults
  - To prepare all input data based on ME designated XML import format with minor efforts
- Improve the productivities of above operations tremendously

Michigan **implementation** slides available based on Request

Thank You

Questions?

Joshua Q. Li, Ph.D., P.E
School of Civil and Environmental Engineering
Oklahoma State University
Email: qiang.li@okstate.edu
Mobile: 405-332-1557

Presentation 11—Halil Ceylan, Iowa State University

IOWA STATE UNIVERSITY
Institute for Transportation
National Concrete Pavement Technology Center

Concrete Overlay Design and Performance Evaluations Using AASHTOWare Pavement ME Design

Presented by
Halil Ceylan, Ph.D., Director, PROSPER

Dept. of Civil, Construction and Environmental Engineering (CCEE)
ISU Site Director for FAA PEGASAS Center of Excellence
Program for Sustainable Pavement Engineering and Research (PROSPER)
Institute for Transportation (InTrans), Iowa State University (ISU)

AASHTO Pavement ME User Group Meeting
Denver, Colorado, October 11-12, 2017

College of Engineering

Authors

- Yu-An Chen, CCEE, ISU
- Halil Ceylan, Ph.D., CCEE, ISU
- Peter C. Taylor, Ph.D., P.E., CP Tech Center, ISU
- Sunghwan Kim, Ph.D., P.E., InTrans, ISU

IOWA STATE UNIVERSITY www.InTrans.iastate.edu 2

Acknowledgments

- TAC – IA DOT
  - Scott Schram, Chris Brakke, and many other colleagues from Iowa DOT
- Snyder and Associates
  - Dale Harrington
  - Melisse Leopold
  - Jerod Gross
- ICPA
  - Gordon L. Smith
  - John Cunningham
  - Daniel E. King
- ISU CP Tech
  - Tom Cackler
  - Steven Tritsch

IOWA STATE UNIVERSITY www.InTrans.iastate.edu 3

PROSPER: Goals

Program for Sustainable Pavement Engineering & Research (PROSPER)

Home | Focus Areas | Research | Publications | Personnel | News

Program Objectives:
- Advance research, development and implementation of next-generation sustainable roadway systems.
- Integrate cutting-edge technologies from various disciplines to tackle real-world highway and airport pavement infrastructure problems.
- Investigate sustainable paving materials and construction technologies, pavement non-destructive testing and evaluation, performance monitoring, maintenance, repair and rehabilitation.

The overall goal of the Program for Sustainable Pavement Engineering & Research (PROSPER) is to advance research, education and technology transfer in the area of sustainable highway and airport pavement infrastructure systems.

http://www.intrans.iastate.edu/prosper/

IOWA STATE UNIVERSITY www.InTrans.iastate.edu 4

PROSPER: Research Agenda

Program for Sustainable Pavement Engineering & Research (PROSPER)

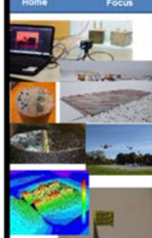
Home | Focus | Research | Publications | Personn | News

IOWA STATE UNIVERSITY Institute for Transportation www.InTrans.iastate.edu 5

PROSPER: Research Areas

Program for Sustainable Pavement Engineering & Research (PROSPER)

Home | Focus | Research | Publications | Personn | News



Roadway Infrastructure Assessment and Modeling
- Rapidly and reliably evaluate the existing condition of infrastructure systems using non-destructive technologies augmented by numerical simulations and artificial intelligence
- Wireless Radio Frequency Identification (RFID) tags in highway and airport construction projects for temperature monitoring and concrete strength estimation using PCC maturity concept
- Development of multi-functional self-powered Micro-Electro-Mechanical Sensor (MEMS) system capable of real-time, remote monitoring of localized strain, temperature and moisture content in highway/airport pavement systems

Mechanistic and Performance Based Pavement Analysis, Design and Construction Technology
- Improving the pavement performance prediction accuracy of Mechanistic-Empirical Pavement Design Guide (MEPDG)/AASHTOWare Pavement ME through local calibration
- Use of RFID/MEMS based real-time field data for mechanistic calibration of pavement performance models
- Development of simplified flexible and rigid pavement design models
- Improved pavement forecasting models for repaired/rehabilitated pavement sections in Iowa

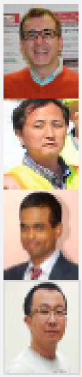
Sustainable Infrastructure/Engineering Materials
- Development of electrically conductive concrete (ECC) with nano-structured superhydrophobic surfaces to achieve ice- and snow-free pavement surfaces
- Economic and energy viability of heated airport pavement systems
- Integrating Alternative/Recycled Materials into PCC Mix Design System
- Use of biomass derived lignin in roadway geo-materials stabilization and unpaved road dust mitigation

IOWA STATE UNIVERSITY Institute for Transportation www.InTrans.iastate.edu 6

PROSPER: Personnel

Personnel

26 Ph.D. and M.S. students with various engineering and science backgrounds



Halil Ceylan, Ph.D.
Director, PROSPER

Professor
Civil, Construction and Environmental Engineering (CCEE), Iowa State University, Ames, IA 50011
Ph: 515-294-8051| Fax: 515-294-8216| E-mail: hceylan@iastate.edu

Sunghwan Kim, Ph.D., P.E.
Associate Director, PROSPER

Assistant Research Scientist IV
Institute for Transportation (InTrans), Iowa State University, Ames, IA 50011
Ph: 515-294-4968| Fax: 515-294-8216| E-mail: sunghwan@iastate.edu

Kasthurirangan (Rangan) Gopalakrishnan, Ph.D.
Affiliate/Collaborator Faculty, PROSPER

Research Associate Professor
Civil, Construction and Environmental Engineering (CCEE), Iowa State University, Ames, IA 50011
Ph: 515-294-3044| Fax: 515-294-8216| E-mail: rangan@iastate.edu

Yang Zhang, Ph.D.
Technical Specialist, PROSPER

Postdoc Research Associate
Civil, Construction and Environmental Engineering (CCEE), Iowa State University, Ames, IA 50011
Ph: 515-294-8852| Fax: 515-294-8216| E-mail: alex19@iastate.edu

PROSPER: Achievements (as of 2017)

- PI/Co-PI of 93 sponsored research projects
  - Over $16 million of cumulative project funds
  - Sponsored by the FHWA, the FAA, NSF, NCHRP, IA DOT, IHRB, MN DOT, MN LRRB, WI DOT, IL DOT, PCA, and other funding agencies
- Over 230 technical publications authored and co-authored
- Over 300 invited and technical lectures
- More than 20 national and international professional committees and organizations

IOWA STATE UNIVERSITY Institute for Transportation *www.InTrans.iastate.edu* 8

Outline

- Background
- Overall Description of Research
- Pavement ME Design Performance Predictions of Iowa Concrete Overlays
- Effect of Structural Design Options on Iowa Concrete Overlay Performances
- Summary

IOWA STATE UNIVERSITY Institute for Transportation *www.InTrans.iastate.edu* 9

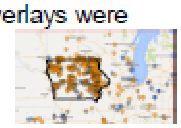
Outline

- Background
- Overall Description of Research
- Pavement ME Design Performance Predictions of Iowa Concrete Overlays
- Effect of Structural Design Options on Iowa Concrete Overlay Performances
- Summary

IOWA STATE UNIVERSITY Institute for Transportation *www.InTrans.iastate.edu* 10

Iowa Concrete Overlay History

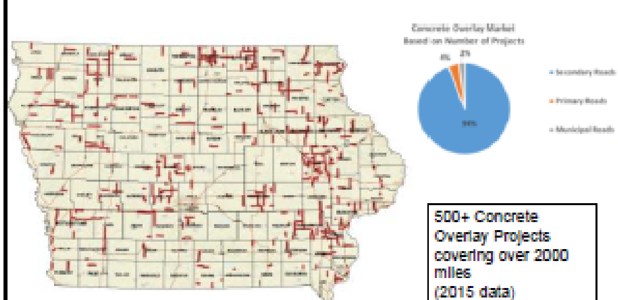
- Over 2,000 miles of concrete overlays have been constructed since the late 1970s
- Over half of concrete overlay projects were constructed since 2005
- Over 80% of concrete overlay projects were on county road system
- Over 500 projects of concrete overlays were included in the study



ACPA Overlay Explorer

IOWA STATE UNIVERSITY Institute for Transportation *www.InTrans.iastate.edu* 11

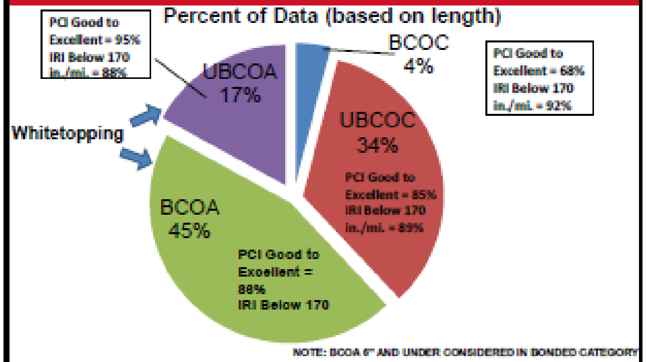
Iowa Concrete Overlay Distribution: Geographical



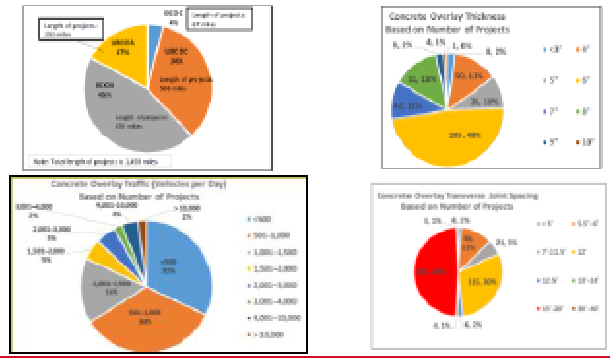
500+ Concrete Overlay Projects covering over 2000 miles (2015 data)

IOWA STATE UNIVERSITY Institute for Transportation *www.InTrans.iastate.edu* 12

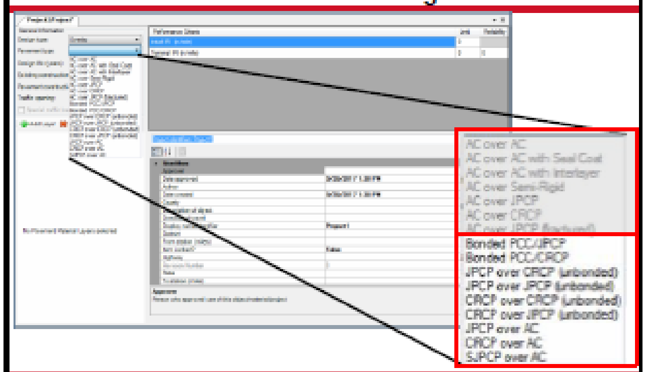
Iowa Concrete Overlay Distribution: Overlay Types (Cont'd)



Iowa Concrete Overlay Distribution: Database Summary



Concrete Overlay Design Options in Pavement ME Design



Concrete Overlay Design Options in Pavement ME Design (Cont'd)

- Bonded PCC/JPCP
- Bonded PCC/CRCP

→ BCOC

- JPCP over CRCP (unbonded)
- JPCP over JPCP (unbonded)
- CRCP over CRCP (unbonded)
- CRCP over JPCP (unbonded)

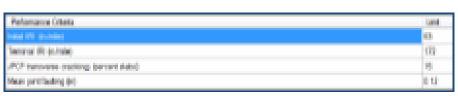
→ UBCOC

- JPCP over AC
- CRCP over AC
- SJPCP over AC

→ BCOA/UBCOA

Concrete Overlay Performance Predictions in Pavement ME Design

- Performance predictions
  - International roughness index (IRI)
  - Transverse cracking
  - Joint faulting



Outline

- Background
- Overall Description of Research
- Pavement ME Design Performance Predictions of Iowa Concrete Overlays
- Effect of Structural Design Options on Iowa Concrete Overlay Performances
- Summary

Overall Description of Research

- Objectives
  - To compare actual Iowa concrete overlay performance measurements with Pavement ME design predictions
  - To investigate effect of structural design options on Iowa concrete overlay performances

Iowa Concrete Overlay Distribution: Thickness

PCC slab thickness (in.)	Total number of projects	Percent of data based on number of projects (%)	Percent of data based on length of projects (%)
>3	8	2	1
4	50	13	19
5	36	9	12
6	185	48	41
7	42	11	12
8	51	13	11
9	8	2	3
10	4	2	1
12	1	0	0
Total	385	100	100

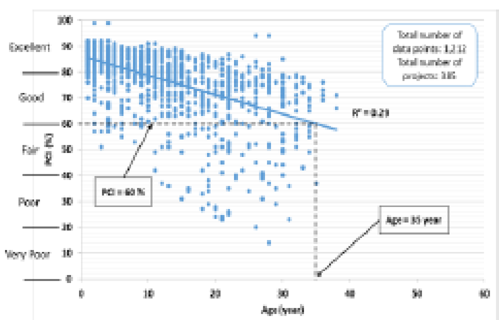
Iowa Concrete Overlay Distribution: Joint Spacing

Joint spacing (ft.)	Total number of projects	Percent of data based on number of projects (%)	Percent of data based on length of projects (%)
< 6	50	13	19
7-11.5	21	5	5
12	115	29	19
12.5-14	10	3	4
15-20	186	49	53
30-40	3	1	0
Total	385	100	100

Iowa Concrete Overlay Distribution: PCI

PCI (%)	Concrete overlay: percent of data based on number of projects (%)	(BCOC): percent of data based on number of projects (%)	(UBCOC): percent of data based on number of projects (%)	(BCOA): percent of data based on number of projects (%)	(UBCOA): percent of data based on number of projects (%)
100-81 (Excellent)	52	21	51	54	57
80-61 (Good)	37	51	39	34	36
60-41 (Fair)	8	21	6	9	6
40-21 (Poor)	3	7	4	3	0
20-0 (Very poor)	0	0	0	0	0
Total	100	100	100	100	100

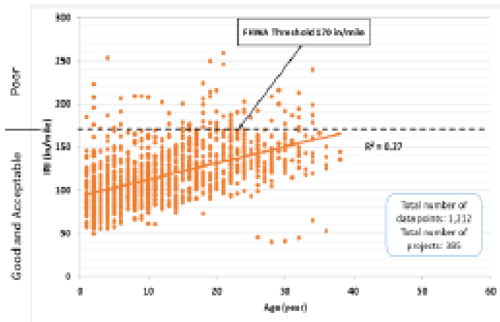
Iowa Concrete Overlay Distribution: PCI



Iowa Concrete Overlay Distribution: IRI

IRI (in/mile)	Concrete overlay: percent of data based on number of projects (%)	(BCOC): percent of data based on number of projects (%)	(UBCOC): percent of data based on number of projects (%)	(BCOA): percent of data based on number of projects (%)	(UBCOA): percent of data based on number of projects (%)
< 95 (Good)	30	40	28	28	40
95-169 (Average)	63	50	65	66	53
> 170 (Poor)	7	10	7	6	7
Total	100	100	100	100	100

Iowa Concrete Overlay Distribution: IRI



Outline

- Background
- Overall Description of Research
- Pavement ME Design Performance Predictions of Iowa Concrete Overlays
- Effect of Structural Design Options on Iowa Concrete Overlay Performances
- Summary

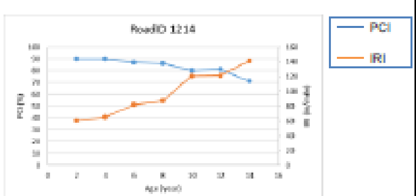
UNBONDED CONCRETE ON CONCRETE (UBCOC)

UBCOC Design Example

- Two of Iowa UBCOC roads
  - Road ID 1214 Cass Co. G30/Highland Rd.
  - Road ID 1188 Dallas Co. P58/K Ave.

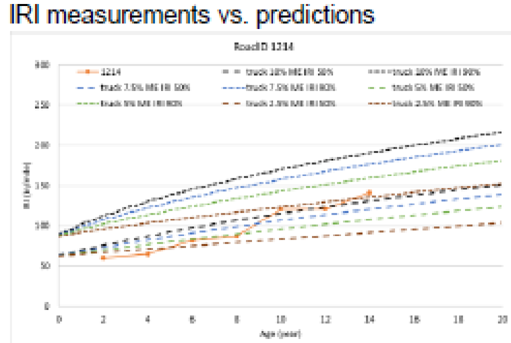
UBCOC Design Example: Road ID 1214 Cass Co. G30/Highland Rd.

- Overlay type: UBCOC
- Thickness: 5 in.
- Joint spacing: 11 ft.
- Traffic (ADT): 1,040
- Overlay construction year: 2001
- Existing pavement construction year: 1963
- Interlayer: Unknown



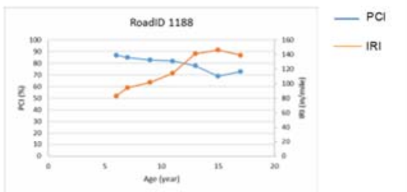
UBCOC Design Example: Road ID 1214 Cass Co. G30/Highland Rd. (Cont'd)

- IRI measurements vs. predictions



UBCOC Design Example: Road ID 1188 Dallas Co. P58/K Ave.

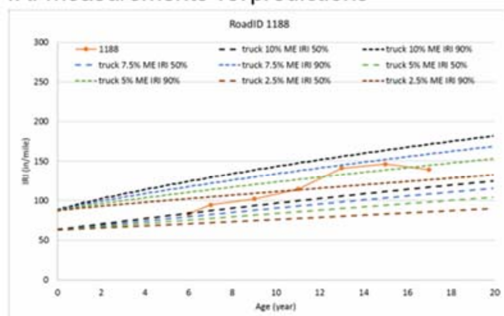
- Overlay type: UBCOC
- Thickness: 6 in.
- Joint spacing: 11 ft.
- Traffic (ADT): 560
- Overlay construction year: 1998
- Existing pavement construction year: 1974
- Interlayer: 1 in. AC



IOWA STATE UNIVERSITY Institute for Transportation www.InTrans.iastate.edu 31

UBCOC Design Example: Road ID 1188 Dallas Co. P58/K Ave. (Cont'd)

- IRI measurements vs. predictions



IOWA STATE UNIVERSITY www.InTrans.iastate.edu 32

BONDED CONCRETE ON ASPHALT (BCOA)

IOWA STATE UNIVERSITY www.InTrans.iastate.edu 33

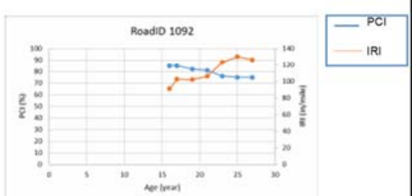
BCOA Design Example

- Two of Iowa BCOA roads
  - Road ID 1092 Dallas Co. P58/J Ave.
  - Road ID 1066 Louisa Co. X37

IOWA STATE UNIVERSITY www.InTrans.iastate.edu 34

BCOA Design Example: Road ID 1092 Dallas Co. P58/J Ave.

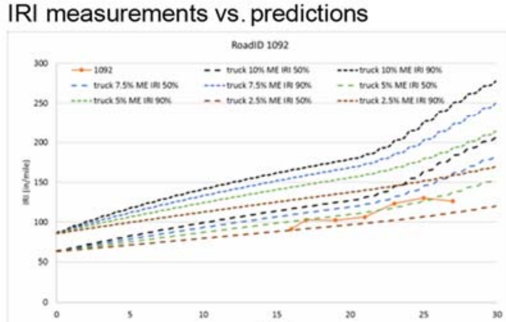
- Overlay type: BCOA
- Thickness: 5 in.
- Joint spacing: 20 ft.
- Traffic (ADT): 870
- Overlay construction year: 1988
- Existing pavement construction year: N/A



IOWA STATE UNIVERSITY Institute for Transportation www.InTrans.iastate.edu 35

BCOA Design Example: Road ID 1092 Dallas Co. P58/J Ave. (Cont'd)

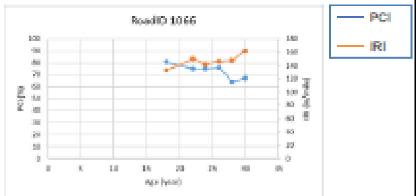
- IRI measurements vs. predictions



IOWA STATE UNIVERSITY www.InTrans.iastate.edu 36

BCOA Design Example: Road ID 1066 Louisa Co. X37

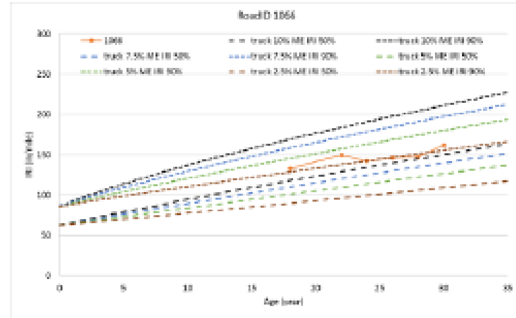
- Overlay type: BCOA
- Thickness: 6 in.
- Joint spacing: 15 ft.
- Traffic (ADT): 690
- Overlay construction year: 1985
- Existing pavement construction year: N/A



IOWA STATE UNIVERSITY Institute for Transportation www.InTrans.iastate.edu 37

BCOA Design Example: Road ID 1066 Louisa Co. X37 (Cont'd)

- IRI measurements vs. predictions



IOWA STATE UNIVERSITY Institute for Transportation www.InTrans.iastate.edu 38

UNBONDED CONCRETE ON ASPHALT (UBCOA)

IOWA STATE UNIVERSITY Institute for Transportation www.InTrans.iastate.edu 39

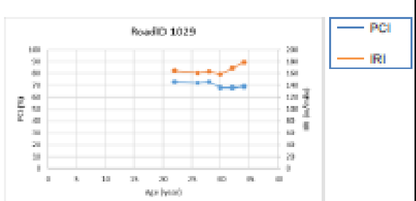
UBCOA Design Example

- Two of Iowa UBCOA roads
  - Road ID 1029 Henry Co. X23/Racine Ave.
  - Road ID 1114 Dubuque Co. D61

IOWA STATE UNIVERSITY Institute for Transportation www.InTrans.iastate.edu 40

UBCOA Design Example: Road ID 1029 Henry Co. X23/Racine Ave.

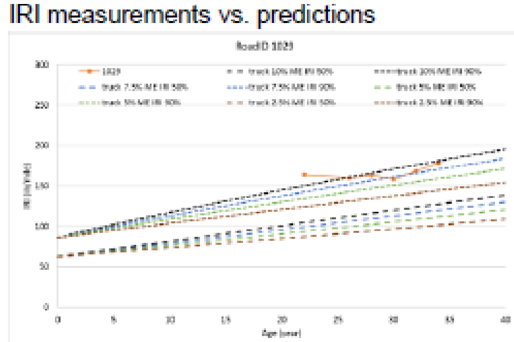
- Overlay type: UBCOA
- Thickness: 8 in.
- Joint spacing: 15 ft.
- Traffic (ADT): 590
- Overlay construction year: 1981
- Existing pavement construction year: N/A



IOWA STATE UNIVERSITY Institute for Transportation www.InTrans.iastate.edu 41

UBCOA Design Example: Road ID 1029 Henry Co. X23/Racine Ave. (Cont'd)

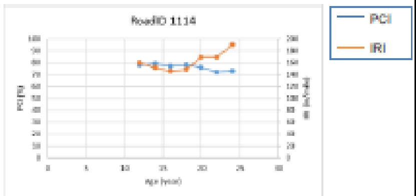
- IRI measurements vs. predictions



IOWA STATE UNIVERSITY Institute for Transportation www.InTrans.iastate.edu 42

UBCOA Design Example: Road ID 1114 Dubuque Co. D61

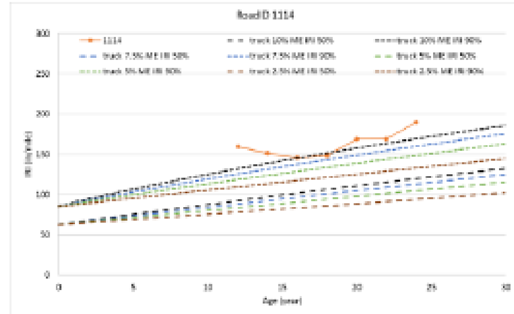
- Overlay type: UBCOA
- Thickness: 7 in.
- Joint spacing: 20 ft.
- Traffic (ADT): 570
- Overlay construction year: 1991
- Existing pavement construction year: N/A



Iowa State University Institute for Transportation www.InTrans.iastate.edu 43

UBCOA Design Example: Road ID 1114 Dubuque Co. D61(Cont'd)

- IRI measurements vs. predictions



Iowa State University Institute for Transportation www.InTrans.iastate.edu 44

Outline

- Background
- Overall Description of Research
- Pavement ME Design Performance Predictions of Iowa Concrete Overlays
- Effect of Structural Design Options on Iowa Concrete Overlay Performances
- Summary

Iowa State University Institute for Transportation www.InTrans.iastate.edu 45

Pavement ME Structural Design Options Investigated

Design parameters	BCOA	UBCOA	UBCOC
Traffic (AADTT)		75	
Climate station		Des Moines	
Joint spacing (ft.)	12 x 12 12 x 15 12 x 20	12 x 12 12 x 15 12 x 20	12 x 12 12 x 15 12 x 20
Thickness (in.)	6	7 to 9	6 to 8
Existing AC/PCC layer thickness (in.)	4 and 6	4 and 6	4 and 6
Interlayer thickness (in.)	N/A	N/A	1

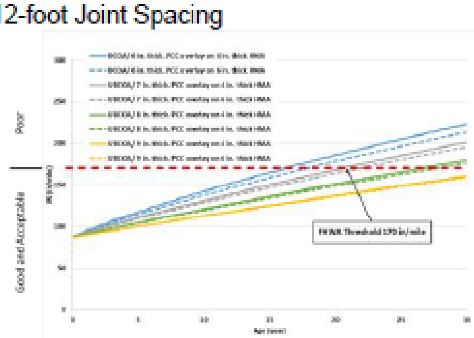
Iowa State University Institute for Transportation www.InTrans.iastate.edu 46

IRI PREDICTIONS

Iowa State University Institute for Transportation www.InTrans.iastate.edu 47

Pavement ME Design IRI Predictions: BCOA/UBCOA

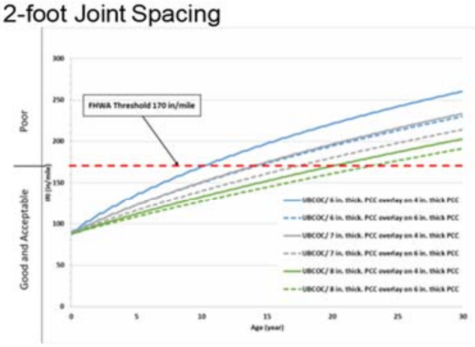
- 12-foot Joint Spacing



Iowa State University Institute for Transportation www.InTrans.iastate.edu 48

Pavement ME Design IRI Predictions: UBCOC

- 12-foot Joint Spacing



IOWA STATE UNIVERSITY *www.InTrans.iastate.edu* 49

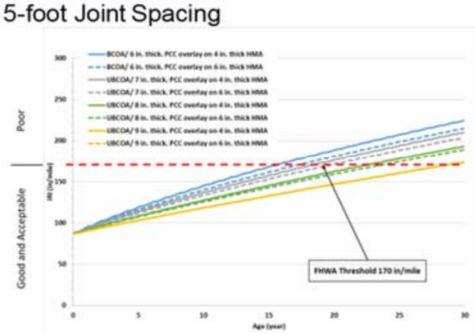
Pavement ME Design IRI Predictions: Key Findings on 12-foot Joint Spacing Case

- Thicker PCC overlay layer could provide the improved IRI predictions
- Thicker existing pavement layer, either HMA or PCC, could provide the improved IRI predictions as well
  - For thickness of concrete overlay greater than 8-inch, the increased existing HMA pavement thickness has a marginal effect on IRI predictions

IOWA STATE UNIVERSITY *www.InTrans.iastate.edu* 50

Pavement ME Design IRI Predictions: BCOA/UBCOA

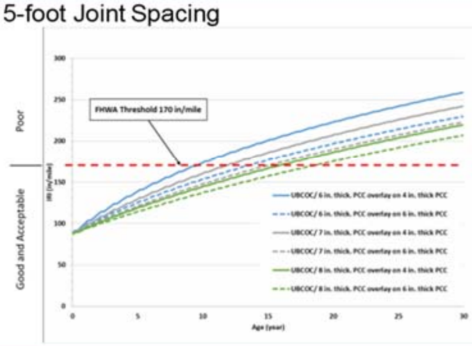
- 15-foot Joint Spacing



IOWA STATE UNIVERSITY *www.InTrans.iastate.edu* 51

Pavement ME Design IRI Predictions: UBCOC

- 15-foot Joint Spacing



IOWA STATE UNIVERSITY *www.InTrans.iastate.edu* 52

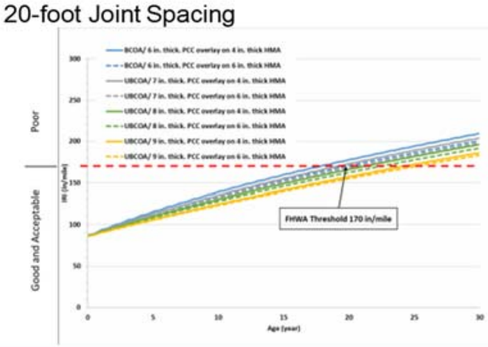
Pavement ME Design IRI Predictions: Key Findings on 15-foot Joint Spacing Case

- The 15-foot long joint design may result in a shorter service
- In case of 9-in of PCC overlay thickness in BCOA/UBCOA
  - IRI predictions seem to be not affected by the thickness changes for the existing HMA layer
- BCOA/UBCOA seems to take longer to reach the established IRI threshold than UBCOC (longer life)

IOWA STATE UNIVERSITY *www.InTrans.iastate.edu* 53

Pavement ME Design IRI Predictions: BCOA/UBCOA

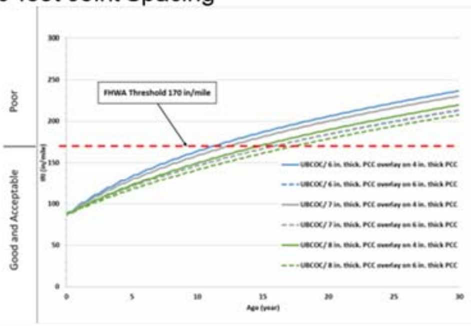
- 20-foot Joint Spacing



IOWA STATE UNIVERSITY *www.InTrans.iastate.edu* 54

Pavement ME Design IRI Predictions: UBCOC

- 20-foot Joint Spacing



IOWA STATE UNIVERSITY www.InTrans.iastate.edu 55

Pavement ME Design IRI Predictions: Key Findings on 20-foot Joint Spacing Case

- In comparisons to 12 and 15-foot joint spacing results, the 20-foot joint would have a shorter service life
- Increasing overlay thickness demonstrates that the IRI predictions are close to one another, probably because 20-foot joint spacing is a bit too long for using concrete overlays
- Increasing the thickness of a UBCOC structure from 6 to 8 inches may result in extending service life from ~12 to ~17 years

IOWA STATE UNIVERSITY www.InTrans.iastate.edu 56

Outline

- Background
- Overall Description of Research
- Pavement ME Design Performance Predictions of Iowa Concrete Overlays
- Effect of Structural Design Options on Iowa Concrete Overlay Performances
- Summary

IOWA STATE UNIVERSITY www.InTrans.iastate.edu 57

Summary

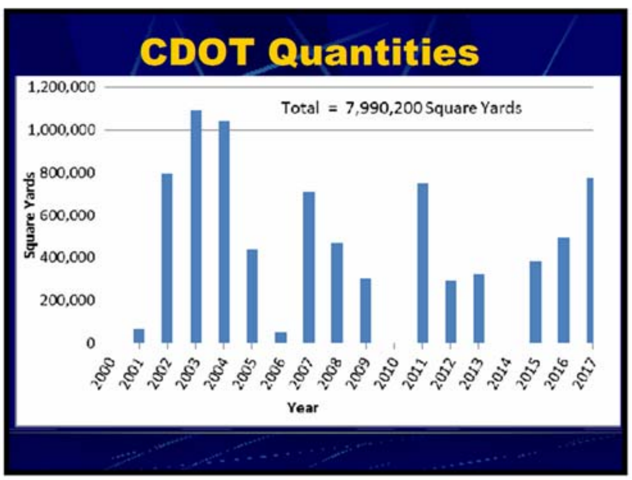
- Iowa concrete overlays have been performing very well based on extensive field studies and evaluations of the pavement performance data
- Pavement ME design demonstrates that higher overlay thickness leads to increased overlay service life, and greater existing pavement thickness, either for HMA or PCC, also leads to extension of overlay service life
- Pavement ME performance predictions are reasonable given that we mostly work with level 2 and 3 data with an uncalibrated version of the software (for concrete overlays)
- In comparisons to 12- and 15-foot joint spacing results, the 20-foot joint would have a shorter service life based on Pavement ME predictions

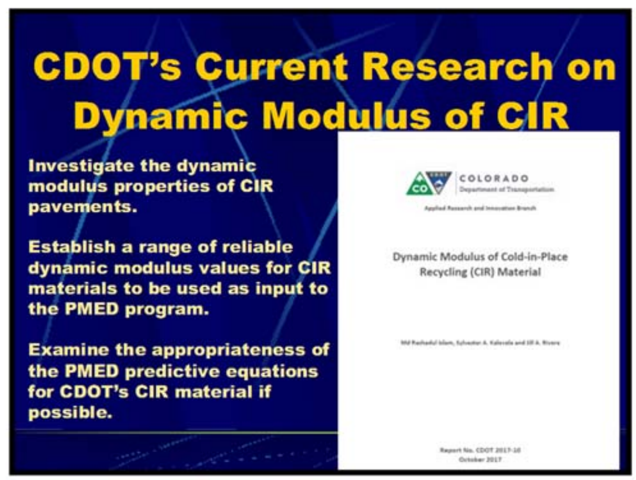
IOWA STATE UNIVERSITY www.InTrans.iastate.edu 58

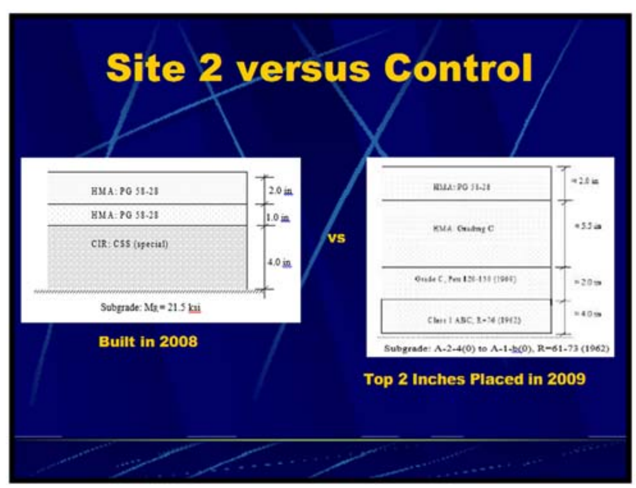
Thank You!

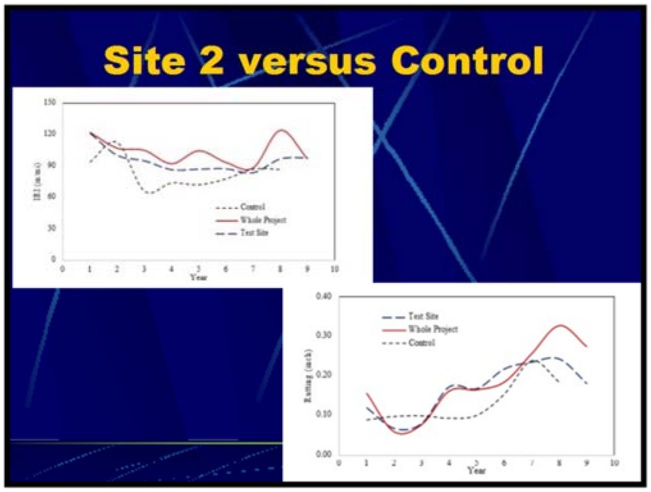
College of Engineering

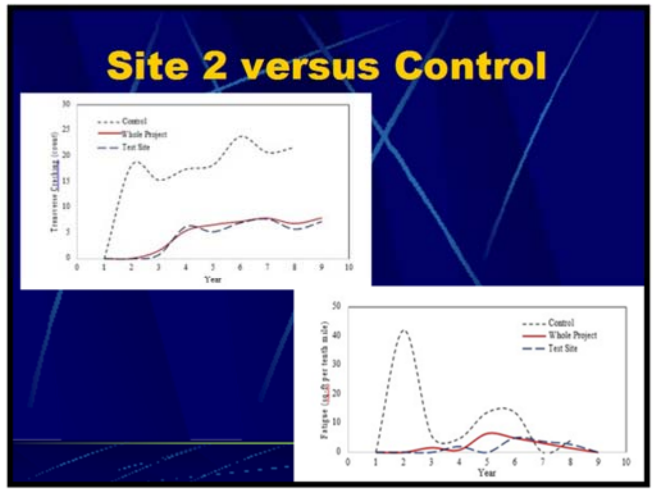
Presentation 12—Jay Goldbaum, Colorado DOT

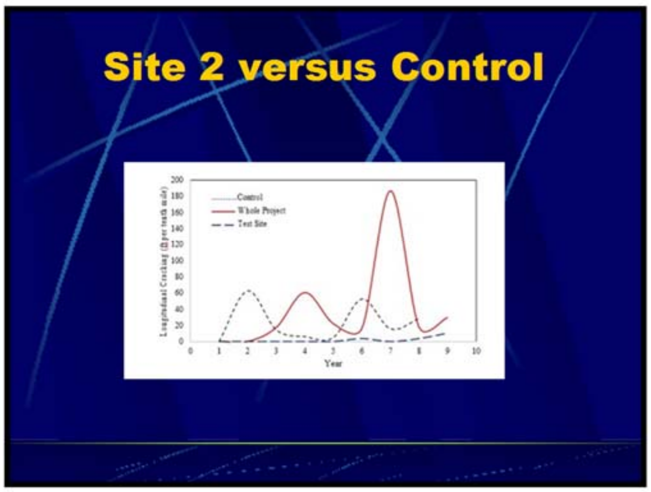


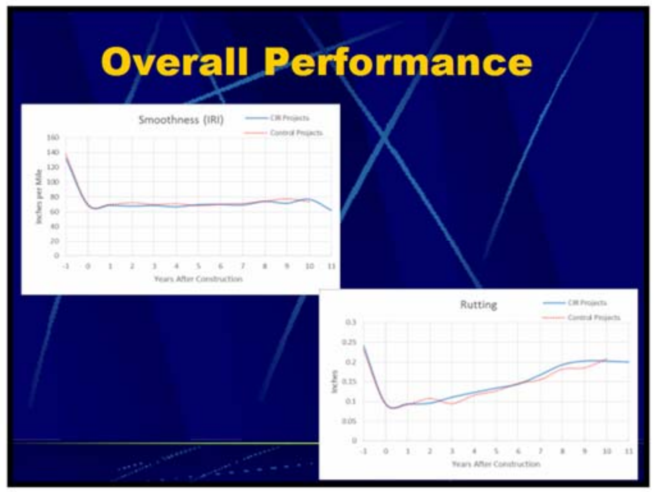


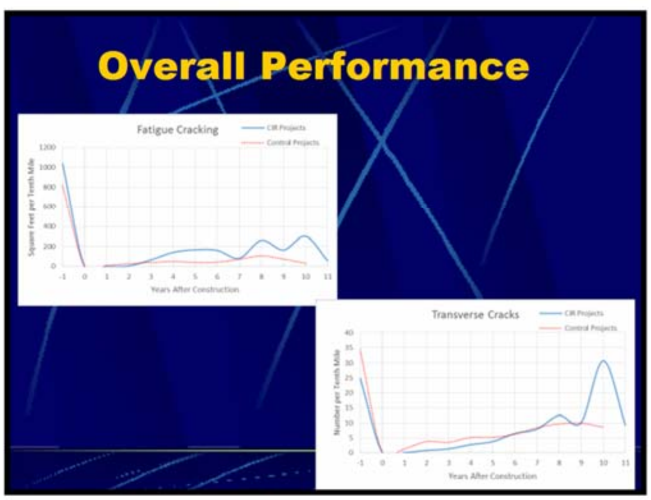


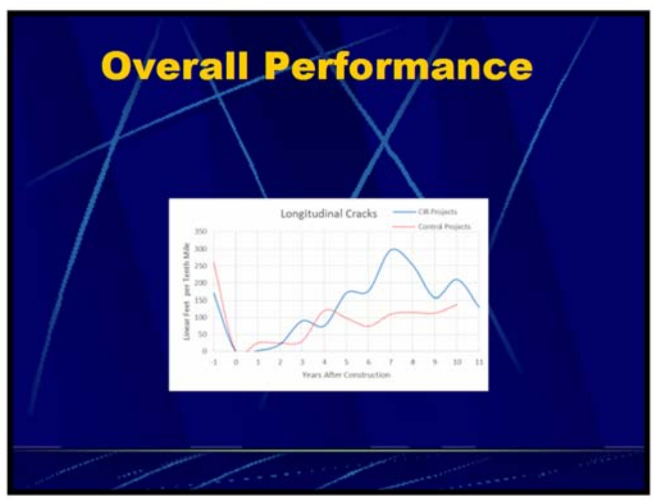

Site 2 versus Control
IRI (in/mi)
Year
Control
Whole Project
Test Site
Rutting (inch)
Year


Site 2 versus Control
Transverse Cracking (count)
Year
Control
Whole Project
Test Site
Fatigue (sq.ft per tenth mile)
Year

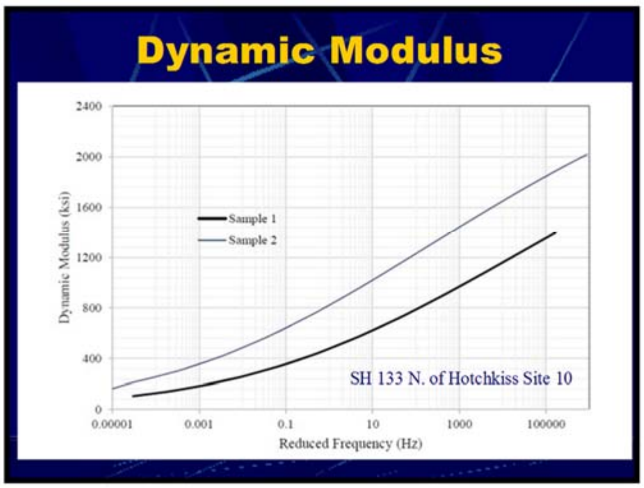

Site 2 versus Control
Longitudinal Cracking (ft per tenth mile)
Control
Whole Project
Test Site
Year

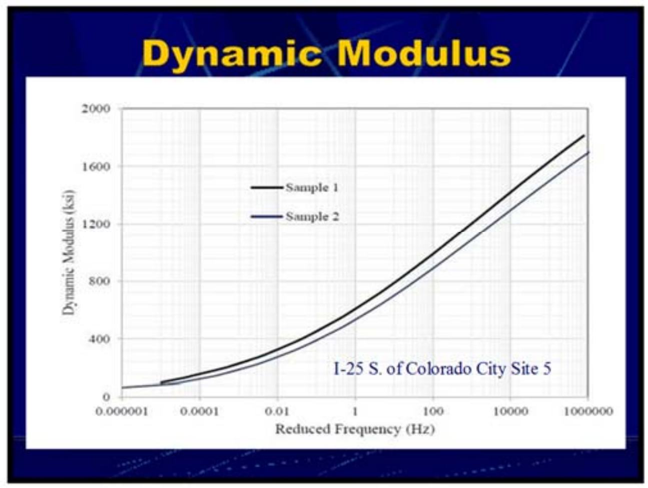

Overall Performance
Smoothness (IRI)
CIR Projects
Control Projects
Inches per Mile
Years After Construction
Rutting
Inches
Years After Construction

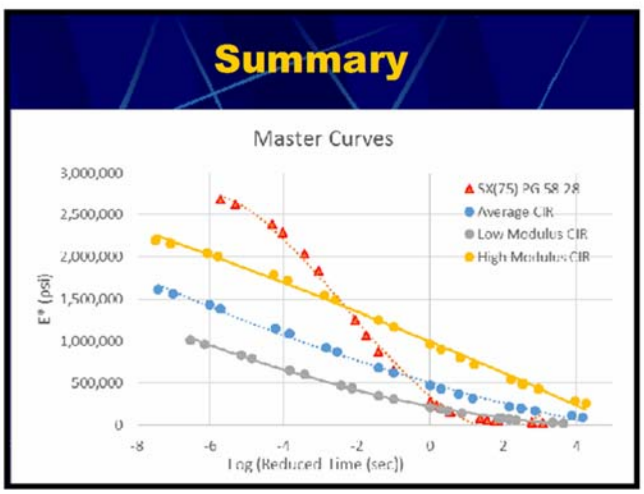

Overall Performance
Fatigue Cracking
CIR Projects
Control Projects
Square Feet per Tenth Mile
Years After Construction
Transverse Cracks
Number per Tenth Mile
Years After Construction

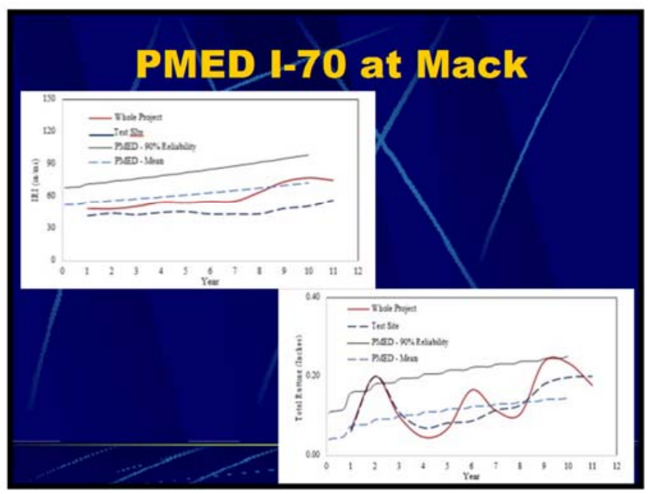

Overall Performance
Longitudinal Cracks
CIR Projects
Control Projects
Linear Feet per Tenth Mile
Years After Construction

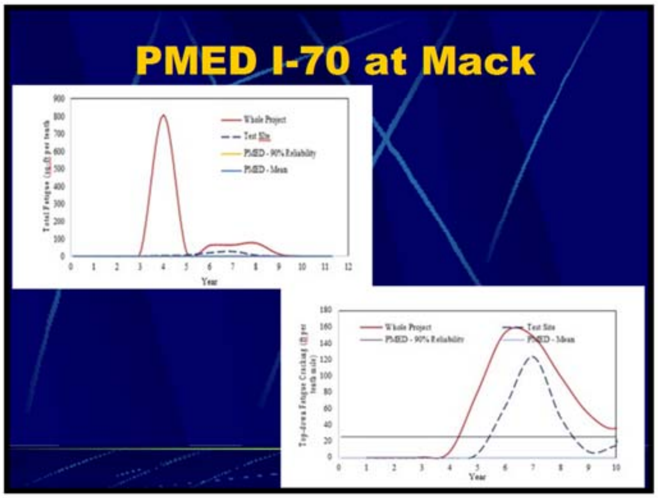

Coring points
1000 ft section


Dynamic Modulus
Sample 1
Sample 2
SH 133 N. of Hotchkiss Site 10
Dynamic Modulus (ksi)
Reduced Frequency (Hz)


Dynamic Modulus
Sample 1
Sample 2
I-25 S. of Colorado City Site 5
Dynamic Modulus (ksi)
Reduced Frequency (Hz)

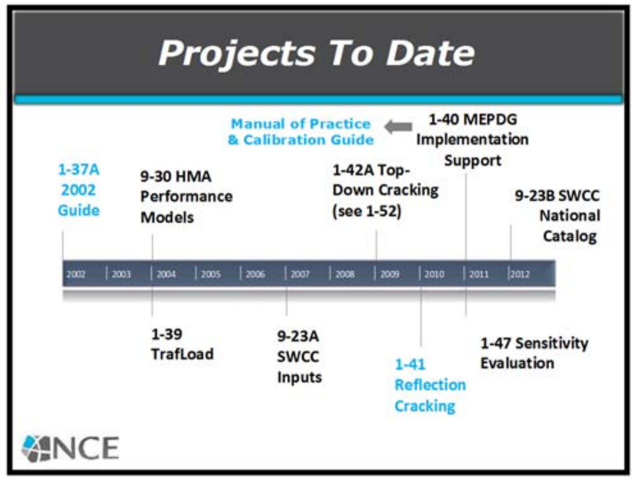

Summary
Master Curves
SX(75) PG 58-28
Average CIR
Low Modulus CIR
High Modulus CIR
E* (psi)
Log (Reduced Time (sec))

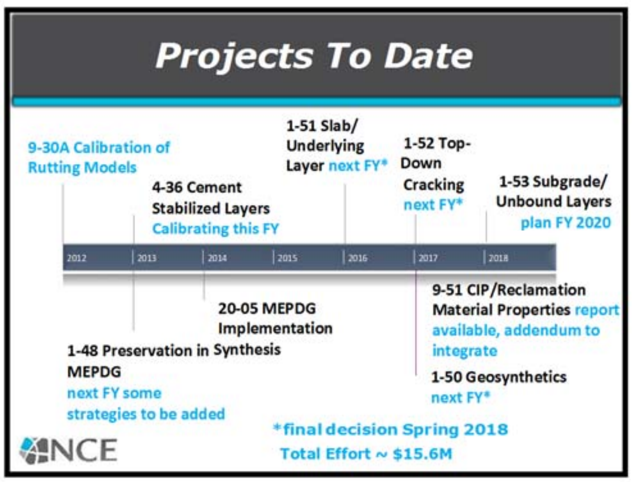

PMED I-70 at Mack
Whole Project
Test Site
PMED - 90% Reliability
PMED - Mean
Year

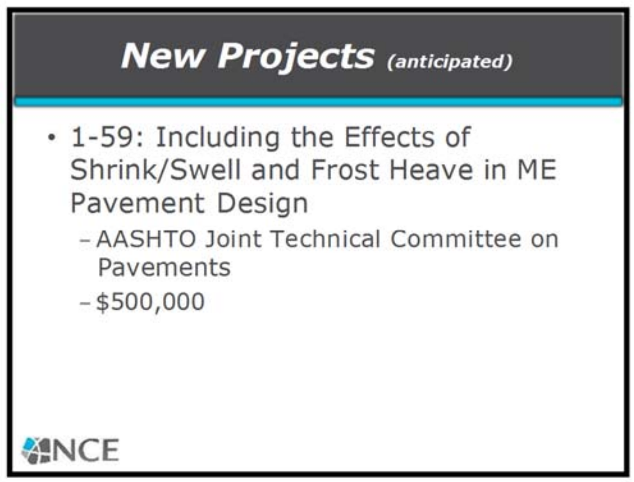

PMED I-70 at Mack
Whole Project
Test Site
PMED - 90% Reliability
PMED - Mean
Year

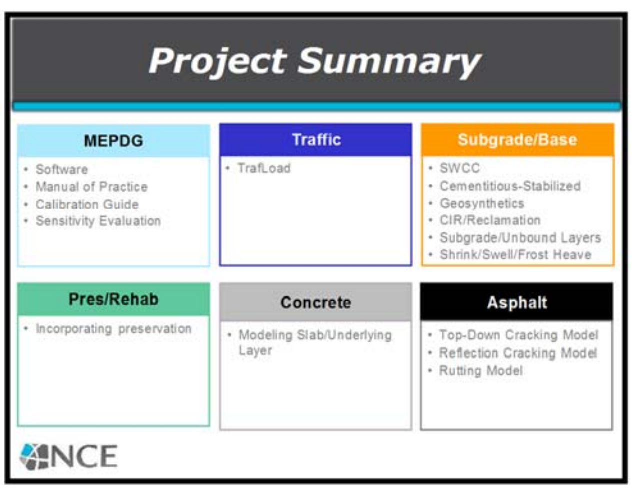

CDOT
CO
COLORADO
Department of
Transportation
Questions?

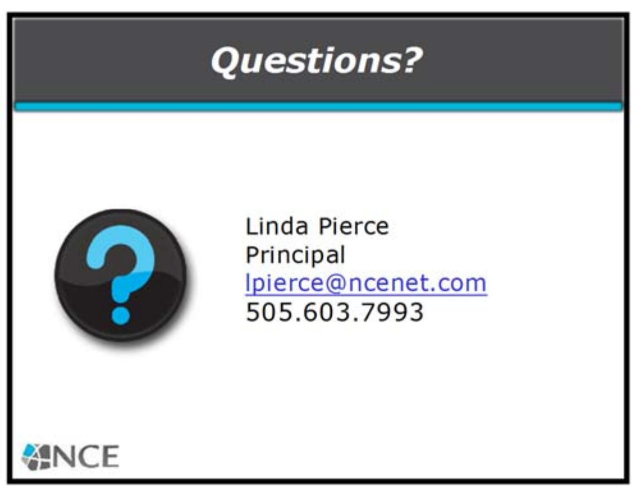
Presentation 13—Linda Pierce, NCE











Presentation 14—Linda Pierce, NCE

Top-Down Cracking Model for Asphalt Pavements

NCHRP 1-52
AASHTO ME User Group Meeting
October 10, 2017
Denver, CO

NCE

ENGINEERING TEXAS A&M UNIVERSITY

Acknowledgements

Based on presentation provided by:
Bob Lytton
Texas A&M University

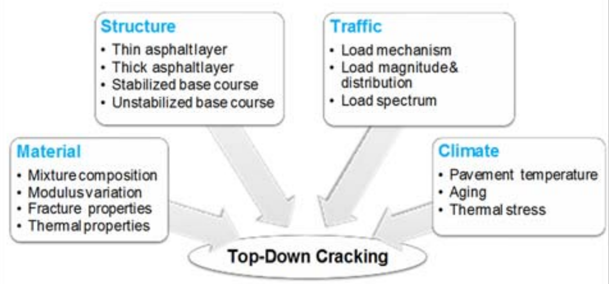
NCHRP 1-52 Objectives

- Develop calibrated ME model for predicting **load-related** top-down cracking
- Compatible with AASHTOWare Pavement ME Design

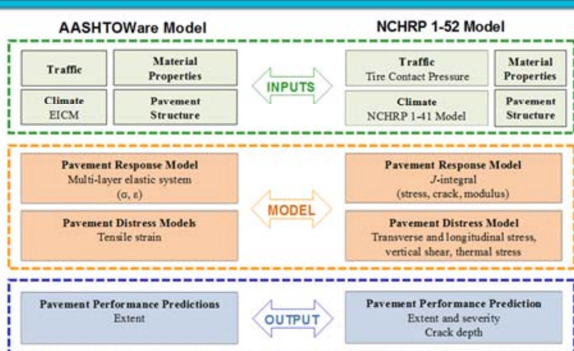
Top-down cracking Longitudinal, wheelpath

Core on top-down cracking Wider on top, narrower at bottom

Factors for Top-Down Crack Development

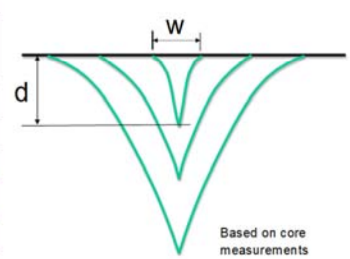


Top-Down Cracking Model



Crack Width to Crack Depth

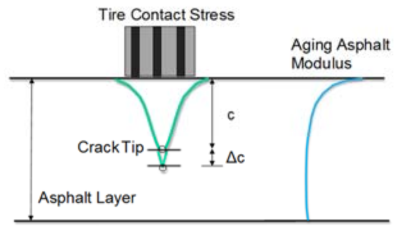
Crack Depth (mm)	Width/ Depth Ratio
0.5	2
5.0	0.6
17.1	0.32
90	0.115
100	0.106



* *Kumara, M. W., Gunaratne, M., Lu, J. J., and Dietrich, B. (2004). Methodology for random surface-initiated crack growth prediction in asphalt pavements.*

By predicting the crack depth, we can determine crack width and crack severity

Predicting Crack Growth



J-Integral Traffic

Paris' Law: $\Delta c = A'[J_R]^{n'} \cdot \Delta N$

Fracture Coefficients

J-Integral

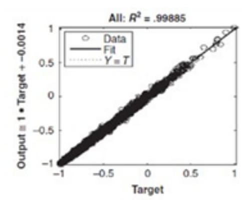
- Depends on (at crack tip):
  - Relaxation modulus
  - Stress level
  - Temperature
- Other material properties:
  - Mean air void content
  - PG grade
  - Aggregate shape

J-Integral (continued)

- Tire contract stress level
- Depth of crack tip
- Temperature at crack tip
- Relaxation modulus at the

→ **Artificial Neural Network** → J-Integral value

↑ Finite Element Modeling



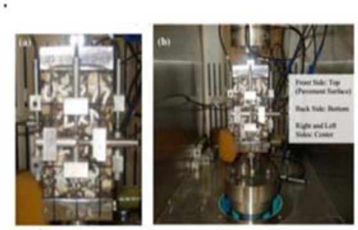
Temperature Model

- Climate data inputs
  - Hourly solar radiation
  - Hourly air temperature
  - Daily average wind speed
- Model parameters
  - Albedo
  - Emissivity
  - Absorption coefficient
  - Thermal diffusivity
  - Heat-transfer coefficient parameters (a, d)

Complex Modulus

Direct Tension Test:

- Temperature: 10, 20, 30°C;
- Maximum Strain: 100 με
- Loading Pattern: Monotonic Tensile Loading
- Ramp Rate: 0.020 mm/min



Specimen Attached with LVDTs in Material Testing System (MTS)

Viscoelastic Properties

Aging effects

- Non-uniform aging in pavement depth
- Long-term field aging

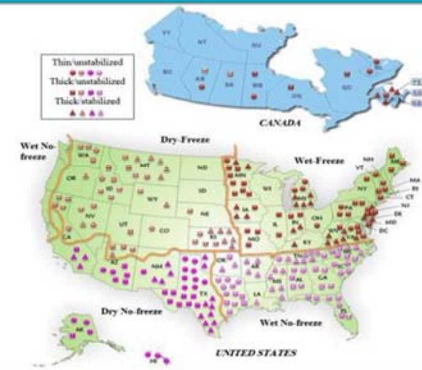
Properties

- Complex modulus (dynamic modulus)
- Poisson's ratio

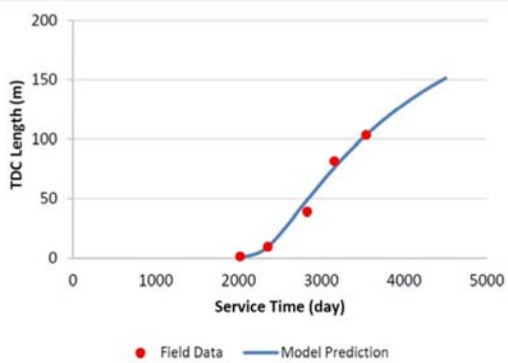
Field core
Dynamic modulus and Poisson's ratio

Lab Mixed, Lab Compacted
Relaxation modulus

Calibrate/Validate Model



Crack Length vs Time



Project Status

- Complete software user interface
- Complete final report
- Anticipated: October 20, 2017

Presentation 15—Linda Pierce, NCE

Improved Consideration of the Influence of Subgrade and Unbound Layers on Pavement Performance

NCHRP 1-53
AASHTO ME User Group Meeting
October 10, 2017
Denver, CO

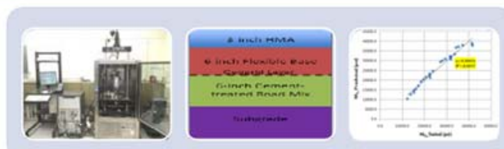
Acknowledgements

Based on presentation provided by:
Bob Lytton
Texas A&M University

Objectives

Propose enhancements to better reflect the influence of subgrade/unbound layers (properties and thickness)

Approach



Testequipment Test protocol …	LTPP Database Pavement structure Material properties Condition …	Moisture-sensitivity Stress-dependent Cross-anisotropic Hierarchical inputs levels …

Models

- Modulus
- Permanent deformation
- Shear strength
- Erosion
- Foundation
- Thickness sensitive (incorporated into above models)

Inputs

- Suction vs water content coefficients
- Thornthwaite moisture index
- Depth to constant suction
- Soil porosity
- Modulus model coefficients
- Pavement deformation model coefficients

Outputs

- Unbound base
  - Base course modulus (anisotropic, stress and suction dependent)
  - Permanent deformation properties
- Subgrade
  - Modulus
  - Equilibrium of depth of constant suction

Project Status

- Start: October 2014
- Completion: June 2018

Presentation 16—Tom Yu, FHWA

Performance Criteria Thresholds for ME Design

AASHTOWare Pavement ME Design AASHTO

H. Thomas Yu, P.E.
Federal Highway Administration
Office of Preconstruction, Construction, and Pavements

October 12, 2017

U.S. Department of Transportation Federal Highway Administration

Objectives of pavement design

- Provide safe, smooth, and quiet riding surface
- Requirements – low cost and least amount of interruptions to users:
  - Good performance – no, lengthy lane closures for maintenance, repair, or rehabilitation
  - Long-life – relates to congestion, cost, and safety

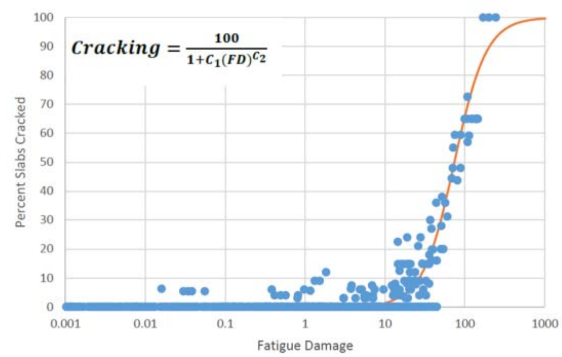
U.S. Department of Transportation Federal Highway Administration

Keys to achieving well-performing pavement

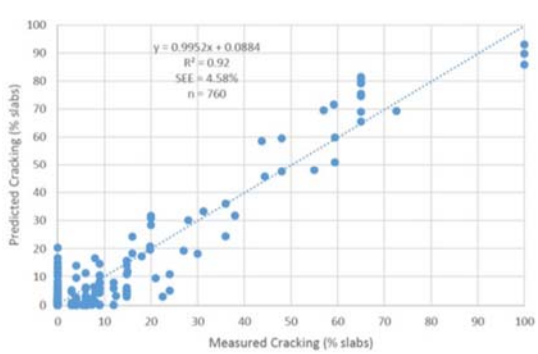
– minimize the risk of poor performance

- **Effective structural design**
  - Good foundation
  - Adequate structural section
  - Appropriate design features
- **Durable material**
  - Durable surface
  - No material-related problems
- **Quality construction**

U.S. Department of Transportation Federal Highway Administration

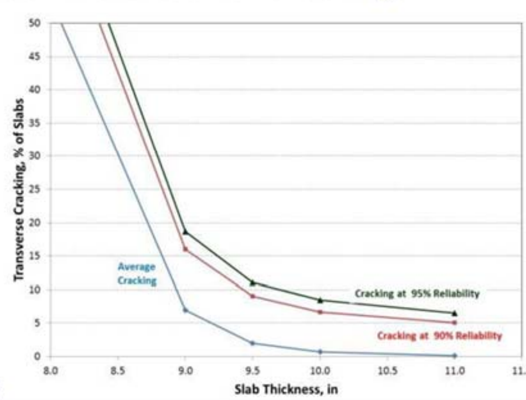


U.S. Department of Transportation Federal Highway Administration

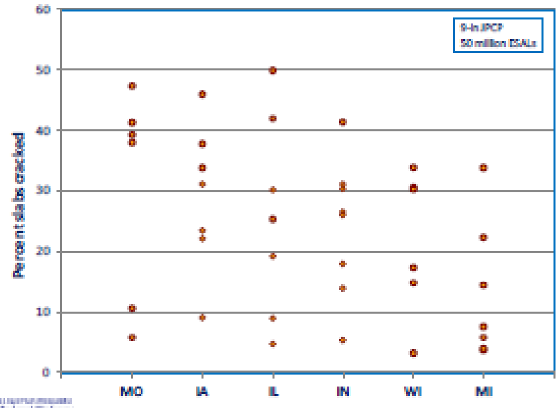


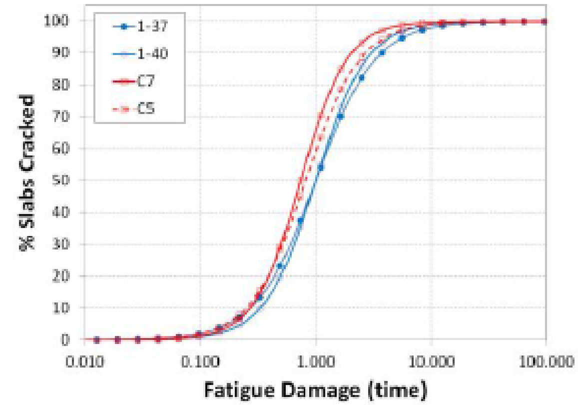
U.S. Department of Transportation Federal Highway Administration

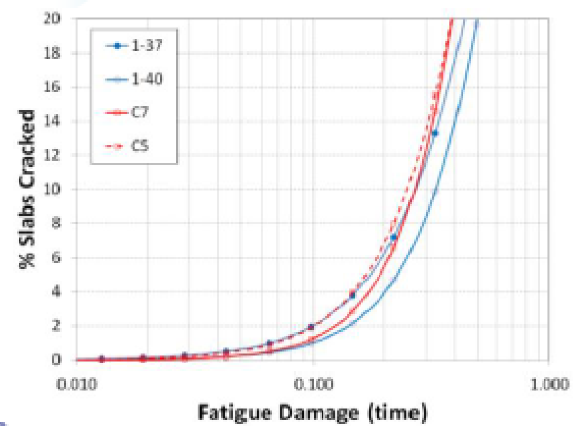
Slab Thickness vs. Cracking



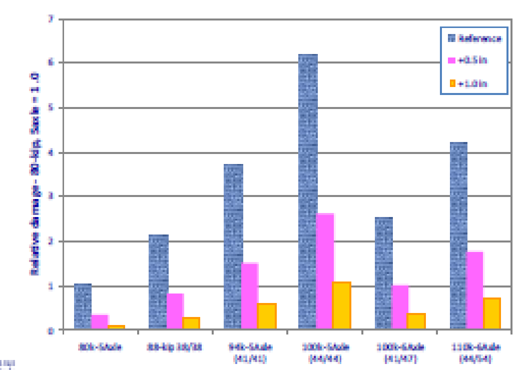
Variations in predicted slab cracking



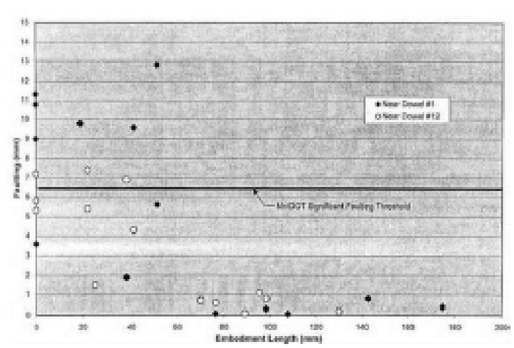




Benefits of Conservative Design



Effects of Embedment Length



Current Design Practice

- Too much emphasis is given to design analysis ➔ thickness design
- Structural design is much more than thickness
  - Appropriate design features should be provided based on traffic level and site conditions
  - Not enough emphasis is given to foundation design in the U.S.

Conclusions

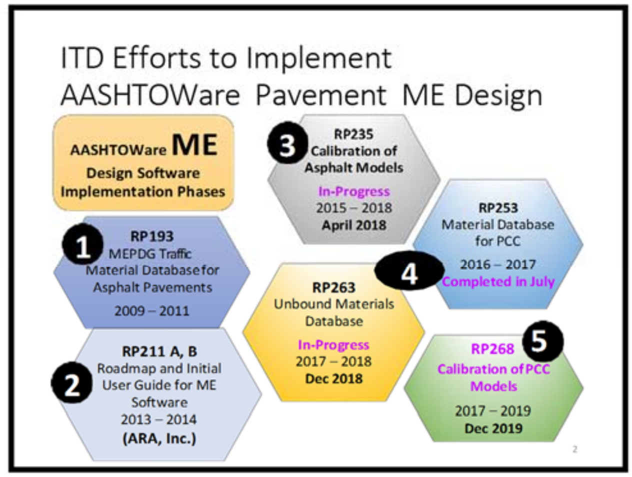
- Pavement design should be about minimizing the risk of poor performance
  - The most costly pavement option is reconstruction
  - The marginal cost of design features that ensure good pavement performance and long-life is insignificant
- Given the variability inherent in pavement performance, designing to a specified level distress is unrealistic
- ME design tools are effective in identifying the inflection point, where the risk of poor performance becomes significant

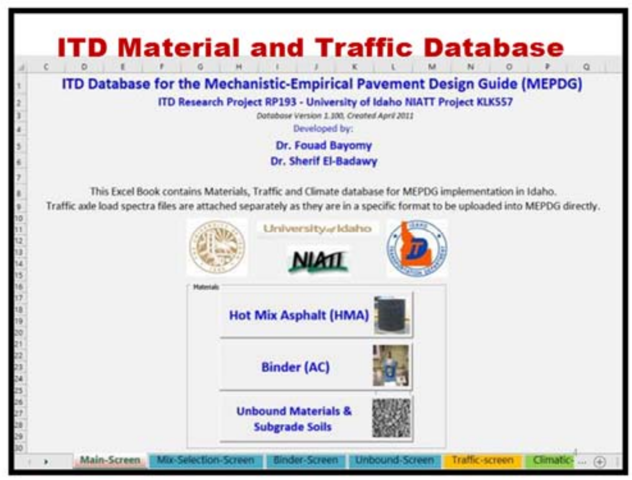
U.S. Department of Transportation Federal Highway Administration

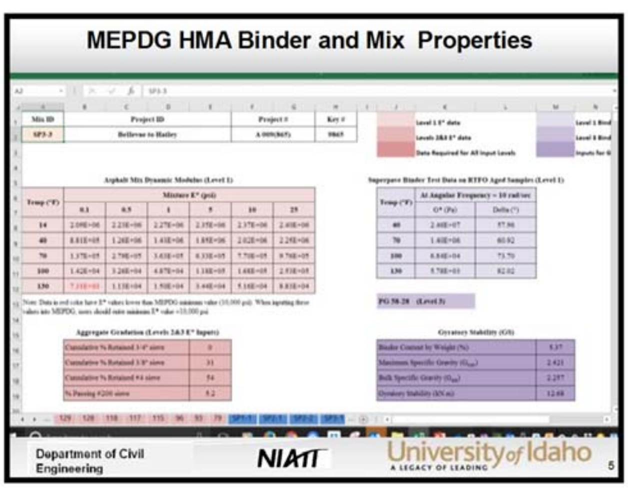
Thank you!

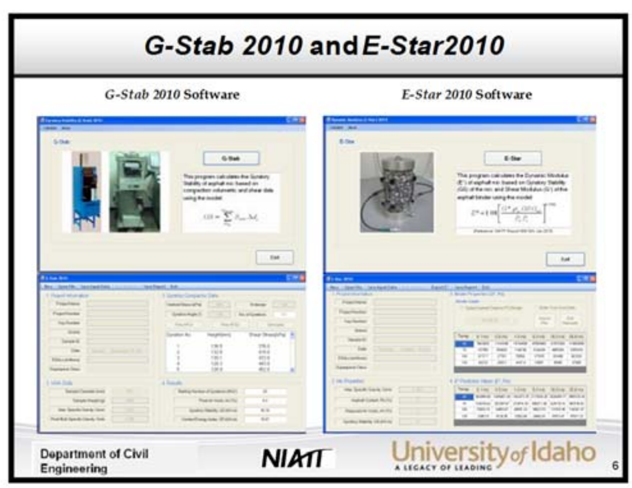
Tom Yu
tom.yu@dot.gov
202-366-1198

Presentation 17—Fouad Bayomy, University of Idaho



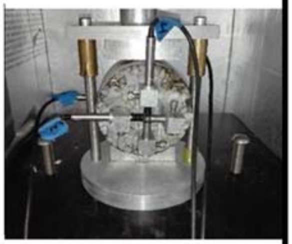






IDT and Creep Compliance

$$TC = \beta_{t1} N \frac{1}{\sigma_d} Log \frac{C_d}{H_{HMA}}$$



- IDT and Creep Compliance data is necessary for the calibration of the Thermal cracking model.
- Tests performed as a separate task during Phase 3.
- Database was updated in 2017 to include these results

Department of Civil Engineering NIATT University of Idaho A LEGACY OF LEADING 7

Unbound Materials and Subgrade Soils

Unbound Base/Subbase Materials and Subgrade Soils Characterization

R-value Model	ITD R-Value Prediction Model for ITD Unbound Granular Materials and Subgrade Soils (Level 2)
Mr Model	ITD Resilient Modulus (Mr) Prediction Model for ITD Subgrade Soils (Level 2)
Typical R-values	Typical Recommended R-Values for ITD Unbound Materials and Subgrade Soils (Level 3)
Typical PI values	Typical Recommended Plasticity Index Values for ITD Unbound Materials and Subgrade Soils
Typical LL values	Typical Recommended Liquid Limit Values for ITD Unbound Materials and Subgrade Soils

Department of Civil Engineering NIATT University of Idaho A LEGACY OF LEADING 8

ITD Unbound/Subgrade Material Characterization (MEPDG Level 2 inputs)

Two Models Developed:

- **R-Value** Models based on ITD Database
- **M_r-R-Value** Model based on literature Mr-Data

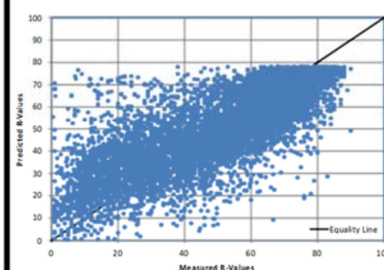
R-Value Model:

- Historical ITD R-Values database **(from 1953 to 2008).**
- **8233** points with soil classification, P200 and PI.
- Collected by Dr. Stanley Miller (UI)
- **ITD-PR 185, NIATT KLK 553:** Developing Statistical Correlations of Soil Properties with R-Value for Idaho Pavement Design.

Department of Civil Engineering NIATT University of Idaho A LEGACY OF LEADING 9

Developed R-Value Model

Measured versus Predicted R-Values



$R = 10^{(1.893 - 0.00159 \cdot P200 - 0.022 \cdot PI)}$

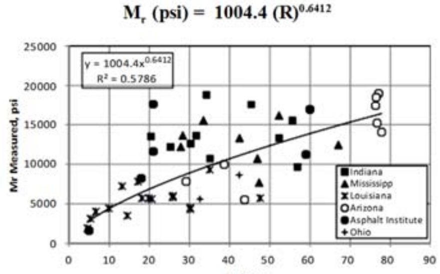
Where:

P200 = % Passing Sieve No. 200
PI = Plasticity Index

Department of Civil Engineering NIATT University of Idaho A LEGACY OF LEADING 10

2010 M_r-R-Value Model

M_r (psi) = 1004.4 $(R)^{0.6412}$



The majority of this literature soils are fine grained materials.

Department of Civil Engineering NIATT University of Idaho A LEGACY OF LEADING 11

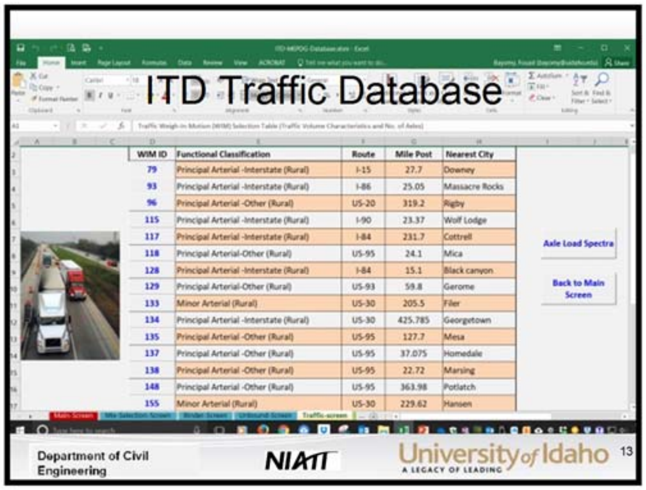
Traffic Database

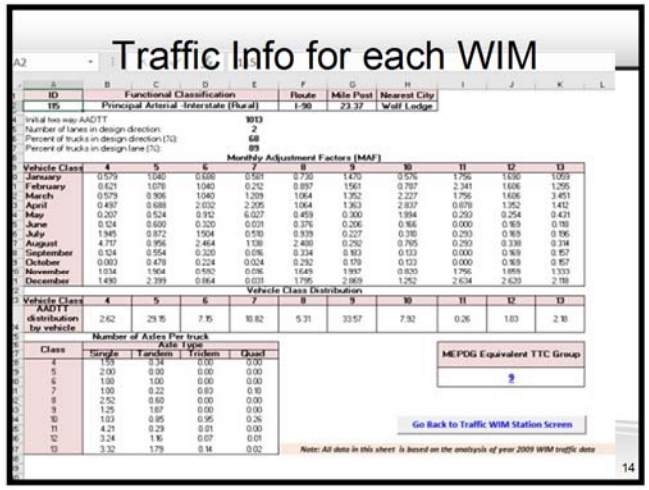
Idaho WIM Sites

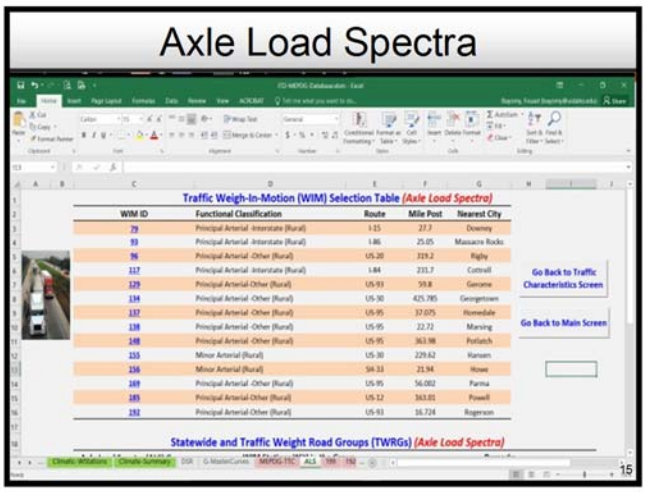
University of Idaho NIATT

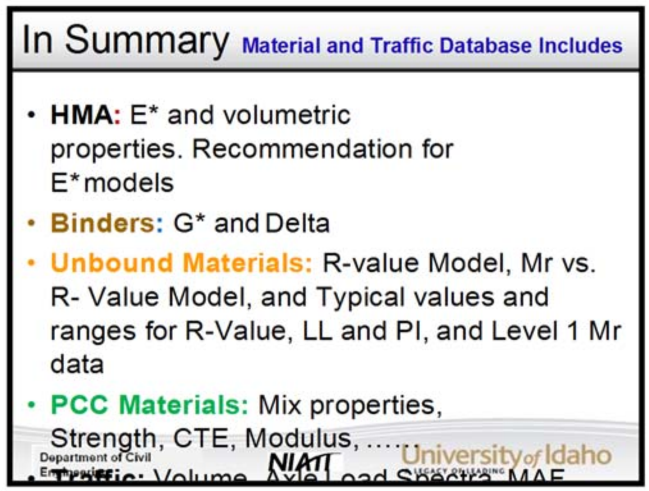
Materials
- Hot Mix Asphalt (HMA)
- Binder (AC)
- Unbound Materials & Subgrade Soils
- Traffic
- Climate & GWT

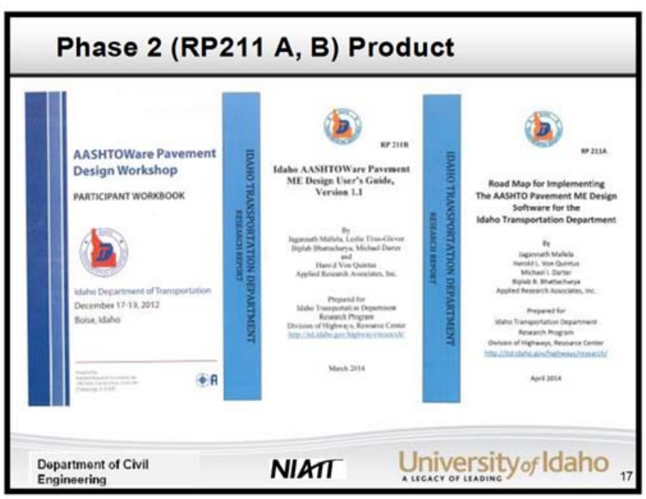
University of Idaho A LEGACY OF LEADING 12

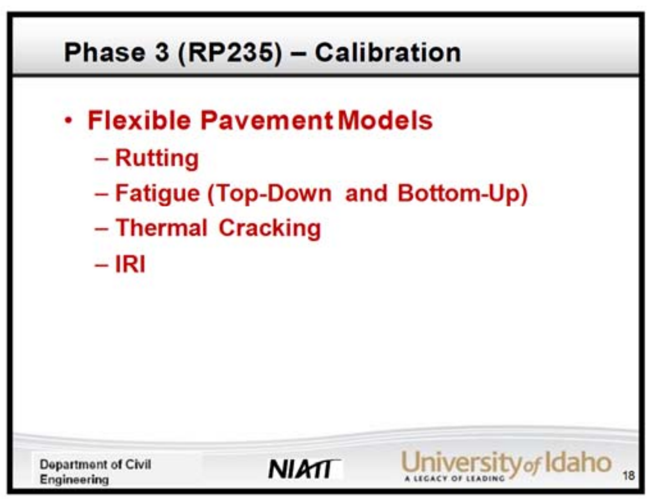

ITD Traffic Database
WIM ID | Functional Classification | Route | Mile Post | Nearest City
79 | Principal Arterial -Interstate (Rural) | I-15 | 27.7 | Downey
93 | Principal Arterial -Interstate (Rural) | I-86 | 25.05 | Massacre Rocks
96 | Principal Arterial -Other (Rural) | US-20 | 319.2 | Rigby
115 | Principal Arterial -Interstate (Rural) | I-90 | 23.37 | Wolf Lodge
117 | Principal Arterial -Interstate (Rural) | I-84 | 231.7 | Cottrell
118 | Principal Arterial-Other (Rural) | US-95 | 24.1 | Mica
128 | Principal Arterial -Interstate (Rural) | I-84 | 15.1 | Black canyon
129 | Principal Arterial-Other (Rural) | US-93 | 59.8 | Gerome
133 | Minor Arterial (Rural) | US-30 | 205.5 | Filer
134 | Principal Arterial -Interstate (Rural) | US-30 | 425.785 | Georgetown
135 | Principal Arterial -Other (Rural) | US-95 | 127.7 | Mesa
137 | Principal Arterial -Other (Rural) | US-95 | 37.075 | Homedale
138 | Principal Arterial -Other (Rural) | US-95 | 22.72 | Marsing
148 | Principal Arterial -Other (Rural) | US-95 | 363.98 | Potlatch
155 | Minor Arterial (Rural) | US-30 | 229.62 | Hansen
Axle Load Spectra
Back to Main Screen
Department of Civil Engineering
NIATT
University of Idaho
13


Traffic Info for each WIM
ID | Functional Classification | Route | Mile Post | Nearest City
115 | Principal Arterial -Interstate (Rural) | I-90 | 23.37 | Wolf Lodge
Monthly Adjustment Factors (MAF)
Vehicle Class Distribution
Number of Axles Per truck
MEPDG Equivalent TTC Group
Go Back to Traffic WIM Station Screen
14

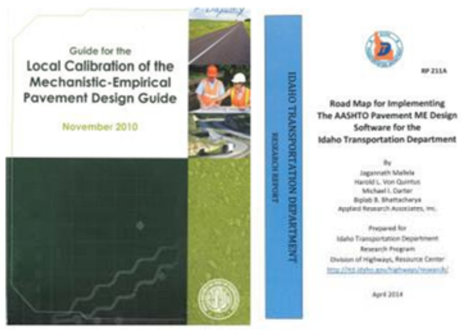

Axle Load Spectra
Traffic Weigh-In-Motion (WIM) Selection Table (Axle Load Spectra)
Go Back to Traffic Characteristics Screen
Go Back to Main Screen
Statewide and Traffic Weight Road Groups (TWRGs) (Axle Load Spectra)
15


In Summary Material and Traffic Database Includes
• HMA: E* and volumetric properties. Recommendation for E* models
• Binders: G* and Delta
• Unbound Materials: R-value Model, Mr vs. R- Value Model, and Typical values and ranges for R-Value, LL and PI, and Level 1 Mr data
• PCC Materials: Mix properties, Strength, CTE, Modulus, …..
Department of Civil Engineering
NIATT
University of Idaho


Phase 2 (RP211 A, B) Product
AASHTOWare Pavement Design Workshop
PARTICIPANT WORKBOOK
Idaho AASHTOWare Pavement ME Design User's Guide, Version 1.1
Road Map for Implementing The AASHTO Pavement ME Design Software for the Idaho Transportation Department
Department of Civil Engineering
NIATT
University of Idaho
17


Phase 3 (RP235) – Calibration
• Flexible Pavement Models
– Rutting
– Fatigue (Top-Down and Bottom-Up)
– Thermal Cracking
– IRI
Department of Civil Engineering
NIATT
University of Idaho
18

Flexible Pavement Sections Selected



Department of Civil Engineering | NIATT | University of Idaho – A LEGACY OF LEADING | 19

Flexible Pavement Sections Selected

- Six Districts
- 32 road sections
- Covering different distresses: Rutting, Fatigue, Longitudinal & thermal Cracking
- Heavy to moderate traffic
- Cover different geographic regions

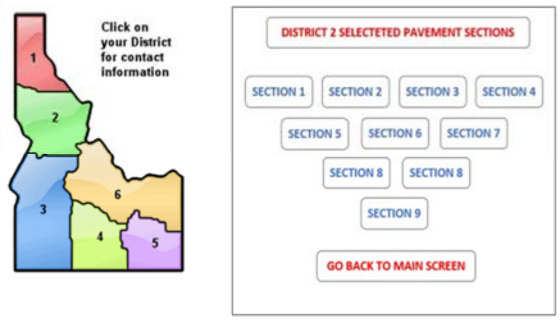
Department of Civil Engineering | NIATT | University of Idaho – A LEGACY OF LEADING | 20

Flexible Pavement Sections Selected

Mix Type	Volume of Truck Traffic	Soil Type	Pavement Structure: New Design – Unbound Aggregate Base	Rehabilitation: HMA Overlay – Flexible	Rehabilitation: HMA Overlay – Rigid	Rehabilitation: CIR	Rehabilitation: FDR Stabilized With Cement
Neat Mixtures	Low	Coarse Grained		D3_16 &20		D1_6	
		Low Plasticity					
		High Plasticity		D1_5			
	High	Coarse Grained		D3_17 & 18			
		Low Plasticity					
		High Plasticity					
Polymer Modified Asphalt	High	Coarse Grained	D2_4 & 5	D1_4 & D5_1		D2_7 & 8	D2_9
		Low Plasticity					
		High Plasticity	D1_3				

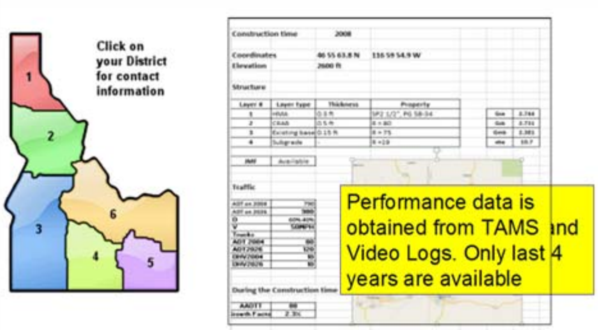
Department of Civil Engineering | NIATT | University of Idaho – A LEGACY OF LEADING | 21

ITD – Performance Database



Department of Civil Engineering | NIATT | University of Idaho – A LEGACY OF LEADING | 22

ITD – Performance Database



Department of Civil Engineering | NIATT | University of Idaho – A LEGACY OF LEADING | 23

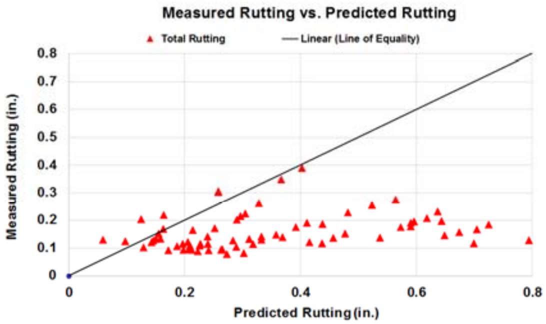
Rutting Model Calibration

$$\Delta_{p(HMA)} = \beta_{1r} k_z \varepsilon_{r(HMA)} 10^{k_{1r}} n^{k_{2r}\beta_{2r}} T^{k_{3r}\beta_{3r}} h_{(HMA)}$$

$$\Delta_{p(soil)} = \beta_{s1} k_{s1} \varepsilon_v h_{soil} \frac{\varepsilon_0}{\varepsilon_r} e^{-\left(\frac{\rho}{n}\right)^{\beta}}$$

Department of Civil Engineering | NIATT | University of Idaho – A LEGACY OF LEADING | 24

Rutting Model Calibration



Department of Civil Engineering · NIATT · University of Idaho · A LEGACY OF LEADING · 25

Eliminate Local Bias of the Rutting Prediction Models

	β_{1r}	β_{2r}	β_{3r}	β_{1s} (Coarse)	β_{1s} (fine)	Bias, er (mean)	Standard Error, Se	se/sy	R2	P-value
NC Factors	1.00	1.00	1.00	1.00	1.00	25.549	0.574	0.112	0.175	0.000225
Trial 1	1.50	1.00	1.00	1.25	1.25	4.3742	0.4677	0.081	0.081	
Trial 2	2.00	1.00	1.00	1.50	1.50	6.5225	0.9814	0.001	0.001	
Trial 3	2.50	1.00	1.00	1.75	1.75	8.6909	1.7013	0.002	0.0022	
Trial 4	3.00	1.00	1.00	2.00	2.00	10.8498	2.6275	0.003	0.0032	
Trial 5	0.75	1.00	1.00	2.25	2.25	6.3580	0.0756	0.077	0.0767	
Trial 6	0.50	1.00	1.00	2.50	2.50	6.4725	1.1975	0.242	0.242	
Trial 7	0.25	1.00	1.00	0.75	0.75	0.5640	0.0880	0.164	0.1642	
Trial 8	1.00	1.50	1.00	0.50	0.50	50.4204	165.0801	0.02	0.0106	
Trial 9	1.00	1.00	1.50	0.25	0.25	37.6204	78.6214	0.027	0.0267	
Trial 10	1.00	1.50	1.50	0.00	0.00	137.8350	642.0000	0.412	0.4116	
Trial 11	1.00	0.50	1.00	1.00	1.00	0.1046	0.1865	0.339	0.3398	
Trial 12	1.00	1.00	0.50	1.00	1.00	0.0582	0.1706	0.279	0.2785	
Trial 13	1.00	0.50	0.50	1.00	1.00	0.2624	0.1963	0.349	0.3494	
Trial 14	3.00	0.50	0.50	0.50	0.50	2.0843	0.1802	0.341	0.3408	
Trial 15	0.603	1.000	1.000	0.640	0.633	4.1223	18.2893	0.202	0.2019	
Trial 16	0.603	1.500	1.000	0.630	0.623	45.8308	107.9035	0.231	0.231	
Trial 17	0.603	0.951	1.000	0.638	0.631	0.5529	0.0580	0.231	0.231	
Trial 18	0.603	0.957	1.000	0.639	0.632	0.5249	0.0574	0.291	0.2907	
Trial 19	0.603	0.957	1.100	0.639	0.632	0.2731	0.0626	0.357	0.3567	
Trial 20	2.450	1.000	1.000	1.000	1.000	4.8241	0.0270	0.28	0.28	
Trial 21	2.450	1.000	1.000	0.640	0.633	4.5297	1.2557	0.321	0.321	
Trial 22	**3.000**	**1.000**	**0.661**	**0.640**	**0.633**	**2.157**	**0.0375**	**0.1097**	**0.265**	**0.157**
Trial 23	3.000	1.100	0.661	0.640	0.633	1.0666	0.1587	0.286	0.286	

Assess Local Bias: Validation of Global Calibration Factors to Local Conditions, Policies, and Materials

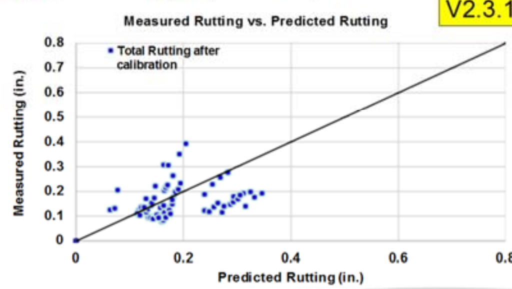
Performance Indicator	Bias, er (mean)	Standard Error, Se	se/sy	P-value	Hypothesis; Ho	Comment
Rutting (in) before Calibration	25.549	0.574	0.112	0.000225	Reject	There is variability, the model is over predicting the rutting.
Rutting (in) After Calibration	2.157	0.0375	0.1097	0.157	Accept	No Bias

Department of Civil Engineering · NIATT · University of Idaho · A LEGACY OF LEADING

Rutting Model Calibration

β_{1r}	3.000	β_{2r}	1.000	β_{3r}	0.661
β_{1s_Coarse}	0.640	β_{1s_Fine}	0.633		

V2.3.1

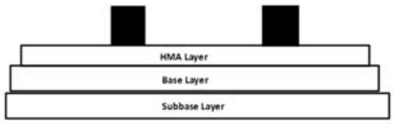


Department of Civil Engineering · NIATT · University of Idaho · A LEGACY OF LEADING · 28

Conduct Field and Forensic Investigations Example: SH-8 (Moscow)

Conduct Field and Forensic Investigations Example: SH-8 (Moscow)

Conduct Field and Forensic Investigations Example: SH-8 (Moscow)



Measurement Location	Edge to the lane	Wheel path	Center of the lane	Wheel path	Edge to the curb
Total rutting (inch)	0	0.19	0	0.21	0
HMA layer thickness	4.92	4.71	4.86	4.79	5.08
HMA Layer thickness reduction	-	0.12	-	0.15	-
The remaining rutting (in)	-	0.07	-	0.06	-

Fatigue Models Calibration

$$N_{f-HMA} = k_{f1}(C)(C_H)\beta_{f1}\ \varepsilon_t^{\,k_{f2}\beta_{f2}}(E_{HMA})^{k_{f3}\beta_{f3}}$$

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

$$FC_{Top} = 10.56\left(\frac{C_4}{1+e^{(C_1-C_2Log(DI_{Top}))}}\right)$$

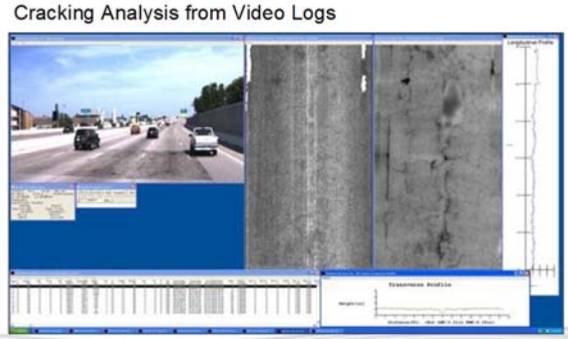
Thermal Cracking

$$TC = \beta_{t1} N \frac{1}{\sigma_d} Log \frac{C_d}{H_{HMA}}$$

Data collected form Video Logs

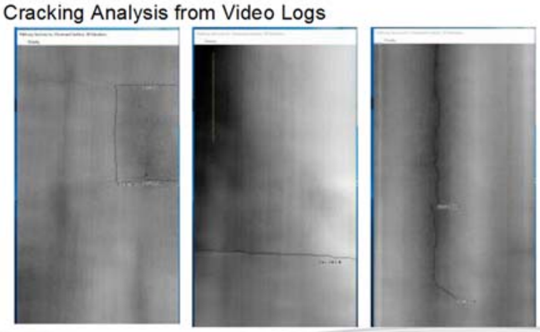
ITD – Performance Database

Cracking Analysis from Video Logs



ITD – Performance Database

Cracking Analysis from Video Logs



ITD – Performance Database

District #	Tracking Number	Route	Beg. MP	End MP	2016 Alligator Cracking (%)	2016 Trans. Cracking (ft/mile)	2016 Long. Cracking (ft/mile)
D1	1	US-95	398.57	401.52	0.28	6.26	103.89
	2	US-95	403.5	408.75	0.00	84.75	22.99
	3	US-95	411.84	415.83	0.00	0.13	6.73
	4	US-95	415.5	421.3	0.01	6.73	98.94
	5	SH-3	76.822	84.201	0.03	12.52	0.55
	6	SH-3	103.15	111.38	7.35	75.46	488.58
	7	US-95	477.1	486.36	0.00	52.50	19.68
D2	1	SH006	100	104.5	0.00	249.84	88.33
	2	SH008	0	1.76	0.08	190.02	663.84
	3	US-95	344	344.57	0.32	42.18	388.33
	4	US-95	366.59	373.03	0.00	0.83	0.96
	5	US-95	319.88	337.67	0.00	1.36	0.00
	6	SH003	5	8.5	0.00	839.64	11.27
	7	SH013	11.257	18.711	-	-	-
	8	SH013	18.68	25.378	-	-	-
	9	US-95	277.28	279.1	0.00	0.00	0.00
	10	US95	344	344.57	2.66	60.50	309.18

IRI Model Calibration

$$IRI = IRI_o + C_1\ RD\ + C_2\ FC_{Total}\ + C_3\ TC\ + C_4 SF$$

Data collected form TAMS Database

Department of Civil Engineering | NIATT | University of Idaho – A Legacy of Leading | 37

Idaho ME Calibration Factors

MEPDG Model	Coefficients before Calibration	Coefficients after Calibration	Net Effect of Calibration
Alligator Fatigue Transfer Function	β_{f1}= 1.00	β_{f1}= 0.729	
	β_{f2}= 1.00	β_{f2}= 1.500	
	β_{f3}= 1.00	-	
	C1= 1.00	-	
	C2= 1.00	-	
Longitudinal Fatigue Transfer Function	β_{f1}= 1.00	-	
	β_{f2}= 1.00	-	
	β_{f3} = 1.00	-	
	C1= 7.00	-	
	C2 = 3.50	-	
AC Rutting Model	β1r = 1.00	β1r = 3.00	
	$\beta 2_r$ = 1.00	$\beta 2_r$ = 1.00	Decreased prediction
	$\beta 3_r$ = 1.00	$\beta 3_r$ = 0.661	
Granular Base Rutting	β_{s1}= 1.00	β_{s1}= 0.640	Decreased prediction
Subgrade Rutting Model	β_{s1}= 1.00	β_{s1}= 0.633	Decreased prediction
IRI Model	C1 = 40	-	
	C2 = 0.4	-	
	C3= 0.08	-	
	C4 = 0.015	-	

Department of Civil Engineering | NIATT | University of Idaho – A Legacy of Leading

Phase 4 – Completing Materials Database

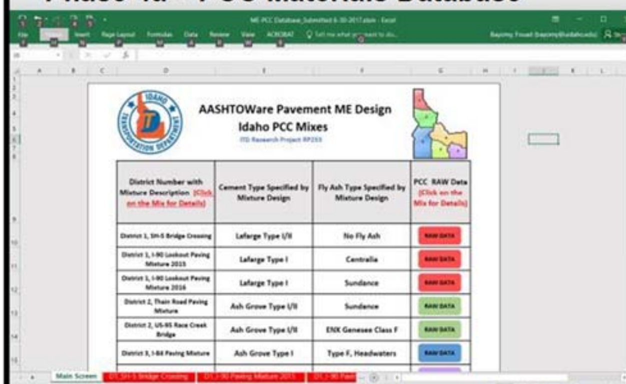
a. PCC Materials Database

b. Unbound Materials

- Subgrade Soils
- Base / Subbase Materials

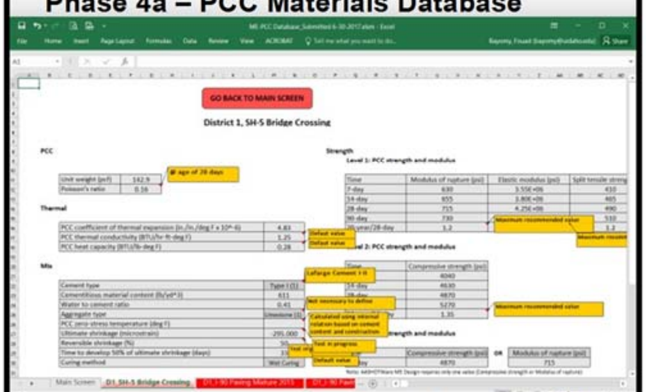
Department of Civil Engineering | NIATT | University of Idaho – A Legacy of Leading | 39

Phase 4a – PCC Materials Database



Department of Civil Engineering | NIATT | University of Idaho – A Legacy of Leading | 40

Phase 4a – PCC Materials Database



Department of Civil Engineering | NIATT | University of Idaho – A Legacy of Leading | 41

Phase 4b – Unbound Materials Database

- Mr testing AASHTO T307
  - Subgrade Soils
  - Base / Subbase

In progress, to be completed by Dec 2018

Department of Civil Engineering | NIATT | University of Idaho – A Legacy of Leading | 42

Phase 5 (RP268) Calibration of PCC Models

- **PCC Rigid Pavements**
  - Cracked Slab
  - Faulting
  - IRI

Department of Civil Engineering NIATT University of Idaho A LEGACY OF LEADING 43

ME Calibration for Idaho

- **Flexible Pavement Models** — **RP235 (April 2018)**
  - IRI
  - Rutting
  - Fatigue (Top-Down and Bottom-Up)
  - Thermal Cracking
- **PCC Rigid Pavements** — **RP268 (July 2019)**
  - IRI
  - Cracked Slab
  - Faulting

Department of Civil Engineering NIATT University of Idaho A LEGACY OF LEADING 44

Acknowledgement

Research Teams

- Fouad Bayomy
- Sherif Elbadawy
- Emad Kassem
- Ahmed Ibrahim
- Ahmed Muftah
- Somayeh Nassiri (WSU)
- Deb Mishra (BSU)

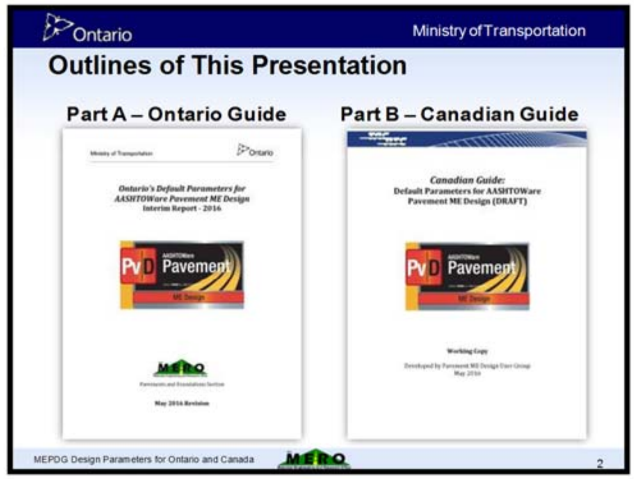
In addition to 10 students (grad and undergrad)

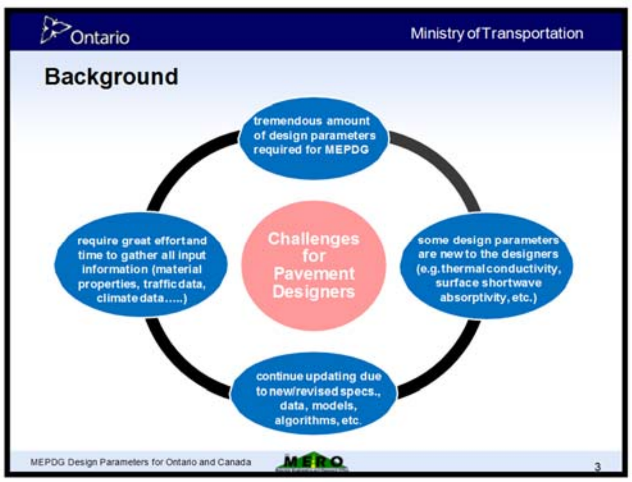
ITD/FHWA Partners

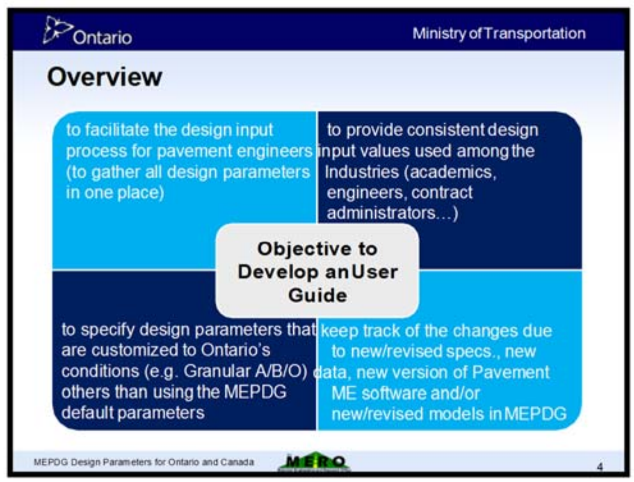
- Michael Santi
- Chad Clawson
- John Arambarri
- Dave Richards
- Mark Wheeler
- Clint Hoops
- James Poorbaugh
- John Builderback
- Ned Parrish
- Kyle Holman

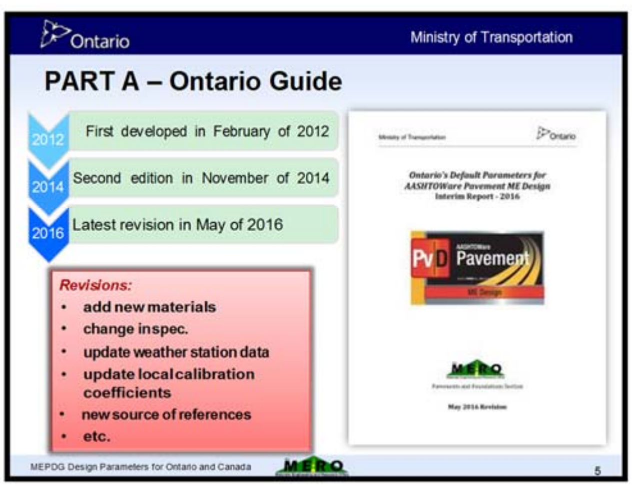
Department of Civil Engineering NIATT University of Idaho A LEGACY OF LEADING 45

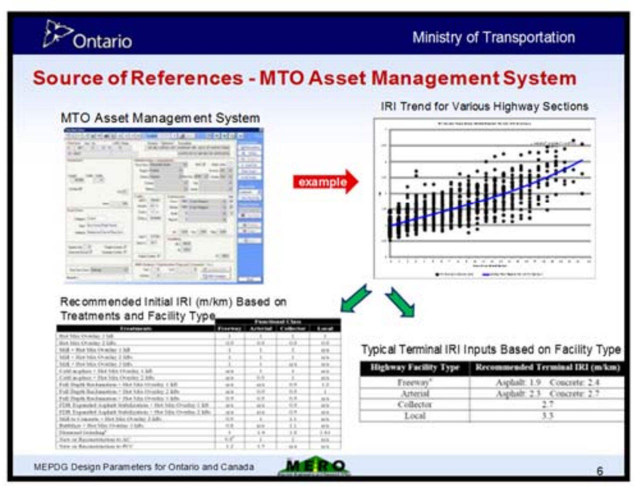
Presentation 18—Warren Lee and Susanne Chan, Ministry of Transportation Ontario

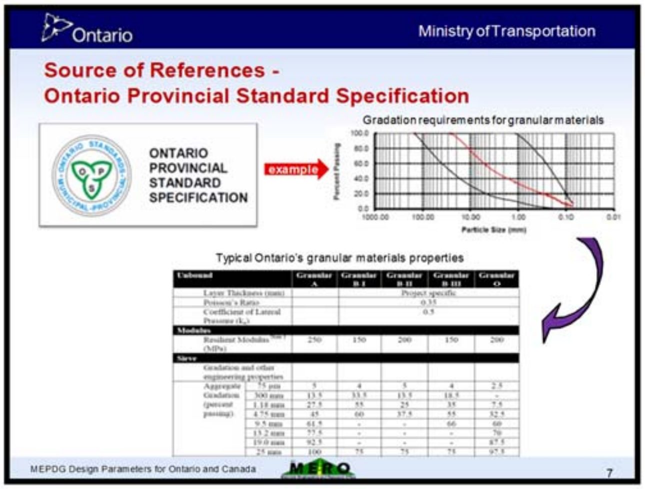


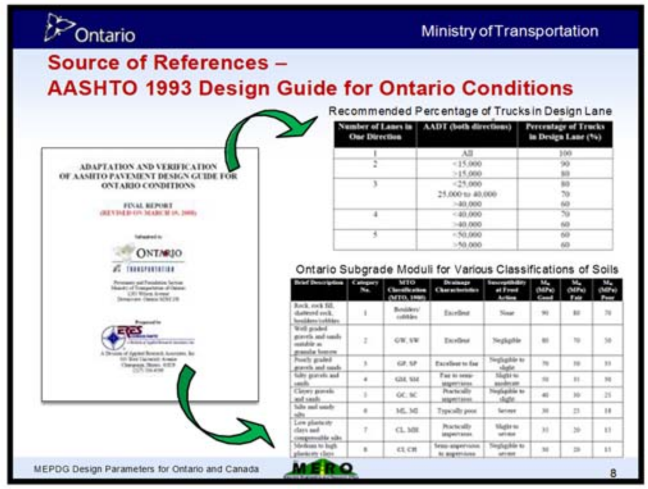


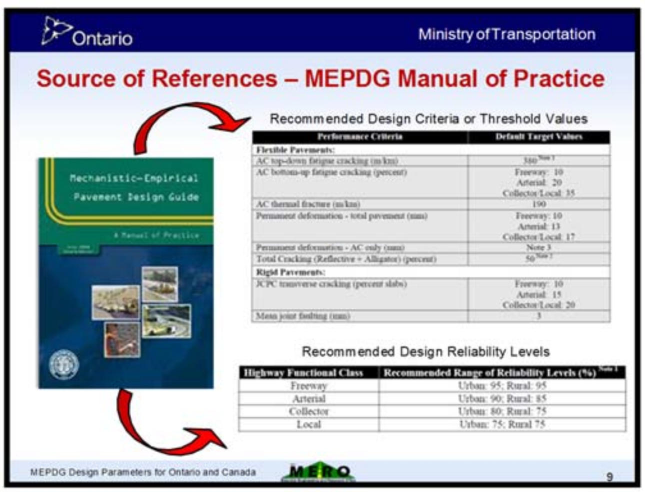




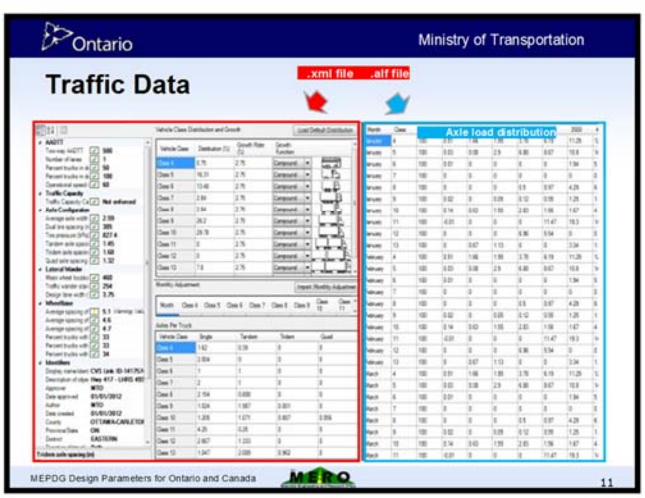


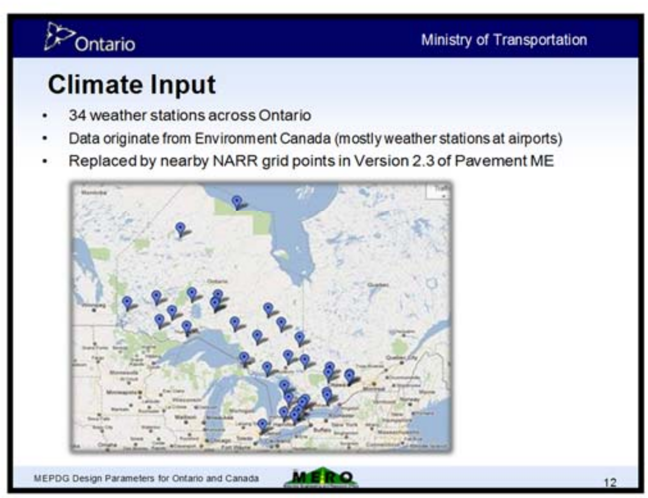

Ontario
Ministry of Transportation
Source of References -
Ontario Provincial Standard Specification
ONTARIO PROVINCIAL STANDARD SPECIFICATION
example
Gradation requirements for granular materials
Percent Passing
Particle Size (mm)
Typical Ontario's granular materials properties
Unbound | Granular A | Granular B I | Granular B II | Granular B III | Granular O
Layer Thickness (mm) | Project specific
Poisson's Ratio | 0.35
Coefficient of Lateral Pressure (k) | 0.5
Modulus
Resilient Modulus (MPa) | 250 | 150 | 200 | 150 | 200
Sieve
Gradation and other engineering properties
Aggregate Gradation (percent passing)
75 µm | 5 | 4 | 5 | 4 | 2.5
300 mm | 13.5 | 33.5 | 13.5 | 18.5 | -
1.18 mm | 27.5 | 55 | 25 | 35 | 7.5
4.75 mm | 45 | 60 | 37.5 | 55 | 32.5
9.5 mm | 61.5 | - | - | 66 | 60
13.2 mm | 77.5 | - | - | - | 70
19.0 mm | 92.5 | - | - | - | 87.5
25 mm | 100 | 75 | 75 | 75 | 97.5
MEPDG Design Parameters for Ontario and Canada
MERO
7


Ontario
Ministry of Transportation
Source of References –
AASHTO 1993 Design Guide for Ontario Conditions
ADAPTATION AND VERIFICATION OF AASHTO PAVEMENT DESIGN GUIDE FOR ONTARIO CONDITIONS
FINAL REPORT
Recommended Percentage of Trucks in Design Lane
Number of Lanes in One Direction | AADT (both directions) | Percentage of Trucks in Design Lane (%)
1 | All | 100
2 | <15,000 | 90
 | >15,000 | 80
3 | <25,000 | 80
 | 25,000 to 40,000 | 70
 | >40,000 | 60
4 | <40,000 | 70
 | >40,000 | 60
5 | <50,000 | 60
 | >50,000 | 60
Ontario Subgrade Moduli for Various Classifications of Soils
MEPDG Design Parameters for Ontario and Canada
MERO
8


Ontario
Ministry of Transportation
Source of References – MEPDG Manual of Practice
Mechanistic-Empirical Pavement Design Guide
A Manual of Practice
Recommended Design Criteria or Threshold Values
Performance Criteria | Default Target Values
Flexible Pavements:
AC top-down fatigue cracking (m/km) | 380
AC bottom-up fatigue cracking (percent) | Freeway: 10 Arterial: 20 Collector/Local: 35
AC thermal fracture (m/km) | 190
Permanent deformation - total pavement (mm) | Freeway: 10 Arterial: 13 Collector/Local: 17
Permanent deformation - AC only (mm) | Note 3
Total Cracking (Reflective + Alligator) (percent) | 50
Rigid Pavements:
JCPC transverse cracking (percent slabs) | Freeway: 10 Arterial: 15 Collector/Local: 20
Mean joint faulting (mm) | 3
Recommended Design Reliability Levels
Highway Functional Class | Recommended Range of Reliability Levels (%)
Freeway | Urban: 95; Rural: 95
Arterial | Urban: 90; Rural: 85
Collector | Urban: 80; Rural: 75
Local | Urban: 75; Rural 75
MEPDG Design Parameters for Ontario and Canada
MERO
9


Ontario
Ministry of Transportation
Traffic Data
iCorridor - a web-based data visualization and information sharing tool
Data feeded by Commercial Vehicle Survey (CVS) on truck volume, axle loads and configuration
Files can be downloaded and imported directly into Pavement ME design to run analysis
MINISTRY OF TRANSPORTATION
.xls
.xml
.alf
1
2
3
4
5
MEPDG Design Parameters for Ontario and Canada
MERO
10


Ontario
Ministry of Transportation
Traffic Data
.xml file
.alf file
Axle load distribution
MEPDG Design Parameters for Ontario and Canada
MERO
11


Ontario
Ministry of Transportation
Climate Input
34 weather stations across Ontario
Data originate from Environment Canada (mostly weather stations at airports)
Replaced by nearby NARR grid points in Version 2.3 of Pavement ME
MEPDG Design Parameters for Ontario and Canada
MERO
12

Ontario — Ministry of Transportation

PART B – Canadian Guide

- Through the Canada's Pavement ME user group effort, a Canadian User Guide is developed based on the Ontario Guide.
- The Guide provides a cross reference of design parameters used by agencies in Canada.
- Design parameters are customized for the local agency conditions.
- Latest version (working copy) – May 2016

MEPDG Design Parameters for Ontario and Canada — 13

Ontario — Ministry of Transportation

Input Parameters

- The Canadian Guide contains customized default input parameters across Canada.
- Contributing agencies provided the customized default values based on their local conditions.
- Currently, four provinces and a city have provided the data.

MEPDG Design Parameters for Ontario and Canada — 14

Ontario — Ministry of Transportation

Analysis Parameters

- Initial and terminal IRI's based on facility type
- Example from **Quebec**:

Treatments	Recommended Initial IRI (m/km) Highway	National	Other
Hot Mix Overlay	1.2	1.4	1.7
Cold in-place recycling + Hot Mix Overlay	1.4	1.4	1.5
Full Depth Reclamation + Hot Mix Overlay	1.2	1.3	1.3
New or Reconstruction to AC	1.2	1.2	1.3
New or Reconstruction to JPCP	1.2	n/a	n/a
New or Reconstruction to CRCP	1.2	n/a	n/a

Highway Facility Type	Recommended Terminal IRI (m/km)
Highway	2.2
National	2.5
Regional	3.0
Collector	3.5
Other	4.5

MEPDG Design Parameters for Ontario and Canada — 15

Ministry of Transportation

Performance Criteria Input

- Based on agency specific design requirement
- Example from **Manitoba**:

Performance Criteria	Target Values
FLEXIBLE PAVEMENTS:	
AC top-down fatigue cracking (m/km)	Ignore
AC bottom-up fatigue cracking (%) Expressway	15
Primary/Secondary Arterials	20
Collector	25
AC thermal fracture (m/km)	200
Permanent deformation -total pavement (mm)	19
Permanent deformation -AC only (mm)	12
Total Cracking (Reflective + Alligator) (%)	50
RIGID PAVEMENTS:	
JPCP transverse cracking (% slab) Expressway	10
Primary/Secondary Arterials	15
Collector	N/A
Mean joint faulting (mm)	3

MEPDG Design Parameters for Ontario and Canada — 16

Ontario — Ministry of Transportation

Reliability Level Input

- Based on different highway type or traffic volume
- Example from **City of Edmonton**:

Roadway Functional Class	Recommended Range of Reliability Levels (%)
Freeway	95
Arterial	90
Collector	85
Local	80

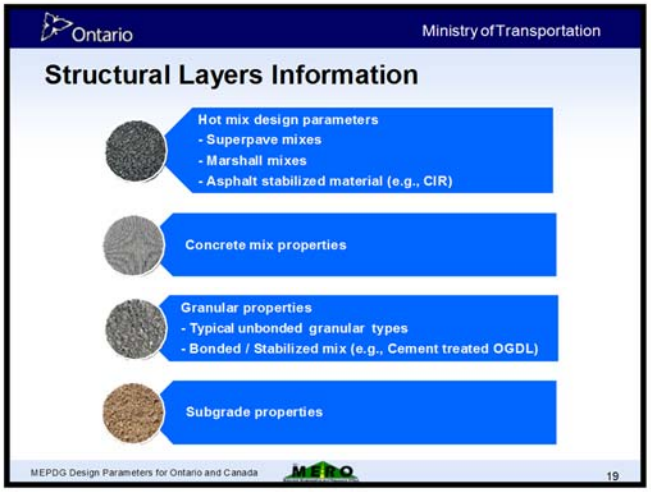
MEPDG Design Parameters for Ontario and Canada — 17

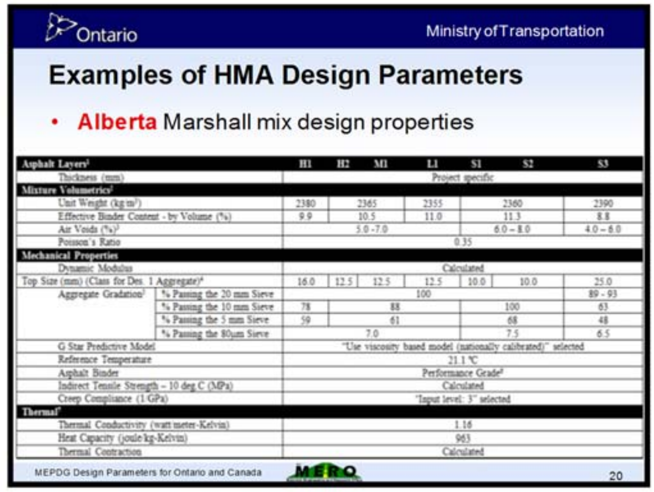
Ministry of Transportation

Climate Input

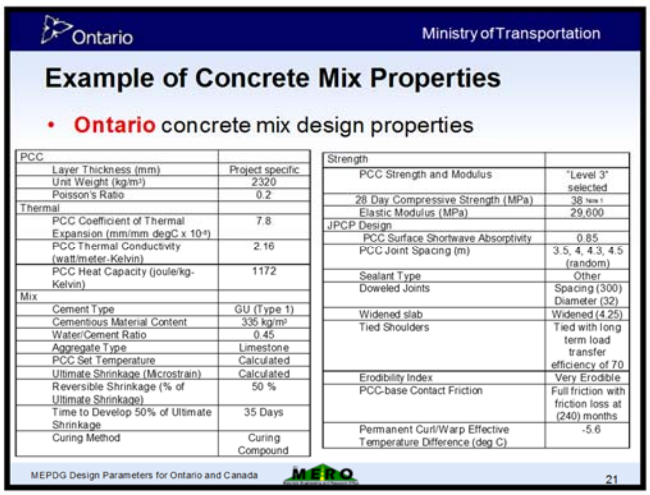
- Information from Environment Canada
- 223 weather stations across Canada
  - Download and import directly for design

MEPDG Design Parameters for Ontario and Canada — 18



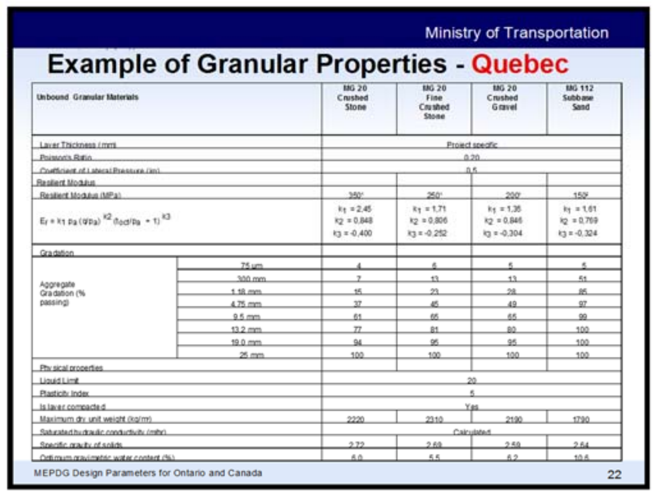


Asphalt Layers[1]		H1	H2	M1	L1	S1	S2	S3
Thickness (mm)		Project specific						
Mixture Volumetrics[2]								
Unit Weight (kg/m³)		2380	2365		2355	2360		2390
Effective Binder Content - by Volume (%)		9.9	10.5		11.0	11.3		8.8
Air Voids (%)[3]		5.0 - 7.0				6.0 – 8.0		4.0 – 6.0
Poisson's Ratio		0.35						
Mechanical Properties								
Dynamic Modulus		Calculated						
Top Size (mm) (Class for Des. 1 Aggregate)[4]		16.0	12.5	12.5	12.5	10.0	10.0	25.0
Aggregate Gradation[5]	% Passing the 20 mm Sieve	100						89 - 93
	% Passing the 10 mm Sieve	78	88			100		63
	% Passing the 5 mm Sieve	59	61			68		48
	% Passing the 80μm Sieve	7.0				7.5		6.5
G Star Predictive Model		"Use viscosity based model (nationally calibrated)" selected						
Reference Temperature		21.1 °C						
Asphalt Binder		Performance Grade[6]						
Indirect Tensile Strength – 10 deg C (MPa)		Calculated						
Creep Compliance (1/GPa)		"Input level: 3" selected						
Thermal[7]								
Thermal Conductivity (watt/meter-Kelvin)		1.16						
Heat Capacity (joule/kg-Kelvin)		963						
Thermal Contraction		Calculated						

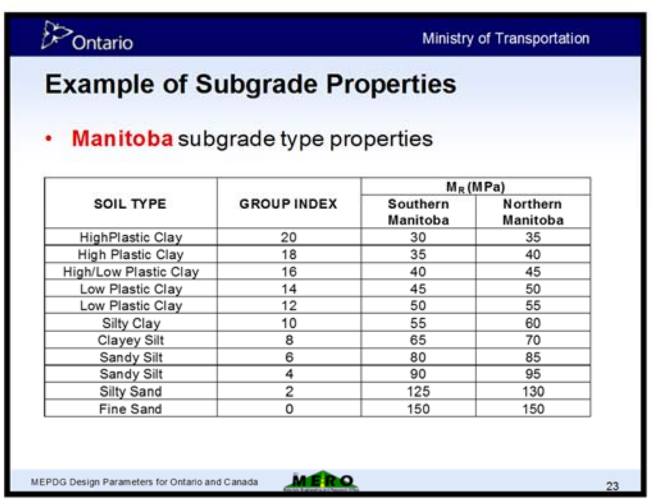


PCC	
Layer Thickness (mm)	Project specific
Unit Weight (kg/m³)	2320
Poisson's Ratio	0.2
Thermal	
PCC Coefficient of Thermal Expansion (mm/mm degC x 10⁻⁶)	7.8
PCC Thermal Conductivity (watt/meter-Kelvin)	2.16
PCC Heat Capacity (joule/kg-Kelvin)	1172
Mix	
Cement Type	GU (Type 1)
Cementious Material Content	335 kg/m³
Water/Cement Ratio	0.45
Aggregate Type	Limestone
PCC Set Temperature	Calculated
Ultimate Shrinkage (Microstrain)	Calculated
Reversible Shrinkage (% of Ultimate Shrinkage)	50 %
Time to Develop 50% of Ultimate Shrinkage	35 Days
Curing Method	Curing Compound

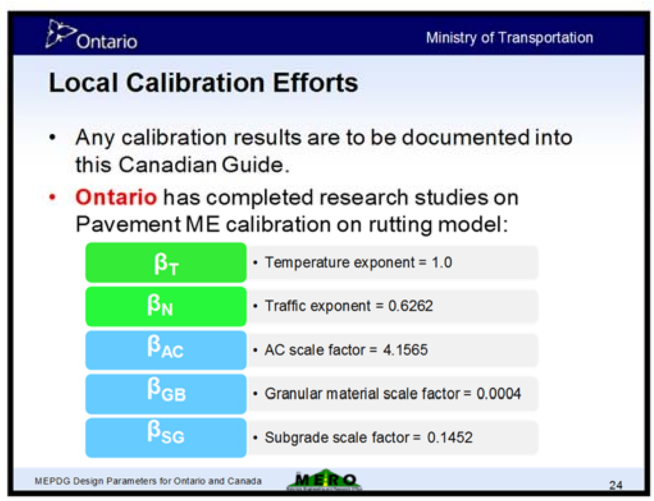
Strength	
PCC Strength and Modulus	"Level 3" selected
28 Day Compressive Strength (MPa)	38 Note 1
Elastic Modulus (MPa)	29,600
JPCP Design	
PCC Surface Shortwave Absorptivity	0.85
PCC Joint Spacing (m)	3.5, 4, 4.3, 4.5 (random)
Sealant Type	Other
Doweled Joints	Spacing (300) Diameter (32)
Widened slab	Widened (4.25)
Tied Shoulders	Tied with long term load transfer efficiency of 70
Erodibility Index	Very Erodible
PCC-base Contact Friction	Full friction with friction loss at (240) months
Permanent Curl/Warp Effective Temperature Difference (deg C)	-5.6

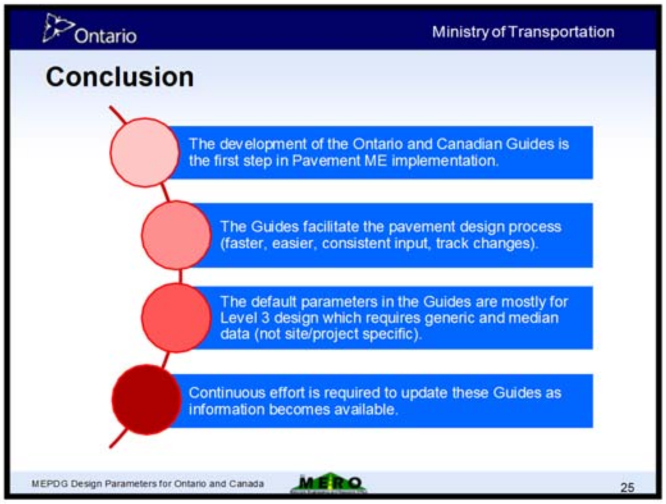


Unbound Granular Materials		MG 20 Crushed Stone	MG 20 Fine Crushed Stone	MG 20 Crushed Gravel	MG 112 Subbase Sand
Layer Thickness (mm)		Project specific			
Poisson's Ratio		0.20			
Coefficient of Lateral Pressure (ko)		0.5			
Resilient Modulus					
Resilient Modulus (MPa)		350'	250'	200'	150²
$E_r = k_1 p_a (\theta/p_a)^{k2} (\tau_{oct}/p_a + 1)^{k3}$		k_1 = 2.45, k_2 = 0.848, k_3 = -0.400	k_1 = 1.71, k_2 = 0.806, k_3 = -0.252	k_1 = 1.36, k_2 = 0.846, k_3 = -0.304	k_1 = 1.61, k_2 = 0.769, k_3 = -0.324
Gradation					
Aggregate Gradation (% passing)	75 μm	4	6	5	5
	300 mm	7	13	13	51
	1.18 mm	15	23	28	85
	4.75 mm	37	45	49	97
	9.5 mm	61	65	65	99
	13.2 mm	77	81	80	100
	19.0 mm	94	95	95	100
	25 mm	100	100	100	100
Physical properties					
Liquid Limit		20			
Plasticity Index		5			
Is layer compacted		Yes			
Maximum dry unit weight (kg/m)		2220	2310	2190	1790
Saturated hydraulic conductivity (m/hr)		Calculated			
Specific gravity of solids		2.72	2.69	2.59	2.64
Optimum gravimetric water content (%)		6.0	5.5	6.2	10.6



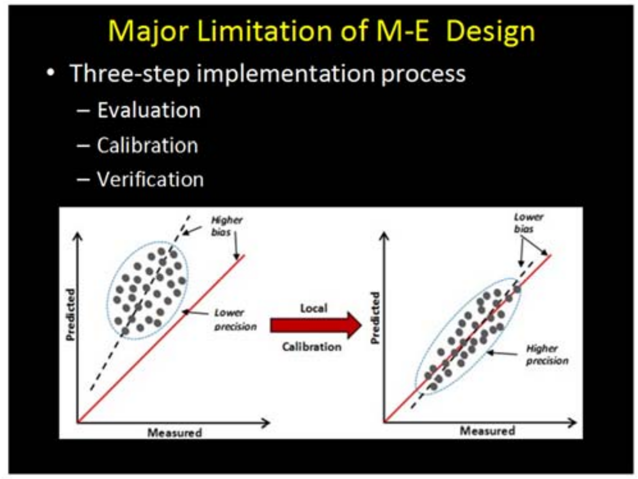
SOIL TYPE	GROUP INDEX	M_R (MPa) Southern Manitoba	Northern Manitoba
HighPlastic Clay	20	30	35
High Plastic Clay	18	35	40
High/Low Plastic Clay	16	40	45
Low Plastic Clay	14	45	50
Low Plastic Clay	12	50	55
Silty Clay	10	55	60
Clayey Silt	8	65	70
Sandy Silt	6	80	85
Sandy Silt	4	90	95
Silty Sand	2	125	130
Fine Sand	0	150	150

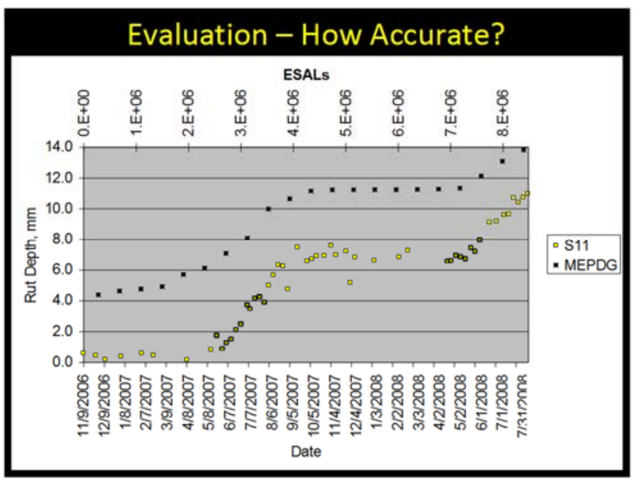


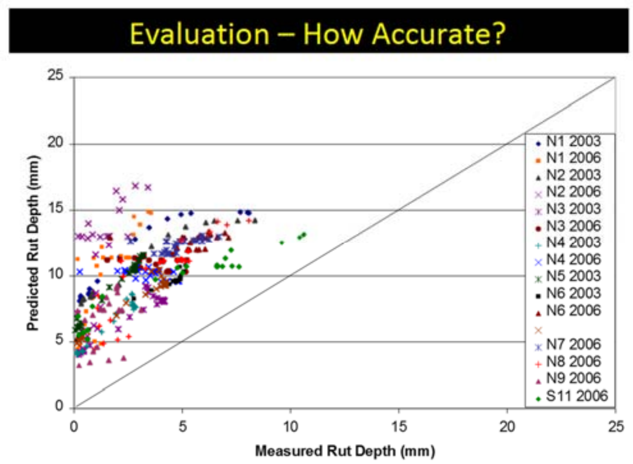

Ontario
Ministry of Transportation
Conclusion
The development of the Ontario and Canadian Guides is the first step in Pavement ME implementation.
The Guides facilitate the pavement design process (faster, easier, consistent input, track changes).
The default parameters in the Guides are mostly for Level 3 design which requires generic and median data (not site/project specific).
Continuous effort is required to update these Guides as information becomes available.
MEPDG Design Parameters for Ontario and Canada
MERO
25

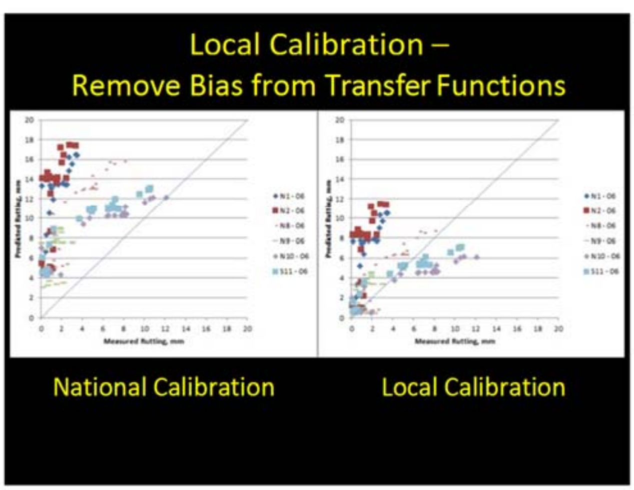

Ontario
Ministry of Transportation
Thank You
QUESTIONS?
Warren Lee, P. Eng., M.A.Sc.
Pavement Design Engineer,
Pavements & Foundations Section
Materials Engineering and Research Office
Tel: 416-235-6643
Email: Warren.Lee@ontario.ca
Susanne Chan, P. Eng., M.A.Sc.
Pavement Design Engineer,
Pavements & Foundations Section
Materials Engineering and Research Office
Tel: 416-235-5311
Email: Susanne.Chan@ontario.ca

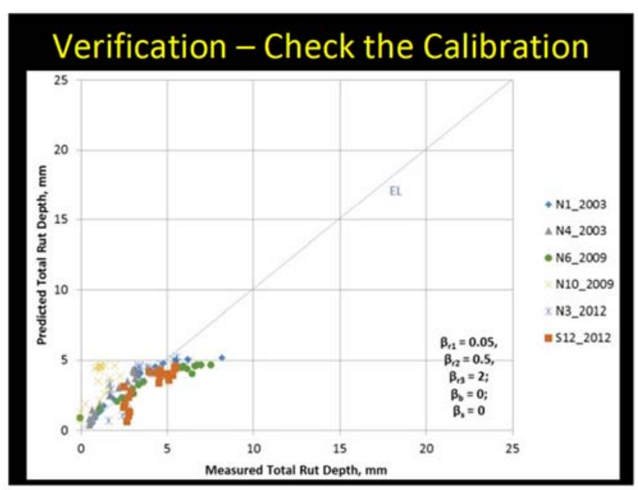
Presentation 19—John Donahue, Missouri DOT

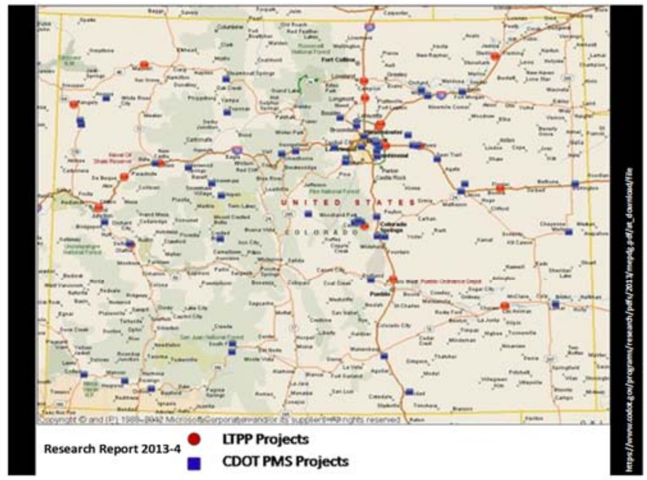












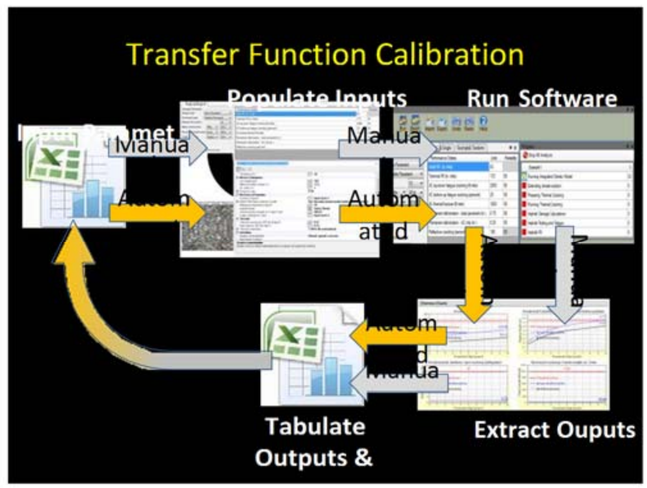
Transfer Function Calibration

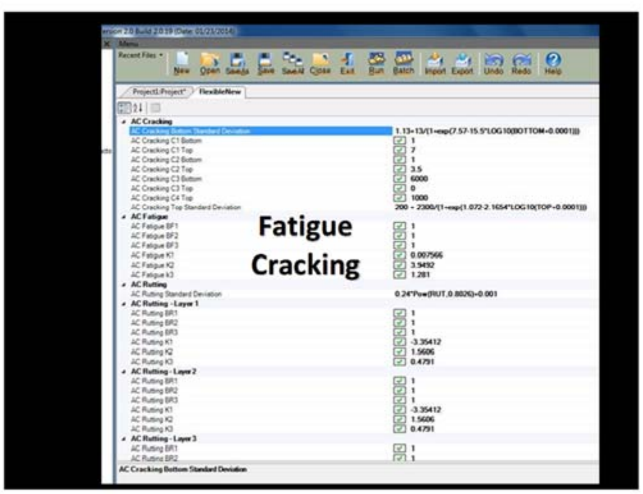
1. Assemble pavement section data
   – As-builts, traffic, climate, performance
2. Generate design files
3. Generate trial transfer function coefficients
4. Run simulations
5. Assess accuracy
6. Repeat steps 3, 4, 5 until error is minimized

$$N_{f-AC} = 0.00432(C)(\beta_{f1})(k_1)\left(\frac{1}{\varepsilon_t}\right)^{k_2\beta_{f2}}\left(\frac{1}{E}\right)^{k_3\beta_{f3}} \quad (A.18)$$

where:

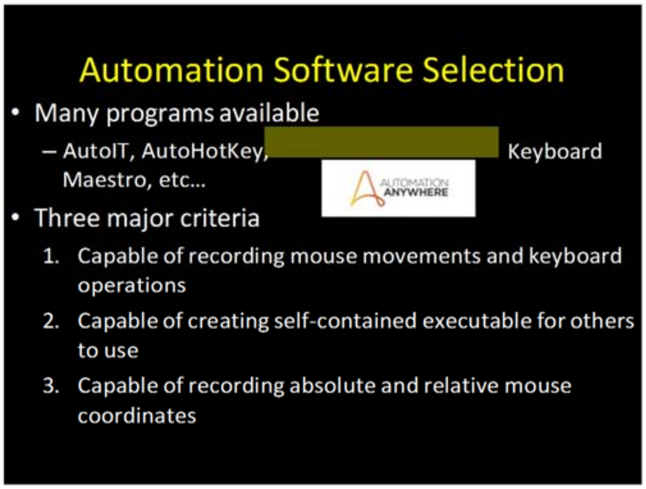
- N_{f-AC} = Allowable number of axle load applications for a flexible pavement and asphalt overlays
- ε_t = Tensile strain at critical locations and calculated by the structural response model, in/in
- E = Dynamic modulus of the HMA measured in compression, psi
- $k_{1,2,3}$ = Global field calibration parameters (k_1 = 0.007566, k_2 = 3.9492, and k_3 = 1.281)
- $\beta_{f1,f2,f3}$ = Local or mixture specific field calibration constants; for the global calibration effort, these constants were set to 1.0

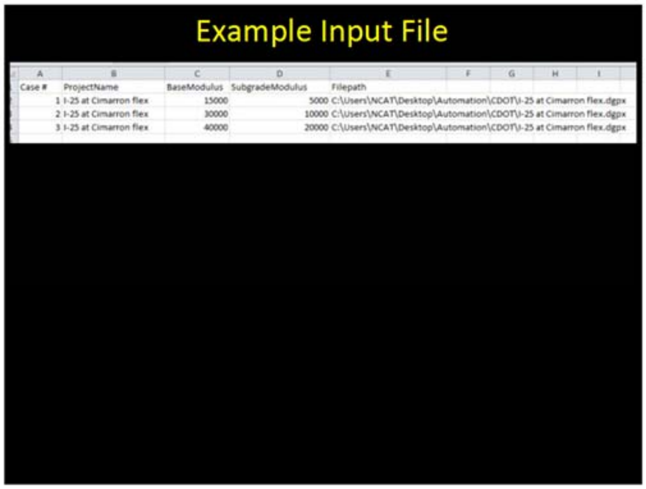




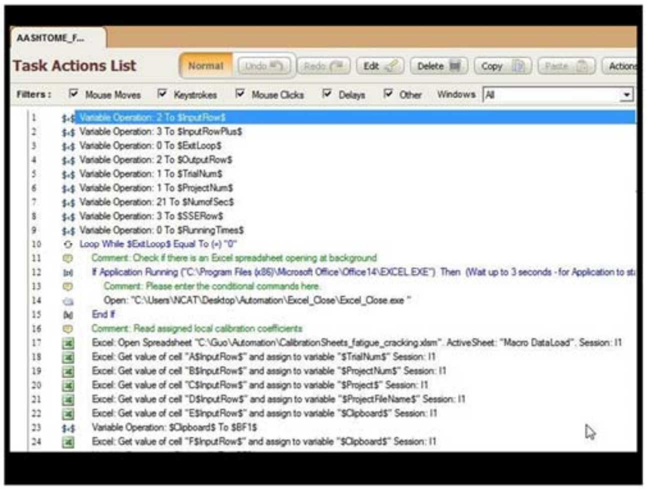
Need for Automation

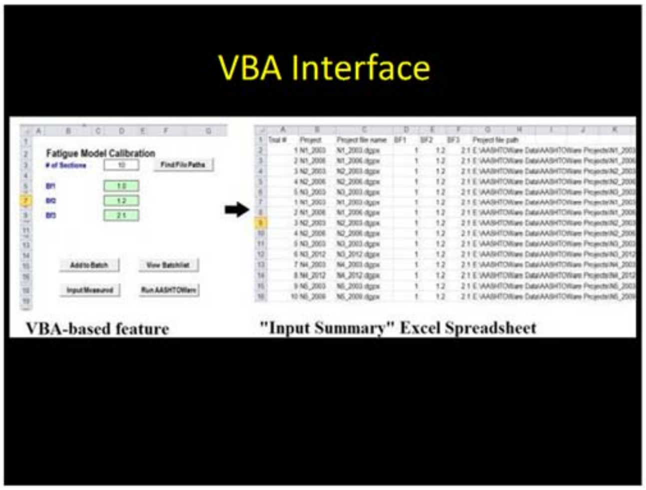
- Many agencies working toward implementation
- Verification, calibration and validation needed
  – Section selection and data assembly is significant
  – Very time consuming to run software
    - Thousands of iterations
    - Human interaction required

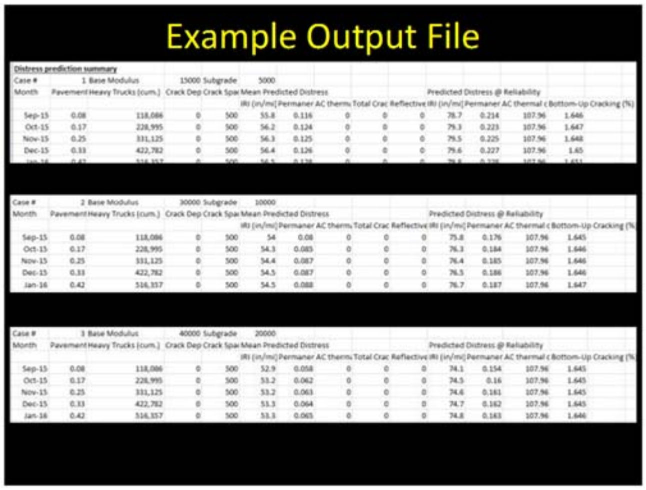

Automation Software Selection
• Many programs available
– AutoIT, AutoHotKey, [redacted] Keyboard Maestro, etc...
AUTOMATION ANYWHERE
• Three major criteria
1. Capable of recording mouse movements and keyboard operations
2. Capable of creating self-contained executable for others to use
3. Capable of recording absolute and relative mouse coordinates


Example Input File
Case # | ProjectName | BaseModulus | SubgradeModulus | Filepath
1 | I-25 at Cimarron flex | 15000 | 5000 | C:\Users\NCAT\Desktop\Automation\CDOT\I-25 at Cimarron flex.dgpx
2 | I-25 at Cimarron flex | 30000 | 10000 | C:\Users\NCAT\Desktop\Automation\CDOT\I-25 at Cimarron flex.dgpx
3 | I-25 at Cimarron flex | 40000 | 20000 | C:\Users\NCAT\Desktop\Automation\CDOT\I-25 at Cimarron flex.dgpx


Automation = Coding
Automation Anywhere


Task Actions List


VBA Interface
Fatigue Model Calibration
VBA-based feature
"Input Summary" Excel Spreadsheet

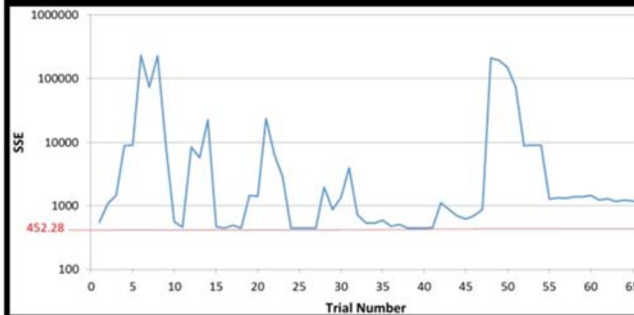

Example Output File

Cumulative Iterations

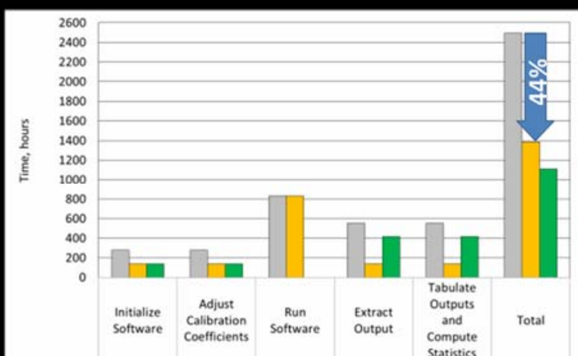
- Fatigue cracking calibration from NCAT Test Track
  - 25 sections
  - 3 coefficients (β_{f1}, β_{f2}, β_{f3})
  - 11 trials / coefficient

25x11x11x11 = 33,275 iterations

Finding the best coefficients



Automated vs Manual Time Resources



	Initialize Software	Adjust Calibration Coefficients	Run Software	Extract Output	Tabulate Outputs and Compute Statistics	Total
Manual	277	277	832	555	555	2,496
Automated	139	139	832	139	139	1,386
Savings	139	139	-	416	416	1,109

Summary & Conclusions

- Caution must be used when using the software
  - Evaluation
  - Calibration
  - Validation
- Design simulations are very labor intensive
- Automation can greatly simplify calibration studies
  - 44% time savings achieved overall
    - 86% achieved when considering only human interaction
- Potential for fewer errors due to data entry

Presentation 20—Harold Von Quintus and Chad Becker, ARA

Software Training

AASHTOWare Pavement ME Design MEPDG Users Group Meeting Denver, Colorado October 12, 2017

Harold L. Von Quintus,

P.E. Chad Becker

Outline

1. Simulating Stabilized Bases
2. Characterization of Existing Flexible Pavements
3. Rehabilitation Design Example; I-84 in Boise, Idaho
4. Calibration Process Example

Simulating Stabilized Bases

- New Pavement Design
  - Asphalt Stabilized Base Mixtures; flexible pavements
  - Permeable Asphalt Treated Base; flexible pavements.
  - Chemically Stabilized Base Mixtures; semi-rigid pavements
- Rehabilitation Design

Simulating Stabilized Bases

- Rehabilitation Design:
  - AC Overlay of Semi-Rigid Pavement
  - Cold in Place Recycled Layer
    - No material added
    - Asphalt emulsion added
  - Full-Depth Reclamation – simulate as new pavement design strategy; pavement type depends on type of stabilized material:

Asphalt Stabilized Base

MEPDG Manual of Practice:

1. Plant mixed material; simulate as a dense-graded AC layer.
2. In place mixed material; simulate as a dense-graded AC layer.
3. Cold Recycled Asphalt or RAP Layer; simulate as an aggregate base layer; E=30,000 psi.

(Items 1 and 2:) Assumes the fatigue strength coefficients are the same as for a dense-graded AC mix.

Only plant produced bituminous mixtures were included in original global calibration!

Permeable Asphalt Treated Base

MEPDG Manual of Practice: "Features and Factors Not Included within the MEPDG Process" (Chapter 3)

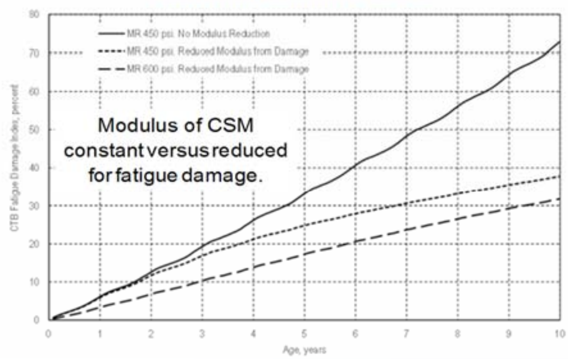
- Simulate as an aggregate base mixture with a constant high modulus base, because:
  - High air voids (greater than 15 percent) for PATB layers significantly reduces the allowable number of load applications
  - Significant bias in fatigue cracking for the SPS-1 sections with PATB layers in comparison to the SPS-1 sections without a PATB layer.

Chemically Stabilized Base

- Simulation Options:
  1. High quality aggregate base layer; elastic modulus remains constant over time.
  2. Stabilized layer:
     a) Elastic modulus remains constant throughout design period.
     b) Elastic modulus degrades (softens) based on accumulative damage.

ARA Proprietary ©2015 Applied Research Associates, Inc. 7

Chemically Stabilized Base



ARA Proprietary ©2015 Applied Research Associates, Inc. 8

Chemically Stabilized Base

- Simulation Options, examples; GA, MS, MT:

Description of CTB Layer	28-Day Compressive Strength, psi	28-Day Elastic Modulus, psi	Modulus of Rupture, psi
High Strength CTB (intact, testable cores recovered)	1,400	2,250,000	350
Moderate Strength CTB (untestable cores recovered)	500	1,000,000	200
Low Strength CTB (cores not recovered)	Semi-Rigid Pavement Simulation not applicable; assume conventional flexible pavement with high stiffness GAB layer.		

ARA Proprietary ©2015 Applied Research Associates, Inc. 9

Chemically Stabilized Base

- Preliminary calibration coefficients for chemically stabilized layers:

Description of CTB Layer	Fatigue Equation		Transfer Function	
High Strength CTB (intact, testable cores recovered) and Moderate Strength CTB (untestable cores recovered)	Kc1	0.972	C1	0.0
	Kc2	0.825	C2	100
	Bc1	1.0	C3	4.0
	βc2	1.0	C4	2.0
Low Strength CTB (cores not recovered)	Semi-Rigid Pavement Simulation not applicable; assume conventional flexible pavement with high stiffness GAB layer.			

Assumes full bond between layers.

ARA Proprietary ©2015 Applied Research Associates, Inc. 10

Simulating Stabilized Bases

Example demonstration and comparison of different stabilized bases from a roadway segment west of Amarillo, TX:

1. Asphalt stabilized base
2. Cold recycled asphalt base; E = 30,000 psi
3. Chemically stabilized base
4. Soil-cement (modification); E = 65,000 psi

Layer Type	Thickness, inches
AC Wearing Surface; PG 64-28	4
Stabilized Base	6 or 7
Aggregate Base	4
Subgrade Soil	A-2-4

ARA Proprietary ©2015 Applied Research Associates, Inc. 11

Simulating Stabilized Base

Software and inputs for the chemically stabilized base for examples.

Moderate and higher strength CSM values.

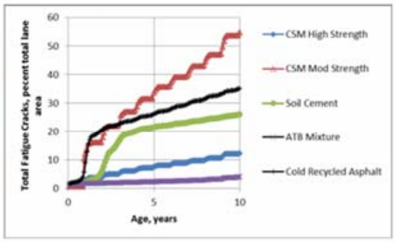
No E-value degradation with damage index.

ARA Proprietary ©2015 Applied Research Associates, Inc. 12

Simulating Stabilized Bases

Example demonstration and comparison of different stabilized bases from a roadway segment east of Amarillo, TX:

Layer Type	Thickness, inches
AC Wearing Surface	4
Stabilized Base	6 or 7
Aggregate Base	4
Subgrade Soil	A-2-4



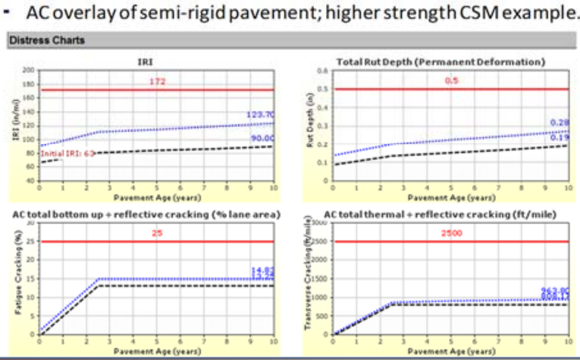
Recommendation is to assume 28-day elastic modulus and minimum E are equal.

Simulating Stabilized Base

AC overlay of semi-rigid pavement; higher strength CSM example.

Simulating Stabilized Base

- AC overlay of semi-rigid pavement; higher strength CSM example.



Simulating Stabilized Base

Questions?

Outline

1. Modeling Stabilized Bases
2. Characterization of Existing Flexible Pavements
3. Rehabilitation Design Example; I-84 in Boise, Idaho
4. Calibration Process Example

Characterization of Existing Flexible Pavements

- In Place Damage Determination
  - Input Level 1 – FWD Deflection Basins
  - Input Level 2 – Distress Surveys
  - Input Level 3 – Condition Categories
- Field Investigations
  - Type of cracking?
  - Mixture disintegration or moisture damage?
  - Debonding between adjacent AC layers?
  - Saturated unbound layers?

Characterization of Existing Pavement

Example demonstrations for two projects in the northern part (colder climate) of the U.S.:

1. Low severity fatigue cracks (25 percent) with a cold in place recycled asphalt base along a primary arterial to be repaired.
   - No transverse cracks
   - Average rut depths less than 0.25 inches
2. High severity longitudinal cracking (12 percent) with an asphalt stabilized base (CIR with an emulsion) along a secondary arterial roadway to be repaired.
   - Transverse cracks exhibited at an amount of 500 ft./mi.
   - Average rut depths less than 0.35 inches

Project #1

Distress Type	Amount	Severity
Fatigue Cracks, percent	26	Low
Transverse Cracks, ft./mi.	0	NA
Rut Depth, inches	0.25	NA

Layer Type	Thickness
AC Wearing Surface	1.5
AC Leveling Course	2.0
Cold in Place Recycled; nothing added; mixed in place	7.25
4-inch Aggregate Base & A-3 Embankment	22
Subgrade Soil	A-2-4

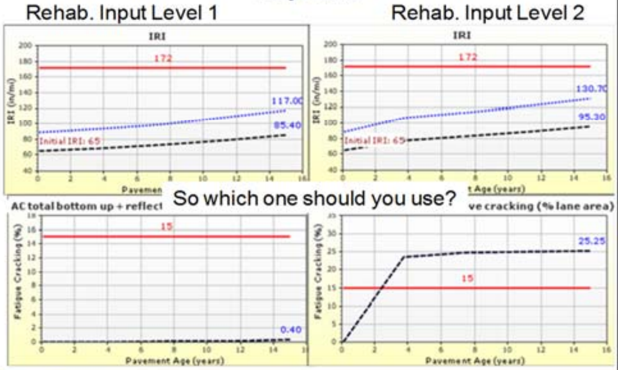
Project #1

AC Layers	E, psi	Air Voids	AC
AC Wearing Surface	2,600,000	7.5	11.7
AC Leveling Course		8.3	11.1
Unbound Layers	**E, psi**	**WC**	**Density**
Cold in Place Recycled; nothing added; mixed in place	100,000	8.5	137
A-3 Embankment, elevated	26,000	6	128
Subgrade Soil, A-2-4	29,000	10	125

Project #1

Software demonstration and use for comparing rehabilitation input level 1 and 2.

Project #1



Project #1

Cracking confined to about ½ depth of the wearing surface.

Milling and nonstructural overlay was the repair option.

Project #2

Distress Type	Amount	Severity
Fatigue Cracks, percent	12	Moderate
Transverse Cracks, ft./mi.	500	Moderate
Rut Depth, inches	0.35	NA

Layer Type	Thickness
AC Wearing Surface	1.75
AC Leveling Course	1.0
Cold in Place Recycled; nothing added; mixed in place	5.5
A-3 Embankment	18
Subgrade Soil	A-4

 25

Project #2

AC Layers	E, psi	Air Voids	AC
AC Wearing Surface	425,000	5.5	10.0
AC Leveling Course		5.5	10.0
Cold in Place Recycled; HF-150 Emulsion added; mixed in place	161,000	9.8	10.5
Unbound Layers	**E, psi**	**WC**	**Density**
A-3 Embankment, elevated	24,000	11.5	125
Subgrade Soil, A-2-4	18,000	14	124

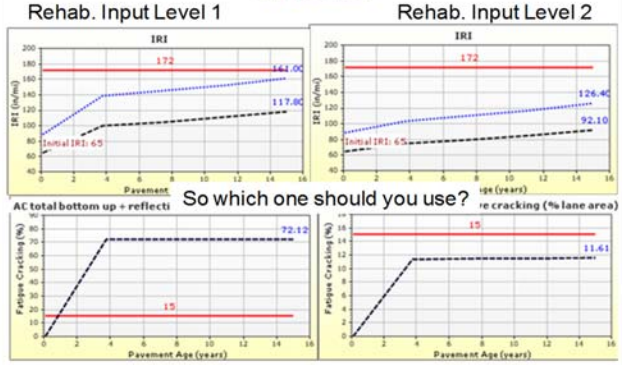
 26

Project #2

Software demonstration and use for comparing rehabilitation input level 1 and 2.

 27

Project #2



 28

Project #2

Cracking extends through all layers and CIR bottom layer is disintegrating. Selected option is to reconstruct.

 29

Characterization of Existing Flexible Pavements

Questions?

 30

Outline

1. Modeling Stabilized Bases
2. Characterization of Existing Flexible Pavements
3. Rehabilitation Design Example; I-84 in Boise, Idaho
4. Calibration Process Example

31

I-84 Rehabilitation; Boise, Idaho

- Surface Condition: severe transverse and longitudinal cracks and moderate fatigue cracking.
- FWD Deflection Basin Testing
- Destructive Sampling: cores recovered to observe condition of different layers.
- Rehabilitation Design – Demonstration

32

I-84 Rehabilitation; Boise, Idaho

Portion of interstate where cores found to be intact in reasonably good condition.

Layer	Thick.
Asphalt Concrete	10
Crushed Gravel Base	9
A-4 Subgrade Soil	

Portion of interstate where cores broke apart and found to be in poor condition.

33

I-84 Rehabilitation; Boise, Idaho

Example rehabilitation design demonstration using the restrictions for project.

- BcT demonstration
- Pavement ME file set up.

34

I-84 Rehabilitation; Boise, Idaho

Design Parameter	Repair Option			
	1	2	3	4
Description	Baseline	Thin Mill	Deep Mill Overlay	Deep Mill, Thicker Overlay
Rehabilitation Input Level to determine the in place damage.	2	2	2	2
Surface Preparation, Mill Depth, inches	0	3	4.8	4.8
Overlay Thickness, inches	6	3	4.8	6.0
Thickness of Existing AC layer Remaining In Place, inches	10	7	5.2	5.2
Terminal IRI, in./mi.	145.5	208.1	126.0	120.2
Total Rut Depth, inches	0.23	0.56	0.33	0.29
Total AC Fatigue Cracking, % total lane area	84.4	100	23.3	14.6
Total Transverse Cracking, ft./mi.	1279	1292	1301	1289
AC Top-Down Cracking, for information purposes, ft./mi.	263	3306	1765	690
Service Life, years	4.0	0.5	12.0	20+

35

I-84 Rehabilitation; Boise, Idaho

Design Parameter	Repair Option		
	5	6	7
Description	Deep Mill, Overlay	Deep Mill, Thicker Overlay	Deep Mill, Overlay with Interlayer
Rehabilitation Input Level to determine the in place damage.	1	1	1
Surface Preparation, Mill Depth, inches	4.8	4.8	4.8
Overlay Thickness, inches	4.8	6.8	4.8 plus interlayer
Thickness of Existing AC layer Remaining In Place, inches	5.2	5.2	5.2
Terminal IRI, in./mi.	133.8	118	122.6
Total Rut Depth, inches	0.30	0.25	0.26
Total AC Fatigue Cracking, % total lane area	40.7	14.2	20.1
Total Transverse Cracking, ft./mi.	1301	1291	1302
AC Top-Down Cracking, for information purposes, ft./mi.	587	229	307
Service Life, years	9.1	20+	16.0

36

I-84 Rehabilitation; Boise, Idaho

Questions?

37

Outline

1. Modeling Stabilized Bases
2. Characterization of Existing Flexible Pavements
3. Rehabilitation Design Example; I-84 in Boise, Idaho
4. Calibration Process Example

38

Calibration

Discussion on Wednesday identified concerns and issues related to calibration and Pavement ME use relative to material characterization.

First, how do the global and local calibration coefficients compare between different agencies?

1. Rut depth
2. Bottom-up fatigue cracking
3. Transverse cracking

39

Calibration: Rut Depth Coefficients

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

40

Calibration: Fatigue Cracking Coefficients

Layer or Material	Coefficient	Global Values	Local Values	
			Material Specific	Range of Values
AC; fatigue strength relationship	Kf1	0.007566	√	0.007566 to 0.000757
	Bf1	**1.0**		**0.96 to 249.0**
	Kf2	3.9492	√	
	Bf2	1.0	√	0.724 to 1.0
	Kf3	1.281	√	
	Bf3	1.0		0.60 to 1.233
Transfer Function	C1	1.0		0.07 to 2.2
	C2	**1.0**	√	**0.225 to 4.35**
	C3	6,000		

41

Calibration: Transverse Cracking Coefficients

Layer or Material	Coefficient	Global Values	Local Values	
			Material Specific	Range of Values
AC	**Kt1**	**1.5**		**0.625 to 50**
	Kt2	**0.5**		**0.625 to 50**
	Kt3	**1.5**		**0.625 to 50**

Result or key take away:

- A lot of variation between and within the global and local calibration coefficients.
- Why?

42

Calibration: Points/Question being Considered

Global calibration based on using:

1. Neat AC mixtures designed via Marshall or Hveem; does this make a difference?
2. Few projects included RAP; when high RAP added, are the coefficients applicable?
3. Many sections had low levels of distress; do not just add sections with higher levels of distress – refer to GDOT.
4. Coefficients were assumed to be independent of other factors; this is not the case.
5. Etc.

Calibration

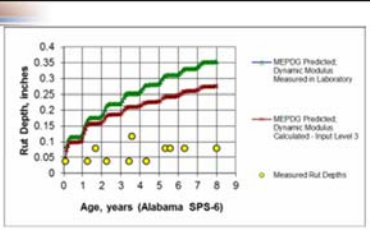
Second, what are the material characterization tests that should be considered for flexible and semi-rigid pavements to increase accuracy?

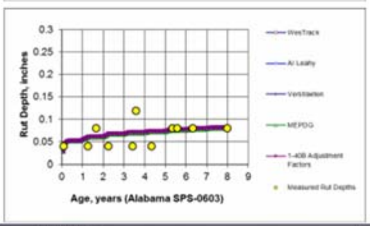
Dynamic modulus is being performed on many mixtures. Is this sufficient?

- Pennsylvania DOT
- Colorado DOT
- Mississippi
- Etc.

Calibration

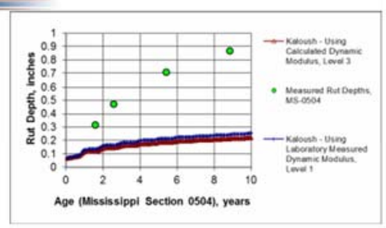
Comparison of predicted versus measured rut depths using E* measured values and input level 3.

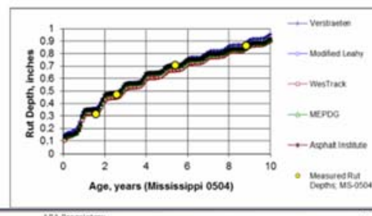




Calibration

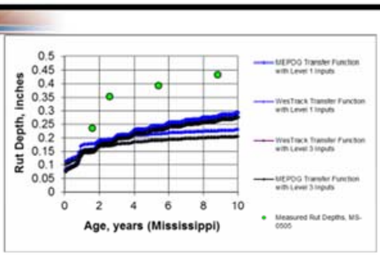
Comparison of predicted versus measured rut depths using E* measured values and input level 3.

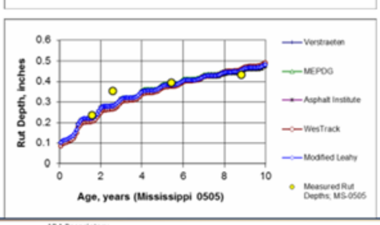




Calibration

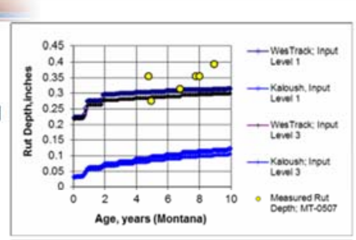
Comparison of predicted versus measured rut depths using E* measured values and input level 3.

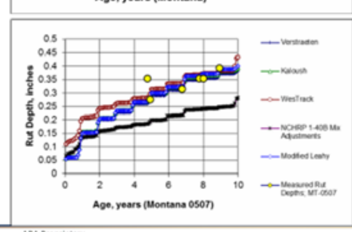




Calibration

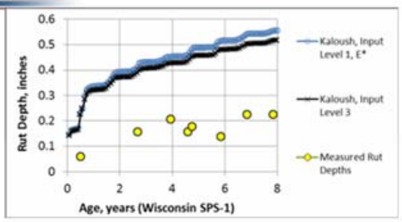
Comparison of predicted versus measured rut depths using E* measured values and input level 3.

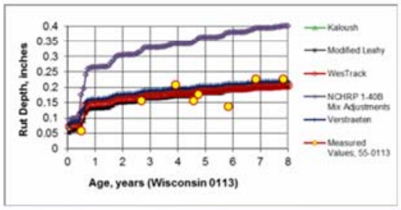




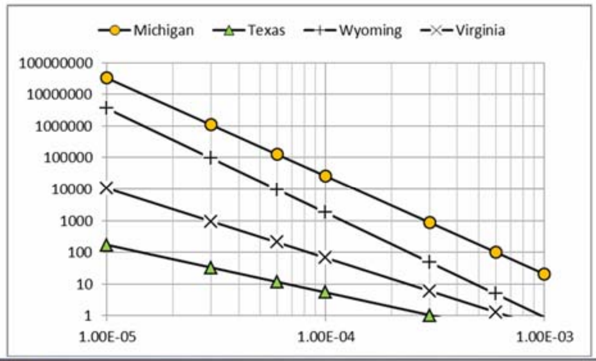
Calibration

Comparison of predicted versus measured rut depths using E* measured values and input level 3.





Calibration



Calibration

Third, material characterization or testing is important – is it cost effective?

Calibration

Trigger Value, inches	Reliability Level, percent	HMA Overlay Project: Small Project, < $1M	HMA Overlay Project: Intermediate Project Size	HMA Overlay Project: Large Project, $5M
0.25	75			
	85	B/C > 1.0	B-C > 1.0	B-C > 1.0
	95			
0.50	75			
	85	B/C > 1.0	B-C > 1.0	B-C > 1.0
	95			
0.75	75			
	85		B/C > 1.0	B-C > 1.0
	95	B/C > 1.0		

The shaded cells have B/C ratios less than one.
Results applicable to mixtures with low slopes or K3 values.

Calibration

Trigger Value, inches	Reliability Level, percent	HMA Overlay Project: Small Project, < $1M	HMA Overlay Project: Intermediate Project Size	HMA Overlay Project: Large Project, $5M
0.25	75			
	85	B/C > 1.0	B/C > 1.0	B/C > 1.0
	95			
0.50	75			
	85		B/C > 1.0	B/C > 1.0
	95	B/C > 1.0		
0.75	75			
	85			B/C > 1.0
	95		B/C > 1.0	

The shaded cells have B/C ratios less than one.
Results applicable to AC mixtures with high slopes or K3 values.

Calibration

Take away:

- Only measuring E* will not significantly increase the accuracy of the predicted values for both rut depth and fatigue cracking.
- My opinion: tests used to predict cracking will be more cost effective than for rut depth.

Calibration

Fourth; many times of Wednesday, uncalibrated model was mentioned – is this true?

- Additional question to be asked prior to starting local calibration: how do the global calibration sections differ from local design strategies, materials, and standard operating practices?

Take away:

- Verification can be very important to guide if and how calibration proceeds.

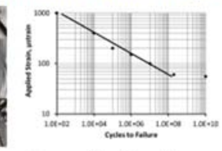
Calibration

- Fifth, automated calibration – what does this mean?
- Sixth, managing calibration – when does it need to be done?
- Remember:
  - PCC has been calibrated on three occasions at the global level.
  - AC was only calibrated once at the global level.
  - Local calibration guide suggests, 5 to 10 year interval.
    - WMA – does this make a difference?
    - High RAP and RAS mixes – do these make a difference?

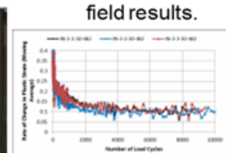
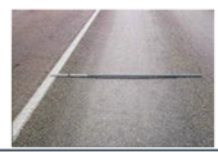
Recalibration Effort: Simple but very Complex

- What we have now:
  - Current global calibration coefficients (k-values) are a combination of lab-derived and field-shift values.
    - One set of field-derived calibration coefficients are applicable to all material conditions for a specific design strategy.
  - New mixtures – no consistent or formal procedure to convert lab-derived values to field-shifted values.
- What we need to simplify future calibration efforts:
  - Start with lab-derived k-values; select global values from lab studies.
  - Determine the field-shift coefficients or β values.
  - Assumption: field-shift coefficients are applicable to all future mixtures.

Recalibration Effort: Simple but very Complex


Currently, K-values are a combination of lab and field results.

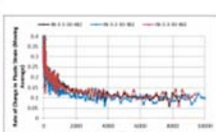




Recalibration Effort: Simple but very Complex



K-values defined by lab results.

β-values defined from field.


Recalibration of Flexible and Semi-Rigid Pavements

- Completed in accordance with the Guide for the Local Calibration of the Mechanistic-Empirical Pavement Design Guide, dated November 2010.
- Verify and update the global calibration coefficients of the flexible and semi-rigid pavement transfer function coefficients.
- Calibration database for flexible and semi-rigid pavements being turned over to AASHTO.

Calibration Process

The k-values are dependent on the mixture and test procedure. Are the β values dependent on the primary tiers of the sampling matrix or factorial?

- Define what is important
- Sampling matrix for selecting sites
- Number of sections and number of observations
- Magnitude of distress

Recalibration of Flexible and Semi-Rigid Pavements

Sampling matrix for selecting calibration sites; Pavement Structures.

New Construction	AC Overlays of Flexible Pavement	AC Overlays of Semi-Rigid	AC Overlays of Rigid Pavements
1. Conventional	1. AC over AC without interlayers	1. AC over AC without interlayers	1. AC over intact JPCP without interlayer
			2. *AC over intact JPCP w/interlayer*
2. Deep-Strength	2. AC over AC with interlayer/seal coat	2. AC over AC w/interlayer/seal coat	3. AC over intact CRCP
3. Full-Depth	*3. Hot in place recycling*		4. AC over fractured JPCP; SPS-6
4. Semi-Rigid	*4. AC over CIPR*		
	5. Full-Depth Reclamation		

Recalibration of Flexible and Semi-Rigid Pavements

Sampling matrix for selecting calibration sites; other factors.

Factors	Factor Level				
AC Total Thickness, in.	< 6	6 to 10	10 to 15	> 15 inches	
AC Mixture	Without RAP	Low amounts of RAP, < 20%	With high RAP, > 35%		
Asphalt Binder	Neat		Polymer Modified		
Truck Traffic; AADTT	< 500	500 to 1,500	1,500 to 3,000	> 3,000	
Subgrade Soil	Fine-Grained, high plasticity	Fine-Grained, low plasticity	High percentage silt	High percentage sand	Coarse-Grained
Climate	Dry-No Freeze	Dry-Freeze	Wet-Freeze	Wet-No Freeze	

Calibration Process

- Flexible Pavements
- Semi-Rigid Pavements; chemically stabilized mixtures
- Distresses
  - Bottom-Up Fatigue Cracking
  - Total Rut Depth
  - Transverse Cracking
  - Reflection Cracking (transverse and fatigue cracking)
- Roughness or smoothness degradation – IRI

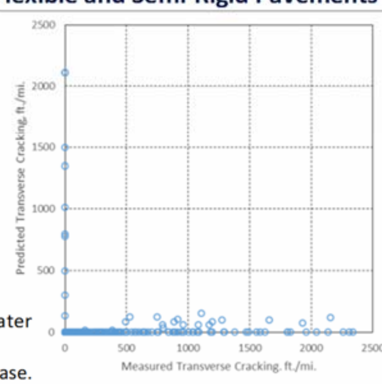
Recalibration Effort: Simple but Complex

Specific points of recalibration:

1. Climate
   - MERRA database being used.
   - Climate start date coincides with construction date.
2. Unbound material property, resilient modulus
   - Use laboratory equivalent moduli because resilient modulus test data available for most test sections.
   - Water content and dry density coincide with resilient modulus.
3. Initial IRI backcasted
4. AC air voids backcasted

Recalibration of Flexible and Semi-Rigid Pavements

Transverse cracking: using the global calibration values



NOTE: Measured transverse cracks greater than 2,500 ft./mi. eliminated from database.

Recalibration of Flexible and Semi-Rigid Pavements

Transverse cracking dependent on:

- Truck traffic
- AC thickness
- Temperature or climate

Bias = Pred. – Obser.

Factor	Low	Middle	High
Truck Traffic	<100,000	100,000 to 3,000,000	>3,000,000
Bias	-56	-190	-394
AC Thick	< 6	8 to 12	> 13
Bias	-120	-262	-154
MAAT	< 50	50 to 60	> 60
Bias	-112	-257	-271

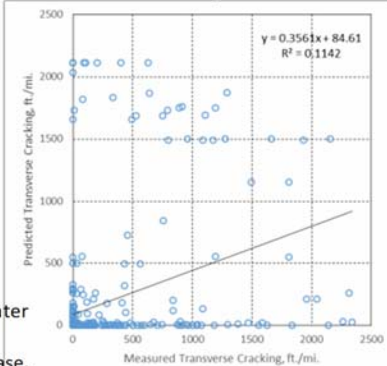
Result, Transverse Cracking Calibration Coefficient:

- Dependent on truck traffic.; also reported for SPS-8 experiment.
- Dependent on climate
- Mechanism accounts for thickness effect.

ARA Proprietary ©2015 Applied Research Associates, Inc. 67

Recalibration of Flexible and Semi-Rigid Pavements

Transverse cracking: using preliminary calibration values



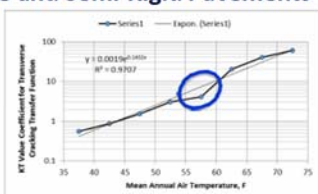
NOTE: Measured transverse cracks greater than 2,500 ft./mi. eliminated from database.

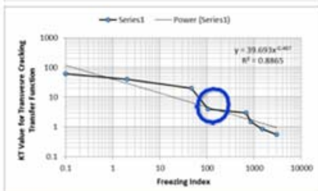
ARA Proprietary ©2015 Applied Research Associates, Inc. 68

Recalibration of Flexible and Semi-Rigid Pavements

Transverse cracking calibration coefficient dependent on:

- Temperature or climate factors
  - Mean annual air temperature
  - Freezing index
- Blue circle designates a different mechanism causing transverse cracks in warmer climates – shrinkage?





ARA Proprietary ©2015 Applied Research Associates, Inc. 69

Recalibration of Flexible and Semi-Rigid Pavements

Transverse cracking calibration coefficient dependent on temperature.

Annual Air Temp	K Coefficient
> 70	60
65 to 69	40
60 to 64	20
55 to 59	4
50 to 54	3
45 to 49	1.5
40 to 44	0.85
<40	0.55

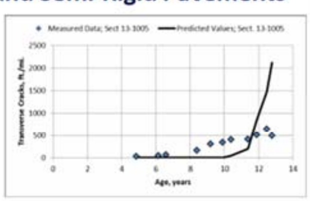
k coefficient	Bias
k = 0.55	34.9
k = 0.85	107.4
k = 1.5	12.9
k = 3	-133.6
k = 4	-134.1
k = 20	-109.3
k = 40	34.3
k = 60	21.8

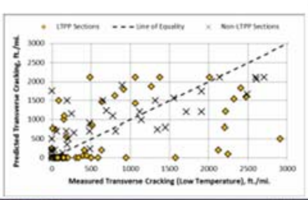
Preliminary standard error is high (623 ft./mi.), because model does not include all mechanisms causing transverse cracks.

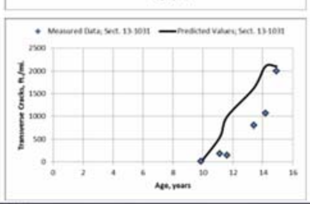
ARA Proprietary ©2015 Applied Research Associates, Inc. 70

Recalibration of Flexible and Semi-Rigid Pavements

Transverse cracking prediction examples:



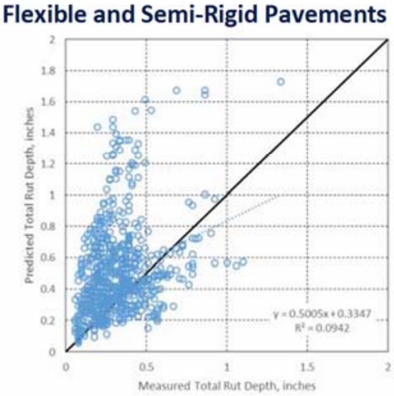




ARA Proprietary ©2015 Applied Research Associates, Inc. 71

Recalibration of Flexible and Semi-Rigid Pavements

Rutting: using the global calibration values



ARA Proprietary ©2015 Applied Research Associates, Inc. 72

Recalibration of Flexible and Semi-Rigid Pavements

Rut depth dependent on: Bias = Pred. – Obser.

Factor	Low	Middle	Middle	High
Truck Traffic	<200,000	200,000 to 500,000	500,000 to 1,000,000	>1,000,000
Bias	0.0712	0.0957	0.108	0.32
AC Thick	< 6	6 to 9	9 to 13	>13
Bias	0.237	0.298	0.088	0.010
MAAT	< 50	50 to 60	60 to 70	>70
Bias	0.099	0.064	0.233	0.281

Result, Rut Depth Calibration Coefficient:
- Dependent on truck traffic
- Dependent on climate
- Dependent on AC thickness
- Dependent on soil type
- Dependent on base type
- Dependent on mix type

ARA Proprietary © 2015 Applied Research Associates, Inc. 73

Recalibration of Flexible and Semi-Rigid Pavements

Rut depth dependent on: Bias = Pred. – Observ.

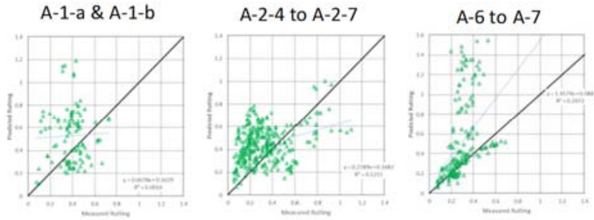
Factor	Asphalt Type		
Binder/Mix Type	Penetration Based	Viscosity Based	Superpave PG Based
Bias	0.079	0.127	0.554

ARA Proprietary © 2015 Applied Research Associates, Inc. 74

Recalibration of Flexible and Semi-Rigid Pavements

Effect of Unbound Material/Soil Type of Rut Depth Residual Errors

A-1-a & A-1-b | A-2-4 to A-2-7 | A-6 to A-7

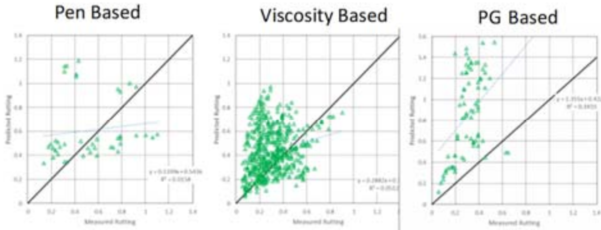


ARA Proprietary © 2015 Applied Research Associates, Inc. 75

Recalibration of Flexible and Semi-Rigid Pavements

Effect of Unbound Material/Soil Type of Rut Depth Residual Errors

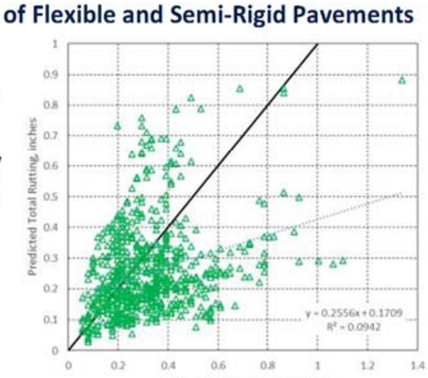
Pen Based | Viscosity Based | PG Based



ARA Proprietary © 2015 Applied Research Associates, Inc. 76

Recalibration of Flexible and Semi-Rigid Pavements

Rut depth: using preliminary calibration values



ARA Proprietary © 2015 Applied Research Associates, Inc. 77

Recalibration of Flexible and Semi-Rigid Pavements

Extensive interrelationship between parameters within LTPP.

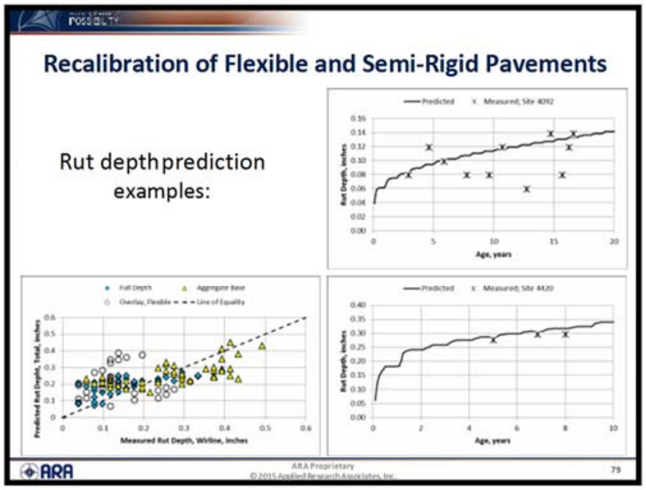
Rut Depth calibration coefficient dependent on material.

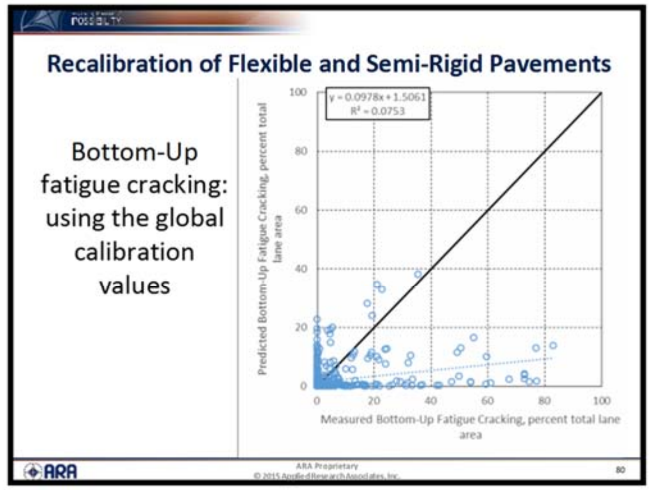
HMA Rutting	Coefficient value
K1	-3.294
K2	1.5606
K3	0.3

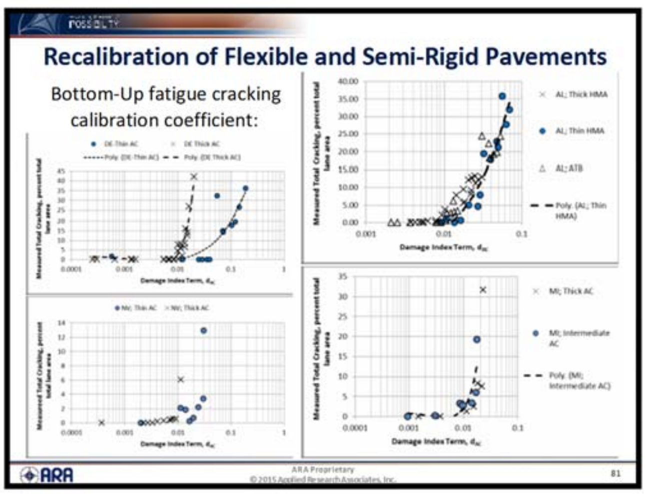
Unbound Material K values

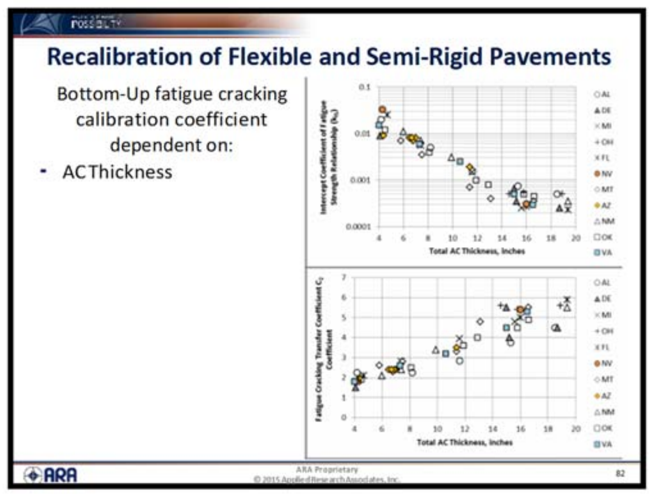
Type	Classification	Adjustment Factor	Global K Value	Revised K Value
Fine	A-7-6	0.5	1.35	0.637
Fine	A-6	0.5	1.35	0.637
Combined	A-2-4, A-2-5, A-2-7, A-4	0.5	2.03	0.958
Coarse	A-3	0.35	2.03	0.671
Coarse	A-1-a, A-1-b	0.5	2.03	0.958

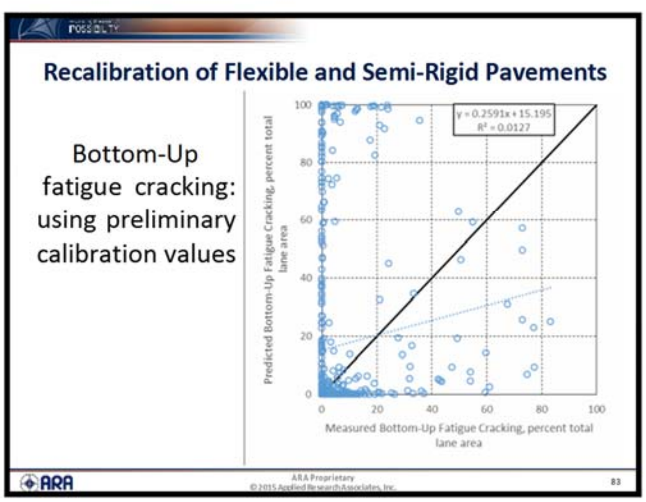
ARA Proprietary © 2015 Applied Research Associates, Inc. 78

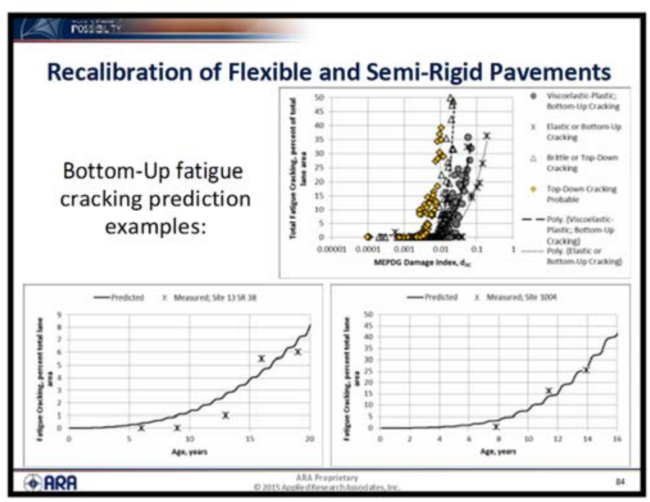

Recalibration of Flexible and Semi-Rigid Pavements
Rut depth prediction examples:
Predicted
Measured; Site 4092
Rut Depth, inches
Age, years
Measured; Site 4420
Full Depth
Aggregate Base
Overlay, Flexible
Line of Equality
Predicted Rut Depth, Total, inches
Measured Rut Depth, Wirline, inches
ARA Proprietary
© 2015 Applied Research Associates, Inc.
79


Recalibration of Flexible and Semi-Rigid Pavements
Bottom-Up fatigue cracking: using the global calibration values
y = 0.0978x + 1.5061
R² = 0.0753
Predicted Bottom-Up Fatigue Cracking, percent total lane area
Measured Bottom-Up Fatigue Cracking, percent total lane area
ARA Proprietary
© 2015 Applied Research Associates, Inc.
80


Recalibration of Flexible and Semi-Rigid Pavements
Bottom-Up fatigue cracking calibration coefficient:
AL; Thick HMA
AL; Thin HMA
AL; ATB
MI; Thick AC
MI; Intermediate AC
Measured Total Cracking, percent total lane area
Damage Index Term
ARA Proprietary
© 2015 Applied Research Associates, Inc.
81


Recalibration of Flexible and Semi-Rigid Pavements
Bottom-Up fatigue cracking calibration coefficient dependent on:
AC Thickness
Total AC Thickness, inches
ARA Proprietary
© 2015 Applied Research Associates, Inc.
82

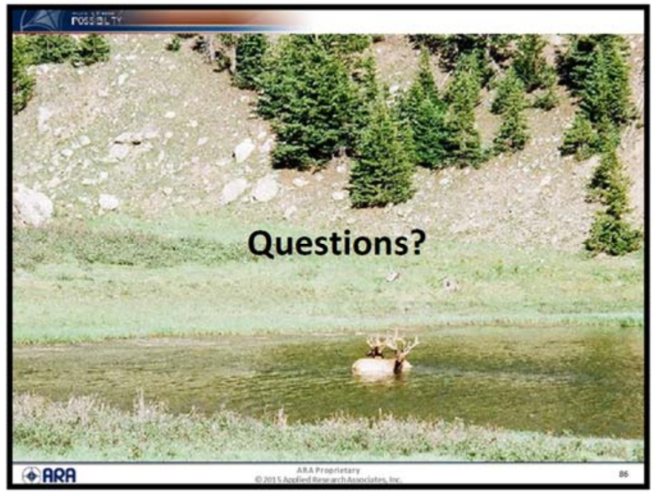

Recalibration of Flexible and Semi-Rigid Pavements
Bottom-Up fatigue cracking: using preliminary calibration values
y = 0.2591x + 15.195
R² = 0.0127
Predicted Bottom-Up Fatigue Cracking, percent total lane area
Measured Bottom-Up Fatigue Cracking, percent total lane area
ARA Proprietary
© 2015 Applied Research Associates, Inc.
83


Recalibration of Flexible and Semi-Rigid Pavements
Bottom-Up fatigue cracking prediction examples:
Viscoelastic-Plastic; Bottom-Up Cracking
Elastic or Bottom-Up Cracking
Brittle or Top-Down Cracking
Top-Down Cracking Probable
MEPDG Damage Index
Predicted
Age, years
ARA Proprietary
© 2015 Applied Research Associates, Inc.
84

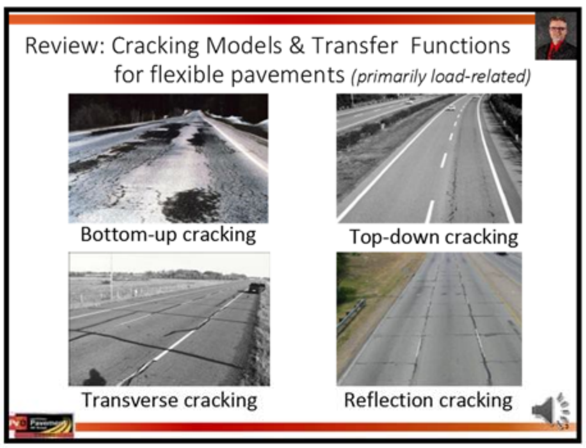
Recalibration of Flexible and Semi-Rigid Pavements

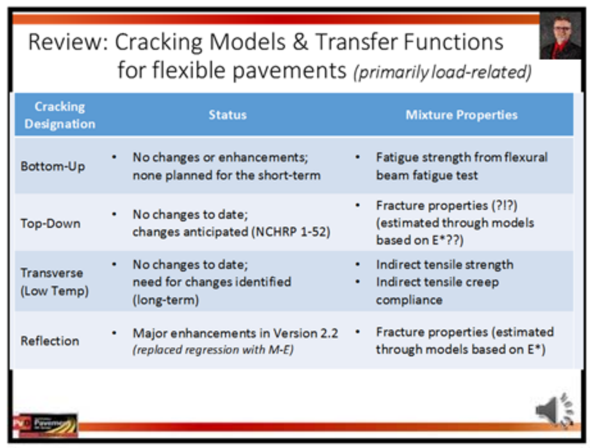
Issue – Bottom-Up or Top-Down Cracking?

- Type of fatigue cracks are unknown in LTPP database
- All area fatigue cracks are assumed to be bottom-up fatigue cracks.
- After top-down cracking model integrated into Pavement ME – will the bottom-up cracking need to be revised?

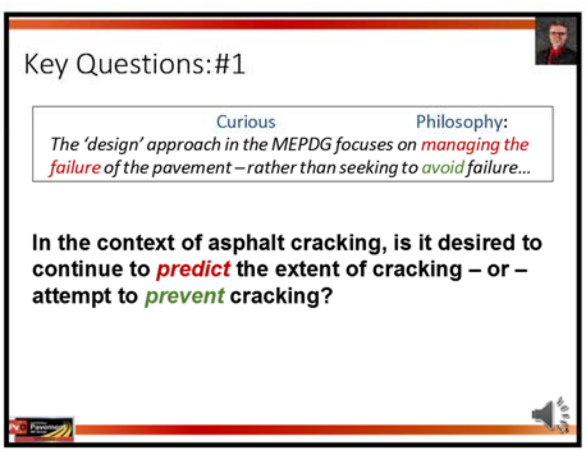


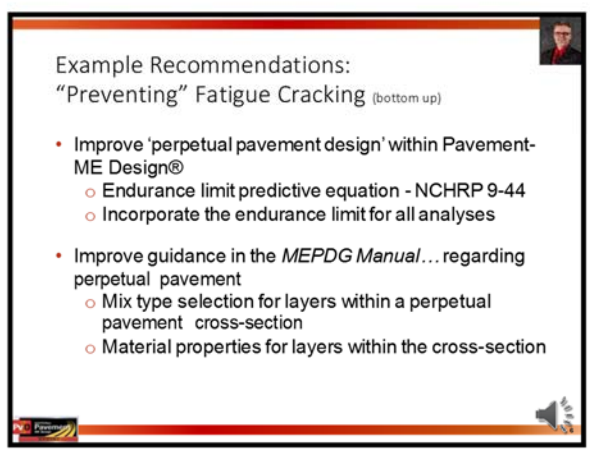
Presentation 21—Kevin Hall, University of Arkansas





Cracking Designation	Status	Mixture Properties
Bottom-Up	• No changes or enhancements; none planned for the short-term	• Fatigue strength from flexural beam fatigue test
Top-Down	• No changes to date; changes anticipated (NCHRP 1-52)	• Fracture properties (?!?) (estimated through models based on E*??)
Transverse (Low Temp)	• No changes to date; need for changes identified (long-term)	• Indirect tensile strength • Indirect tensile creep compliance
Reflection	• Major enhancements in Version 2.2 *(replaced regression with M-E)*	• Fracture properties (estimated through models based on E*)





Key Questions: #2

Is it important and/or desirable to model all forms of load-related cracking using the same general approach and/or mechanistic basis?

e.g. Asphalt Cracking:

- Reflection: fracture
- Top-Down: regression–but, moving to (?) fracture
- Bottom-up: bending/flexure

Example Recommendations: Common Basis for Asphalt Cracking Models

- Develop and implement a fracture-based bottom-up fatigue cracking model
  - Pursue a fracture-based model form similar to that used for reflection cracking and is anticipated for top-down cracking.
  - Ensure that any new fatigue cracking model is compatible with the concepts of perpetual pavement design.
- Seek, insofar as possible, to link the requirements for material characterization – so that (insofar as possible) a single characterization 'feeds' all cracking performance models ***directly***.

Key Questions: #3

Is it important and/or desirable to integrate, more fully, asphalt mixture characterization between the processes for asphalt mixture design and flexible pavement structural design?

For example, should performance-related tests used for asphalt *mixture* design yield material properties which are also used in *structural* design models?

Example Recommendations: Integrating Asphalt Structural and Mixture Design

Develop/refine Visco-Elastic Continuum Damage (VECD) design procedures

- Streamline laboratory testing and data analysis procedures for "Simplified" VECD (or S-VECD) in the context of asphalt mixture design;
- Refine and expand structural pavement design procedures contained in the Linear VECD (or LVECD) program.
  - Publish global calibration metrics for the LVECD design system;
  - Provide procedures for executing local calibration studies.
  - Produce a comprehensive pavement design guide based on the LVECD system.
- Support FHWA PRS Efforts
  - FlexMAT™, FlexPAVE™, PASSFlex™

Recap: Key Questions *in the local context…*

Is it important and/or desirable to model all forms of load-related cracking using the same general approach and/or mechanistic basis?

Near-Term — *Mid-Term* — *Long-Term*

In the context of asphalt cracking, is it desired to continue to *predict* the extent of cracking – or – attempt to *prevent* cracking?

Is it important and/or desirable to integrate, more fully, asphalt mixture characterization between the processes for asphalt mixture design and flexible pavement structural design?

For example, should performance-related tests used for asphalt *mixture* design yield material properties which are also used in *structural* design models?

Key Questions *in the* GLOBAL *context…*

Can we better 'link' our approach(es)/bases for similar distress mechanisms – and subsequently streamline required materials characterization?

Near-Term — *Mid-Term* — *Long-Term*

"Design" philosophy: is it desired to continue to *predict* pavement distress – or – attempt to *prevent* distress?

Can we directly link materials design and characterization with structural design / distress mechanisms?

Bonus Question: What is the next BIG thing?

In other words…will we continue to 'tweak' Pavement-ME into the foreseeable future? What does its "next generation" look like?


I hope the goal was accomplished:
CAUTION: This presentation is designed to be provocative
pro·voc·a·tive adjective
1.causing annoyance, anger, or another strong reaction, especially deliberately
Powered by Oxford Dictionaries
THANK YOU!!!
(Now, discuss…)