AASHTOWare Pavement ME: JPCP Walk-through and Sensitivity Analysis

Jim Powell, P.E.
Executive Director
Northwest Chapter
American Concrete Pavement Association

Outline

- Review of Pavement ME's Concrete Design Options
- JPCP Design Input Walkthrough
- Example Runs and How to Interpret Them
- Review of Critical Inputs
- Engineering Solutions
- ME Calibration Impact
- Additional Resources

MEPDG / DARWin-ME / AASHTOWare Pavement ME

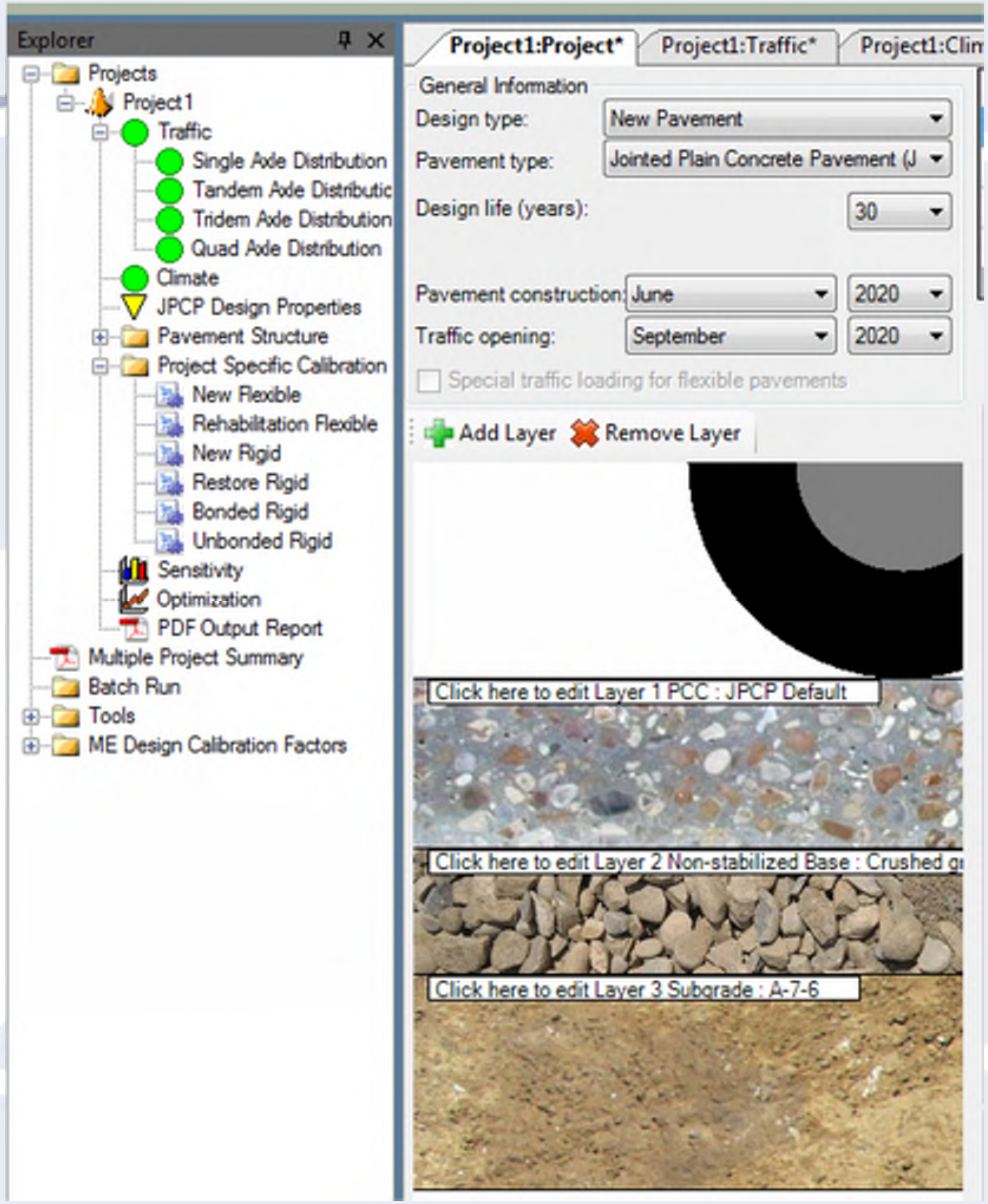
Concrete Pavement Design Options

Pavement ME's Concrete Pavement Designs

- New Pavement
  - Jointed Plain Concrete Pavement (JPCP)
  - Continuously Reinforced Concrete Pavement (CRCP)
- Overlay
  - Bonded PCC over JPCP or CRCP
  - Unbonded JPCP or CRCP over JPCP or CRCP
  - JPCP over AC
  - CRCP over AC
  - SJPCP over AC

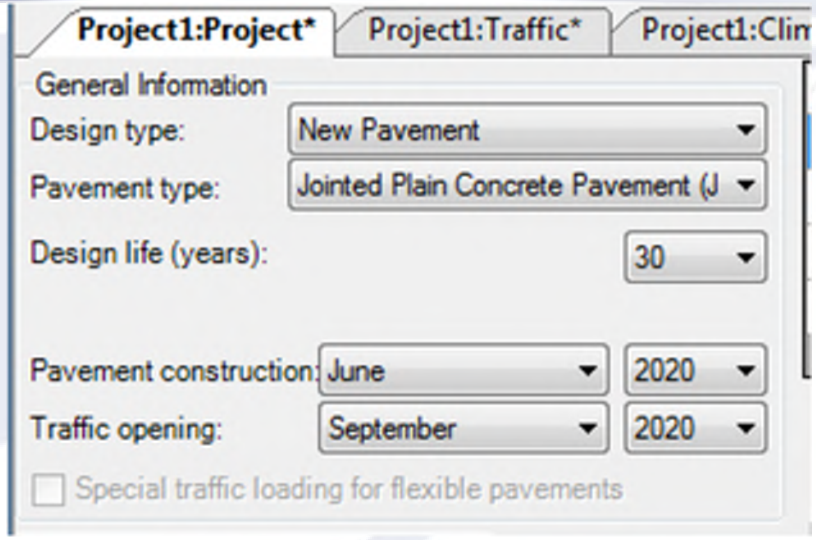
Jointed Plain Concrete Pavement (JPCP)

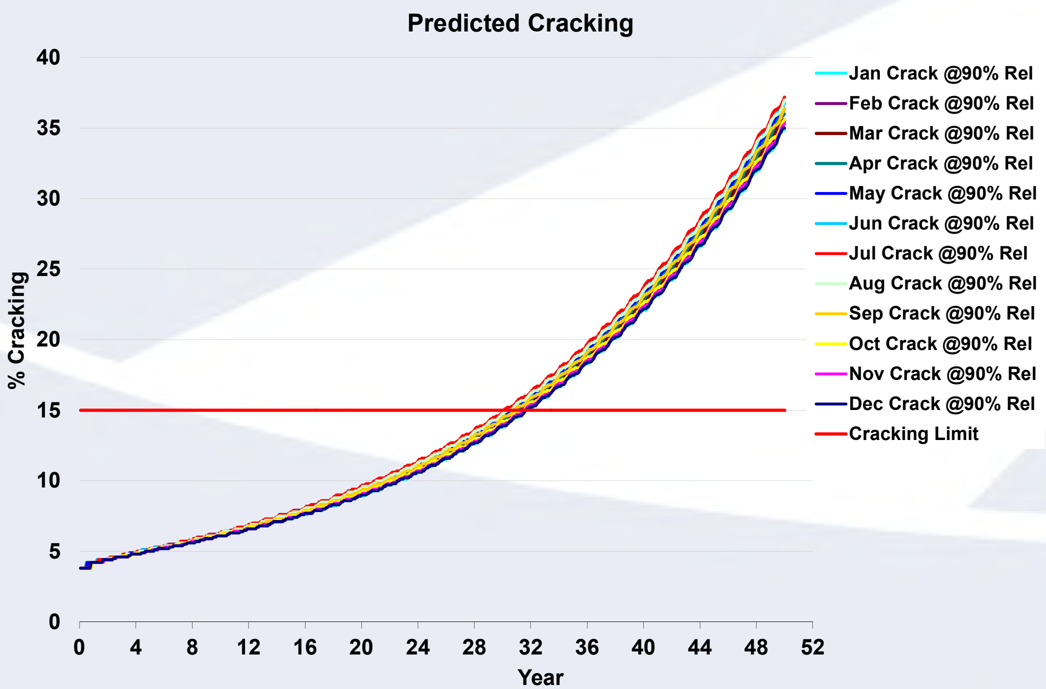
- JPCP Design Process
  - General Info and Performance Criteria
  - Traffic Details
  - Climate
  - Characterizing Pavement Structure
  - JPCP Design Properties

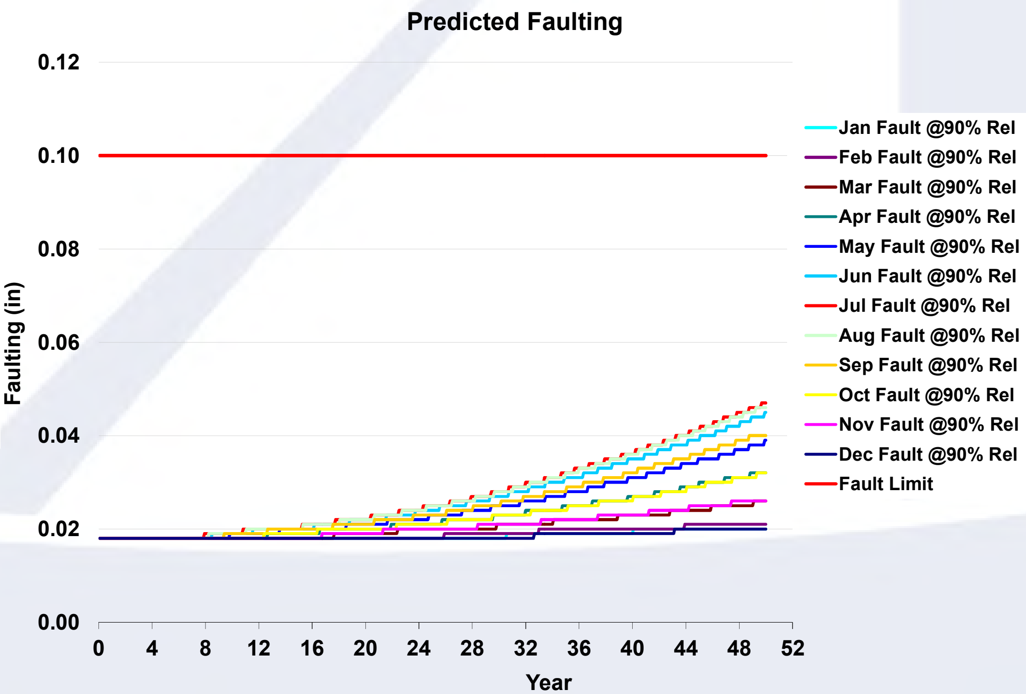


Jointed Plain Concrete Pavement (JPCP)

- General Information
  - Design Life
  - Construction/Opening Timeframe



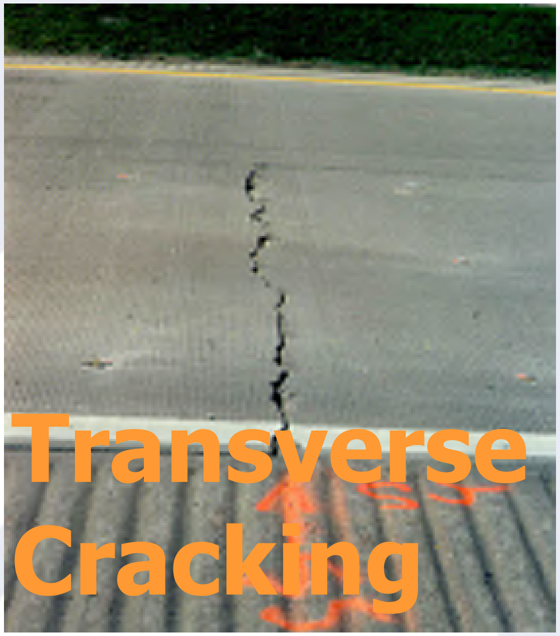




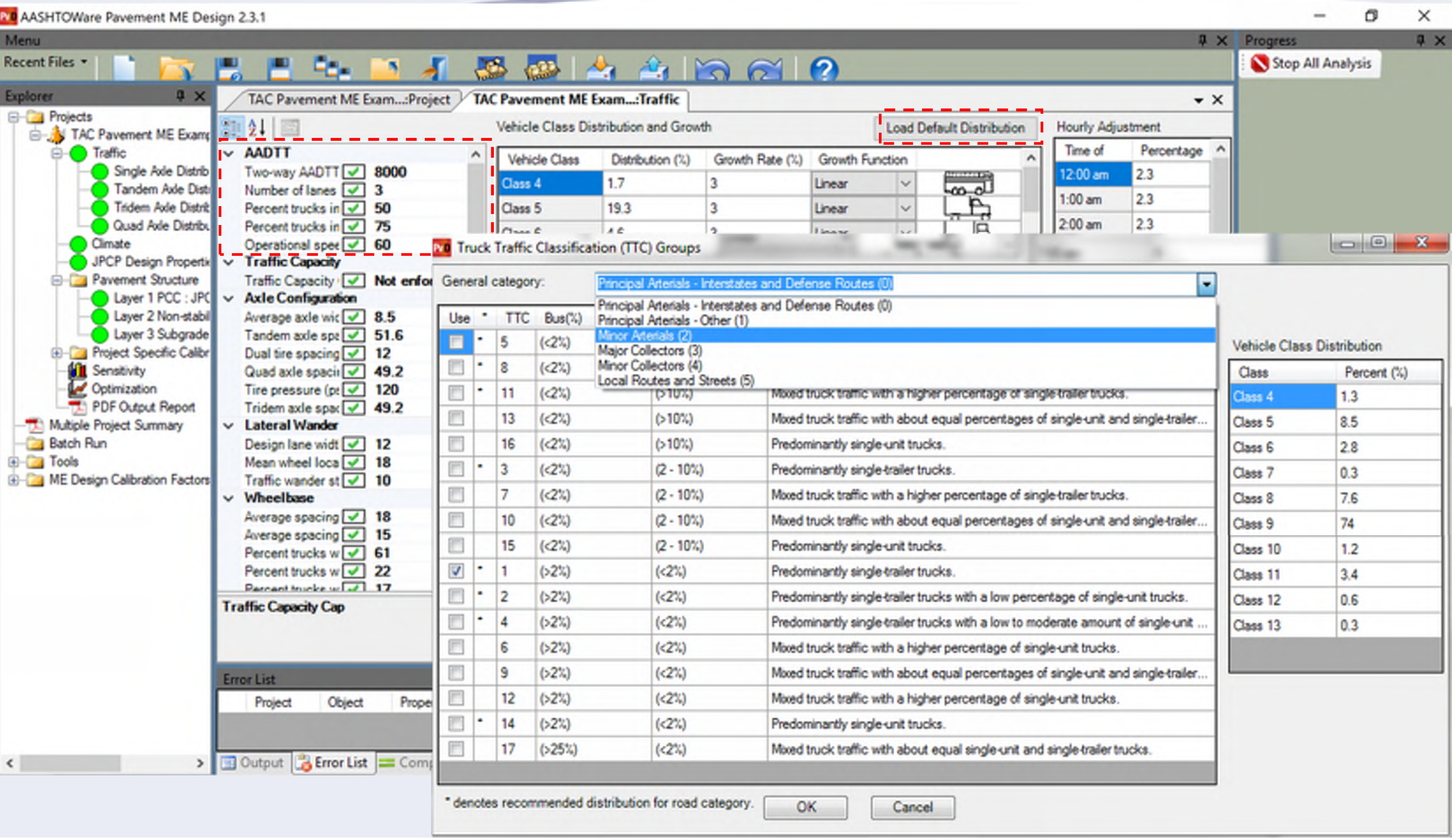
Jointed Plain Concrete Pavement (JPCP)

- Performance Indicators and Failure Criteria:

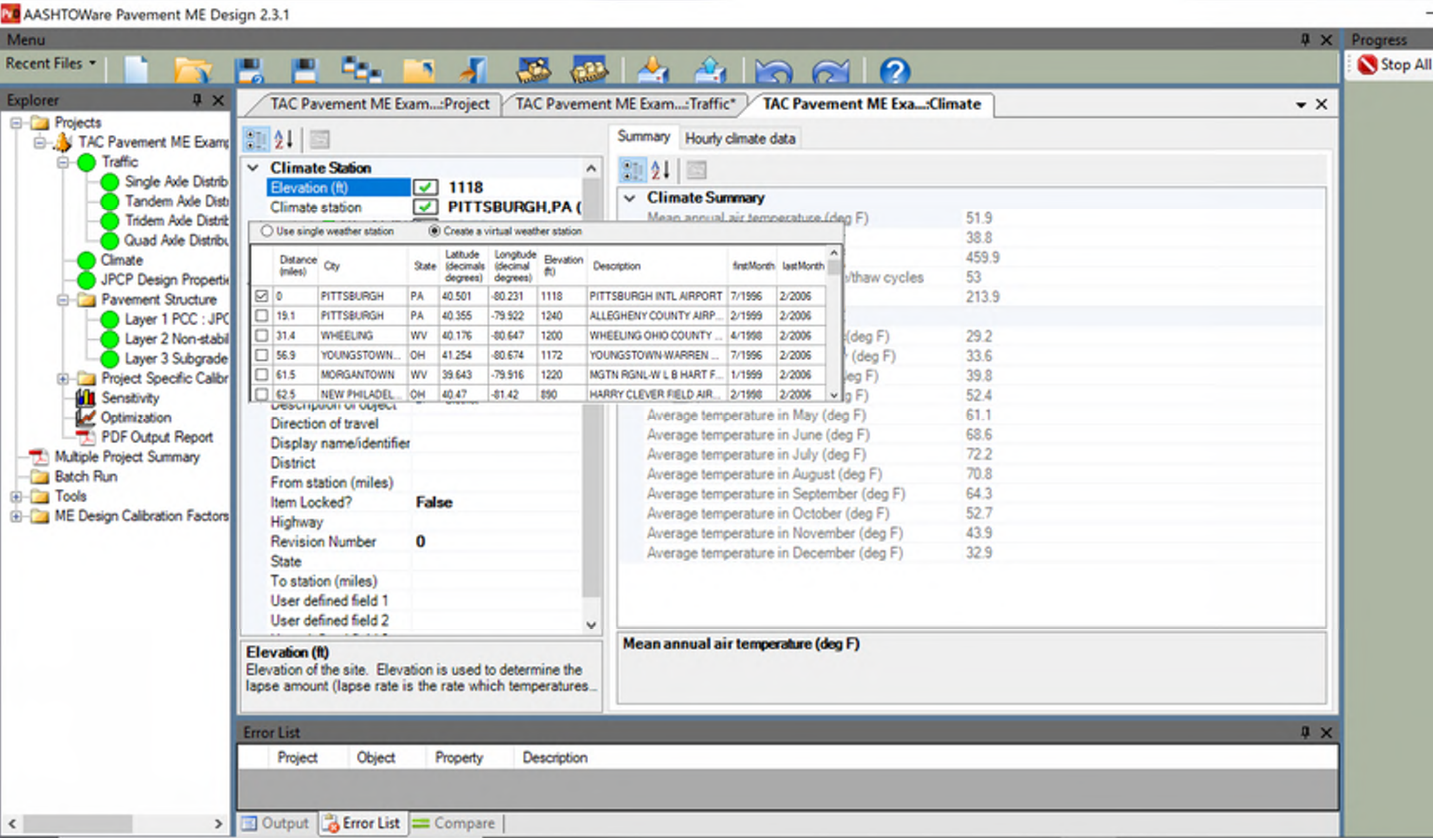
Performance Criteria	Limit	Reliability
Initial IRI (in/mile)	63	
Terminal IRI (in/mile)	172	90
JPCP transverse cracking (percent slabs)	15	90
Mean joint faulting (in)	0.12	90



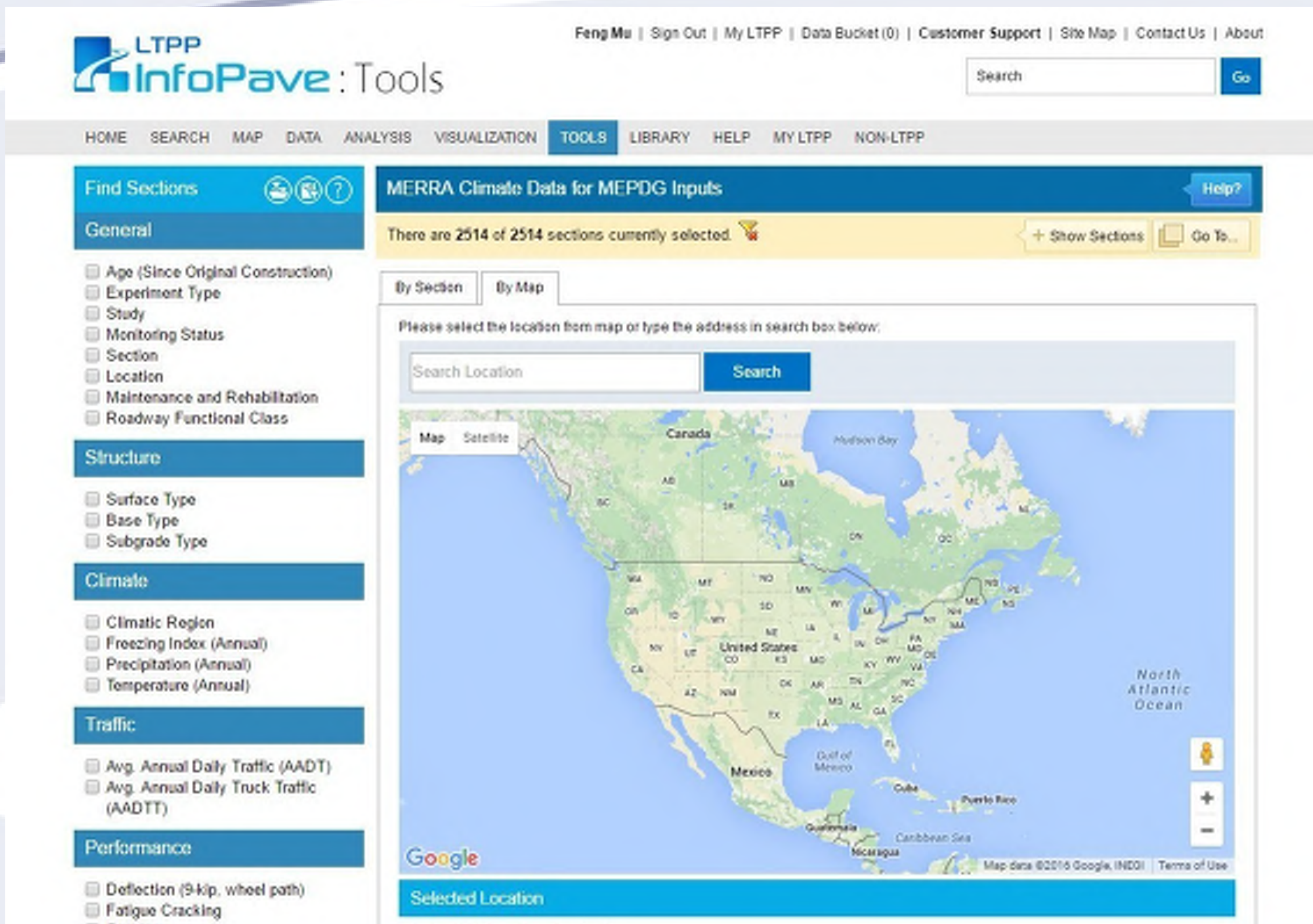
JPCP – Traffic Details



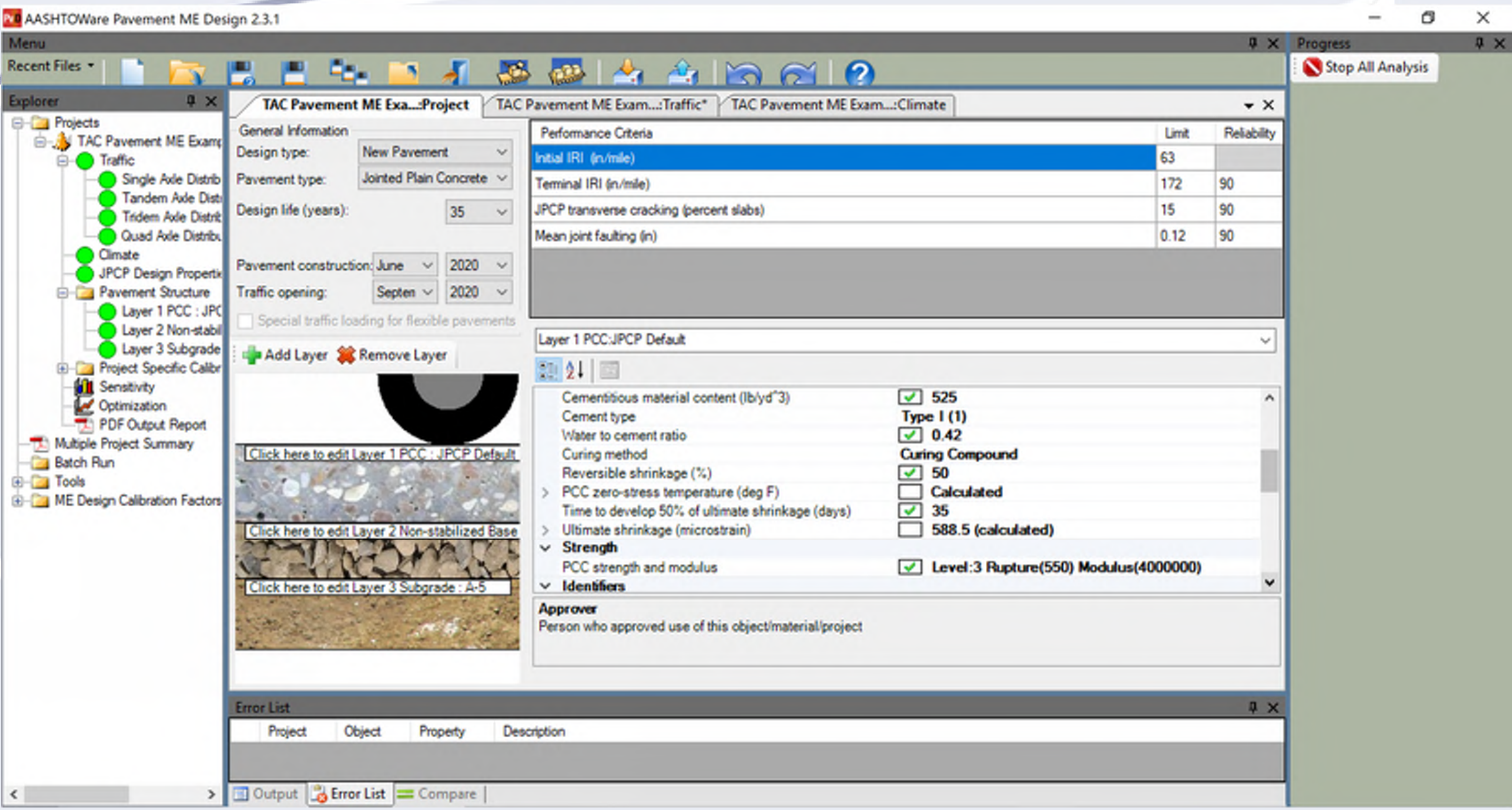
JPCP – Climate



JPCP – Climate



JPCP – Characterizing Pavement Structure

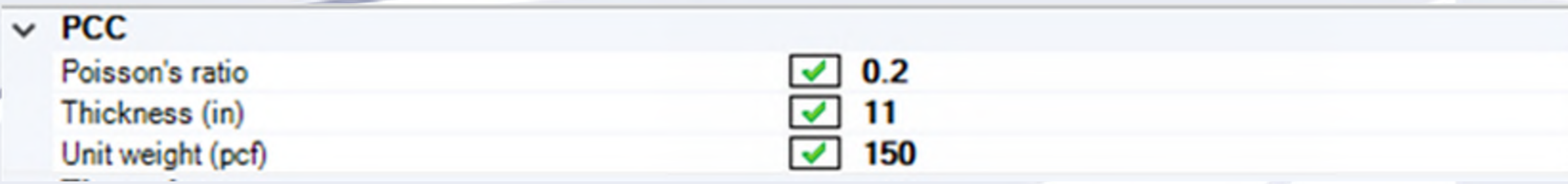


JPCP – Pavement Structure – PCC Materials

PCC		
Poisson's ratio	✓	0.2
Thickness (in)	✓	11
Unit weight (pcf)	✓	150
Thermal		
PCC coefficient of thermal expansion (in/in/deg F x 10^-6)	✓	5.5
PCC heat capacity (BTU/lb-deg F)	✓	0.28
PCC thermal conductivity (BTU/hr-ft-deg F)	✓	1.25
Mix		
Aggregate type		Limestone (1)
Cementitious material content (lb/yd^3)	✓	525
Cement type		Type I (1)
Water to cement ratio	✓	0.42
Curing method		Curing Compound
Reversible shrinkage (%)	✓	50
PCC zero-stress temperature (deg F)	☐	Calculated
Time to develop 50% of ultimate shrinkage (days)	✓	35
Ultimate shrinkage (microstrain)	☐	588.5 (calculated)
Strength		
PCC strength and modulus	✓	Level:3 Rupture(550) Modulus(4000000)

Let's Break it Down

JPCP – Pavement Structure – PCC Materials



- Poisson's Ratio
  - 0.2 (Semi-constant, ranges from 0.15 to 0.2)
- Thickness
  - What we're designing for.
- Unit Weight
  - 150 lb/ft^3 (default)
    - Typical range 140-155 lb/ft^3
    - (Semi-constant; default is fine in absence of actual mix data)

JPCP – Pavement Structure – PCC Materials

Thermal		
PCC coefficient of thermal expansion (in/in/deg F x 10^-6	✓	5.5
PCC heat capacity (BTU/lb-deg F)	✓	0.28
PCC thermal conductivity (BTU/hr-ft-deg F)	✓	1.25

- CTE
  - Typical range 4 - 7 $*10^{-6}/^{o}F$ (dependent on aggregate type)*
- Heat Capacity
  - 0.28 BTU/lb-degree F (Semi-constant)
- Thermal Conductivity
  - 1.25 BTU/hr-ft-deg F (Semi-constant)

* https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/pccp/thermal.cfm

JPCP – Pavement Structure – PCC Materials

Mix	
Aggregate type	Limestone (1)
Cementitious material content (lb/yd^3)	☑ 525
Cement type	Type I (1)
Water to cement ratio	☑ 0.42
Curing method	Curing Compound
Reversible shrinkage (%)	☑ 50
PCC zero-stress temperature (deg F)	☐ Calculated
Time to develop 50% of ultimate shrinkage (days)	☑ 35
Ultimate shrinkage (microstrain)	☐ 588.5 (calculated)

- Agg Type
  - Drop down – Mix dependent
- Cementitious
  - 594 lb/ft^3 (Default) but can use project-specific cementitious content from 200 – 800 lb/ft^3
- Cement type
  - I (Default, most common), II, or III
- w/cm
  - Typically 0.4 – 0.45

JPCP – Pavement Structure – PCC Materials

Mix	
Aggregate type	Limestone (1)
Cementitious material content (lb/yd^3)	[x] 525
Cement type	Type I (1)
Water to cement ratio	[x] 0.42
Curing method	Curing Compound
Reversible shrinkage (%)	[x] 50
PCC zero-stress temperature (deg F)	[ ] Calculated
Time to develop 50% of ultimate shrinkage (days)	[x] 35
Ultimate shrinkage (microstrain)	[ ] 588.5 (calculated)

• Curing Method	• Curing compound (default) or wet curing
• Reversible Shrinkage	• 50% (Good default)
• 0 Stress Temp.	• Calculated

JPCP – Pavement Structure – PCC Materials

Mix	
Aggregate type	Limestone (1)
Cementitious material content (lb/yd^3)	☑ 525
Cement type	Type I (1)
Water to cement ratio	☑ 0.42
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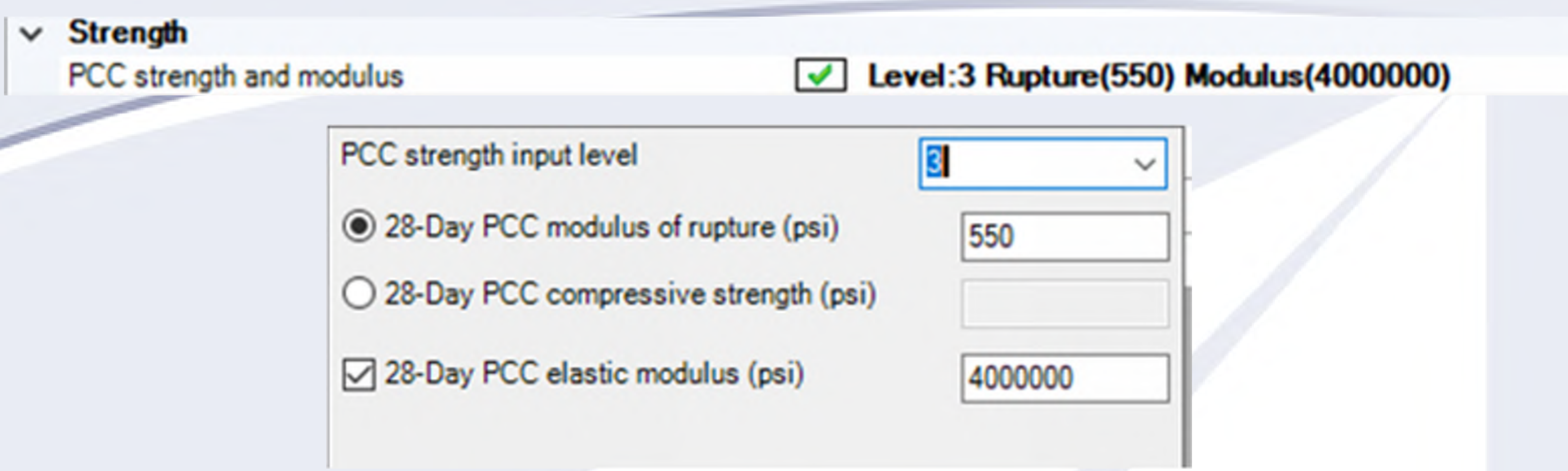
Reversible shrinkage (%)	☑ 50
PCC zero-stress temperature (deg F)	☐ Calculated
Time to develop 50% of ultimate shrinkage (days)	☑ 35
Ultimate shrinkage (microstrain)	☐ 588.5 (calculated)

- Time to 50% of ultimate shrinkage
- 35 days (Good default value)
- Ultimate shrinkage
- 588.5 (mixture-specific, calculated or specific input)

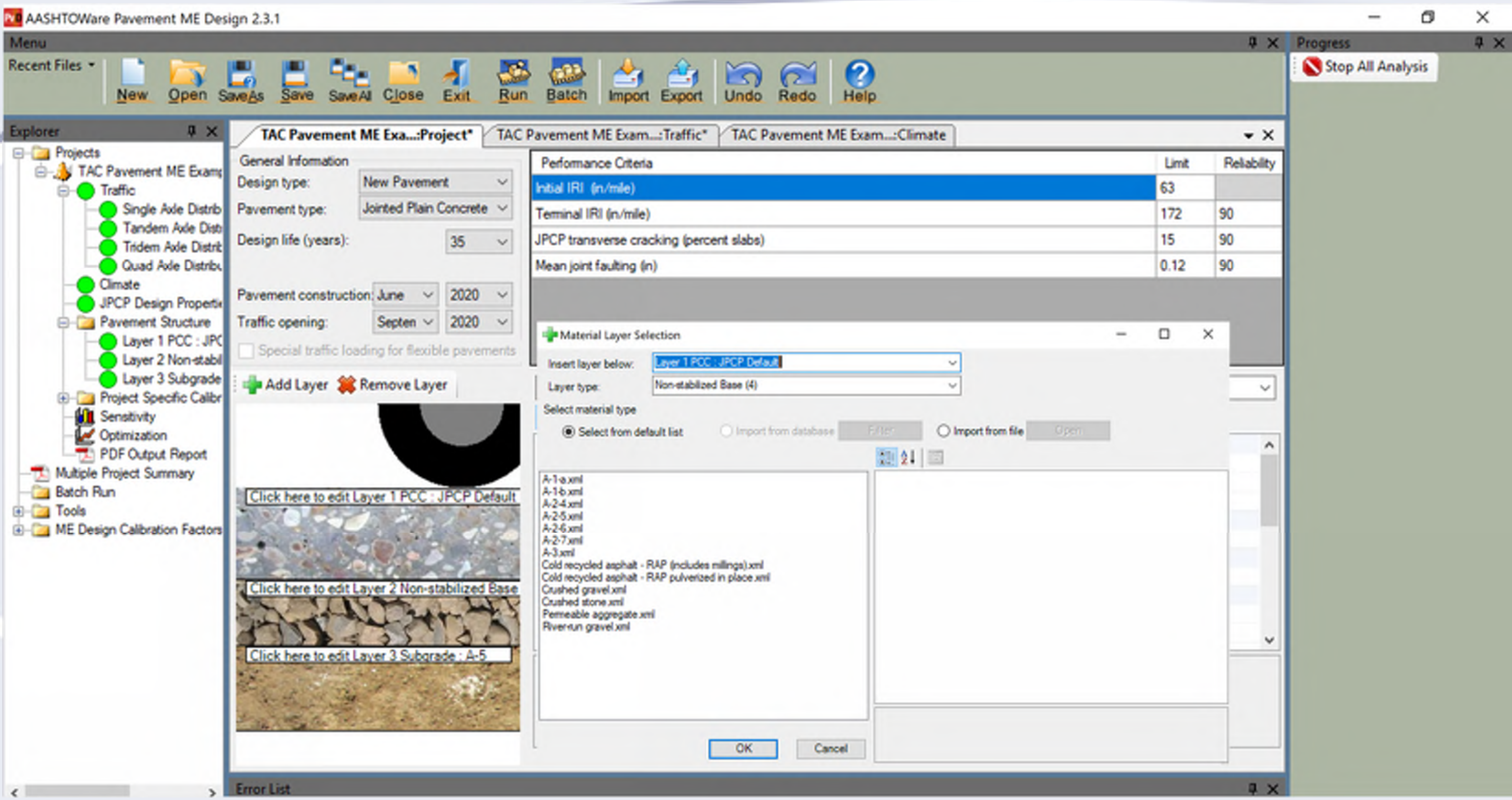
JPCP – Pavement Structure – PCC Materials



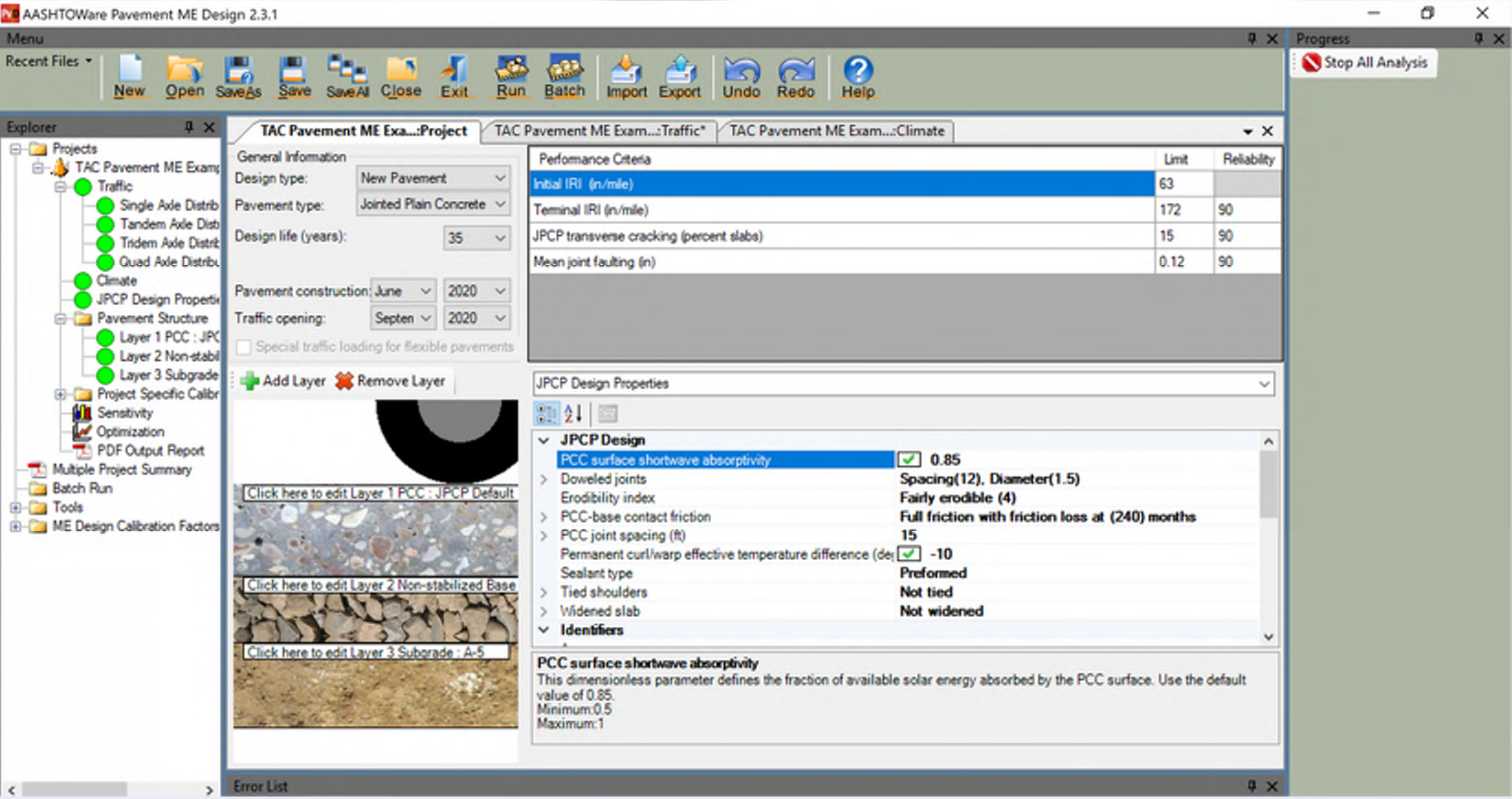
- Strength
  - Mixture dependent. Multiple ways to input. MOR = 500 -750 psi f'c = 3000 – 5500 psi
- Modulus (E)
  - Mixture dependent. Typically ranges from 3.2 – 5.0 x10^6 psi (Estimations can be used*)

* http://apps.acpa.org/applibrary/StrengthConverter/

JPCP – Pavement Structure – Support Layers



JPCP – Design Properties



JPCP – Design Properties

JPCP Design	
PCC surface shortwave absorptivity	☑ 0.85
Doweled joints	Spacing(12), Diameter(1.5)
Erodibility index	Fairly erodible (4)
PCC-base contact friction	Full friction with friction loss at (240) months
PCC joint spacing (ft)	15
Permanent curl/warp effective temperature difference (de	☑ -10
Sealant type	Preformed
Tied shoulders	Not tied
Widened slab	Not widened

Let’s Break it Down

JPCP – Design Properties

⌄ JPCP Design	
PCC surface shortwave absorptivity	☑ 0.85
› Doweled joints	Spacing(12), Diameter(1.5)

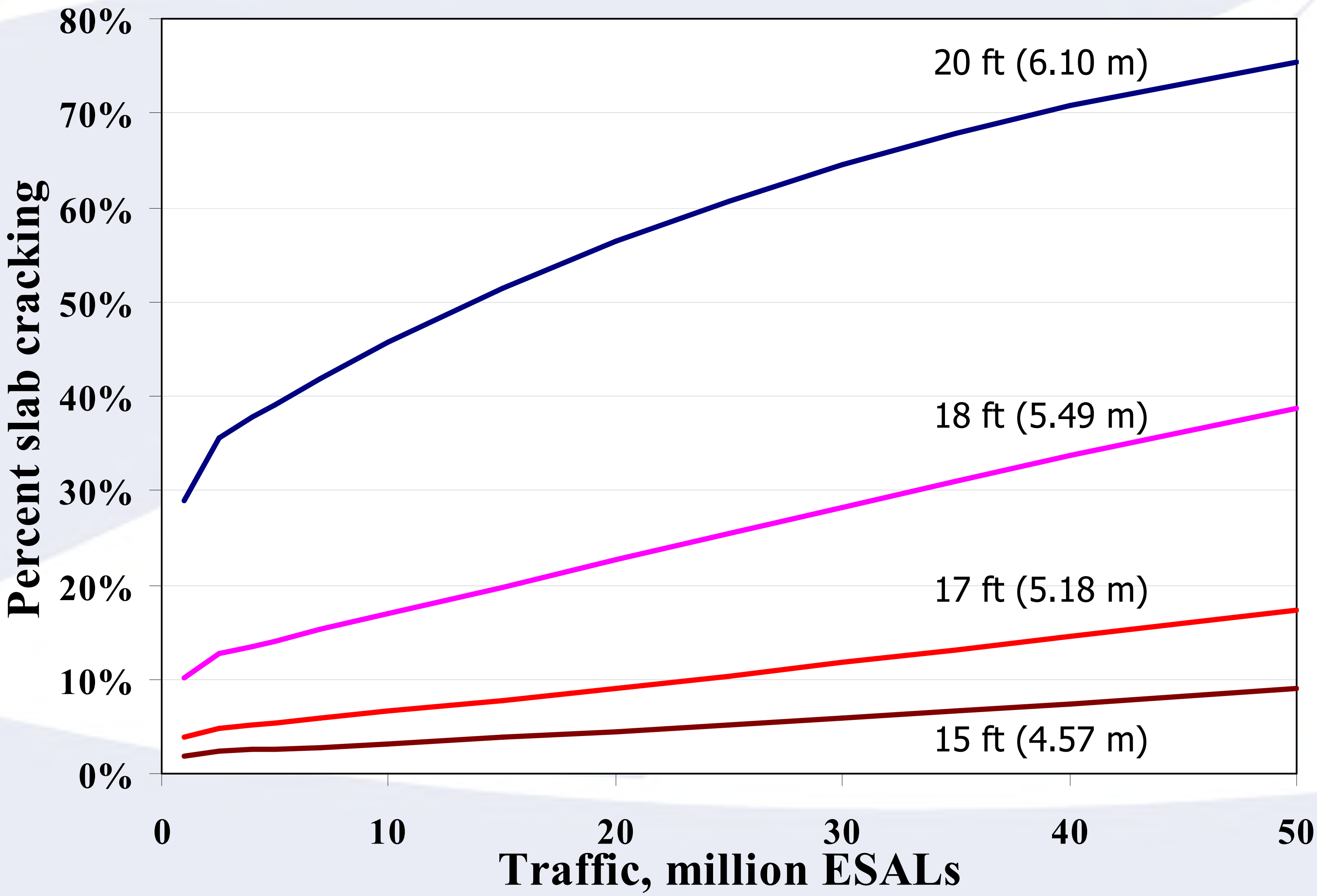
- SSA
  - 0.85 (Default and semi-constant)
- Doweled Joints
  - Typically used if thickness > 8 in
- Diameter
  - Often depends on thickness
    - 1 inch for 8 inches or less thickness
    - 1.25 inches for 8 – 10 inches thickness
    - 1.5 inches for >10 inches
- Spacing
  - 12 inches is most common

JPCP – Design Properties

Erodibility index	**Fairly erodible (4)**
PCC-base contact friction	**Full friction with friction loss at (240) months**
PCC joint spacing (ft)	**15**

- Erodibility
- Depends on soil conditions
- Base Friction
- Good defaults
- Joint Spacing
- Typical range = 12 – 20 ft

Effects of Joint Spacing



JPCP – Design Properties

Permanent curl/warp effective temperature difference (de;	✓ -10
Sealant type	Preformed
› Tied shoulders	Not tied
› Widened slab	Not widened

- Curl/Warp Temp.
  - -10^{o}F (Good default)
- Sealant Type
  - Preformed or Other (none, liquid, silicone)
- Tied Shoulder
  - Project dependent
- Widened Slab
  - Project dependent

Summary of Unique JPCP Critical Inputs

- Performance Criteria
  - IRI, cracking, faulting Levels
- Thickness
- Coef. of Thermal Exp. (CTE)
- Mix Design
  - Cement type, cementitious content, w/cm
- Strength
- Modulus
- Curing Method
- Joint Spacing
- Dowel Design
- Lane Width
- Shoulder Type
- Base Erodibility

MEPDG / DARWin-ME / AASHTOWare Pavement ME

JPCP Design Walk Through

New JPCP Design

- General Info
  - Design Life – 35
- Traffic
  - TTC 8 traffic distribution
  - 8,000 AADTT
  - 3 Lanes with 75% in design lane
- Climate
  - Pitt, PA Climate

All other inputs left as defaults

- JPCP
  - Thickness – 11 in (280 mm)
  - CTE – $5.5*10^{-6}/^{o}F$ ($9.9*10^{-6}/^{o}C$)
  - Limestone Agg
  - Cementitious – 525 lb/cy (311 kg/m^3)
  - MOR – 550 psi (3.8 MPa)
  - E – 4,000,000 psi (27,600 MPa)
- Crushed Stone Agg Base
  - Thickness – 8 in (203 mm)
- Subgrade
  - A-5 Defaults
- JPCP Design Properties
  - Dowel Diameter – 1.5 in (38 mm)
  - Erodibility Index – Fairly Erodible (4)

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Summary of Unique JPCP Critical Inputs

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- Strength
- Modulus
- Curing Method
- Joint Spacing
- Dowel Design
- Lane Width
- Shoulder Type
- Base Erodibility

Top 10 ME Design Most Sensitive

1. Concrete Flexural Strength at 28-Days
2. Concrete Thickness
3. Surface Shortwave Absorptivity (SSA)
4. Joint Spacing
5. Concrete Modulus of Elasticity at 28-Days
6. Design Lane Width with a 14 ft (4.3 m) Widened Slab
7. Edge Support via Widened Slab
8. Concrete Thermal Conductivity
9. Concrete Coefficient of Thermal Expansion (CTE)
10. Concrete Unit Weight

Project 1-47

Sensitivity Evaluation of MEPDG Performance Prediction

Final Report

Prepared for the
NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
TRANSPORTATION RESEARCH BOARD
OF
THE NATIONAL ACADEMIES

Charles W. Schwartz
Rui Li
University of Maryland
College Park, MD

Sung Hwan Kim
Halil Ceylan
Kasthurirangan Gopalakrishnan
Iowa State University
Ames, IA

December 2011

http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP01-47_FR.pdf

Other Sensitivity Reports

	Pitt (Mu et al. 2011)	UW-Madison (Li and Cramer 2012)	OK State (Ley et al. 2012)	Iowa State (Ceylan et al. 2013)	Sensitivity in Common
Transverse Cracking	• Climate • Jt spacing • Base type • Strength • Thickness • Traffic • Edge support • CTE	• Thickness • Strength • CTE • Traffic ➢ wheel location ➢ Traffic wander ➢ AADTT ➢ Truck%	• CTE • Strength • Asphalt base • Climate • Unit weight • Poisson's • Thermal conductivity	• Strength • Thickness • Jt spacing • Width • CTE • Unit weight • Poisson's • Thermal conductivity	• Strength (-) • Thickness (-) • Jt spacing (+) • Slab width (-) • CTE (+) • Traffic (+) • Edge support (-) • Climate (n/a) • Base support (n/a)
Joint Faulting	• Dowel Dia. • Thickness • CTE • Base Erod. • Traffic • Wet days • Jt spacing • CTE	• CTE • Dowel Dia.	• Edge support • Dowel Dia. • CTE • Thickness • Jt spacing	• Dowel Dia. • CTE • Base • Subgrade • Climate	• Dowel Dia. (-) • CTE (+) • Base Erod. (+) • Traffic (+) • Jt spacing (+) • Thickness (n/a) • Climate (n/a)
IRI	= Function (cracking, faulting, spalling, site factor)				

Notes:
1. Grey indicates semi-constant values
2. (+)/(-) indicates the sign of the tangential slope of Δ (Distress) / Δ (parameter)

(Mu, 2017)

How Traffic Impacts JPCP Design?

- Just as rigid and flexible ESALs are different because of their different response…
  - Single, tandem and tridem axle groups (and at differing loads) cause differing relative damages
    - Single-axles usually cause more fatigue damage
    - Tandem and tridem axles usually cause more erosion damage

… so even within just rigid pavement design, ESAL count for same traffic spectrum and # of trucks in the design lane is really different for each distress type modeled!?!

Summary

- Only a handful (10 or less) of design inputs greatly impact a new JPCP design, which includes
  - Strength (-)
  - Thickness (-)
  - Jt spacing (+)
  - Slab width (-)
  - CTE (+)
  - Traffic (+)
  - Edge support (-)
  - Dowel diameter (-)
  - Climate (n/a)
  - Base type (n/a)

  (+)/(-) indicates the sign of the tangential slope of Δ (Distress) / Δ (parameter)
- A Pavement ME run can be established without the loss of accuracy by only determining these most sensitive inputs and leaving the others as default.
- The effort required to establish the inputs for a Pavement ME run is not significantly greater than that for a AASHTO 1993 design.

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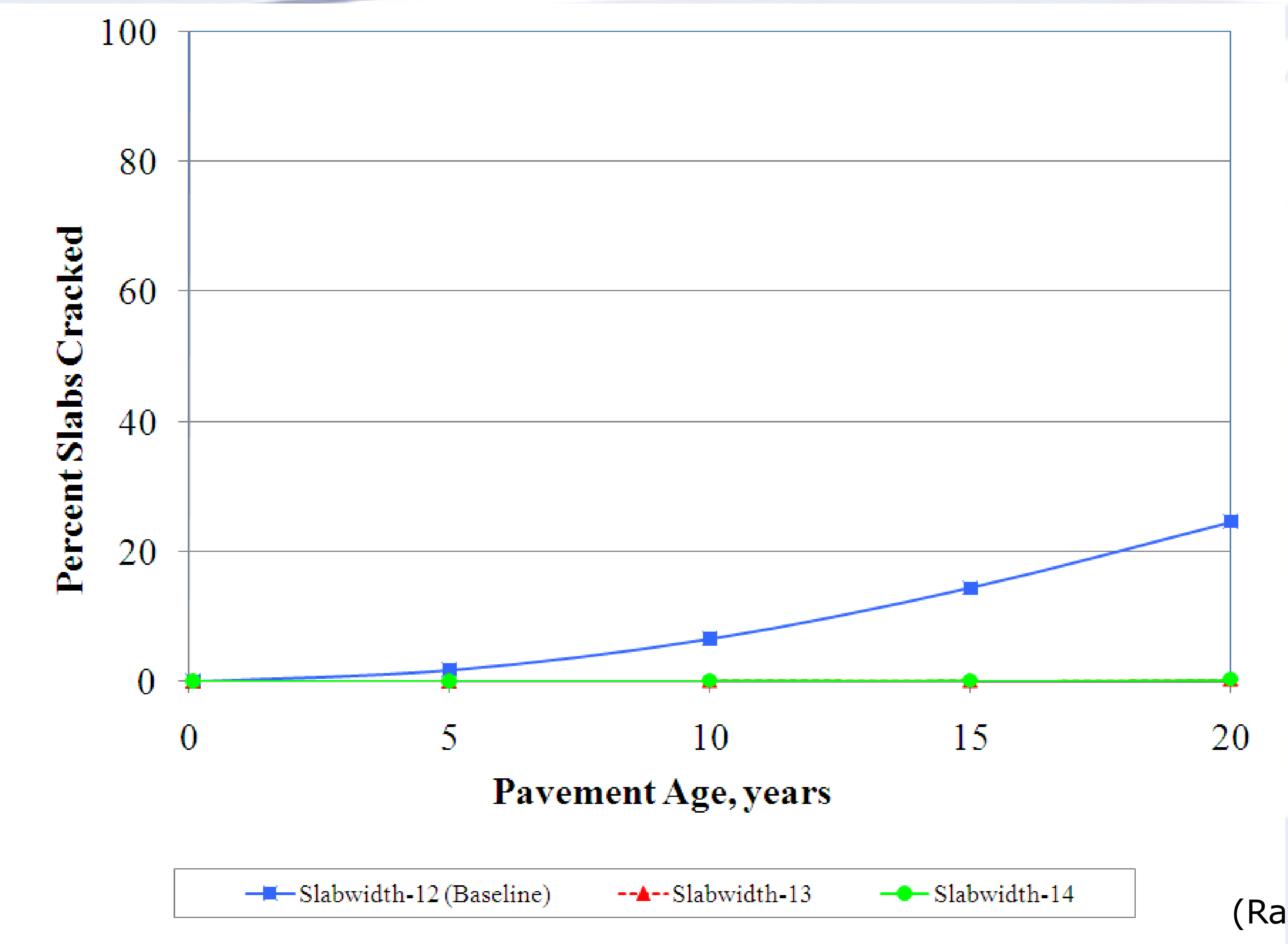
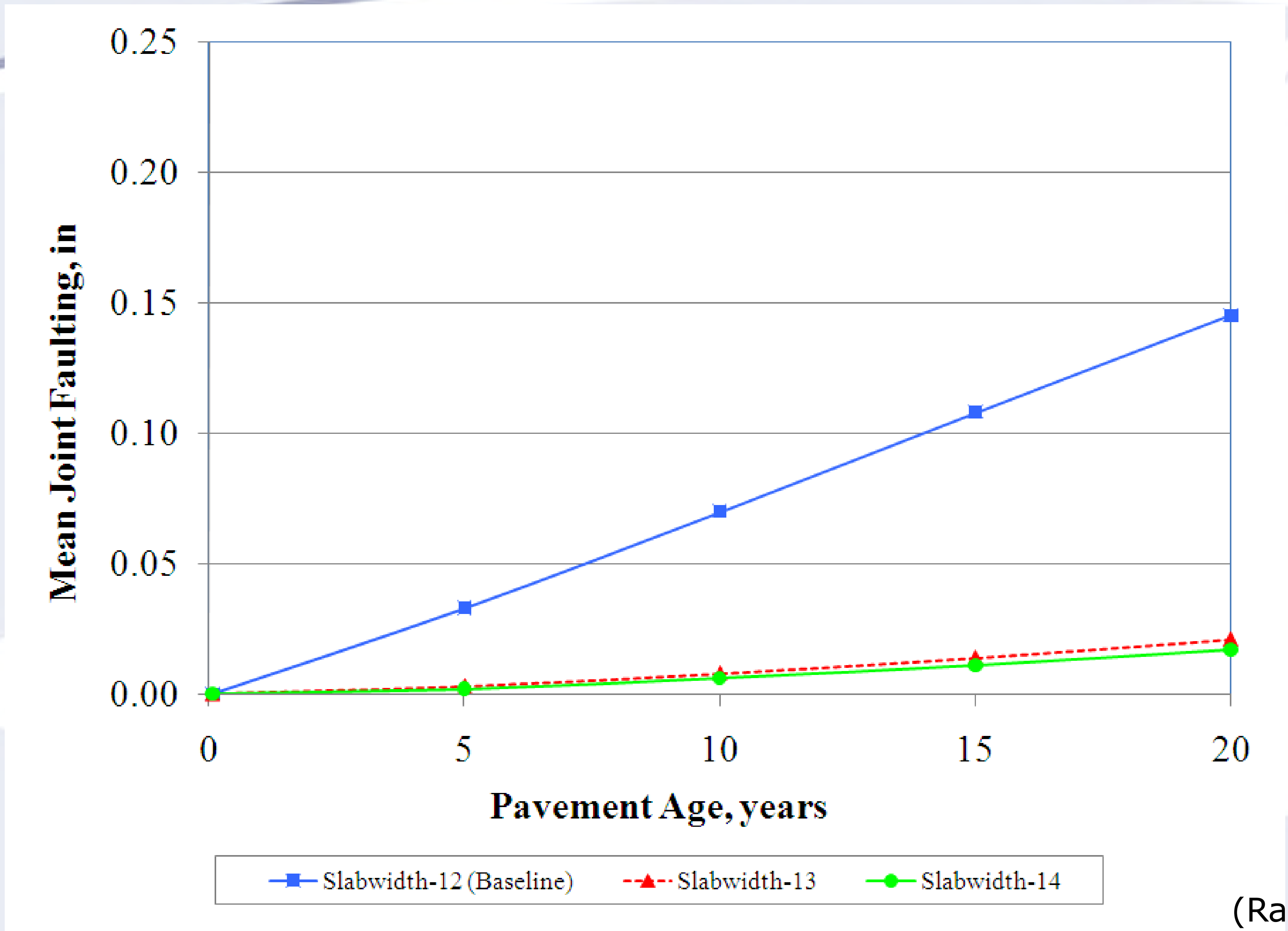
Engineering Solutions – Widened Slab Example



(Rao, 2018)

Engineering Solutions – Widened Slab Example



(Rao, 2018)

Engineering Solutions – Widened Slab Example

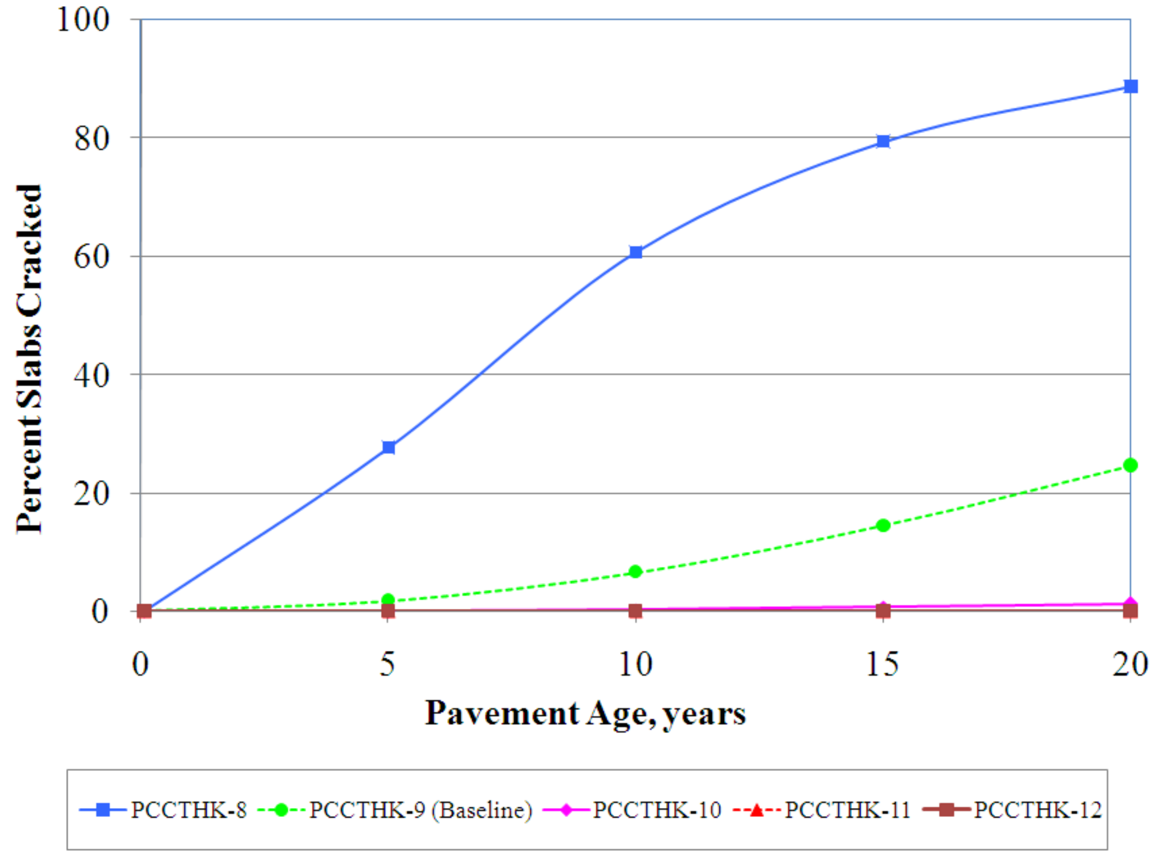
- Widening the slab reduces longitudinal edge midpanel stresses but this could increase stresses in other locations not considered in Pavement ME

- With 14 ft wide slab there is a much higher risk of longitudinal cracking due to increased stresses at interior transverse joint edge locations

(Rao, 2018)

Engineering Solutions – Base/Subbase Example

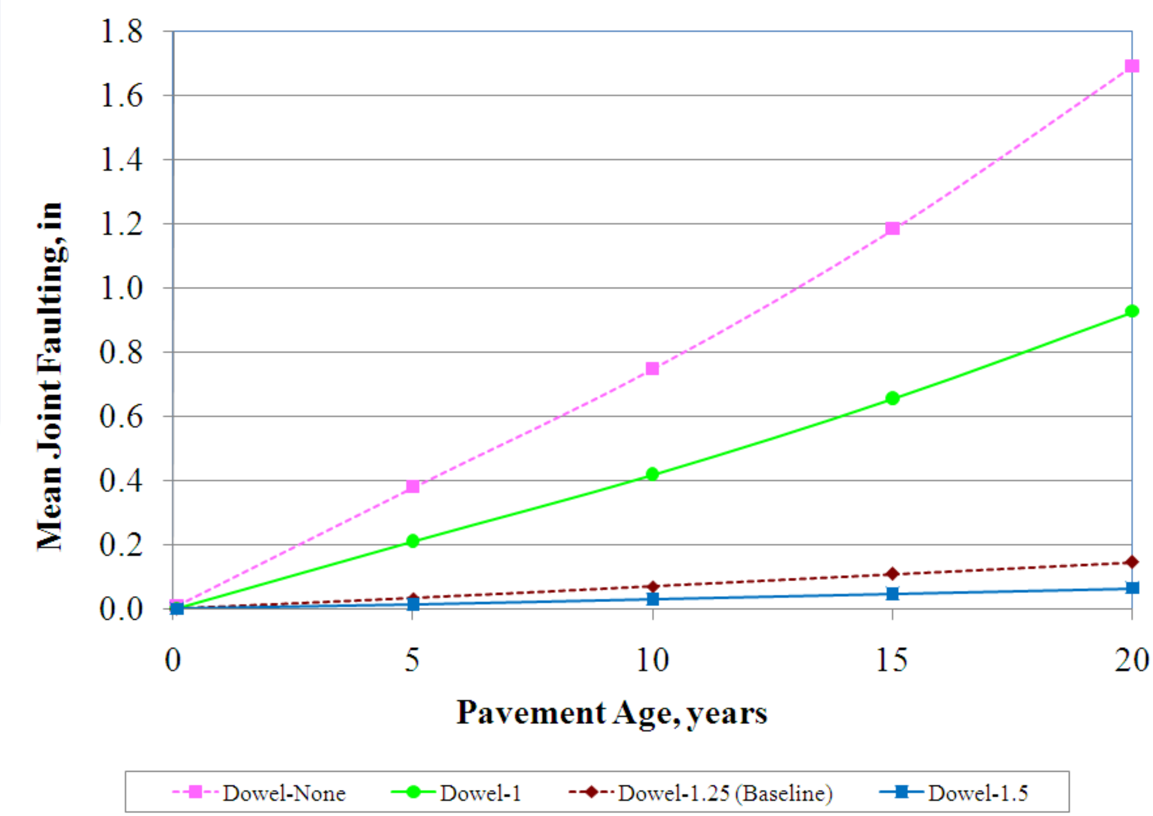
- In pavement ME, PCC thickness drives fatigue cracking performance.
- The contribution of base type and base thickness on cracking at higher PCC thickness is negligible.
- It is tempting to increase PCC thickness at the expense of base thickness/quality.



(Rao, 2018)

Engineering Solutions – Base/Subbase Example

- In Pavement ME, dowel bars drive faulting (and IRI) performance.
- The contribution of base type and base thickness on faulting in doweled pavements is negligible.
- It is tempting to not pay attention to base thickness/quality when dowels are used.



(Rao, 2018)

Engineering Solutions – Base/Subbase Example

- Rigid pavement performance requires uniform support that is free of any abrupt spatial and material changes. This is somewhat “baked” into the sections used for calibration.

- Base/subbase protects the subgrade from long-term degradation and provides uniform support to the concrete.

(Rao, 2018)

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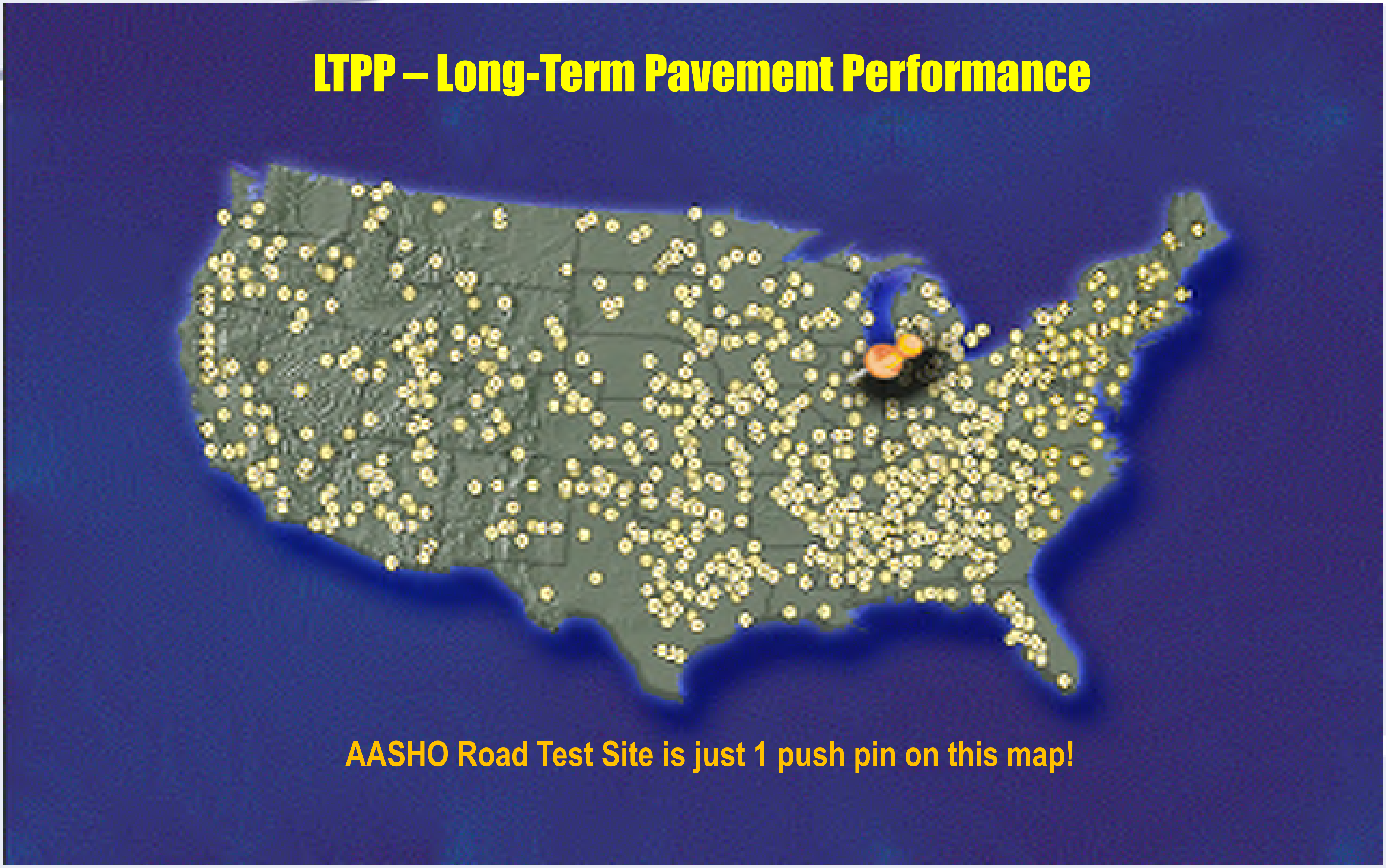
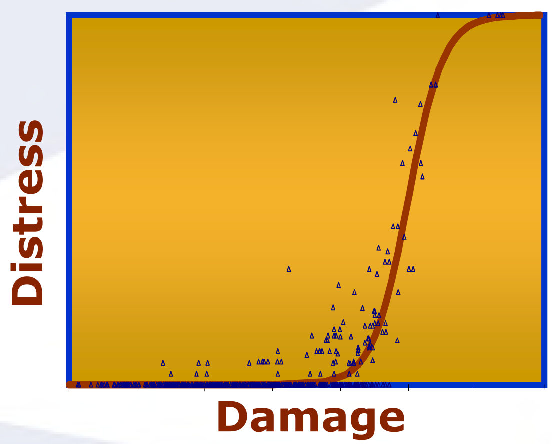
Calibration



Calibrated Distress Performance Models

- Mechanistically computed response or damage is correlated to observed distress (empirical link) through **calibrated** performance equations
- Quality of the observations, statistical techniques used, and adequacy of the mathematical model used in calibration affect the behavior of the **transfer function**



Three National Calibrations For New JPCP So Far

Most JPCP designs have been done using the 2nd Calibration

Cal. 1 (NCHRP 1-37)

Cal. 2 (NCHRP 1-40D)
- Models updated
- Cal. database expanded

Cal. 2.5 (NCHRP 20-07 Task 288)
- To correct CTE testing

Cal. 3 (NCHRP 20-07 Task 327)
- To validate Task 288

DARWin ME

AASHTOWare Pavement ME Design

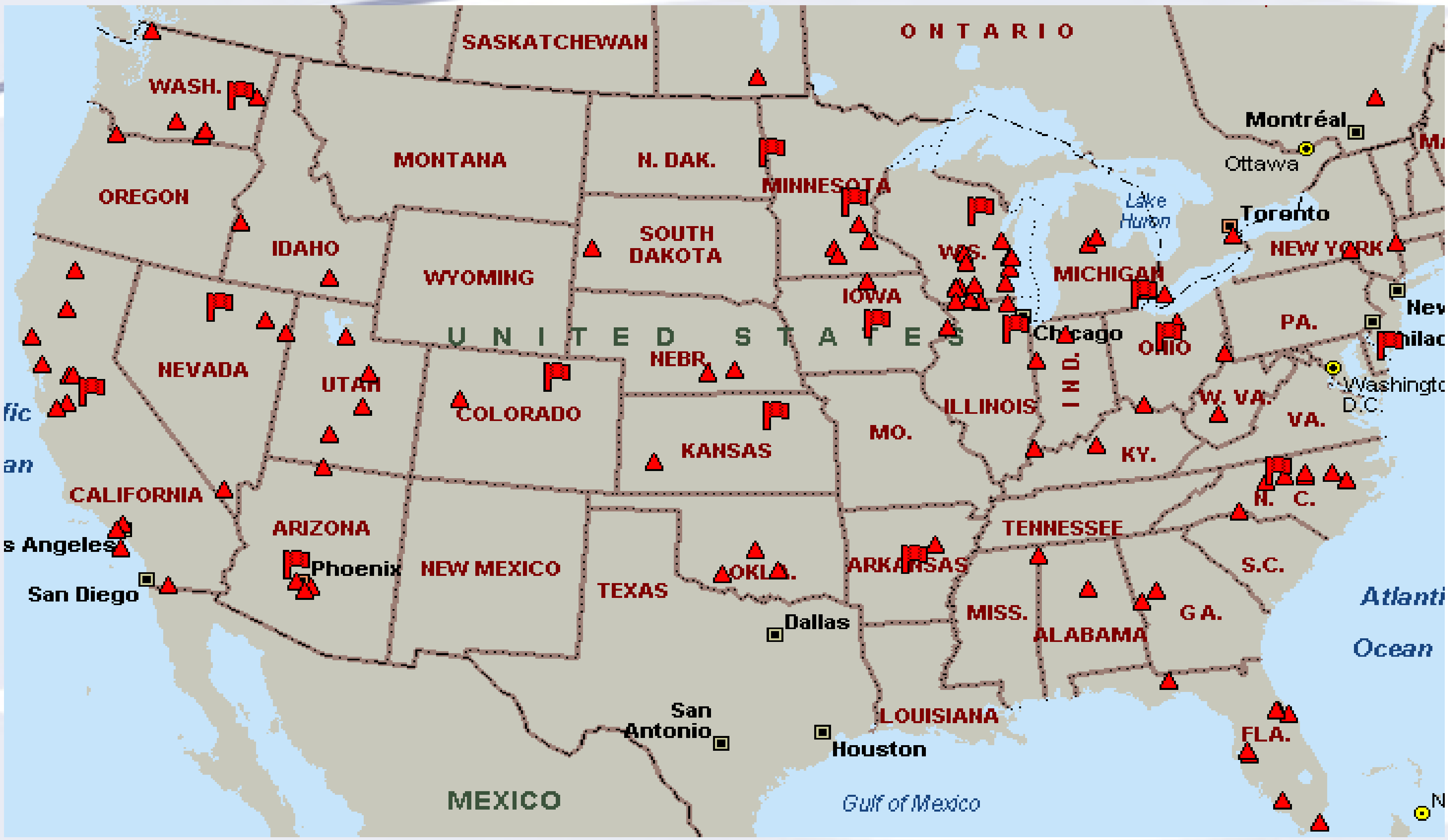
MEPDG 0.7 — **2004**

MEPDG 1.0 - Pavement ME — **2007**

2.1 — **2011**

Pavement ME 2.2 and 2.3 — **Since August, 2015**

JPCP 2006 Calibration



LTPP GPS-3 & RPPR JPCP Sections

LTPP SPS-2, MnROAD, & AASHO JPCP Sections

Local Calibration?

- ***Verification*** — checking if ***"global"*** models work as intended locally
- ***Calibration*** — changing ***"global coefficients"*** to ***"STATE local coefficients"*** that make distress & IRI predictions match State field measurements
  - ***May also include adjustment of some INPUTS (e.g., built-in temp, months of full friction)***
- ***Validation*** — checking that the ***"local"*** models works as intended (used 10% data)

Sounds Easy Enough, Right?

$$Fault_m = \sum_{i=1}^{m} \Delta Fault_i$$

$$\Delta Fault_i = C_{34} * (FAULTMAX_{i-1} - Fault_{i-1})^2 * DE_i$$

$$FAULTMAX_i = FAULTMAX_0 + C_7 * \sum_{j=1}^{m} DE_j * Log(1 + C_5 * 5.0^{EROD})^{C_6}$$

$$FAULTMAX_0 = C_{12} * \delta_{curling} * \left[Log(1 + C_5 * 5.0^{EROD}) * Log\left(\frac{P_{200} * WetDays}{p_s}\right) \right]^{C_6}$$

$$\sigma_0 = \frac{E_{PCC} \Delta \varepsilon_{tot}}{2(1 - \mu_{PCC})}$$

$$IRI = IRI_I + C1*CRK + C2*SPALL + C3*TFAULT + C4*SF$$

$$SCF = -1400 + 350 \cdot AIR\% \cdot (0.5 + PREFORM) + 3.4 f'c \cdot 0.4 - 0.2\ (FTCYC \cdot AGE) + 43\ h_{PCC} - 536\ WC\_Ratio$$

$$cw = Max\left(L \cdot \left(\varepsilon_{shr} + \alpha_{PCC} \Delta T_{\varsigma} - \frac{c_2 f_\sigma}{E_{PCC}} \right) \cdot 1000 \cdot CC, 0.001 \right)$$

n = traffic path.

he damage increments were discussed previously in this section.

he applied number of load applications ($n_{i,j,k,l,m,n}$) is the actual number of axle type k of load vel l that passed through traffic path n under each condition (age, season, and temperature ifference). The allowable number of load applications is the number of load cycles at which tigue failure is expected (corresponding to 50 percent slab cracking) and is a function of the pplied stress and PCC strength. The allowable number of load applications is determined using e following fatigue model:

$$\log(N_{i,j,k,l,m,n}) = C_1 \cdot \left(\frac{MR_i}{\sigma_{i,j,k,l,m,n}} \right)^{C_2} + 0.4371 \qquad (3.4.10)$$

here,

- $N_{i,j,k,...}$ = allowable number of load applications at condition i, j, k, l, m, n
- MR_i = PCC modulus of rupture at age i, psi
- $\sigma_{i,j,k,...}$ = applied stress at condition i, j, k, l, m, n
- C_1 = calibration constant = 2.0
- C_2 = calibration constant = 1.22

The fatigue damage calculation is a simple process of summing damage from each damage increment, except that a numerical integration scheme is used to accurately determine the effects of traffic wander. The fatigue damage at the critical damage location caused by an axle load placed at any random distance away from the pavement edge (point j) is given by the following:

$$FD_{ij}^{*} = P(COV_j) \cdot FD_{ij} \qquad (3.4.11)$$

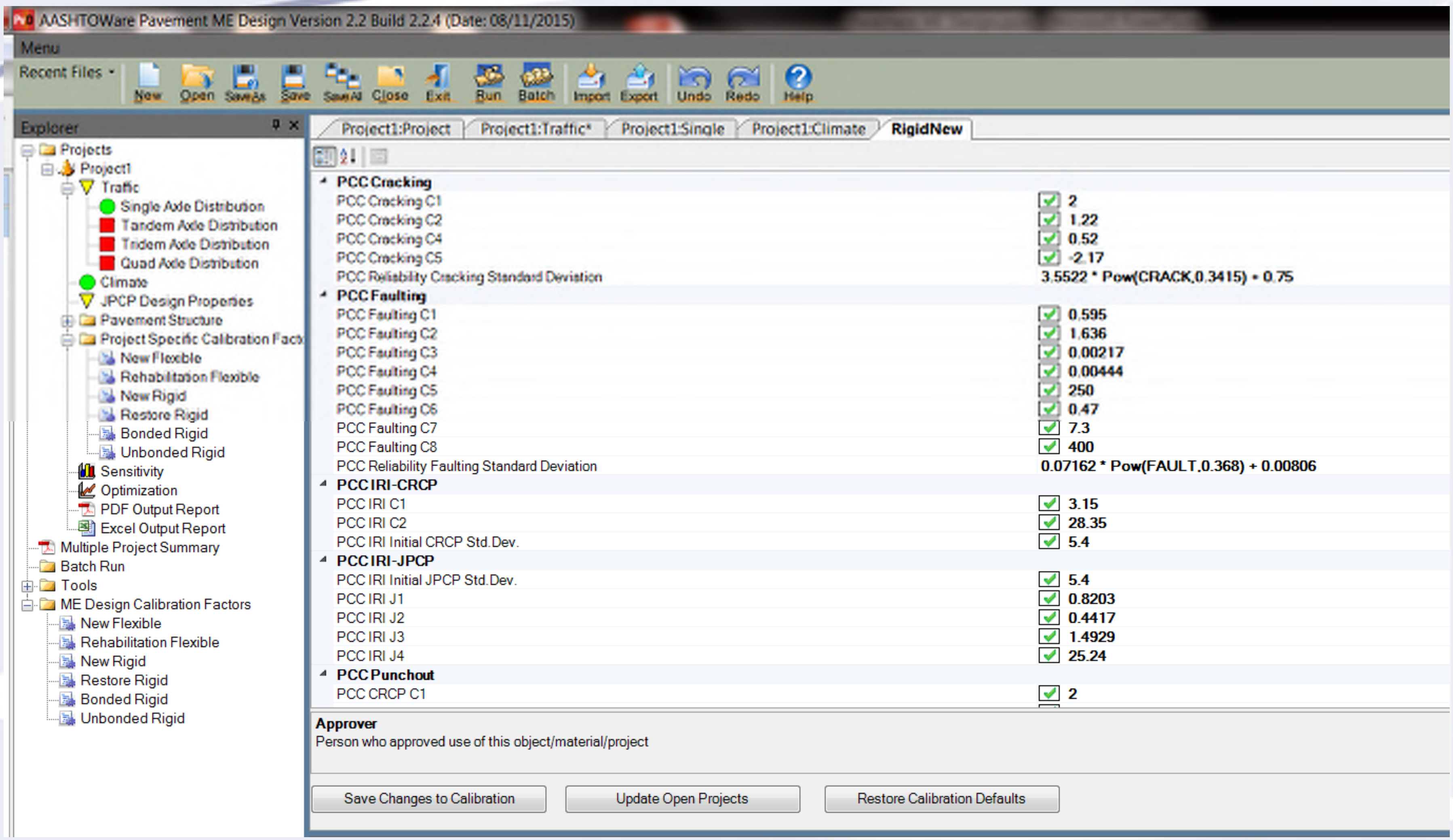
The probability of coverage is determined assuming normal distribution.

$$NORMDIST = \frac{1}{SD_{wf}\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2} \qquad (3.4.12)$$

- = normal distribution density function.
- = wheel location – distance from pavement edge (or outside of the paint stripe for widened slab) to the outer edge of outermost wheel, in.

3.4.64

Pavement ME Allows Agencies To Develop And Use Local Calibration Coefficients



You can save your local calibration coefficients as default or restore the national as default at one click

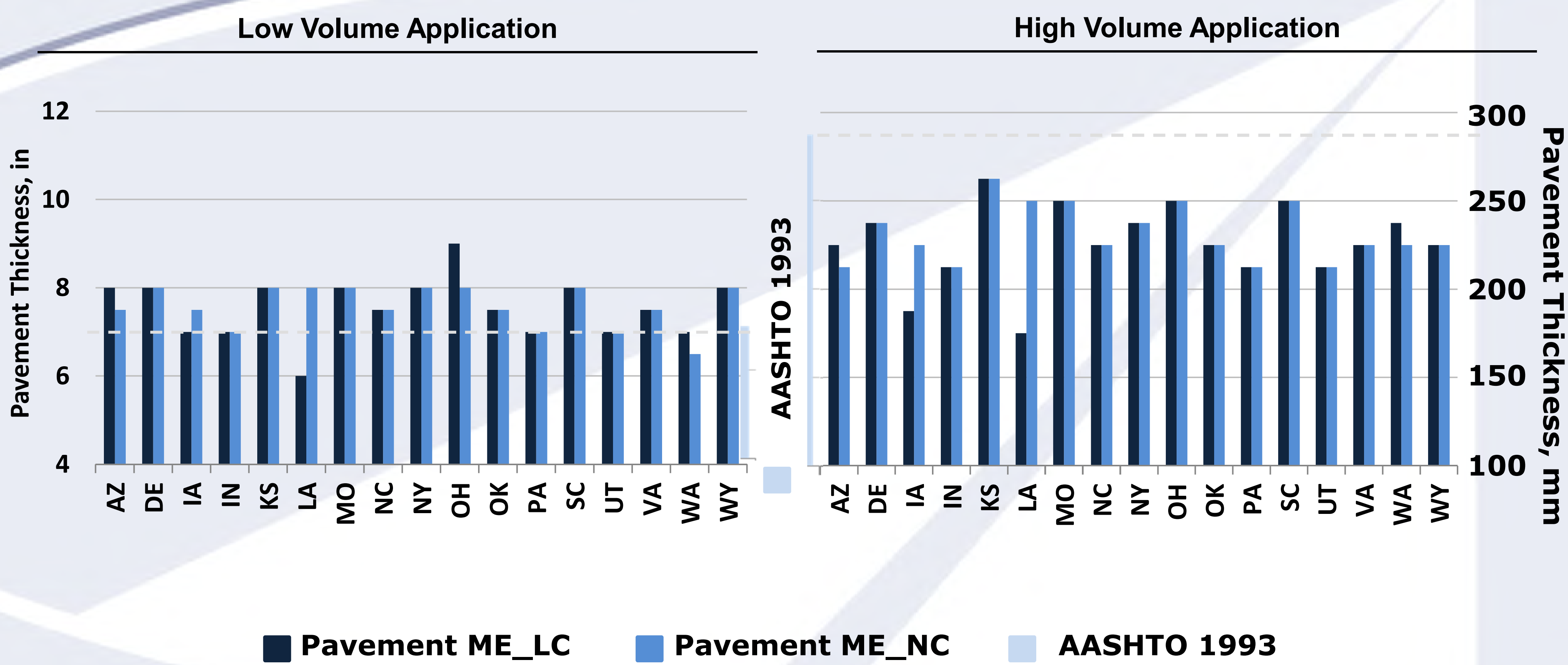
Local Calibration Examples

- Indiana DOT:
  - Changed JPCP IRI J3 from 1.4929 to 1.05 because it was too sensitive to it
- Ohio DOT:
  - Changed JPCP IRI calibrations

Calibration Coefficient	Default (national)	Ohio
PCC IRI J1	0.8203	0.82
PCC IRI J2	0.4417	3.7
PCC IRI J3	1.4929	1.711
PCC IRI J4	25.24	5.703
PCC IRI JPCP Standard Deviation	5.4	5.4

- Many states at this point are working on or have completed local calibrations.

Local Calibration Result In ½-In Or Less Difference In Required Thickness Vs. National Calibration



However, using Pavement ME result in ~2-3 in thinner JPCPs when compared to the AASHTO 93 guide.

(Mu, 2017)

Simpler ME Option: Design Tables

APPLIED RESEARCH ASSOCIATES, INC.
TRANSPORTATION
EXPANDING THE REALM OF POSSIBILITY

METHODOLOGY FOR THE DEVELOPMENT OF EQUIVALENT PAVEMENT STRUCTURAL DESIGN MATRIX FOR MUNICIPAL ROADWAYS

INCLUDING MAINTENANCE & REHABILITATION SCHEDULES AND LIFE CYCLE COST ANALYSIS

January 18, 2011

Submitted to:

Ready Mixed Concrete Association of Ontario & Cement Association of Canada

Cement Association of Canada
Association Canadienne du Ciment
RMCAO

ARA Project Number 000830

5401 Eglinton Avenue West, Suite # 105 | Toronto, Ontario M9C 5K6 | transportation@ara.com

WWW.ARA.COM/TRANSPORTATION

...c (AADTT) - 25 Year Pavement Design

							Major Arterial			
							2,500	5,000	7,500	10,000
Subgrade Strength	30 MPa (CBR=3)	PCC					200 mm PCC 200 mm Granular A	200 mm PCC 200 mm Granular A	210 mm PCC 200 mm Granular A	230 mm PCC 200 mm Granular A
		HMA					40 mm SP 12.5 FC1 110 mm SP 19 150 mm Granular A 450 mm Granular B	40 mm SP 12.5 FC1 120 mm SP 19 150 mm Granular A 600 mm Granular B	40 mm SP 12.5 FC1 130 mm SP 19 150 mm Granular A 600 mm Granular B	40 mm SP 12.5 FC2 140 mm SP 19 150 mm Granular A 600 mm Granular B
	40 MPa (CBR=4)	PCC					200 mm PCC 200 mm Granular A	200 mm PCC 200 mm Granular A	200 mm PCC 200 mm Granular A	210 mm PCC 200 mm Granular A
		HMA					40 mm SP 12.5 FC1 100 mm SP 19 150 mm Granular A 400 mm Granular B	40 mm SP 12.5 FC1 120 mm SP 19 150 mm Granular A 450 mm Granular B	40 mm SP 12.5 FC1 130 mm SP 19 150 mm Granular A 500 mm Granular B	40 mm SP 12.5 FC2 140 mm SP 19 150 mm Granular A 550 mm Granular B
	50 MPa (CBR=5)	PCC	200 mm Granular A	200 mm Granular A	200 mm Granular A	200 mm Granular A	200 mm PCC 200 mm Granular A	200 mm PCC 200 mm Granular A	200 mm PCC 200 mm Granular A	200 mm PCC 200 mm Granular A
		HMA	40 mm SP 12.5 80 mm SP 19 150 mm Granular A 300 mm Granular B	40 mm SP 12.5 80 mm SP 19 150 mm Granular A 300 mm Granular B	40 mm SP 12.5 FC1 80 mm SP 19 150 mm Granular A 300 mm Granular B	40 mm SP 12.5 FC1 100 mm SP 19 150 mm Granular A 300 mm Granular B	40 mm SP 12.5 FC1 100 mm SP 19 150 mm Granular A 350 mm Granular B	40 mm SP 12.5 FC1 110 mm SP 19 150 mm Granular A 400 mm Granular B	40 mm SP 12.5 FC1 130 mm SP 19 150 mm Granular A 450 mm Granular B	40 mm SP 12.5 FC2 140 mm SP 19 150 mm Granular A 500 mm Granular B
Concrete Slab and Joint Properties			No dowels Slab length = 4 m Tied shoulder/curb *		32M Dowel bars, 300 mm spacing Slab length = 4.5 m Tied shoulder/curb *		32M Dowel bars, 300 mm spacing Slab length = 4.5 m Tied shoulder/curb *		32M Dowel bars, 300 mm spacing Slab length = 4.5 m 0.5 m Widened outside slab or integral curb *	

Outline

- Review of Pavement ME's Concrete Design Options
- JPCP Design Input Walkthrough
- Example Runs and How to Interpret Them
- Review of Critical Inputs
- Engineering Solutions
- ME Calibration Impact
- Additional Resources

Resources

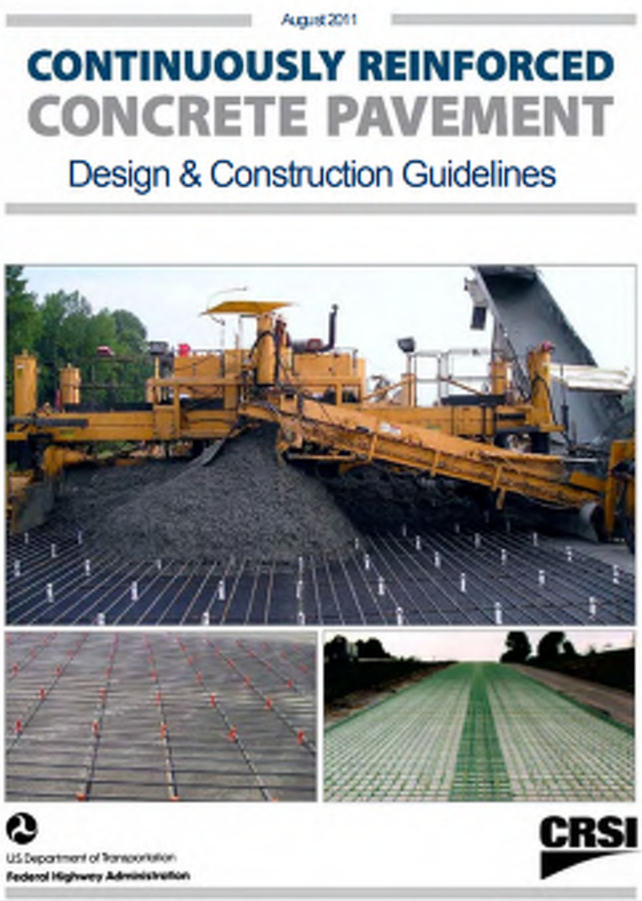
- NCHRP 1-37 MEPDG Home: http://onlinepubs.trb.org/onlinepubs/archive/mepdg/guide.htm
- Recorded Webinars: https://www.fhwa.dot.gov/pavement/dgit/aashtoware.pdf
- North American Usergroup Summary Page: http://www.pooledfund.org/Details/Study/549
- ME Design Help: http://www.me-design.com/MEDesign/data/HTML%20Help/US/index.html?design_inputs_1.htm
- Application Library: http://apps.acpa.org/

Resources

- Some States with Pavement ME User Guides
  - Michigan: https://www.michigan.gov/documents/mdot/MDOT_Mechanistic_Empirical_Pavement_Design_User_Guide_483676_7.pdf
  - Colorado: https://www.codot.gov/business/designsupport/matgeo/manuals/pdm/2017-m-e-pavement-design-manual/chapter-1.pdf
  - Indiana: http://www.in.gov/indot/design_manual/files/Ch304_2013.pdf
  - Arizona: https://apps.azdot.gov/ADOTLibrary/publications/project_reports/PDF/AZ606.pdf
  - Virginia: http://www.virginiadot.org/VDOT/Business/asset_upload_file108_3638.pdf
  - Utah: https://www.udot.utah.gov/main/uconowner.gf?n=20339215312776663

Continuously Reinforced Concrete Pavement (CRCP)

- Resources: Check out crcpavement.org for more!



Rasmussen et al. (2011)

Roesler & Hiller (2013)

Roesler et al. (2016)

THANK YOU!
Questions?

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Jim Powell, P.E.
Executive Director
NW Chapter
American Concrete Pavement Association
jim@nwpavement.com
360-951-1463