State Experience with ME Pavement Design

(MEPDG Implementation at ADOT)

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MEPDG Implementation at ADOT

Outline

- Where we've come from
- Where we're at now
- Where we're going…

Where we've come from

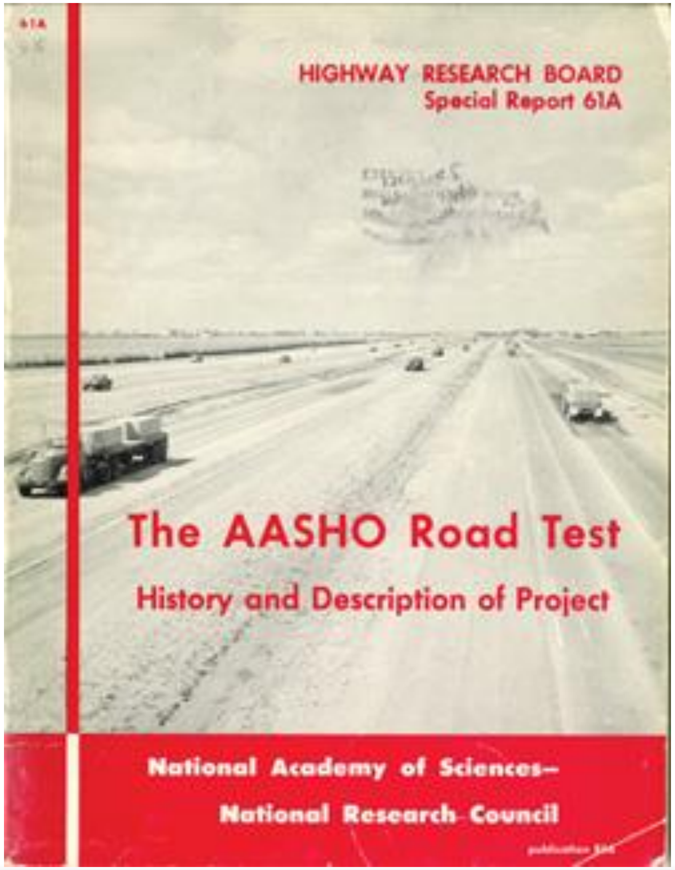
New Pavement Design

- ADOT has used the AASHTO Design Guide for Pavements as it basis for designing new pavements since it was first issued as an "Interim" guide in 1961/2.
- Updates to the guide were made in 1972, 1981, 1986 and 1993.

Where we've come from

New Pavement Design – AASHO Road Test

- **The AASHTO Design Guide is based on the AASHO Road Test from the late 1950's**



Where we've come from

New Pavement Design – AASHO Road Test

- Consisted of six, two-lane loops constructed along the future alignment of Interstate 80 in Ottawa, Illinois.
- The pavement structure within each loop was varied.
- Each loop was loaded with a specific vehicle type and weight so that the interaction between vehicle loads and pavement structure could be investigated.
- The outcome of this road test was a general equation which relates the loss in pavement serviceability to the pavement structure and load applications.

Where we've come from

New Pavement Design – AASHTO Design Guide

Design equation for Flexible pavements:

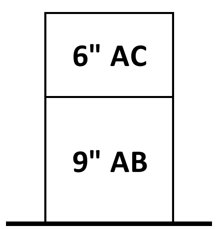
$$\text{Log}_{10}(W_{18}) = Z_R \times S_O + 9.36 \times \log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left[\frac{\Delta PSI}{4.2-1.5}\right]}{0.40 + \frac{1094}{(SN+1)^{5.19}}} + 2.32 \times \log_{10}(M_R) - 8.07$$

Where we've come from

New Pavement Design – AASHTO Design Guide

$$SN = a_1 D_1 + a_2 D_2 m_2 + a_3 D_3 m_3$$

- $a_1 D_1$: *Asphalt*
- $a_2 D_2 m_2$: *Aggregate Base*
- $a_3 D_3 m_3$: *Aggregate Subbase*

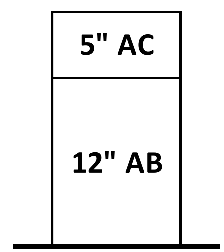


6 X 0.44 = 2.64

9 X 0.14 = 1.26

3.90

SN = 3.90



5 X 0.44 = 2.20

12 X 0.14 = 1.68

3.88

SN = 3.88

Where we've come from

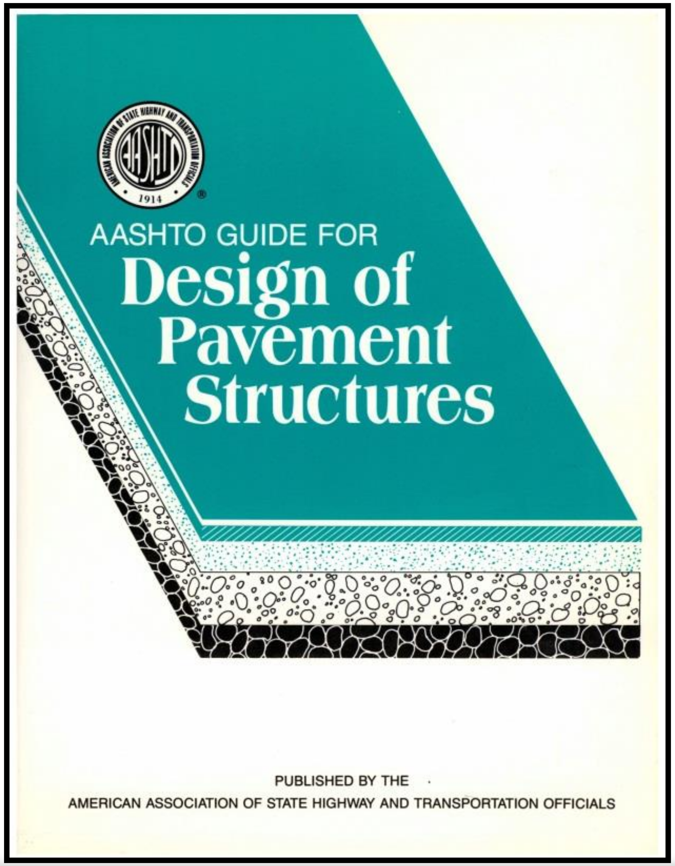
New Pavement Design – AASHTO Design Guide

- The AASHTO Design Guide was used to design much of the original Interstate Highway System.
- Most of these pavements lasted the expected 20 years while carrying traffic volumes in excess of those predicted at the time of design.
- After nearly 6 decades since the completion of the AASHO Road Test, the design procedure continues to serve as the cornerstone for both PCC and HMA pavements.

Where we've come from

New Pavement Design – 1993 Design Guide

- **ADOT's "official" design methodology for new pavement is still the 1993 AASHTO Design Guide.**



Where we've come from

New Pavement Design

- **Despite it's successful use over many decades, the procedure has many shortcomings.**

Where we've come from

1993 Design Guide Shortcomings

- Only one soil type
- Only one climate
- AC thickness between one and six inches
- Limited traffic (1 Million Axle Load Cycles)
- Only one set of materials
- Can only predict ΔPSI
- Virtually every pavement design we conduct today using the 1993 AASHTO Guide is an EXTRAPOLATION!

Where we've come from

Pavement Rehabilitation

- ADOT has used the Structural Overlay Design for Arizona (SODA) method for pavement rehabilitation since the early 80's
- The method was developed using regression analysis of 24 overlay projects constructed in the 1970's
- Overlay thickness is a function of ESAL's, pavement deflections, SVF, milling depth, and roughness
- Despite successful use for many years, it has many shortcomings

Where we've come from

SODA Shortcomings

- **Materials quality, construction methods, etc. have changed considerably since the 1970's**
- **The average overlay thickness for projects used to develop the method was approximately 2"**
- **Projects were overlayed only without any milling**
- **So, most pavement rehabilitation designs conducted using the SODA method is an EXTRAPOLATION!**

Where we're at now

Implementation of the MEPDG

- ADOT has been in the process of implementing the MEPDG since the late 90's.
- Allows for a more accurate prediction of pavement performance over time (better decisions relative to life-cycle cost and cash flow).
  - Utilizes both mechanistic and empirical principles.
  - Accounts for variations in materials and construction.
  - Utilizes more representative inputs for climate and vehicle loading.

Where we're at now

A Few Terms…

- **Mechanistic – relationship supported by laws of mechanics.**
- **Empirical – relationship supported by experiment or observation.**
- **Mechanistic-Empirical Pavement Design Guide (MEPDG) - Pavement design methodology developed under NCHRP 1-37a.**
- **AASHTOWare Pavement ME Design – Pavement design software used to analyze and design pavements based on M-E principles developed under NCHRP 1-37a.**

AASHTOWare Pavement ME

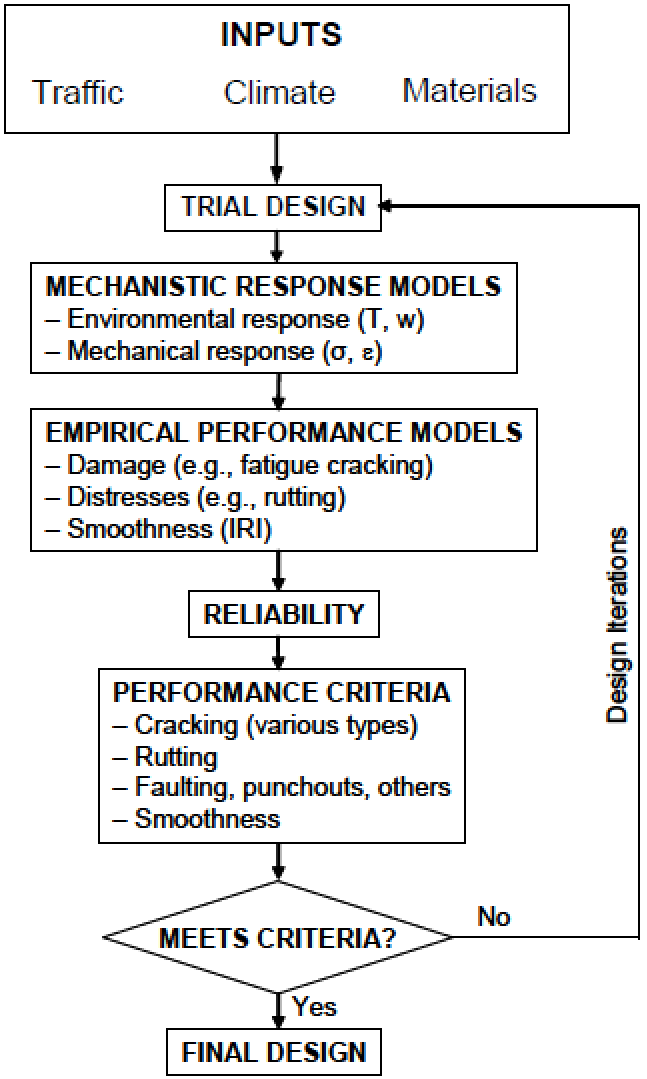
Overview

- **State-of-the-practice tool for the design and analysis of new and rehabilitated pavements, based on mechanistic-empirical (ME) principles.**
- **Pavement ME calculates pavement response (stresses strains, and deflections) and used those responses to compute incremental damage over time.**
- **Predicts multiple performance indicators and provides a direct tie between materials, structural design, construction, climate, and traffic.**

Pavement ME

Process Flow Chart

- Define the traffic, climate and materials property inputs
- Select a trial design to analyze
- Analyze the pavement response
- Empirically relate pavement response to distress
- Adjust predicted distresses for the specified design reliability
- Compare predicted distress against design limits



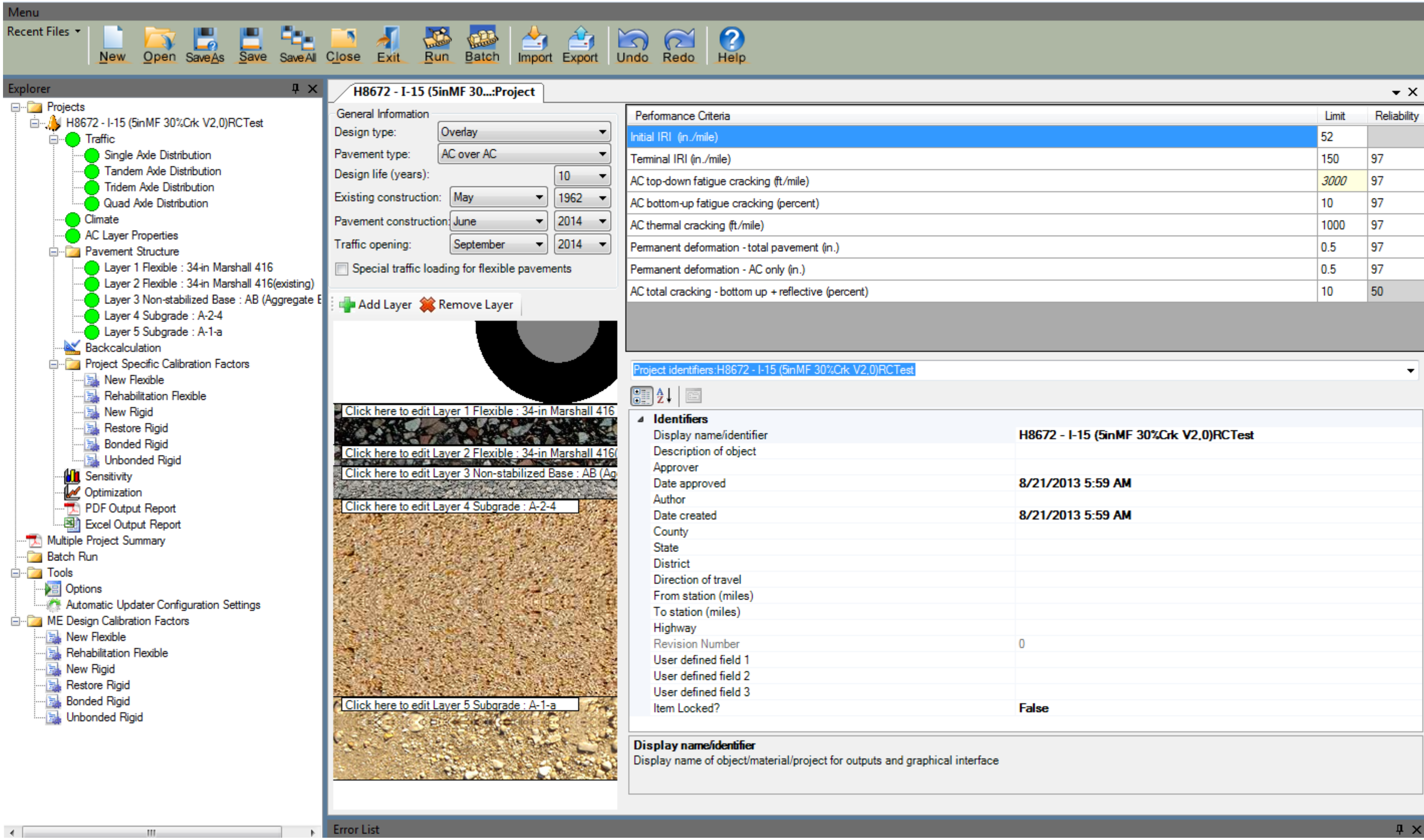
Pavement ME

Inputs

- Design method incorporates a hierarchical approach for specifying all design inputs.
- Approach is based on the philosophy that the level of engineering effort exerted in determining design inputs should be commensurate with the relative importance, size and cost of the project.
- Three levels are provided in the NCHRP 1-37A procedure.

Pavement ME
Inputs (cont.)

- **Level 1 – Provides the highest accuracy and lowest uncertainty. Typically requires project specific field or laboratory evaluation (e.g. FWD, triaxial testing).**
- **Level 2 – Provides an intermediate level of accuracy. Typically derived from a limited testing program or estimated via correlations, or agency specific database (e.g. M_r estimated from R-values, ADOT Materials Libraries).**
- **Level 3 – Lowest level of accuracy. Derived from local or National default values (e.g. M_r based on soil class).**


Menu
Recent Files
New
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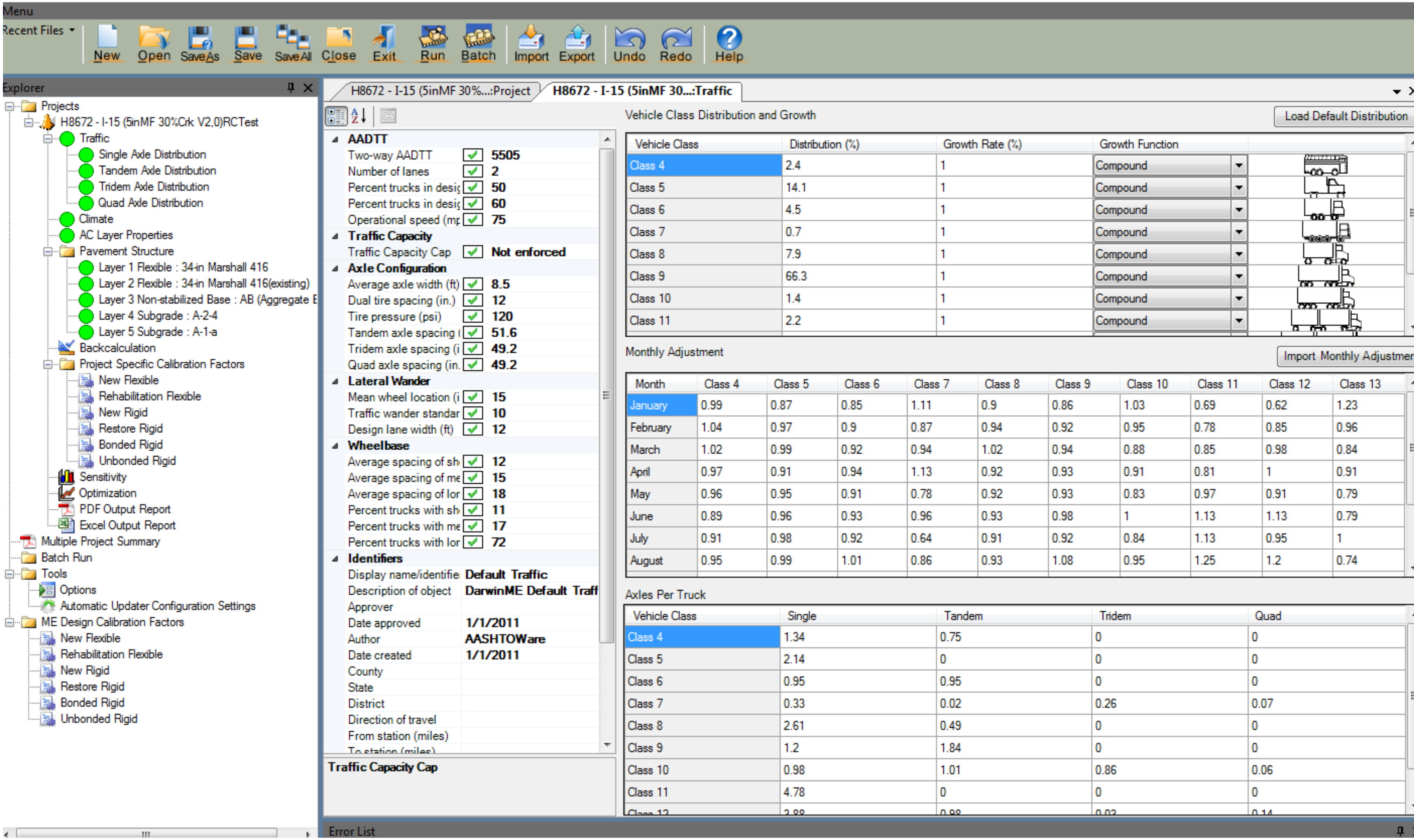
Undo
Redo
Help
Explorer
Projects
H8672 - I-15 (5inMF 30%Crk V2.0)RCTest
Traffic
Single Axle Distribution
Tandem Axle Distribution
Tridem Axle Distribution
Quad Axle Distribution
Climate
AC Layer Properties
Pavement Structure
Layer 1 Flexible : 34-in Marshall 416
Layer 2 Flexible : 34-in Marshall 416(existing)
Layer 3 Non-stabilized Base : AB (Aggregate B
Layer 4 Subgrade : A-2-4
Layer 5 Subgrade : A-1-a
Backcalculation
Project Specific Calibration Factors
New Flexible
Rehabilitation Flexible
New Rigid
Restore Rigid
Bonded Rigid
Unbonded Rigid
Sensitivity
Optimization
PDF Output Report
Excel Output Report
Multiple Project Summary
Batch Run
Tools
Options
Automatic Updater Configuration Settings
ME Design Calibration Factors
New Flexible
Rehabilitation Flexible
New Rigid
Restore Rigid
Bonded Rigid
Unbonded Rigid
H8672 - I-15 (5inMF 30...:Project
General Information
Design type: Overlay
Pavement type: AC over AC
Design life (years): 10
Existing construction: May 1962
Pavement construction: June 2014
Traffic opening: September 2014
Special traffic loading for flexible pavements
Add Layer
Remove Layer
Click here to edit Layer 1 Flexible : 34-in Marshall 416
Click here to edit Layer 2 Flexible : 34-in Marshall 416(
Click here to edit Layer 3 Non-stabilized Base : AB (Ag
Click here to edit Layer 4 Subgrade : A-2-4
Click here to edit Layer 5 Subgrade : A-1-a
Performance Criteria | Limit | Reliability
Initial IRI (in./mile) | 52 |
Terminal IRI (in./mile) | 150 | 97
AC top-down fatigue cracking (ft/mile) | 3000 | 97
AC bottom-up fatigue cracking (percent) | 10 | 97
AC thermal cracking (ft/mile) | 1000 | 97
Permanent deformation - total pavement (in.) | 0.5 | 97
Permanent deformation - AC only (in.) | 0.5 | 97
AC total cracking - bottom up + reflective (percent) | 10 | 50
Project identifiers:H8672 - I-15 (5inMF 30%Crk V2.0)RCTest
Identifiers
Display name/identifier H8672 - I-15 (5inMF 30%Crk V2.0)RCTest
Description of object
Approver
Date approved 8/21/2013 5:59 AM
Author
Date created 8/21/2013 5:59 AM
County
State
District
Direction of travel
From station (miles)
To station (miles)
Highway
Revision Number 0
User defined field 1
User defined field 2
User defined field 3
Item Locked? False
Display name/identifier
Display name of object/material/project for outputs and graphical interface
Error List



Vehicle Class	Distribution (%)	Growth Rate (%)	Growth Function
Class 4	2.4	1	Compound
Class 5	14.1	1	Compound
Class 6	4.5	1	Compound
Class 7	0.7	1	Compound
Class 8	7.9	1	Compound
Class 9	66.3	1	Compound
Class 10	1.4	1	Compound
Class 11	2.2	1	Compound

Month	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10	Class 11	Class 12	Class 13
January	0.99	0.87	0.85	1.11	0.9	0.86	1.03	0.69	0.62	1.23
February	1.04	0.97	0.9	0.87	0.94	0.92	0.95	0.78	0.85	0.96
March	1.02	0.99	0.92	0.94	1.02	0.94	0.88	0.85	0.98	0.84
April	0.97	0.91	0.94	1.13	0.92	0.93	0.91	0.81	1	0.91
May	0.96	0.95	0.91	0.78	0.92	0.93	0.83	0.97	0.91	0.79
June	0.89	0.96	0.93	0.96	0.93	0.98	1	1.13	1.13	0.79
July	0.91	0.98	0.92	0.64	0.91	0.92	0.84	1.13	0.95	1
August	0.95	0.99	1.01	0.86	0.93	1.08	0.95	1.25	1.2	0.74

Vehicle Class	Single	Tandem	Tridem	Quad
Class 4	1.34	0.75	0	0
Class 5	2.14	0	0	0
Class 6	0.95	0.95	0	0
Class 7	0.33	0.02	0.26	0.07
Class 8	2.61	0.49	0	0
Class 9	1.2	1.84	0	0
Class 10	0.98	1.01	0.86	0.06
Class 11	4.78	0	0	0

Pavement ME
Implementation Efforts to Date

- SPR-402: Development of Performance Related Specifications for Asphalt Pavements in the State of Arizona. (ASU, 1999-2006)
- Phase I – Development of Work Plan.
- Phase II – Characterization of Material (Binders, AC Mixtures, Unbound Materials).
- Phase III – Local Calibration of MEPDG, and Development of Performance Related Specifications

Pavement ME

Implementation Efforts to Date

- **SPR-606: Calibration and Implementation of the AASHTO Mechanistic-Empirical Pavement Design Guide in Arizona. (ASU/ARA, 2007 - 2012)**
- **Calibrate and Validate the MEPDG, and accompanying software, for Arizona conditions.**
- **Develop an ADOT Users Guide for the MEPDG.**
- **Provide training in the use of the MEPDG**

Pavement ME
Implementation Efforts to Date

- SPR-672: Development of a Traffic Data Input System in Arizona for the MEPDG. (ARA, 2009 - 2010)
- Developed default recommendations or Level 2/3 statewide traffic inputs for Arizona.
- Developed and action plan for future work to obtain Level 1 traffic inputs.

Pavement ME

Implementation Efforts to Date

- **Since completing the local calibration in 2012, ADOT has been performing parallel designs on all major new construction and rehabilitation projects.**

Design Example

US93 MP 116.3 – 119.7 (1993 Design Guide)

- ESALS – 10,998,000
- R-value - 40
- SVF – 1.5
- Mr – 19,150 psi
- Reliability – 99%

- SN_{req} – 4.31
- 7” AC over 9” AB
- SN_{des} – 4.34

Design Example

US93 MP 116.3 – 119.7 (Pavement ME)

US 93 Carrow

File Name: C:\My DarwinME\US 93 Carrow.dgpx

Design Inputs

Design Life: 20 years
Design Type: Flexible Pavement

Base construction: May, 2017
Pavement construction: June, 2017
Traffic opening: September, 2017

Climate Data Sources (Lat/Lon): 35.259, -113.937

Design Structure

Layer type	Material Type	Thickness (in.):
Flexible	34-in Marshall 416	9.0
NonStabilized	AB (Aggregate Base)	11.0
Subgrade	A-2-6	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	10.8
Air voids (%)	7.6

Traffic

Age (year)	Heavy Trucks (cumulative)
2017 (initial)	1,528
2027 (10 years)	2,879,110
2037 (20 years)	6,748,380

Design Outputs

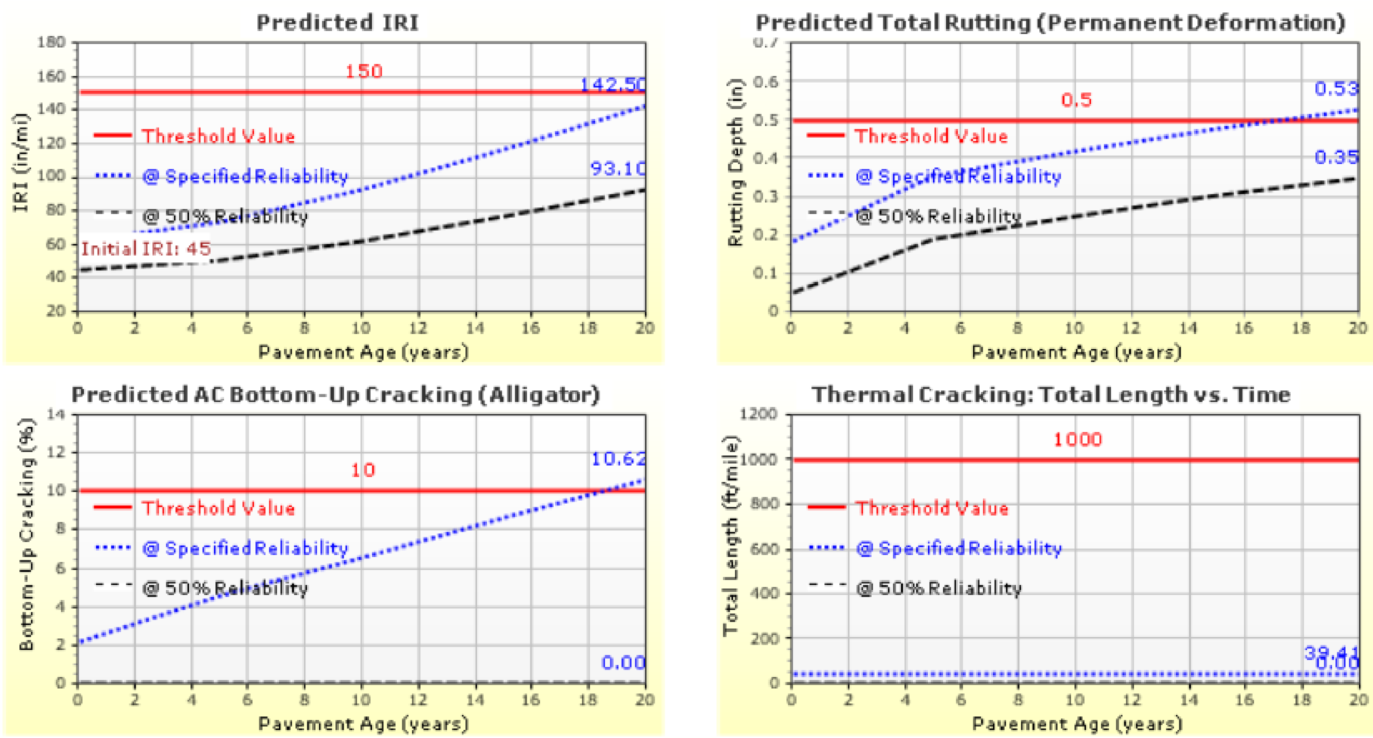
Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	150.00	142.53	97.00	98.48	Pass
Permanent deformation - total pavement (in.)	0.50	0.53	97.00	94.26	Fail
AC bottom-up fatigue cracking (percent)	10.00	10.62	97.00	96.17	Fail
AC thermal cracking (ft/mile)	1000.00	39.41	97.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	2000.00	1520.30	97.00	99.34	Pass
Permanent deformation - AC only (in.)	0.50	0.44	97.00	99.59	Pass

Design Example

US93 MP 116.3 – 119.7 (Pavement ME)

Distress Charts



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5/25/2016 8:38 AM

Created by:
on: 6/3/2014 3:45 PM

Approved by:
on: 6/3/2014 3:45 PM

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Design Example

US93 MP 116.3 – 119.7

- 1993 Design Guide indicates we need 7” AC over 9’ AB (SN = 4.34)
- Pavement ME indicates we need 9” AC over 11” AB (SN = 5.50)

What do we do???

Design Example

US93 MP 116.3 – 119.7

- In general, Pavement ME results for new flexible pavement have been more conservative than our 1993 Design Guide results.
- We have had a number of 1993 Design Guide projects that have not met their 20-year design life.
- We should be able to have significant confidence in our Pavement ME results due to the fact that we have performed a local calibration.
- Performed a verification on an adjacent project constructed in 2008.

Design Example

Verification Project (US93)

- 2006 Pavement design, based on 93 AASHTO Design Guide, required 6” AC over 8” AB.
- Construction completed in 2008 (9-year old pavement).
- 2016 Photolog shows extensive alligator cracking including pumping of fines.

Design Example

Verification of Adjacent Project (US93 MP 119.8)

Design Example

Verification of Adjacent Project (US93 MP 120.9)

Pavement ME

Pavement ME Design Example

- In general, we are making final design recommendations based on Pavement ME results, unless there is good evidence to do otherwise.
- As is the case with the 1993 AASHTO Design Guide, and SODA, the AASHTOWare Pavement ME has it's shortcomings.

Pavement ME

Pavement ME Shortcomings

- Occasionally we get results that are counter to what experience tells us
- Composite (PCC + FC) pavement modeling questionable
- Significant investment to characterize materials, perform a local calibration and purchase the software
- Extensive training required
- Can easily become a “Black Box”
- Software changes on a regular basis

Where we’re going

- Continue to run parallel designs
- Continue to participate in Pavement ME training opportunities as well as User Group Meetings
- Consider future re-calibration of some or all of the models
- Construction of additional WIM stations
- Long term plan is to fully adopt the use of Pavement ME

Pavement ME
For Further Information

- **SPR-606: Calibration and Implementation of the AASHTO Mechanistic-Empirical Pavement Design Guide in Arizona**
- **SPR-672: Development of a Traffic Data Input System in Arizona for the MEPDG**
- **Training Webinars at http://me-design.com/MEDesign/Webinars.html**
- **Scott Weinland (602) 712-8131**