

# **AASHTOWare Pavement ME: JPCP Walk-through and Sensitivity Analysis**



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# 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

The screenshot displays a software interface for JPCP design, divided into two main sections: a project explorer and a design properties panel.

**Project Explorer:** Shows a hierarchical tree structure for 'Project 1'. The 'Traffic' folder is expanded, listing 'Single Axle Distribution', 'Tandem Axle Distribution', 'Tridem Axle Distribution', and 'Quad Axle Distribution'. Other folders include 'Climate', 'JPCP Design Properties', 'Pavement Structure', 'Project Specific Calibration' (with sub-items: 'New Flexible', 'Rehabilitation Flexible', 'New Rigid', 'Restore Rigid', 'Bonded Rigid', 'Unbonded Rigid'), 'Sensitivity', 'Optimization', 'PDF Output Report', 'Multiple Project Summary', 'Batch Run', 'Tools', and 'ME Design Calibration Factors'.

**Design Properties Panel:** Titled 'Project1:Project\*', it contains the following settings:

- General Information:** Design type: 'New Pavement'; Pavement type: 'Jointed Plain Concrete Pavement (J)'; Design life (years): '30'.
- Pavement construction:** 'June' 2020.
- Traffic opening:** 'September' 2020.
- Special traffic loading for flexible pavements.
- Buttons: '+ Add Layer' and '- Remove Layer'.

**Pavement Structure Visualization:** A cross-section diagram shows three layers:

- Layer 1: PCC : JPCP Default (Jointed Plain Concrete Pavement).
- Layer 2: Non-stabilized Base : Crushed aggregate.
- Layer 3: Subgrade : A-7-6.

# Jointed Plain Concrete Pavement (JPCP)

- General Information
  - Design Life
  - Construction/Opening Timeframe

Project1:Project\*    Project1:Traffic\*    Project1:Clin

General Information

Design type: New Pavement

Pavement type: Jointed Plain Concrete Pavement (J

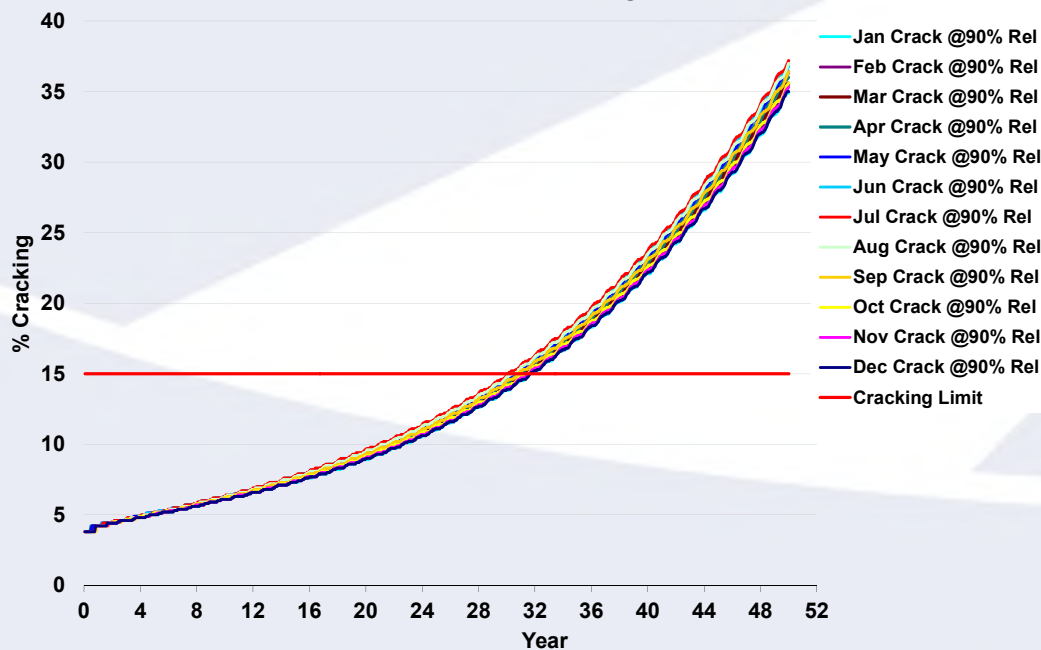
Design life (years): 30

Pavement construction: June 2020

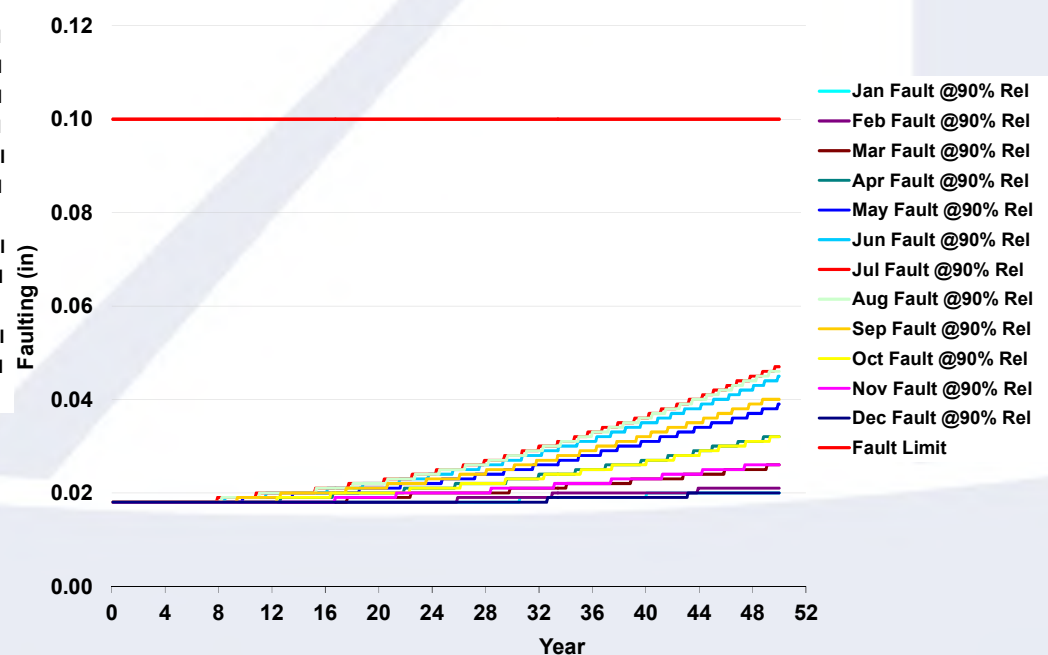
Traffic opening: September 2020

Special traffic loading for flexible pavements

Predicted Cracking



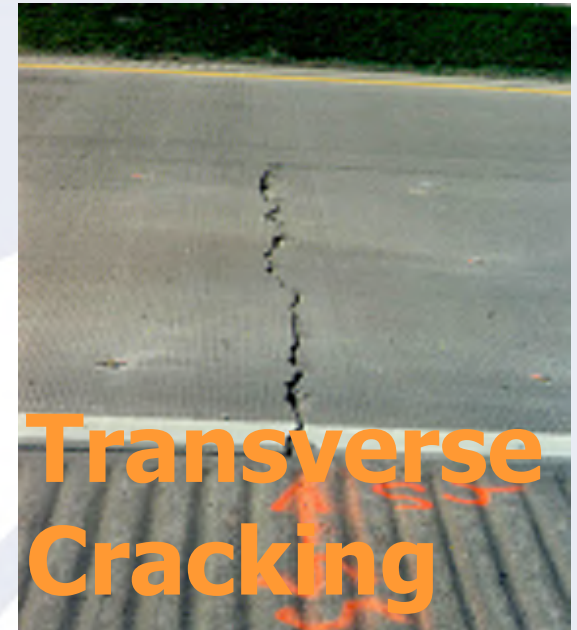
Predicted Faulting



# 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

AASHTOWare Pavement ME Design 2.3.1

Menu Recent Files Explorer

TAC Pavement ME Exam...Project TAC Pavement ME Exam...Traffic

Vehicle Class Distribution and Growth Load Default Distribution Hourly Adjustment

Vehicle Class	Distribution (%)	Growth Rate (%)	Growth Function
Class 4	1.7	3	Linear
Class 5	19.3	3	Linear

Hourly Adjustment

Time of	Percentage
12:00 am	2.3
1:00 am	2.3
2:00 am	2.3

Truck Traffic Classification (TTC) Groups

General category: Principal Arterials - Interstates and Defense Routes (0)

Use	TTC	Bus(%)	Description
<input type="checkbox"/>	5	(<2%)	Mixed truck traffic with a higher percentage of single-trailer trucks.
<input type="checkbox"/>	8	(<2%)	Mixed truck traffic with about equal percentages of single-unit and single-trailer...
<input type="checkbox"/>	11	(<2%)	Predominantly single-unit trucks.
<input type="checkbox"/>	13	(<2%)	Predominantly single-trailer trucks.
<input type="checkbox"/>	16	(<2%)	Mixed truck traffic with a higher percentage of single-trailer trucks.
<input type="checkbox"/>	3	(<2%)	Mixed truck traffic with about equal percentages of single-unit and single-trailer...
<input type="checkbox"/>	7	(<2%)	Predominantly single-unit trucks.
<input type="checkbox"/>	10	(<2%)	Predominantly single-trailer trucks.
<input type="checkbox"/>	15	(<2%)	Mixed truck traffic with a higher percentage of single-unit trucks.
<input checked="" type="checkbox"/>	1	(>2%)	Mixed truck traffic with about equal percentages of single-unit and single-trailer...
<input type="checkbox"/>	2	(>2%)	Mixed truck traffic with a higher percentage of single-unit trucks.
<input type="checkbox"/>	4	(>2%)	Mixed truck traffic with about equal percentages of single-unit and single-trailer...
<input type="checkbox"/>	6	(>2%)	Mixed truck traffic with a higher percentage of single-unit trucks.
<input type="checkbox"/>	9	(>2%)	Mixed truck traffic with about equal percentages of single-unit and single-trailer...
<input type="checkbox"/>	12	(>2%)	Mixed truck traffic with a higher percentage of single-unit trucks.
<input type="checkbox"/>	14	(>2%)	Mixed truck traffic with about equal single-unit and single-trailer trucks.
<input type="checkbox"/>	17	(>25%)	Mixed truck traffic with about equal single-unit and single-trailer trucks.

\* denotes recommended distribution for road category.

OK Cancel

Vehicle Class Distribution

Class	Percent (%)
Class 4	1.3
Class 5	8.5
Class 6	2.8
Class 7	0.3
Class 8	7.6
Class 9	7.4
Class 10	1.2
Class 11	3.4
Class 12	0.6
Class 13	0.3

Project Object Properties

Output Error List



# JPCP - Climate

AASHTOWare Pavement ME Design 2.3.1

Menu Recent Files

Explorer

- Projects
  - TAC Pavement ME Exam...
    - Traffic
      - Single Axle Distrib
      - Tandem Axle Dist
      - Tridem Axle Distrib
      - Quad Axle Distrib
    - Climate
      - JPCP Design Properties
    - Pavement Structure
      - Layer 1 PCC : JPC
      - Layer 2 Non-stabil
      - Layer 3 Subgrade
    - Project Specific Calibration
      - Sensitivity
      - Optimization
      - PDF Output Report
    - Multiple Project Summary
    - Batch Run
    - Tools
    - ME Design Calibration Factors

TAC Pavement ME Exam...:Project TAC Pavement ME Exam...:Traffic\* TAC Pavement ME Exam...:Climate

Summary Hourly climate data

Climate Station

Elevation (ft)  1118

Climate station  PITTSBURGH, PA (

Use single weather station  Create a virtual weather station

Distance (miles)	City	State	Latitude (decimal degrees)	Longitude (decimal degrees)	Elevation (ft)	Description	firstMonth	lastMonth
<input checked="" type="checkbox"/> 0	PITTSBURGH	PA	40.501	-80.231	1118	PITTSBURGH INTL AIRPORT	7/1996	2/2006
<input type="checkbox"/> 19.1	PITTSBURGH	PA	40.355	-79.922	1240	ALLEGHENY COUNTY AIRP...	2/1999	2/2006
<input type="checkbox"/> 31.4	WHEELING	WV	40.176	-80.647	1200	WHEELING OHIO COUNTY ...	4/1998	2/2006
<input type="checkbox"/> 56.9	YOUNGSTOWN..	OH	41.254	-80.674	1172	YOUNGSTOWN-WARREN ...	7/1996	2/2006
<input type="checkbox"/> 61.5	MORGANTOWN	WV	39.643	-79.916	1220	MGTN RGNL-W L B HART F...	1/1999	2/2006
<input type="checkbox"/> 62.5	NEW PHILADEL	OH	40.47	-81.42	890	HARRY CLEVER FIELD AIR...	2/1998	2/2006

Climate Summary

Mean annual air temperature (deg F) 51.9

38.8

459.9

withaw cycles 53

213.9

(deg F) 29.2

(deg F) 33.6

(deg F) 39.8

(deg F) 52.4

Average temperature in May (deg F) 61.1

Average temperature in June (deg F) 68.6

Average temperature in July (deg F) 72.2

Average temperature in August (deg F) 70.8

Average temperature in September (deg F) 64.3

Average temperature in October (deg F) 52.7

Average temperature in November (deg F) 43.9

Average temperature in December (deg F) 32.9

Elevation (ft)

Elevation of the site. Elevation is used to determine the lapse amount (lapse rate is the rate which temperatures...

Mean annual air temperature (deg F)

Error List

Project	Object	Property	Description

Output Error List Compare

# JPCP – Climate

The screenshot shows the LTPP InfoPave Tools web application. At the top, there is a navigation bar with links for 'Feng Ma | Sign Out | My LTPP | Data Bucket (0) | Customer Support | Site Map | Contact Us | About'. Below this is a search bar with a 'Go' button. The main navigation menu includes 'HOME', 'SEARCH', 'MAP', 'DATA', 'ANALYSIS', 'VISUALIZATION', 'TOOLS' (highlighted), 'LIBRARY', 'HELP', 'MY LTPP', and 'NON-LTPP'. The left sidebar contains several filter categories: 'Find Sections' (with icons for search, filter, and help), 'General' (with checkboxes for Age, Experiment Type, Study, Monitoring Status, Section, Location, Maintenance and Rehabilitation, and Roadway Functional Class), 'Structure' (with checkboxes for Surface Type, Base Type, and Subgrade Type), 'Climate' (with checkboxes for Climatic Region, Freezing Index (Annual), Precipitation (Annual), and Temperature (Annual)), 'Traffic' (with checkboxes for Avg. Annual Daily Traffic (AADT) and Avg. Annual Daily Truck Traffic (AADTT)), and 'Performance' (with checkboxes for Deflection (9-kip, wheel path), Fatigue Cracking, and Faulting). The main content area is titled 'MERRA Climate Data for MEPDG Inputs' and shows 'There are 2514 of 2514 sections currently selected.' Below this, there are tabs for 'By Section' and 'By Map'. A search box for 'Search Location' is present, followed by a map of the United States and surrounding regions. The map includes state abbreviations and labels for 'Canada', 'Mexico', 'North Atlantic Ocean', 'Gulf of Mexico', and 'Caribbean Sea'. A 'Selected Location' field is at the bottom of the map area.

LTPP InfoPave: Tools

Feng Ma | Sign Out | My LTPP | Data Bucket (0) | Customer Support | Site Map | Contact Us | About

HOME SEARCH MAP DATA ANALYSIS VISUALIZATION **TOOLS** LIBRARY HELP MY LTPP NON-LTPP

Find Sections

**General**

- Age (Since Original Construction)
- Experiment Type
- Study
- Monitoring Status
- Section
- Location
- Maintenance and Rehabilitation
- Roadway Functional Class

**Structure**

- Surface Type
- Base Type
- Subgrade Type

**Climate**

- Climatic Region
- Freezing Index (Annual)
- Precipitation (Annual)
- Temperature (Annual)

**Traffic**

- Avg. Annual Daily Traffic (AADT)
- Avg. Annual Daily Truck Traffic (AADTT)

**Performance**

- Deflection (9-kip, wheel path)
- Fatigue Cracking
- Faulting

MERRA Climate Data for MEPDG Inputs

There are 2514 of 2514 sections currently selected.

By Section By Map

Please select the location from map or type the address in search box below:

Search Location

Map

Canada Hudson Bay

United States

Mexico Gulf of Mexico Caribbean Sea

North Atlantic Ocean

Google

Map data ©2016 Google, INEGI Terms of Use

Selected Location

# JPCP – Characterizing Pavement Structure

AASHTOWare Pavement ME Design 2.3.1

Menu Recent Files

Progress Stop All Analysis

Explorer

- Projects
  - TAC Pavement ME Exam...
    - Traffic
      - Single Axle Distrib
      - Tandem Axle Dist
      - Tridem Axle Distr
      - Quad Axle Distrib
    - Climate
    - JPCP Design Propert
    - Pavement Structure
      - Layer 1 PCC : JPC
      - Layer 2 Non-stabil
      - Layer 3 Subgrade
    - Project Specific Calibr
    - Sensitivity
    - Optimization
    - PDF Output Report
  - Multiple Project Summary
  - Batch Run
  - Tools
  - ME Design Calibration Factors

TAC Pavement ME Exam...Project

General Information

Design type: New Pavement

Pavement type: Jointed Plain Concrete

Design life (years): 35

Pavement construction: June 2020

Traffic opening: Septen 2020

Special traffic loading for flexible pavements

+ Add Layer - Remove Layer

Performance 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

Layer 1 PCC:JPCP Default

Cementitious material content (lb/yd<sup>3</sup>)  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)**

> **Identifiers**

Approver  
Person who approved use of this object/material/project

Error List

Project	Object	Property	Description

Output Error List Compare

# JPCP – Pavement Structure – PCC Materials

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

**Let's Break it Down**

# JPCP – Pavement Structure – PCC Materials

✓ PCC		
Poisson's ratio	<input checked="" type="checkbox"/>	0.2
Thickness (in)	<input checked="" type="checkbox"/>	11
Unit weight (pcf)	<input checked="" type="checkbox"/>	150

- 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<sup>3</sup> (default)
  - Typical range 140-155 lb/ft<sup>3</sup>
  - (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<sup>-6</sup>)  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<sup>-6</sup>/°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 <sup>3</sup> )	<input checked="" type="checkbox"/> 525
Cement type	Type I (1)
Water to cement ratio	<input checked="" type="checkbox"/> 0.42
Curing method	Curing Compound
Reversible shrinkage (%)	<input checked="" type="checkbox"/> 50
> PCC zero-stress temperature (deg F)	<input type="checkbox"/> Calculated
Time to develop 50% of ultimate shrinkage (days)	<input checked="" type="checkbox"/> 35
> Ultimate shrinkage (microstrain)	<input type="checkbox"/> 588.5 (calculated)

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

# JPCP – Pavement Structure – PCC Materials

✓ <b>Mix</b>	
Aggregate type	Limestone (1)
Cementitious material content (lb/yd <sup>3</sup> )	<input checked="" type="checkbox"/> 525
Cement type	Type I (1)
Water to cement ratio	<input checked="" type="checkbox"/> 0.42
Curing method	Curing Compound
Reversible shrinkage (%)	<input checked="" type="checkbox"/> 50
> PCC zero-stress temperature (deg F)	<input type="checkbox"/> Calculated
Time to develop 50% of ultimate shrinkage (days)	<input checked="" type="checkbox"/> 35
> Ultimate shrinkage (microstrain)	<input type="checkbox"/> 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 <sup>3</sup> )	<input checked="" type="checkbox"/> 525
Cement type	Type I (1)
Water to cement ratio	<input checked="" type="checkbox"/> 0.42
Curing method	Curing Compound
Reversible shrinkage (%)	<input checked="" type="checkbox"/> 50
> PCC zero-stress temperature (deg F)	<input type="checkbox"/> Calculated
Time to develop 50% of ultimate shrinkage (days)	<input checked="" type="checkbox"/> 35
> Ultimate shrinkage (microstrain)	<input type="checkbox"/> 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  
PCC strength and modulus

Level:3 Rupture(550) Modulus(4000000)

PCC strength input level

28-Day PCC modulus of rupture (psi)

28-Day PCC compressive strength (psi)

28-Day PCC elastic modulus (psi)

- Strength
- Modulus (E)
- Mixture dependent. Multiple ways to input. MOR = 500 -750 psi  $f'c = 3000 - 5500$  psi
- Mixture dependent. Typically ranges from 3.2 –  $5.0 \times 10^6$  psi (Estimations can be used\*)

\* <http://apps.acpa.org/applibrary/StrengthConverter/>

# JPCP – Pavement Structure – Support Layers

The screenshot displays the AASHTOWare Pavement ME Design 2.3.1 software interface. The main window is titled "TAC Pavement ME Exam...:Project\*" and shows the following parameters:

- Design type: New Pavement
- Pavement type: Jointed Plain Concrete
- Design life (years): 35
- Pavement construction: June 2020
- Traffic opening: Septen 2020

A "Performance Criteria" table is visible, showing the following data:

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

A "Material Layer Selection" dialog box is open, showing the following options:

- Insert layer below: Layer 1 PCC: JPCP Default
- Layer type: Non-stabilized Base (4)
- Select material type:  Select from default list

The "Select material type" list includes the following options:

- A-1-a.xml
- A-1-b.xml
- A-2-4.xml
- A-2-5.xml
- A-2-6.xml
- A-2-7.xml
- A-3.xml
- Cold recycled asphalt - RAP (includes millings).xml
- Cold recycled asphalt - RAP pulverized in place.xml
- Crushed gravel.xml
- Crushed stone.xml
- Permeable aggregate.xml
- River-run gravel.xml

The main window also shows a "Pavement Structure" section with three layers: Layer 1 PCC: JPCP Default, Layer 2 Non-stabilized Base, and Layer 3 Subgrade: A-5. Each layer has a corresponding "Click here to edit" link and a small image representing the layer's appearance.

# JPCP – Design Properties

AASHTOWare Pavement ME Design 2.3.1

Menu: New, Open, Save As, Save, Save All, Close, Exit, Run, Batch, Import, Export, Undo, Redo, Help

Progress: Stop All Analysis

Explorer: TAC Pavement ME Exam...:Project, TAC Pavement ME Exam...:Traffic\*, TAC Pavement ME Exam...:Climate

General Information

Design type: New Pavement

Pavement type: Jointed Plain Concrete

Design life (years): 35

Pavement construction: June 2020

Traffic opening: Septen 2020

Special traffic loading for flexible pavements

Performance Criteria

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

JPCP Design Properties

JPCP Design

- PCC surface shortwave absorptivity 0.85
- > Dowelled 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 (deg)  -10
- Sealant type Preformed
- > Tied shoulders Not tied
- > Widened slab Not widened

Identifiers

PCC surface shortwave absorptivity

This dimensionless parameter defines the fraction of available solar energy absorbed by the PCC surface. Use the default value of 0.85.  
Minimum:0.5  
Maximum:1

Click here to edit Layer 1 PCC: JPCP Default

Click here to edit Layer 2 Non-stabilized Base

Click here to edit Layer 3 Subgrade - A-5

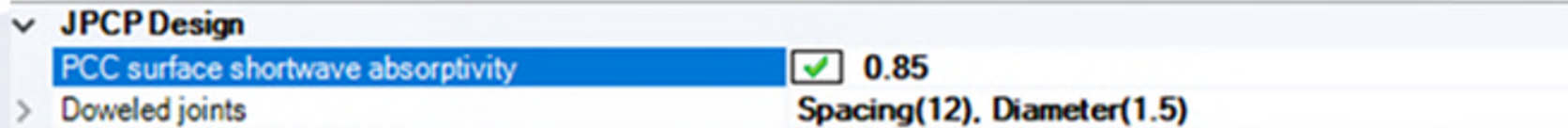
Error List

# JPCP – Design Properties

✓ JPCP Design	
PCC surface shortwave absorptivity	<input checked="" type="checkbox"/> 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 (deg)	<input checked="" type="checkbox"/> -10
Sealant type	Prefomed
> Tied shoulders	Not tied
> Widened slab	Not widened

**Let's Break it Down**

# JPCP – Design Properties



- SSA
- Doweled Joints
- Diameter
- Spacing
- 0.85 (Default and semi-constant)
- Typically used if thickness > 8 in
- 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
- 12 inches is most common

# JPCP – Design Properties

Erodibility index

Fairly erodible (4)

> PCC-base contact friction

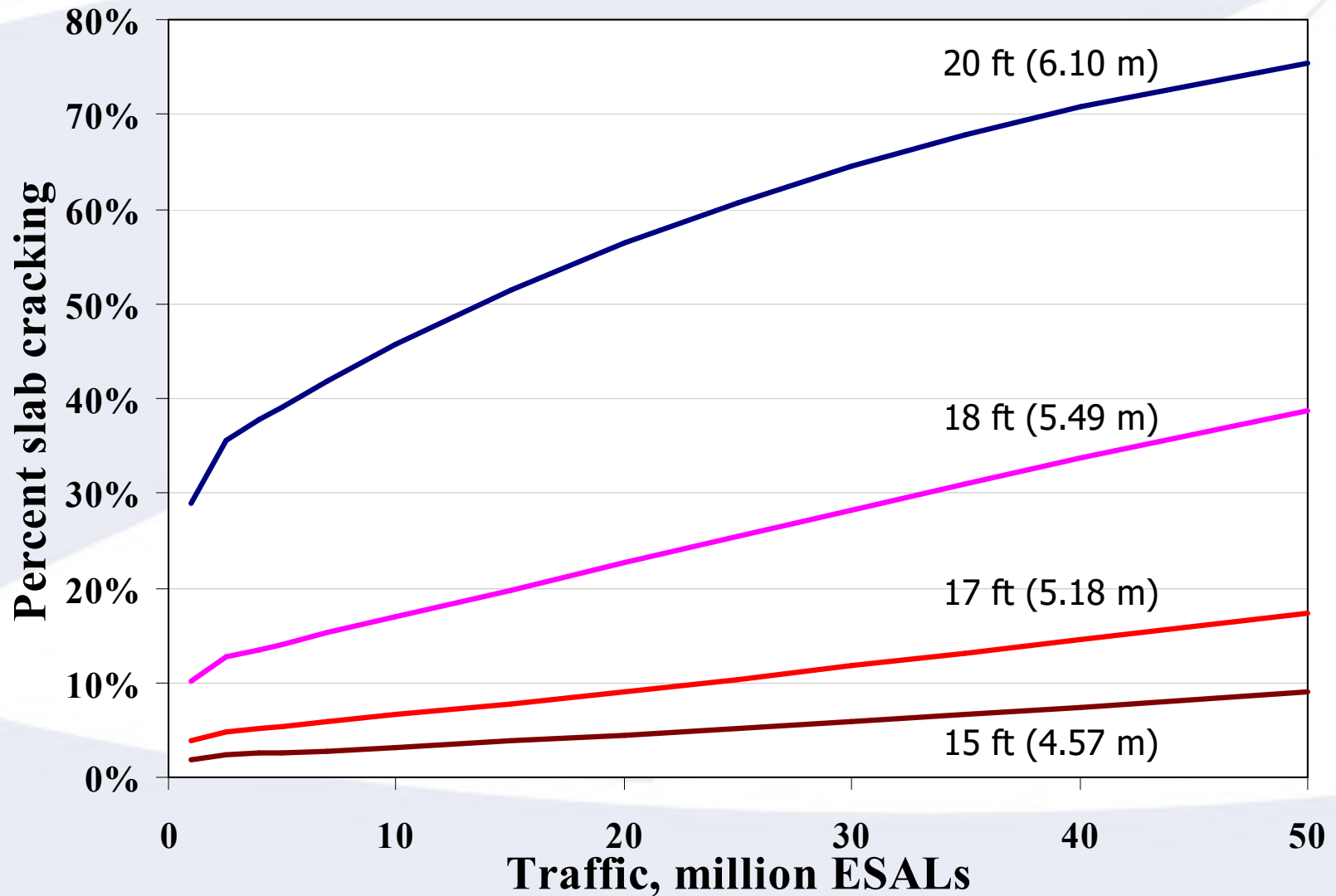
Full friction with friction loss at (240) months

> PCC joint spacing (ft)

15

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

# Effects of Joint Spacing





# JPCP – Design Properties

Permanent curl/warp effective temperature difference (deg)	<input checked="" type="checkbox"/> -10
Sealant type	Preformed
> Tied shoulders	Not tied
> Widened slab	Not widened

- Curl/Warp Temp. ● -10°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 –  $5.5 \times 10^{-6}/^{\circ}\text{F}$  ( $9.9 \times 10^{-6}/^{\circ}\text{C}$ )
  - Limestone Agg
  - Cementitious – 525 lb/cy ( $311 \text{ kg/m}^3$ )
  - 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)

# 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

# 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

# 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

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December 2011

[http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP01-47\\_FR.pdf](http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP01-47_FR.pdf)

# Other Sensitivity Reports

	<b>Pitt</b> (Mu et al. 2011)	<b>UW-Madison</b> (Li and Cramer 2012)	<b>OK State</b> (Ley et al. 2012)	<b>Iowa State</b> (Ceylan et al. 2013)	<b>Sensitivity in Common</b>
<b>Transverse Cracking</b>	<ul style="list-style-type: none"> <li>• Climate</li> <li>• Jt spacing</li> <li>• Base type</li> <li>• Strength</li> <li>• Thickness</li> <li>• Traffic</li> <li>• Edge support</li> <li>• CTE</li> </ul>	<ul style="list-style-type: none"> <li>• Thickness</li> <li>• Strength</li> <li>• CTE</li> <li>• Traffic                             <ul style="list-style-type: none"> <li>➢ wheel location</li> <li>➢ Traffic wander</li> <li>➢ AADTT</li> <li>➢ Truck%</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• CTE</li> <li>• Strength</li> <li>• Asphalt base</li> <li>• Climate</li> <li>• Unit weight</li> <li>• Poisson's</li> <li>• Thermal conductivity</li> </ul>	<ul style="list-style-type: none"> <li>• Strength</li> <li>• Thickness</li> <li>• Jt spacing</li> <li>• Width</li> <li>• CTE</li> <li>• Unit weight</li> <li>• Poisson's</li> <li>• Thermal conductivity</li> </ul>	<ul style="list-style-type: none"> <li>• Strength (-)</li> <li>• Thickness (-)</li> <li>• Jt spacing (+)</li> <li>• Slab width (-)</li> <li>• CTE (+)</li> <li>• Traffic (+)</li> <li>• Edge support (-)</li> <li>• Climate (n/a)</li> <li>• Base support (n/a)</li> </ul>
<b>Joint Faulting</b>	<ul style="list-style-type: none"> <li>• Dowel Dia.</li> <li>• Thickness</li> <li>• CTE</li> <li>• Base Erod.</li> <li>• Traffic</li> <li>• Wet days</li> <li>• Jt spacing</li> <li>• CTE</li> </ul>	<ul style="list-style-type: none"> <li>• CTE</li> <li>• Dowel Dia.</li> </ul>	<ul style="list-style-type: none"> <li>• Edge support</li> <li>• Dowel Dia.</li> <li>• CTE</li> <li>• Thickness</li> <li>• Jt spacing</li> </ul>	<ul style="list-style-type: none"> <li>• Dowel Dia.</li> <li>• CTE</li> <li>• Base</li> <li>• Subgrade</li> <li>• Climate</li> </ul>	<ul style="list-style-type: none"> <li>• Dowel Dia. (-)</li> <li>• CTE (+)</li> <li>• Base Erod. (+)</li> <li>• Traffic (+)</li> <li>• Jt spacing (+)</li> <li>• Thickness (n/a)</li> <li>• Climate (n/a)</li> </ul>

**IRI** = Function (cracking, faulting, spalling, site factor)

## Notes:

1. Grey indicates semi-constant values
2. (+)/(-) indicates the sign of the tangential slope of  $\Delta$  (Distress) /  $\Delta$  (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!?!

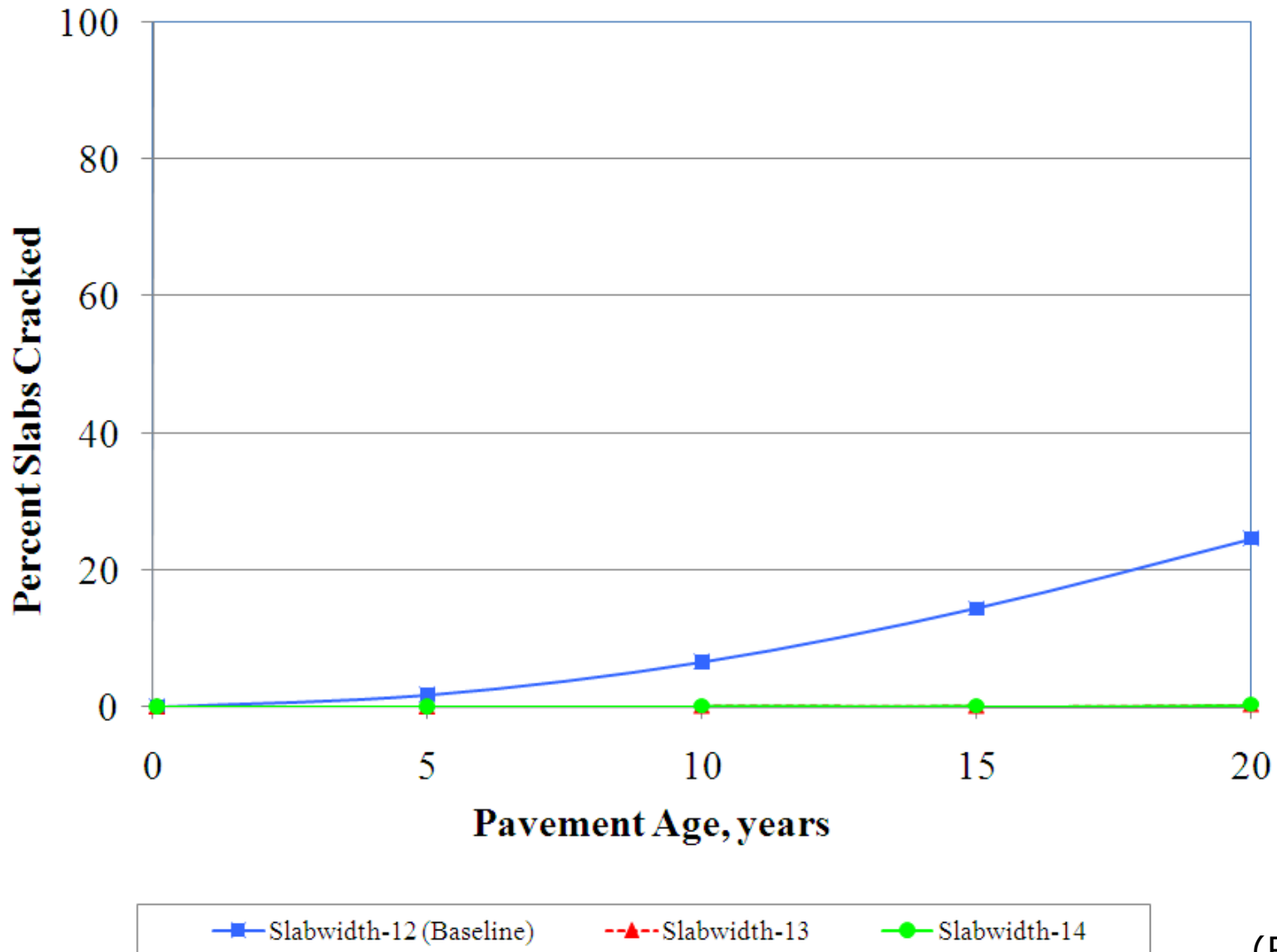
# Summary

- 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  $\Delta$  (Distress) /  $\Delta$  (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.

# Outline

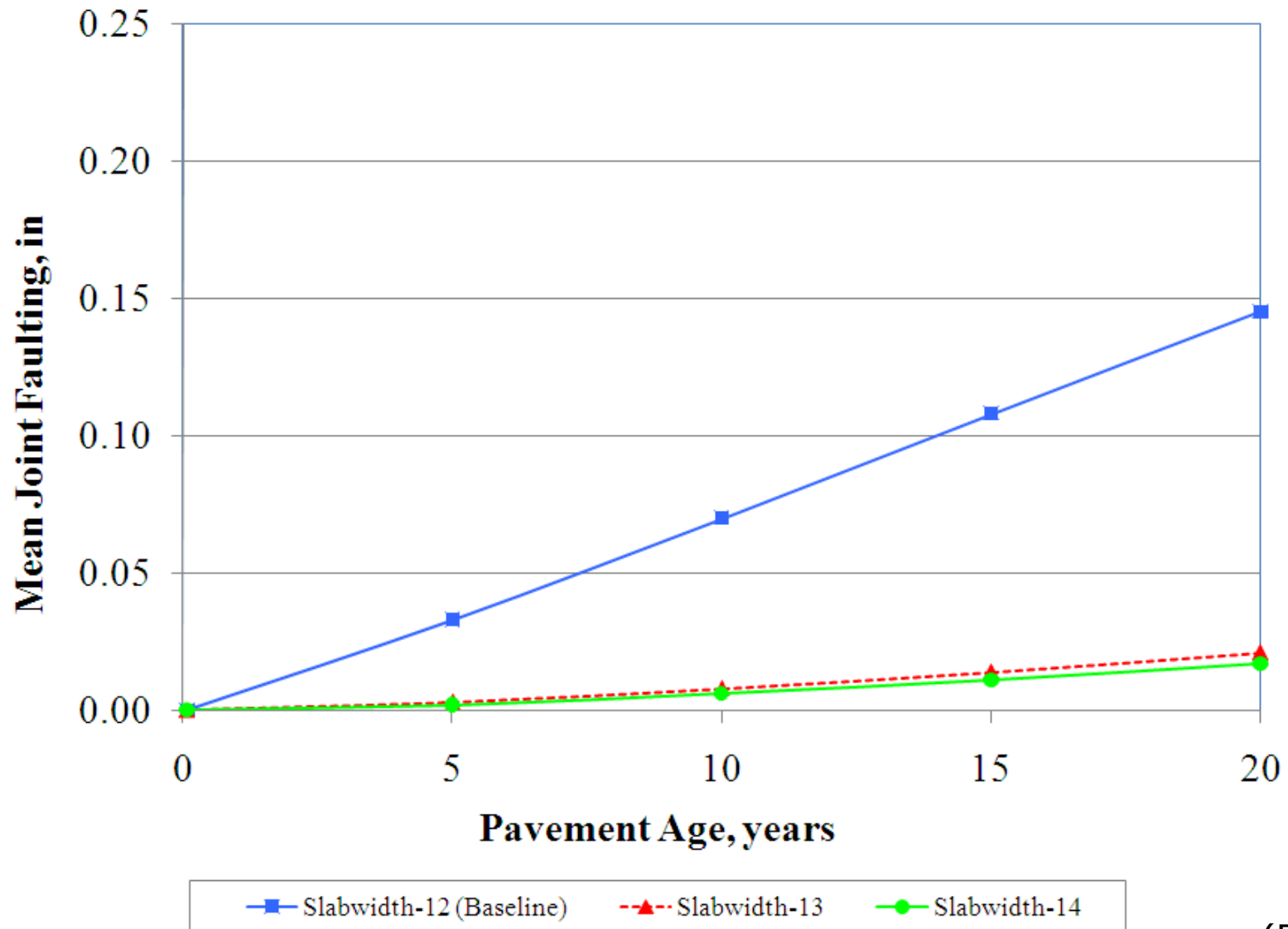
- Review of Pavement ME's Concrete Design Options
- JPCP Design Input Walkthrough
- Example Runs and How to Interpret Them
- Review of Critical Inputs
- Engineering Solutions
- ME Calibration Impact
- Additional Resources

# Engineering Solutions – Widened Slab Example



(Rao, 2018)

# Engineering Solutions – Widened Slab Example



(Rao, 2018)

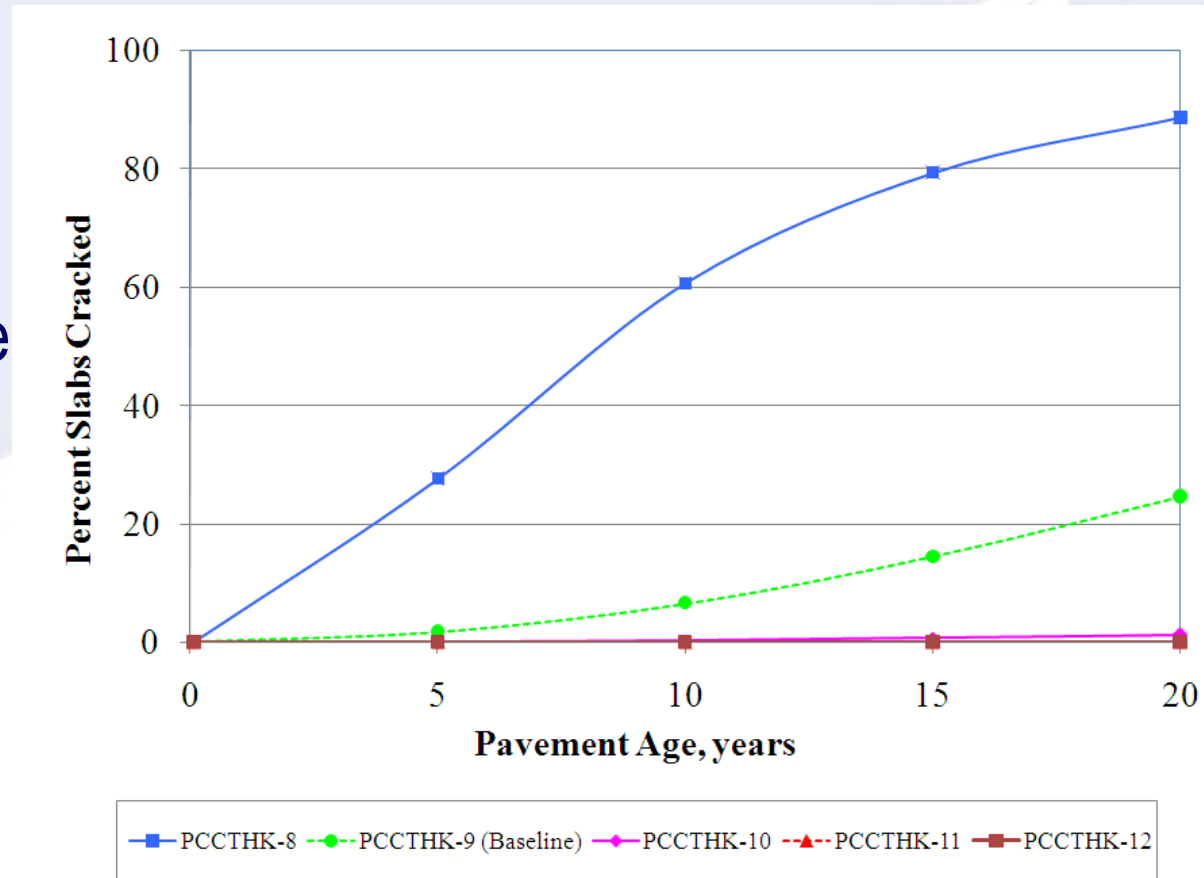
# Engineering Solutions – Widened Slab Example

- 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



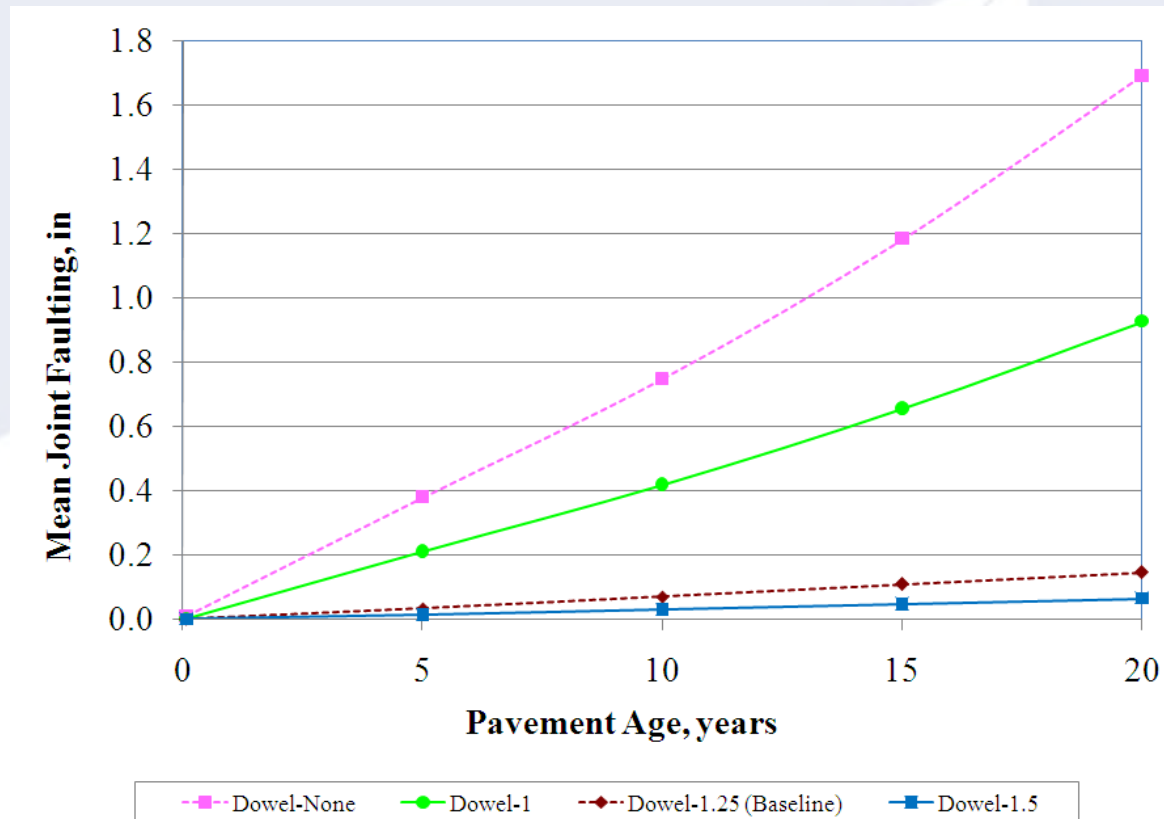
# Engineering Solutions – Base/Subbase Example

- 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.



# 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.





# 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.



# Outline

- Review of Pavement ME's Concrete Design Options
- JPCP Design Input Walkthrough
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- Review of Critical Inputs
- Engineering Solutions
- ME Calibration Impact
- Additional Resources

# Calibration

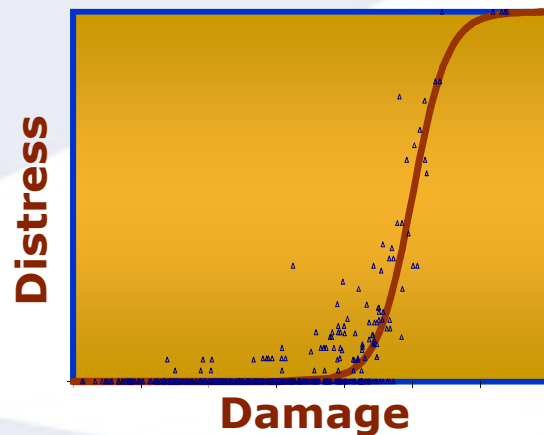
## LTPP – Long-Term Pavement Performance



AASHTO Road Test Site is just 1 push pin on this map!

# 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 2<sup>nd</sup> 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



**MEPDG 0.7**  
**2004**

**MEPDG 1.0 - Pavement ME 2.1**  
**2007**

**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?

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

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

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

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

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

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

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

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

$n$  = traffic path.

The damage increments were discussed previously in this section.

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

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

where:

- $N_{i,j,k,l,m,n}$  = allowable number of load applications at condition  $i, j, k, l, m, n$
- $MR$  = PCC modulus of rupture at age  $i$ , psi
- $\sigma_{i,j,k,l,m,n}$  = 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:

$$FD'_j = P(\text{COV}_j) \cdot FD_j \quad (3.4.11)$$

The probability of coverage is determined assuming normal distribution.

$$\text{NORMDIST} = \frac{1}{SD_{w,j} \sqrt{2\pi}} e^{-\frac{1}{2} \left( \frac{w}{SD_{w,j}} \right)^2} \quad (3.4.12)$$

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

3.4.64



# Pavement ME Allows Agencies To Develop And Use Local Calibration Coefficients

AASHTOWare Pavement ME Design Version 2.2 Build 2.2.4 (Date: 08/11/2015)

Menu

Recent Files

Explorer

Project1:Project Project1:Traffic\* Project1:Single Project1:Climate RigidNew

Category	Item	Value
PCC Cracking	PCC Cracking C1	2
	PCC Cracking C2	1.22
	PCC Cracking C4	0.52
	PCC Cracking C5	-2.17
	PCC Reliability Cracking Standard Deviation	$3.5522 * Pow(CRACK, 0.3415) + 0.75$
	PCC Faulting	
PCC Faulting	PCC Faulting C1	0.595
	PCC Faulting C2	1.636
	PCC Faulting C3	0.00217
	PCC Faulting C4	0.00444
	PCC Faulting C5	250
	PCC Faulting C6	0.47
	PCC Faulting C7	7.3
	PCC Faulting C8	400
PCC Reliability Faulting Standard Deviation	$0.07162 * Pow(FAULT, 0.368) + 0.00806$	
PCC IRI-CRCP	PCC IRI C1	3.15
	PCC IRI C2	28.35
	PCC IRI Initial CRCP Std. Dev.	5.4
PCC IRI-JPCP	PCC IRI Initial JPCP Std. Dev.	5.4
	PCC IRI J1	0.8203
	PCC IRI J2	0.4417
	PCC IRI J3	1.4929
PCC Punchout	PCC IRI J4	25.24
	PCC CRCP C1	2

Approver  
Person who approved use of this object/material/project

Save Changes to Calibration    Update Open Projects    Restore Calibration Defaults

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

# Local Calibration Examples

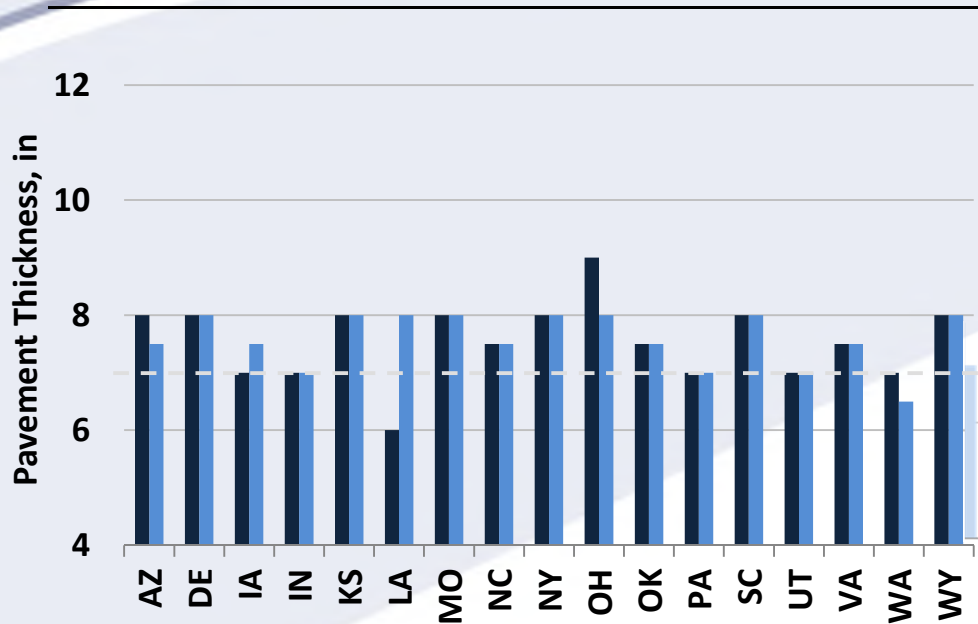
- Indiana DOT:
  - Changed JPCP IRI J3 from 1.4929 to 1.05 because it was too sensitive to it
- Ohio DOT:
  - Changed JPCP IRI calibrations

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

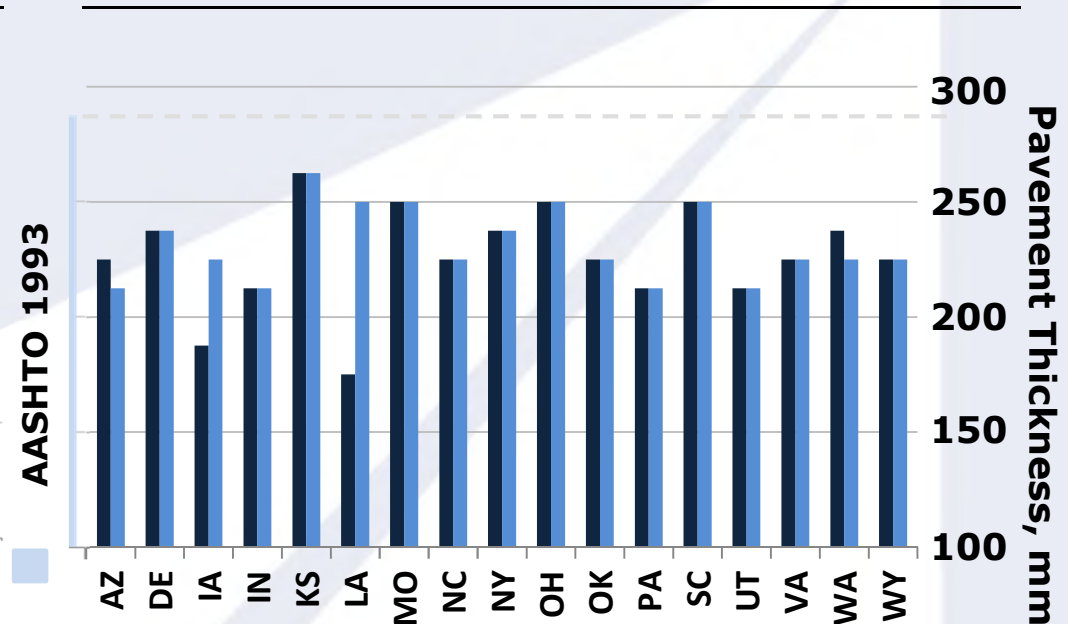
- Many states at this point are working on or have completed local calibrations.

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

Low Volume Application



High Volume Application



■ Pavement ME\_LC

■ Pavement ME\_NC

■ AASHTO 1993


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

# 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



Submitted to:  
Ready Mixed Concrete Association of Ontario & Cement Association of Canada

January 18, 2011



4401 Eglinton Avenue West, Suite # 108 | Toronto, Ontario M3J 5P8 | transportation@ara.com

		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 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
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
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# 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](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](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](http://www.in.gov/indot/design_manual/files/Ch304_2013.pdf)

- Arizona: [https://apps.azdot.gov/ADOTLibrary/publications/project\\_reports/PDF/AZ606.pdf](https://apps.azdot.gov/ADOTLibrary/publications/project_reports/PDF/AZ606.pdf)

- Virginia: [http://www.viriniadot.org/VDOT/Business/asset\\_upload\\_file108\\_3638.pdf](http://www.viriniadot.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](http://crcpavement.org) for more!

August 2011

## CONTINUOUSLY REINFORCED CONCRETE PAVEMENT

Design & Construction Guidelines



U.S. Department of Transportation  
Federal Highway Administration



## Continuously Reinforced Concrete Pavement: Design Using the AASHTOWare Pavement ME Design Procedure

PUBLICATION NO. FHWA-HF-13-025

APRIL 2013



U.S. Department of Transportation  
Federal Highway Administration  
Office of Asset Management,  
Preservation, and Construction  
1200 New Jersey Avenue, SE  
Washington, DC 20590

August 2016

## CONTINUOUSLY REINFORCED CONCRETE PAVEMENT MANUAL

Guidelines for Design, Construction,  
Maintenance, and Rehabilitation



U.S. Department of Transportation  
Federal Highway Administration

FHWA-HF-16-026

Rasmussen et al. (2011)

Roesler & Hiller (2013)

Roesler et al. (2016)



# THANK YOU!

## Questions?



Main Website | [acpa.org](http://acpa.org)

Free Apps | [apps.acpa.org](http://apps.acpa.org)

Resources | [resources.acpa.org](http://resources.acpa.org)

Your Local Contact | [local.acpa.org](http://local.acpa.org)

Pavement Design | [PavementDesigner.org](http://PavementDesigner.org)

Jim Powell, P.E.

Executive Director

NW Chapter

*American Concrete Pavement  
Association*

[jim@nw pavement.com](mailto:jim@nw pavement.com)

360-951-1463