Improved Performance of JPCP Through a Better Awareness of Plastic Shrinkage and Drying Shrinkage

Transportation Forum

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February 5th, 2014

Shrinkage

- Plastic shrinkage cracking
  - Occurs in fresh concrete
  - Rate of evaporation exceeds surface water produced by bleeding
- Drying shrinkage
  - Effects slab shape
  - Influences fatigue stress

Approach

- Review
  - construction practices
  - specifications
- Lab study

Finishing

Wet burlap drag micro texture

Excess surface water added

Wet burlap drag micro texture

Excess surface water added

Finishing

- Excess surface water worked into surface
- Micro texture removed by finishers

Excess surface water

Increases surface w/cm

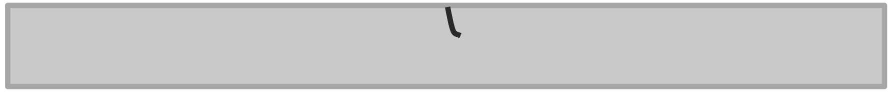
Plastic shrinkage cracking

Decreases durability of wearing surface

Plastic shrinkage cracking

- Effect on performance
  - Decreases surface durability
  - Potentially develop full depth if in central portion of the slab

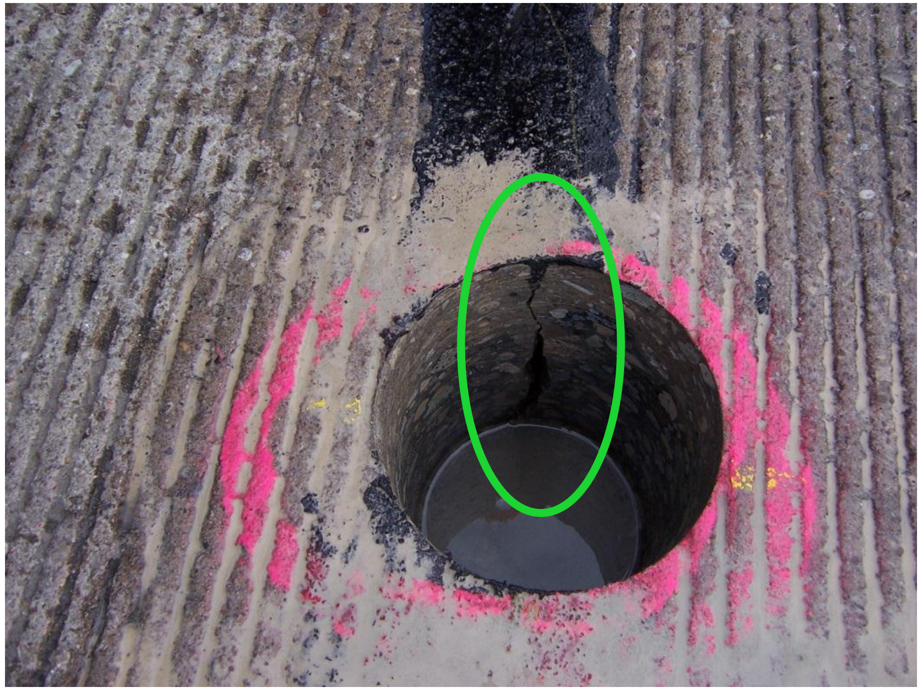
Top View



Side View

Full depth cracking

I-80 in Clinton County, PA



Plastic shrinkage cracking

I-80 in Clinton County, PA

(Crack has been digitally enhanced)

On core surface

(Cracks have been digitally enhanced)

WO12: 4 out of 6 projects exhibited plastic shrinkage cracking

Polishing/erosion

I-80

Vanport Limestone

SR-22

Recommendations

- Eliminate soaked burlap
- Texture after finishing
- Other micro texture options

Astroturf drag

Broom

Resulting texture

Curing

Curing compound application

Application with hand wand

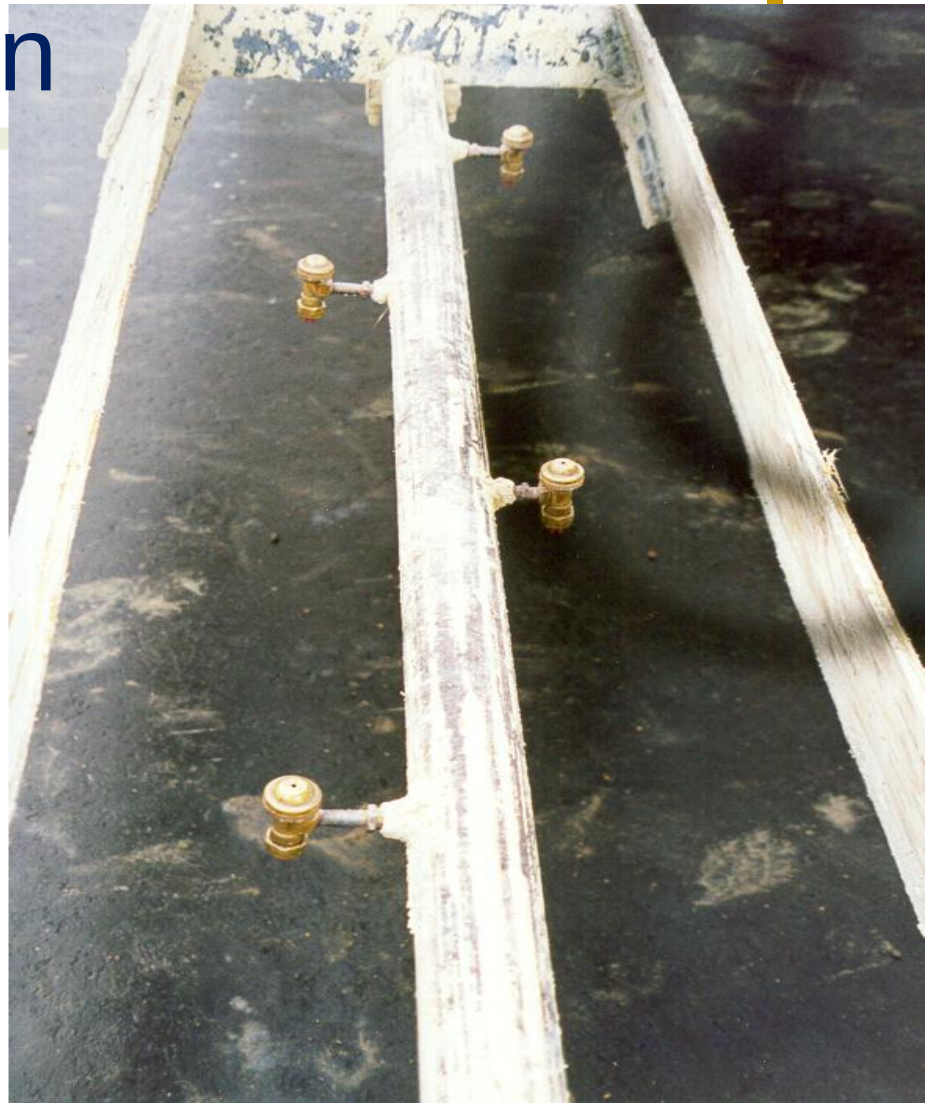
Nonuniform

Curing compound application

PennDOT specification requires curing cart

More uniform

Curing compound application



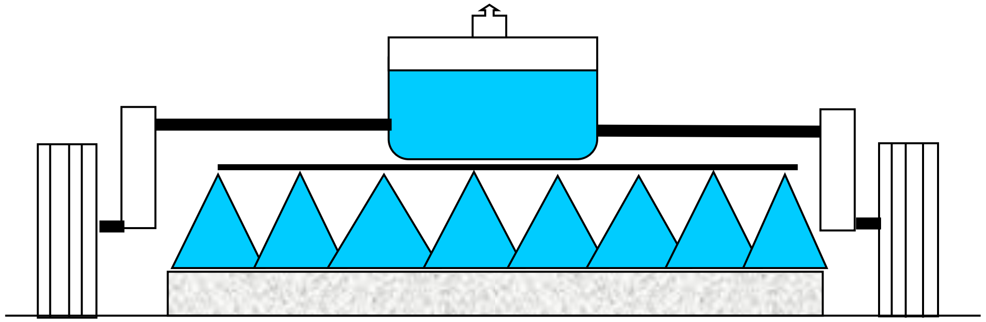
Curing compound application

- Nozzles must direct cure from 2 different lateral directions

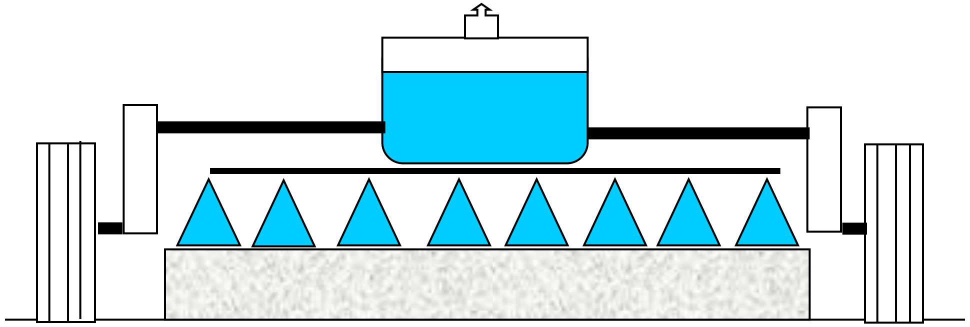
or….

- 2 sets of nozzles along 2 traverse lines, each line capable of complete coverage

Coverage



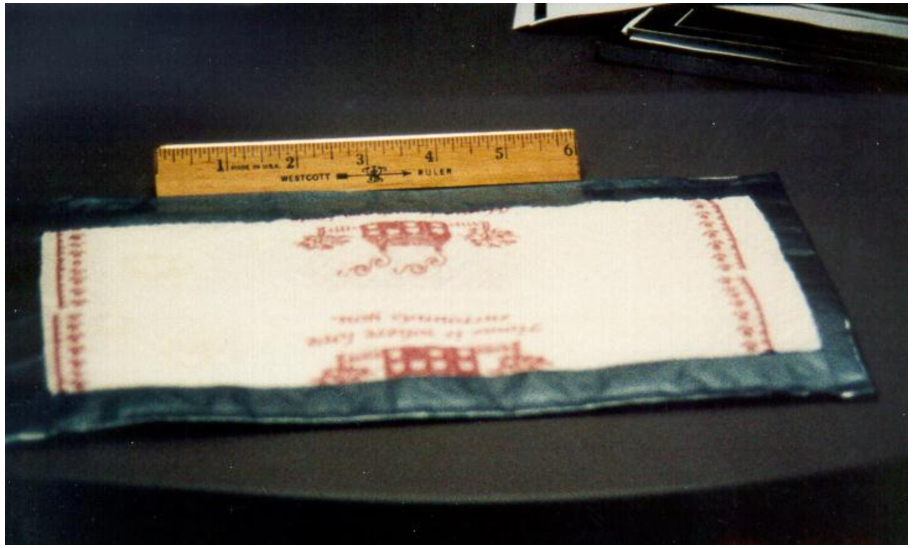
8-in PCCP



10-in PCCP

Application rate

Measured: **220 sq ft/ gallon**



PA spec.: **150 sq ft/ gallon**

Manufacturer's recommendations: **200 sq ft/ gallon**

Cart speed

$$\text{Mph} = \frac{0.13636 \;\; \text{GPM}}{\text{GPF} \times \text{W}}$$

Mph = miles per hour
GPM= gal. per minute per nozzle
GPF = gal. per ft^2
W = nozzle spacing (in)

Example: 8004 nozzle @ 40 psi pump pressure ⟹ **0.45 mph (or 2400 ft/hr)**

Curing compound storage

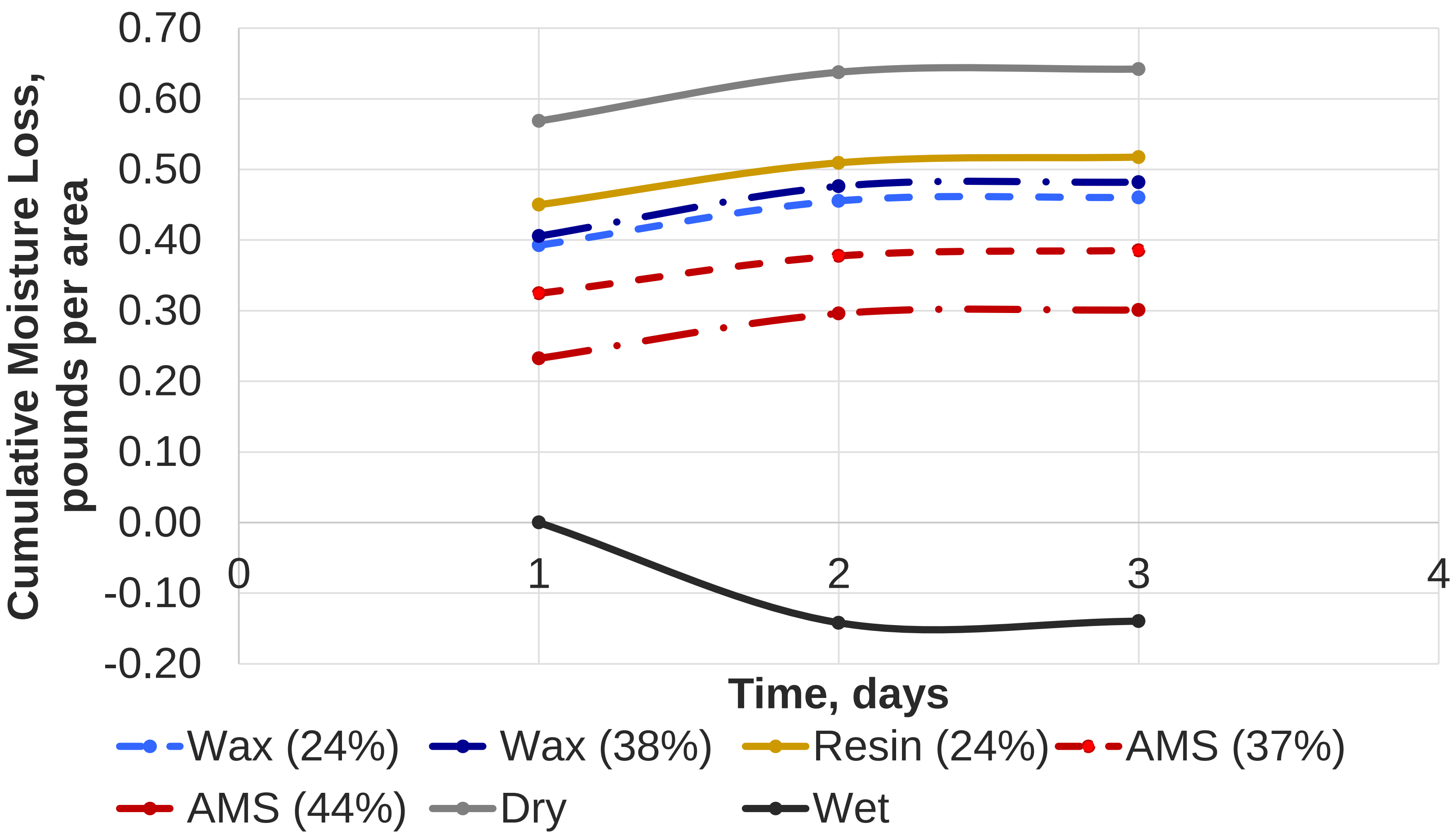
- Limit shelf life (1 yr from manufactured date)
  - Manufacturers recommendation
  - Don’t allow to freeze

Effectiveness of curing compounds

- Variables considered
  - Wax vs resin
  - Resin type (Poly alpha methylstyrene (AMS), other)
  - % solids
- Parameters measured
  - Moisture loss
  - Strength
  - Permeability

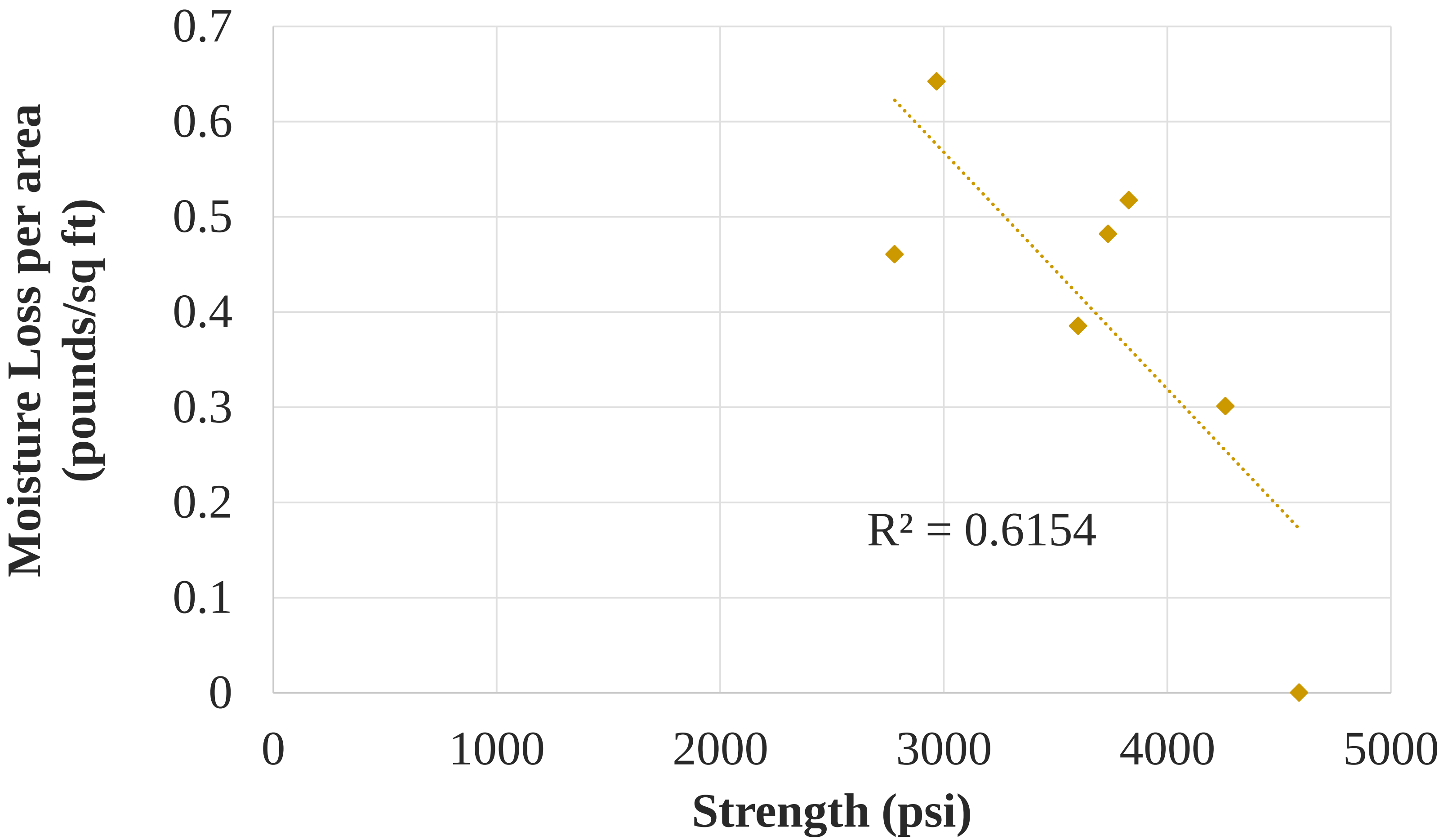
Moisture loss

Moisture loss, 3-day

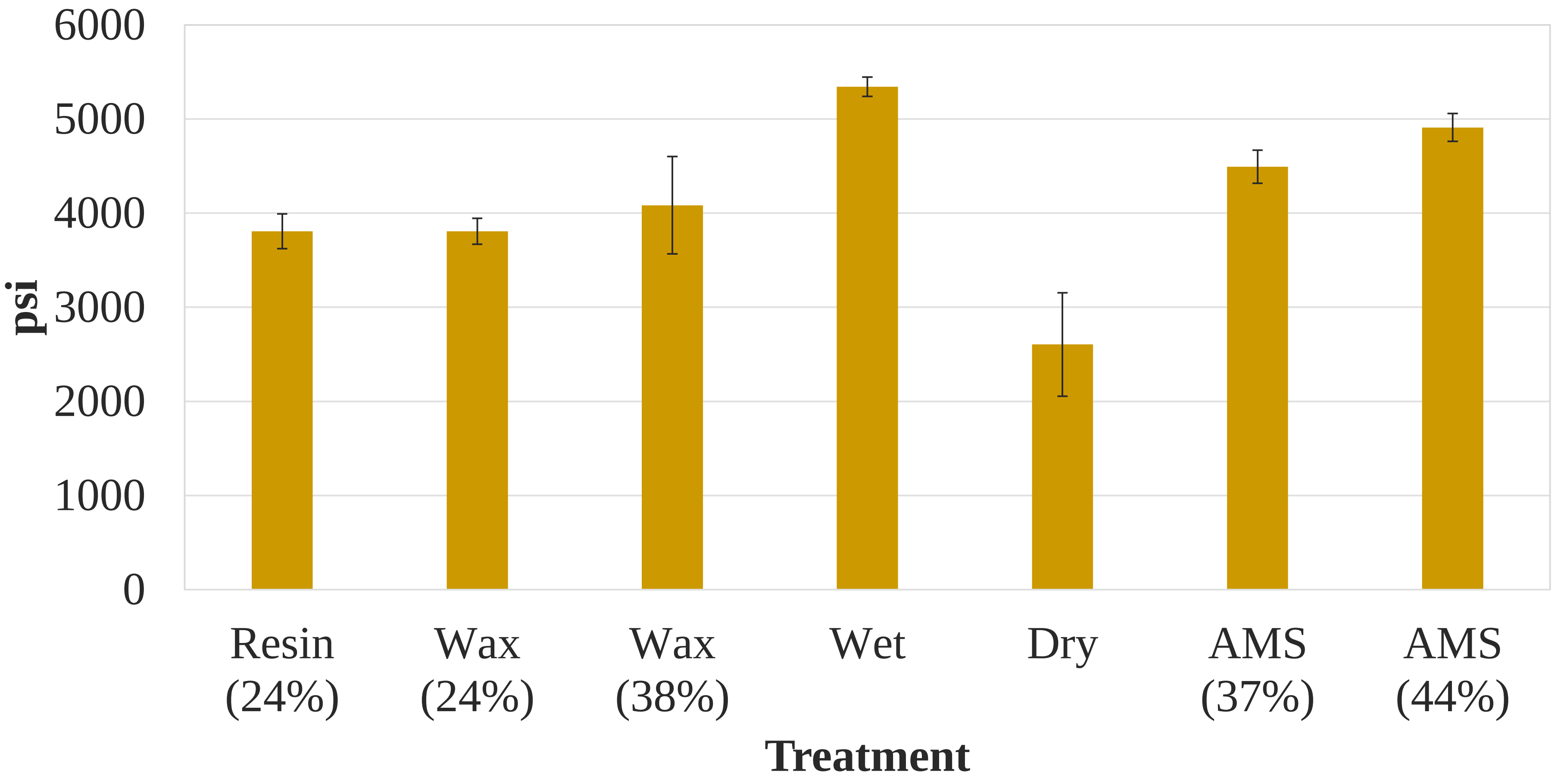


Performance

Compression strength, 3-day



Compression strength, 7-day



Recommendations- Curing

- 44% Poly alpha methylstyrene

Poly alpha methylstyrene requirements	
Total solids (% by weight)	42 min
% reflectance in 72 hours	65 min
Loss of water in 24 hrs, lb/sf	0.03 max
Loss of water in 72 hrs, lb/sf	0.08 max
VOC content, lb/gal	2.93 max
Infrared spectrum, vehicle	100% alpha methylstyrene

Mix design

Criteria	Pennsylvania
Max. w/c ratio	0.47
Max cement content	752 lb/cyd

4 PennDOT Projects evaluated in 2011:

w/cm =0.45, 0.47, 0.49 and 0.46

Min. cement content (600 lbs) and w/c ratio (0.40) to increase durability and decrease shrinkage

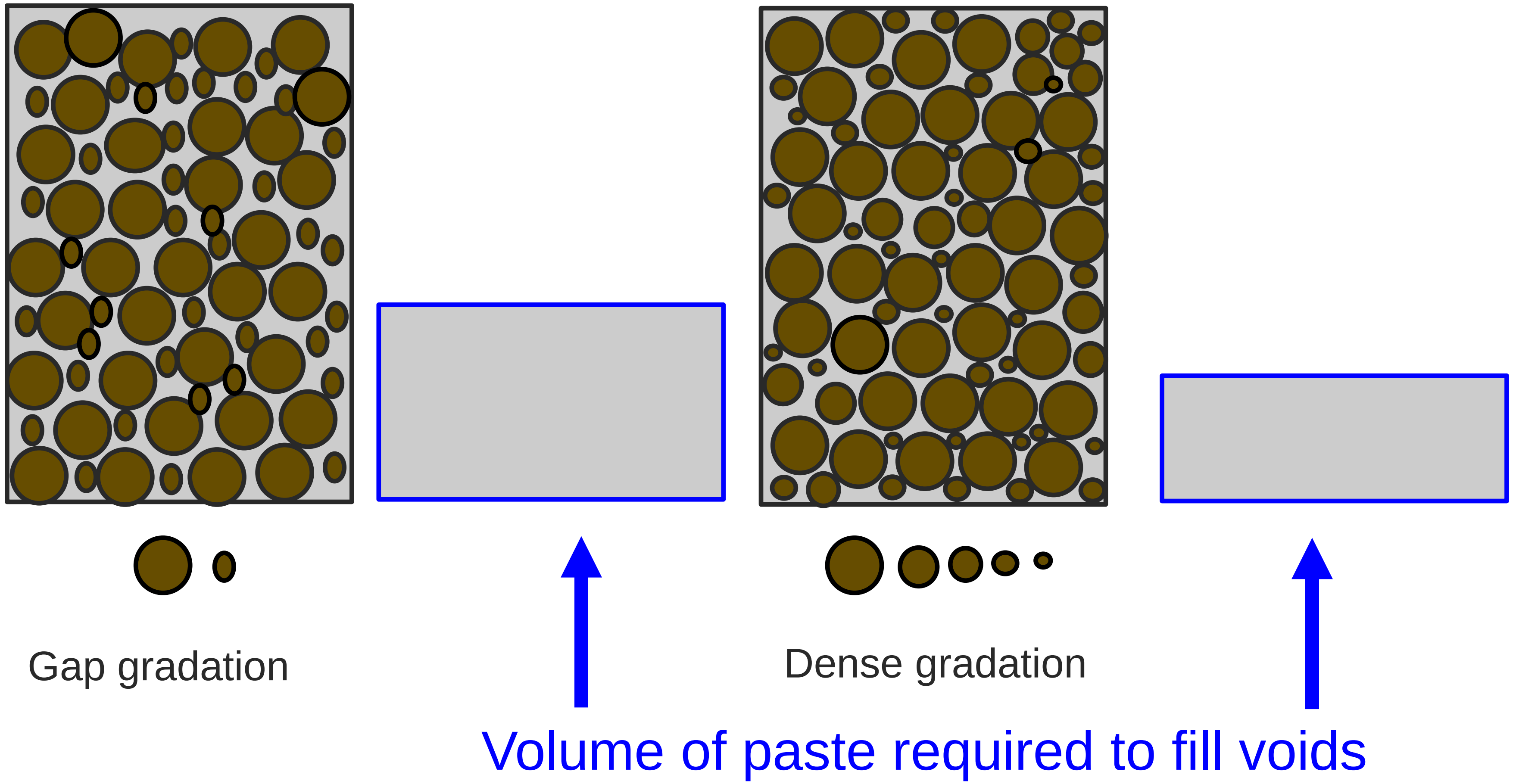
Coarse aggregate gradation

Sieve	MN	PA
1 ½ in	100	100
1 ¼ in	95-100	
1 in		95-100
¾ in	55-85	
½ in		35-60
3/8 in	20-45	
No. 4	0-7	0-10
No. 8		0-5

Specification allows for gap gradation

- Higher paste demand
- Segregation

Cement demand



Segregation

SR 202
Chester county, PA

SR 22
Murrysville, PA

I-79
Washington county, PA

Observed frequently for WO12

Coarseness factor chart

Zone I: Coarse gap-graded tends to segregate

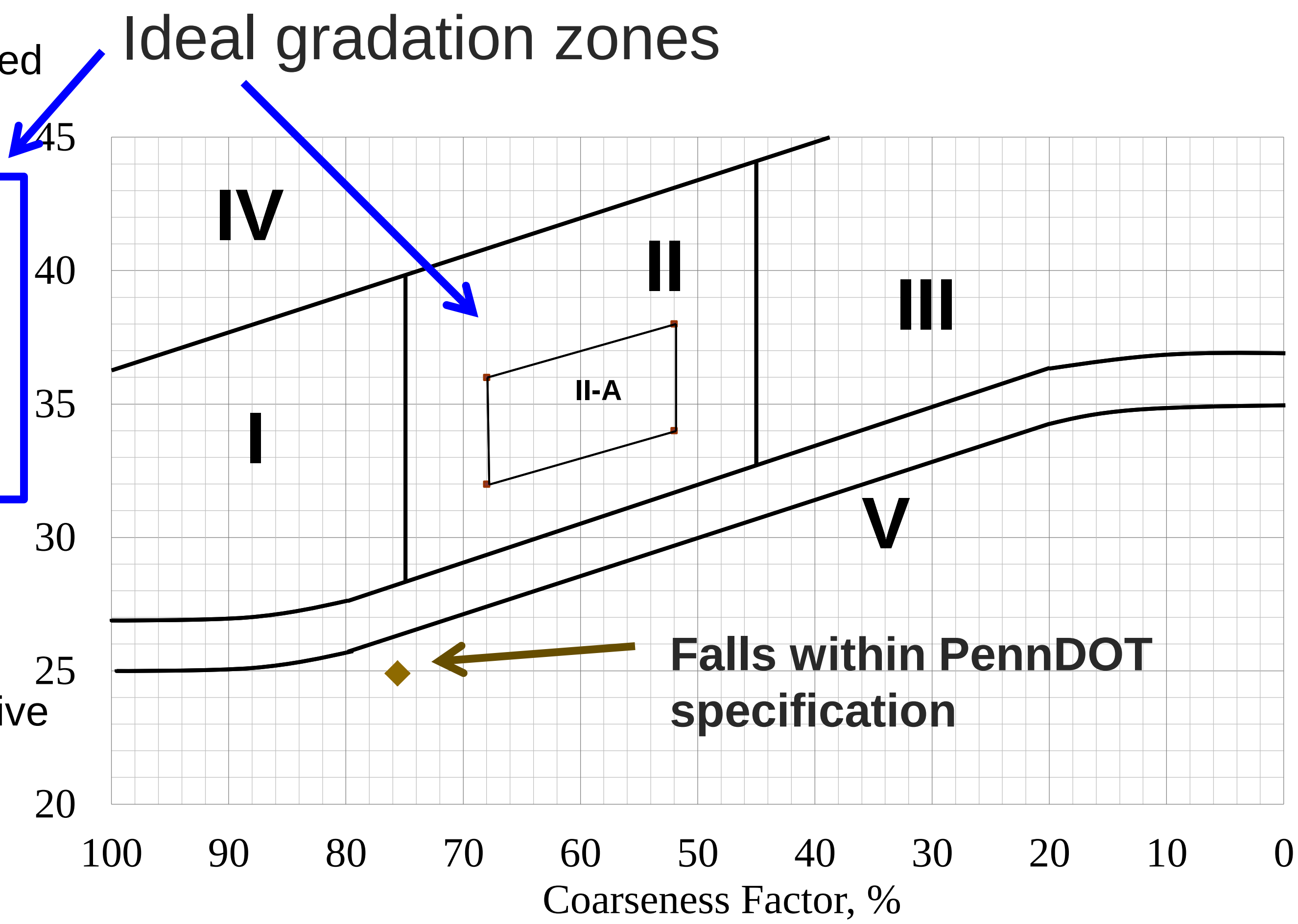
Zone II: Well graded 2" thru 3/4"

Zone II-A: Well-graded aggregate gradation incentive

Zone III: 3/4" minus mixtures

Zone IV: Sandy - excessive fines

Zone V: Rocky - non-plastic



Recommendations- Mix design

- Minimize cement content
  - Adopt more densely graded aggregate
- w/cm ratio
  - New target of 0.40
  - Should fall between 0.38 and 0.42

Critical areas

Construction → Finishing

Construction → Curing

- Application rate
- Application technique
- Curing compound type

Mix design → w/cm

Mix design → Aggregate gradation/cement content

Acknowledgements

Project coordination and technical assistance

- Mr. Steven Marsinko, Mr. Leonard Kubitza and Mr. William Kovach

Site visits

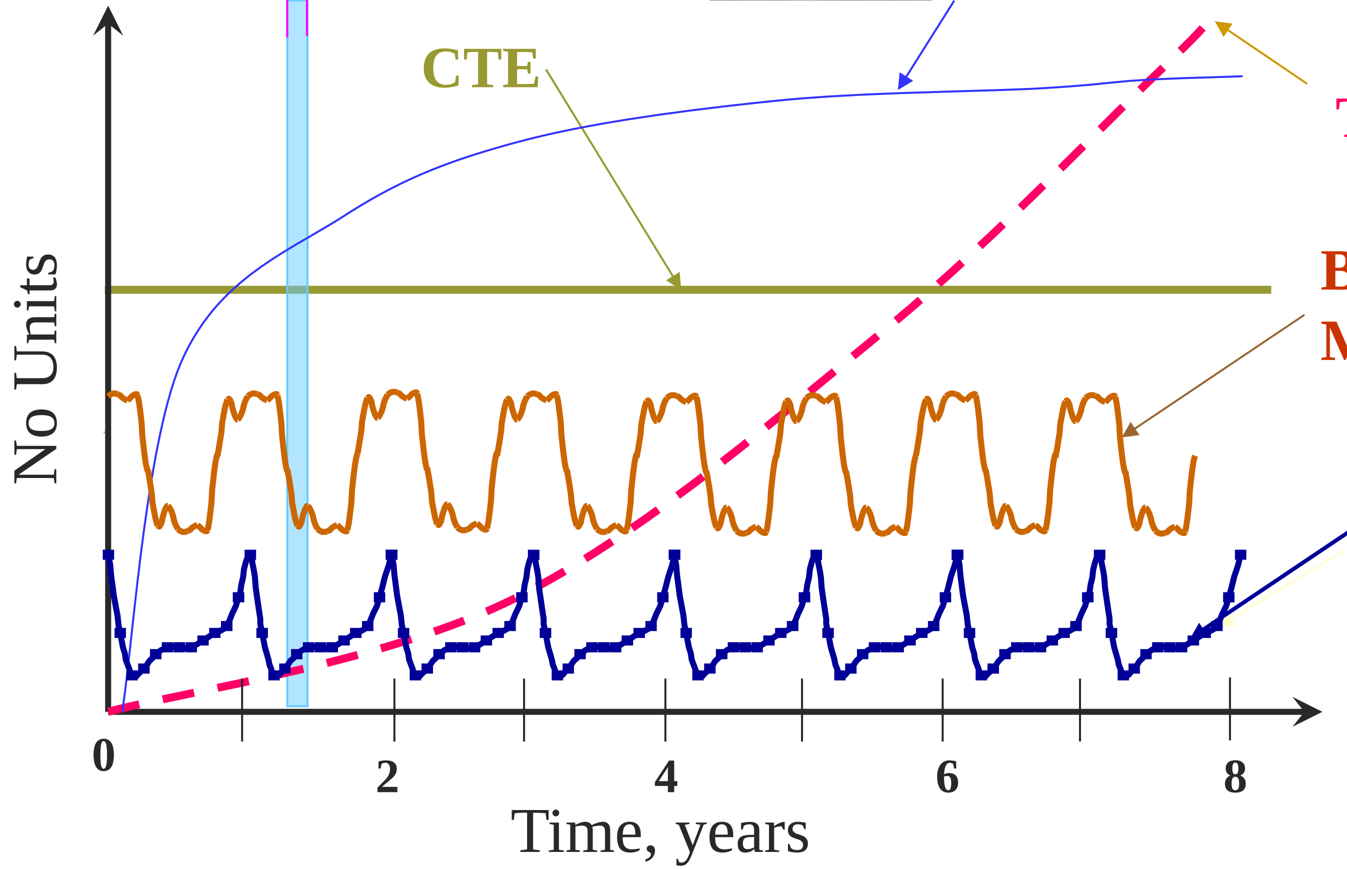
- Mr. William Snyder, Ms. Roxanne Rossi, and Mr. David Schaeffer

National Calibration of PCC Performance Models in AASHTO ME Pavement Design

NCHRP Project 20-07/Task 327

Julie M. Vandenbossche, P.E., Ph.D.
Steven Sachs
University of Pittsburgh

Models Consider Changing Conditions



Applied Research Associates

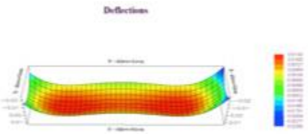
New AASHTO Design PAVEMENT ME

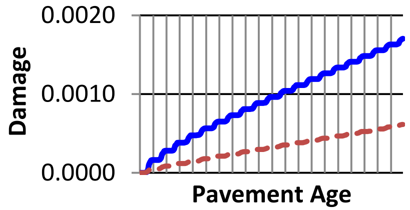
INPUTS
Slab thickness
k-value
Axle Loads and Volumes
PCC M_r
Climate

STRUCTURAL MODEL (NN)

$\sigma, \varepsilon, \delta$

FATIGUE DAMAGE MODEL



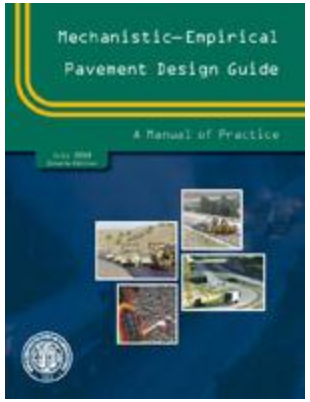


$$\log(N) = C1 \cdot \left(\frac{MR}{\sigma}\right)^{C2}$$

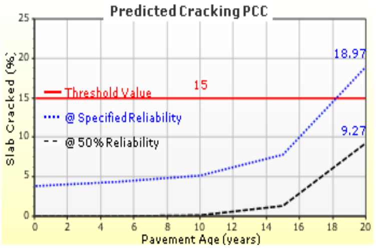
$$CRK = \frac{100}{1 + C4\, FD^{C5}}$$

CALIBRATION WITH FIELD DISTRESS

OUTPUTS
Performance Prediction:
Cracking, Faulting, IRI



www.darwinme.org



www.fhwa.dot.gov

JPCP joint faulting

$$FMAX_0 = (C_1 + C_2 * FR^{0.25}) * \delta_{curl} * \left[Log(1 + C_5 * 5^{EROD}) * Log\left(\frac{P_{200} * WetDays}{p_s}\right)\right]^{C_6}$$

$$FMAX_i = FMAX_{i-1} + C_7 * DE_i * \left[Log(1 + C_5 * 5^{EROD})\right]^{C_6}$$

$$\Delta Fault_i = (C_3 + C_4 * FR^{0.25}) * (FMAX_{i-1} - Fault_{i-1})^2 * DE_i$$

$$Fault_i = Fault_{i-1} + \Delta Fault_i$$

$$\Delta DOWDAM_{tot} = \sum_{j=1}^{3} \sum_{i=1}^{N} C_8 * F_{ij} \frac{n_{ij}}{df_c^*}$$

M-E PDG (2004)
(NCHRP 1-37A)

Original Performance Model Calibrations

→

M-E PDG (2006)
(NCHRP 1-40)

Recalibrated Performance Models

- Expanded datasets
- Updated software

↓

DARWin-ME (2011)

AASHTOWare software version

- Improved GUI
- Decreased run times

←

Pavement ME (2013)

Functionally same version of the software

AASHTOWare Pavement ME Design

Error in estimating Coefficient of Thermal Expansion (CTE)

- 304 SS CTE inaccurate over typical PCC service temp.s
  - $0^oC – 500^oC \rightarrow 17.3*10^{-6}/^oC$
  - $10^oC – 50^oC \rightarrow 15.8\text{-}16.2*10^{-6}/^oC$

- Steel CTE too high → PCC CTE to high

LTPP ∴ database populated w/ incorrect CTEs
Models need recalibration with correct CTEs

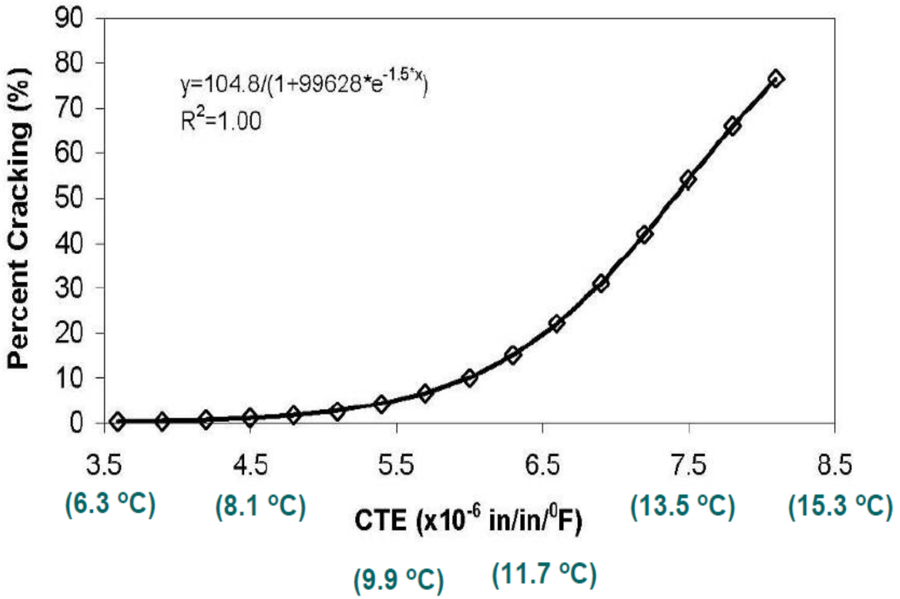
Importance of CTE for pavements

Can contribute to:

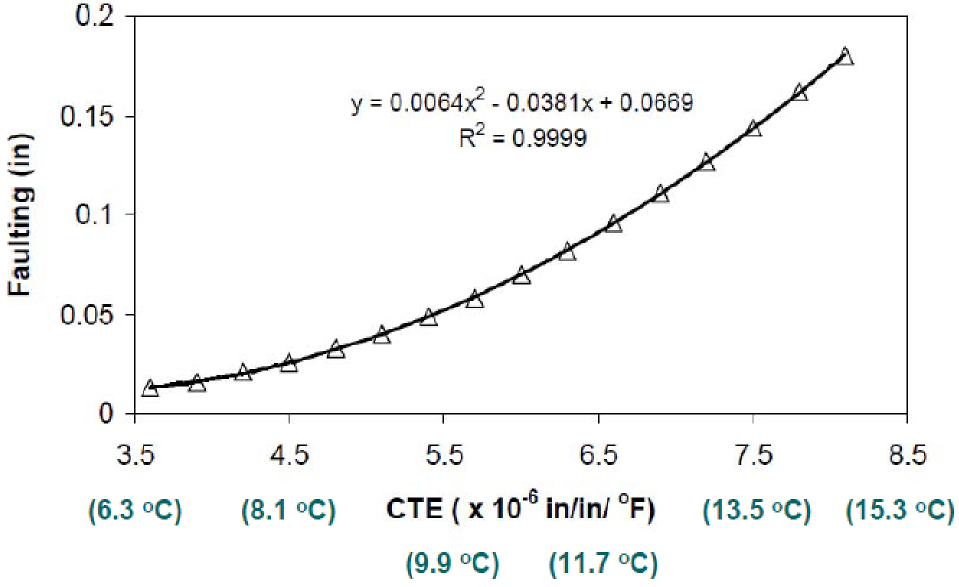
- LTE, Spalling & Faulting → Joint opening
- % Cracking Cracking → Thermal curling

www.pavementinteractive.org

Pavement ME Design Guide Sensitivity to CTE



Effect of CTE variability of Concrete Pavement Performance as predicted using the Mechanistic - Empirical Pavement Design Guide, Jussara Tanesi, M. Emin Kutay, Ala Abbas, and Richard Meininger, Transportation Research Board 2007.



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Recalibration

NCHRP Project 20-07/Task 288 initiated

- Recalibrated:
  - JPCP (transverse cracking and faulting)
  - CRCP (crack width and punchout)
- Predicted slab thickness should be similar to original models
- Not implemented due to discrepancies in thickness designs

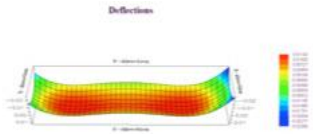
Previous National Calibration	1-37A	Task 288
*Average Predicted Slab Thickness (in)	11.37	10.57

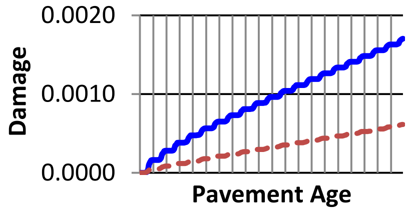
*Avg of sites w/in cracking factorial design (slab thickness required to meet default performance limits)

New AASHTO Design PAVEMENT ME

INPUTS
Slab thickness
k-value
Axle Loads and Volumes
PCC M_r
Climate

→ STRUCTURAL MODEL (NN) → σ, ε, δ → FATIGUE DAMAGE MODEL





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CALIBRATION WITH FIELD DISTRESS

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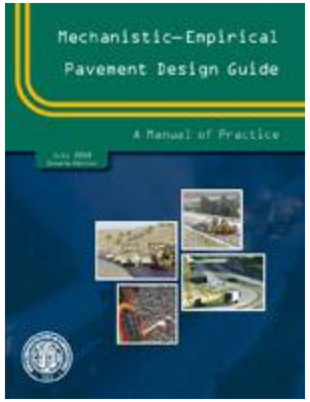
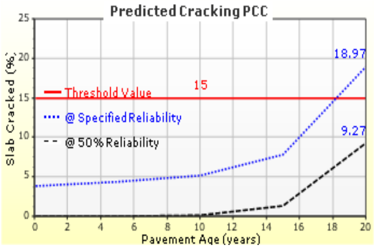


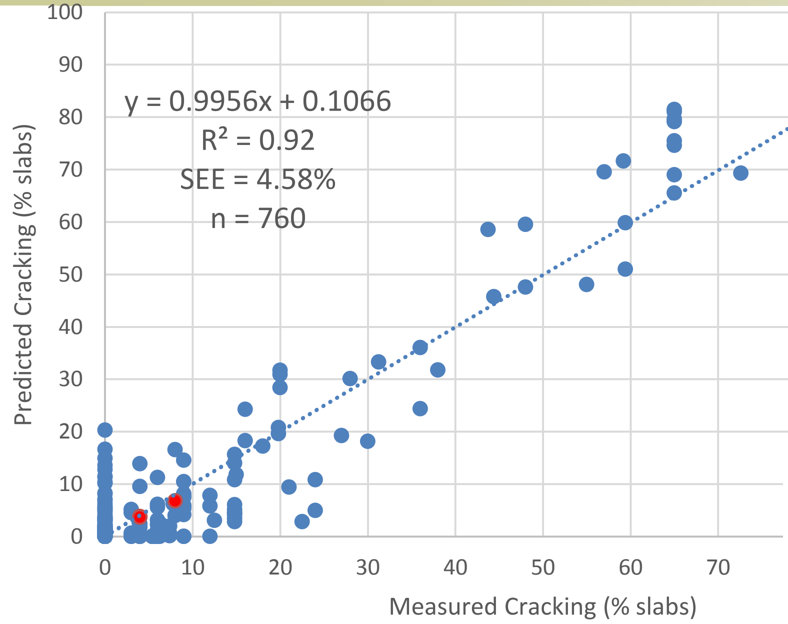
www.darwinme.org



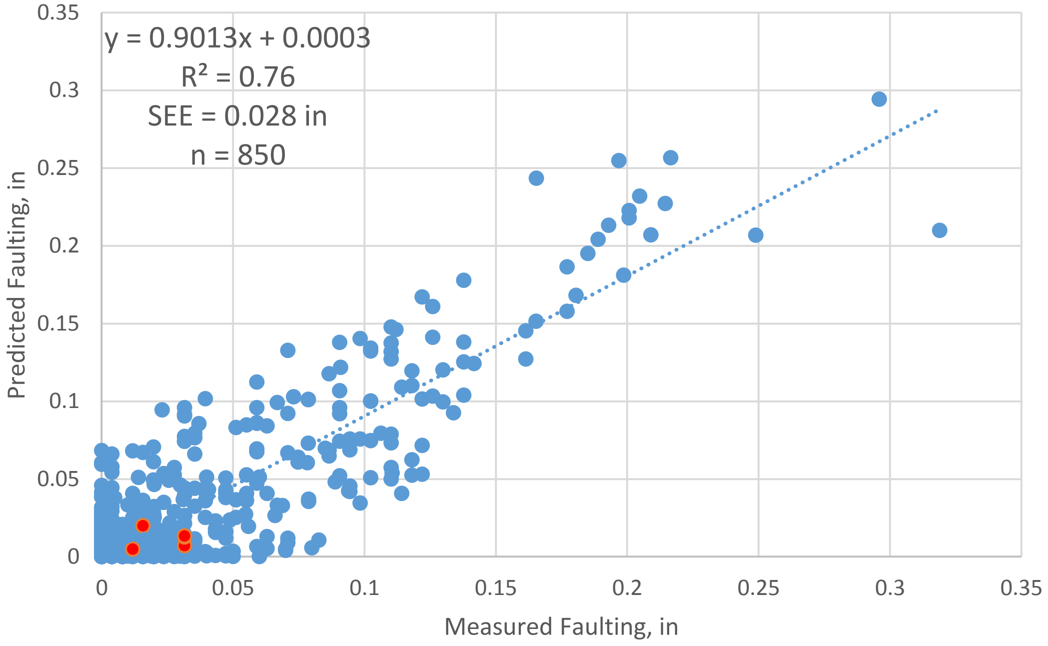
LTPP

www.fhwa.dot.gov

PA LTPP included in national calibration



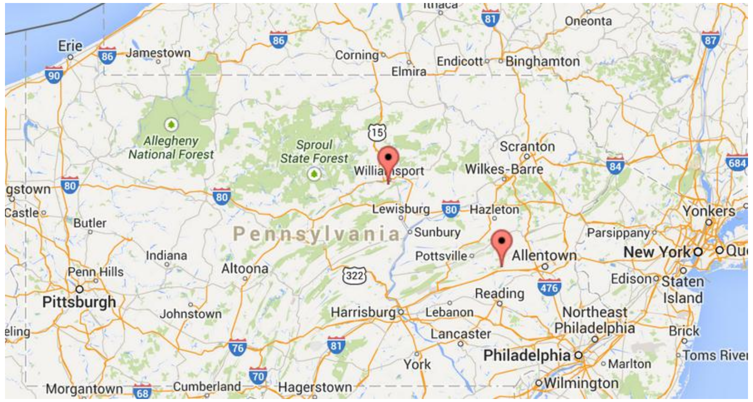
National calibration performed as part of NCHRP 20-07 Task 327.7

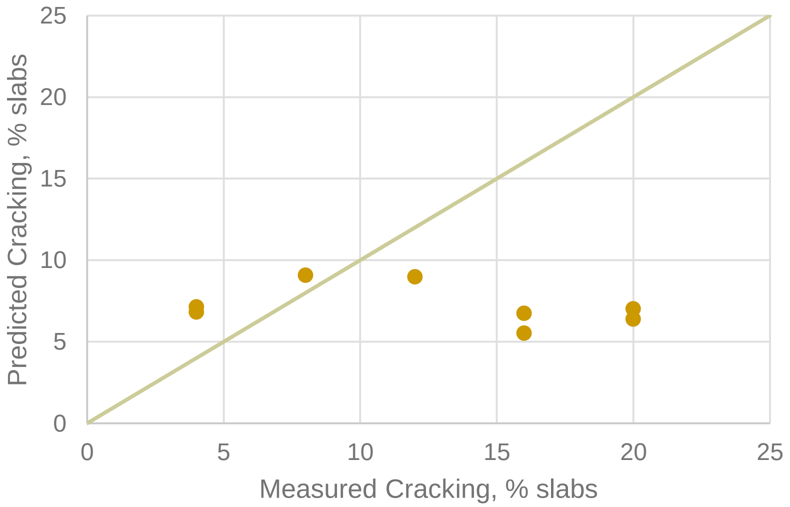


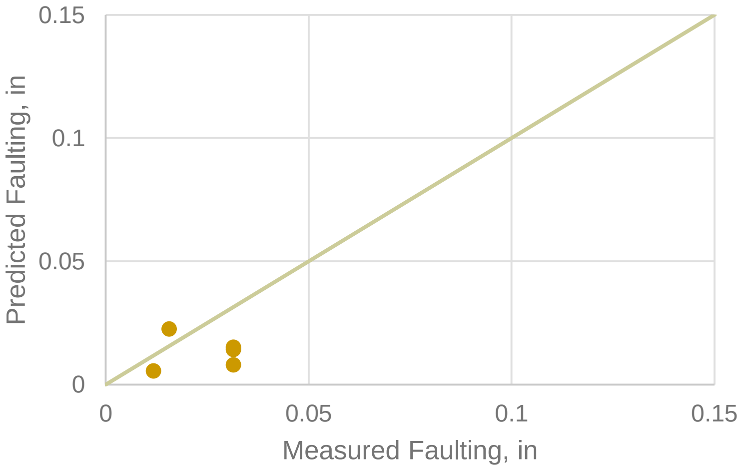
PA site highlighted in red

PA LTPP Sites

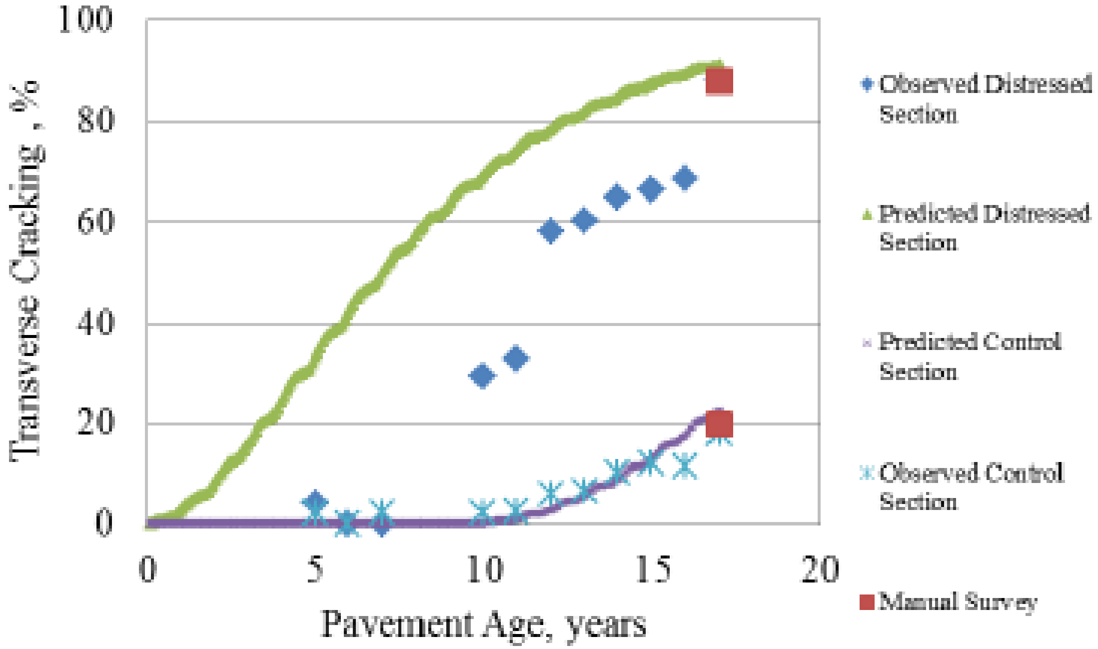
- Only 2 JPCP sites in national calibration database
- Principal Arterial – Interstate
- Part of GPS-3 (JPCP)





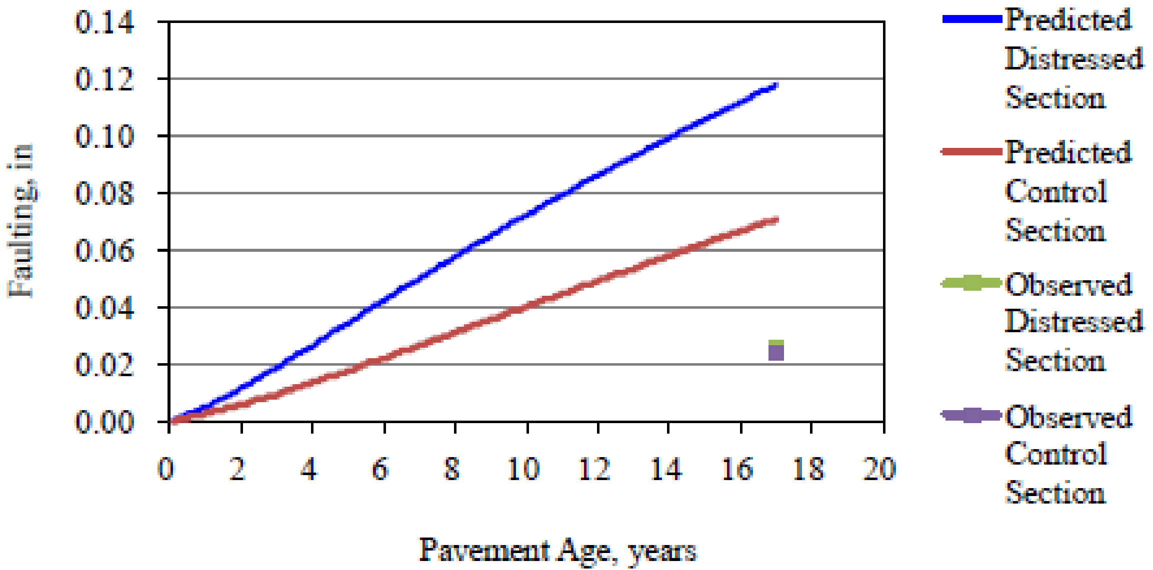


PA Predicted vs. Measured



SR60:
Segments 323 and 303

From PennDOT WO # 12
Report:
Premature Deterioration of Jointed Plain Concrete Pavements



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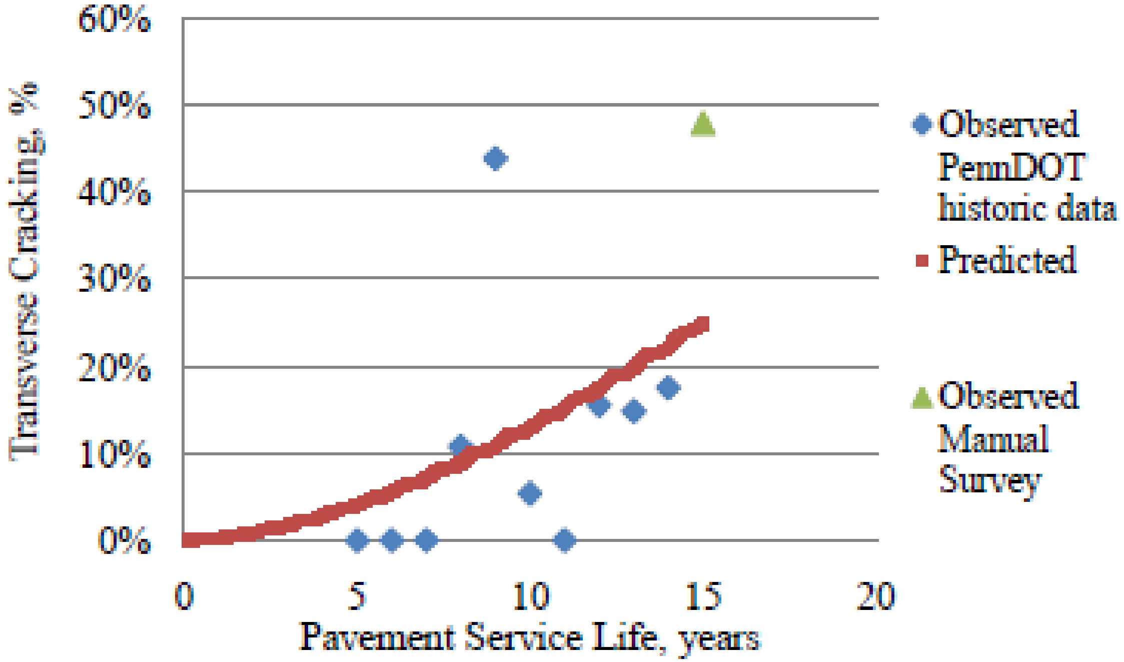
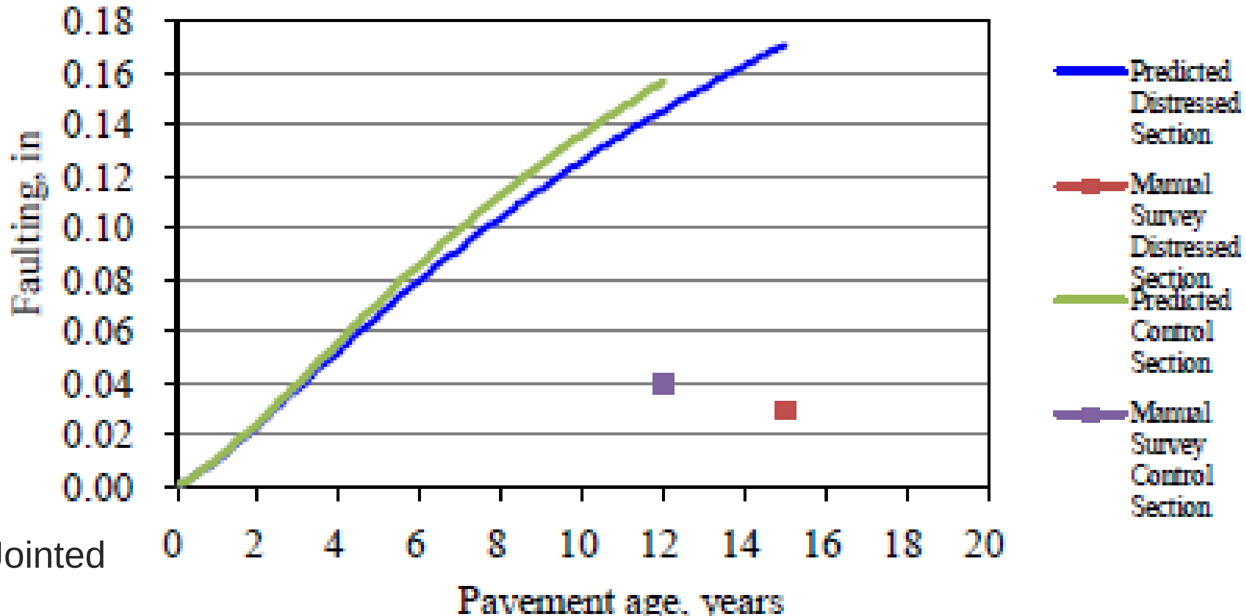


I-79: Segments 470 and 480



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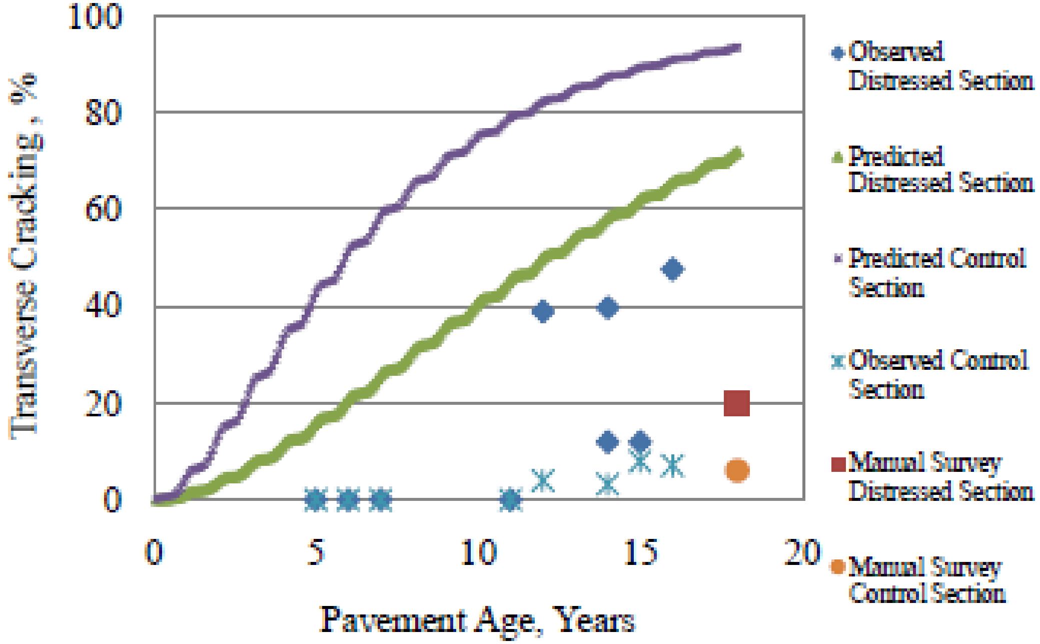
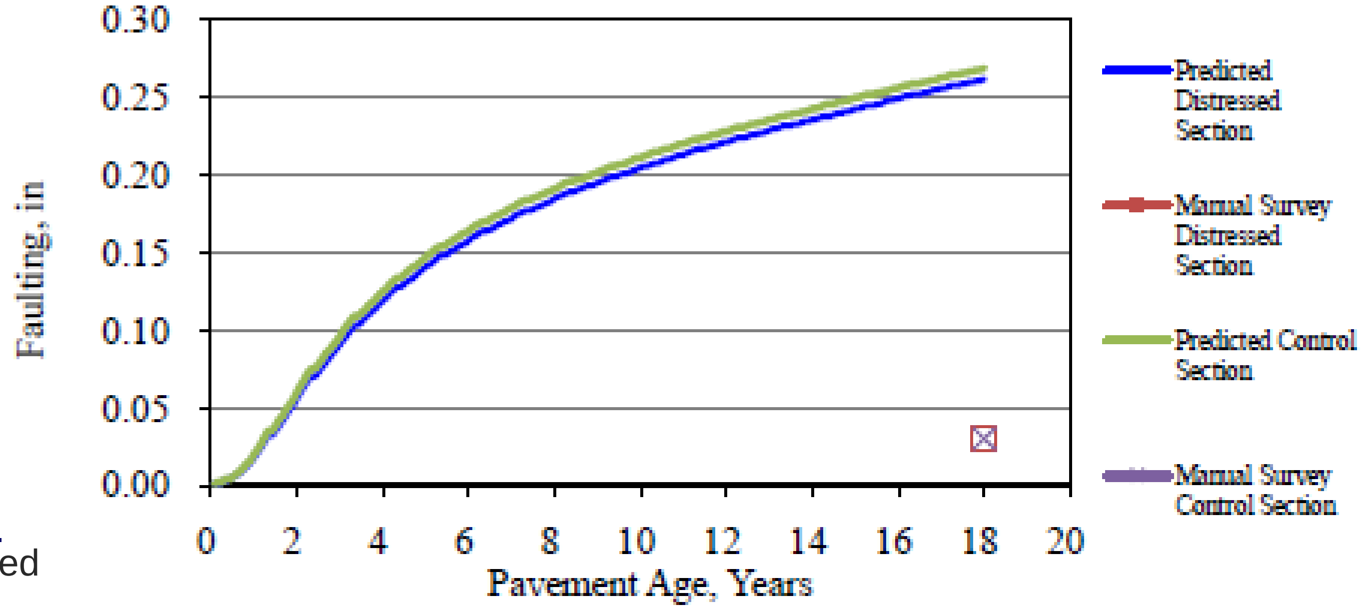


I-80 Segments 1914 and 1920



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PA Local Calibration

- Representative date for recalibration
- Friction values
- Built-in gradient

Available PA calibration data

- 29 JPCP sections in PA
- Only 15 have distress data available
- Of those 15 sites, only 5 were not repaired with patching or another rehabilitation

Thank You

Any Questions?

Email: jmv7@pitt.edu