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TRB Webinar
Continuously Reinforced Concrete Pavement - Part 2:
Mechanistic-Empirical Design and Details for CRCP
June 03, 2015
2:00-3:30 PM

AASHTO Pavement ME Design for CRCP

Presentation Overview

- CRCP Design Resources
- Introduction to Mechanistic-Empirical Design of CRCP
- AASHTO Pavement ME Design Principles and Inputs
- AASHTO ME Input Sensitivity
- Design Example with AASHTO Pavement ME

Key CRCP Design Questions to Answer

- **Consulting / Gov't pavement engineer**
  - Interested in M-E design of CRCP
- Why use AASHTO Pavement ME for CRCP?
- What are the basics of AASHTO Pavement ME?
- What are key inputs to gather?
- What are expected sensitive inputs/variables?
- Where can the CRCP design be optimized?
- Design examples and sensitivities
  - New CRCP and CRCP overlay

CRCP ME Design Resources

Roesler & Hiller (2013)

Rasmussen et al. (2011)

AASHTO 2008 MEPDG CRCP Design

- New State-of-the-Art CRCP design procedure
- Development of mechanistic based models:
  - **Crack spacing—long term mean**
  - **Crack width—varies monthly & increases w/time**
  - **Crack load transfer efficiency—monthly**
  - **Punchout—repeated load edge failure**
- Development of empirical IRI model
  - **IRI = f(Initial IRI, future distress, site conditions)**

AASHTO (2008)

Introduction to Mechanistic-Empirical Design of CRCP

- Why the need for mechanistic-empirical design for CRCP?
  - AASHTO 1986/1993 - empirical
    - Higher traffic volumes
    - Extended-life designs
    - Sustainable design
  - Local climatic / site effects
  - Effect of design inputs on CRCP thickness
  - Material, support layer, construction effects
  - CRCP Overlay design

CRCP Failure Modes

- Too small crack spacing; Larger crack widths
- LTE deterioration of transverse cracks and spalling
- Punchouts & subbase erosion

Why Mechanistic-Empirical Design of CRCP?

- Benefits of mechanistic-empirical design
  - Rational method to compare with other pavement types M-E structural design
  - Designer has large control of inputs
  - Optimized designs possible (Level 1 -3)
  - Nationally calibrated models
  - More cost effective design than AASHTO 1993
  - Confident design extrapolations

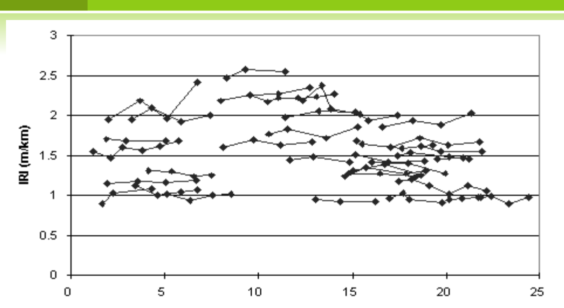
What can Engineer Control with ME Design of CRCP

- CRCP design inputs
  - Slab thickness
  - Layer type and properties
  - Concrete properties, i.e., strength, stiffness, CTE, shrinkage
  - Base type/friction/erodibility
  - Subgrade soil
  - Steel content; bar size and placement depth
  - Shoulder type / Edge support
  - Climate
  - Construction time
  - Traffic
  - Failure criteria limits
  - Reliability

AASHTO Pavement ME CRCP Design Principles

- CRCP Design Objectives (New & Rehab)
  - Provide smooth, long-life pavement with minimal maintenance
  - Sustainable solution
- CRCP Design failure criteria
  - Classic punchout
    - Crack spacing
    - Crack width
  - Nonerodible subbase layer
  - IRI
    - Empirical model

Long Term Smoothness CRCP (LTPP GPS-5)



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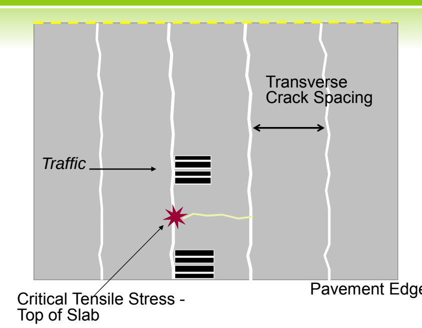
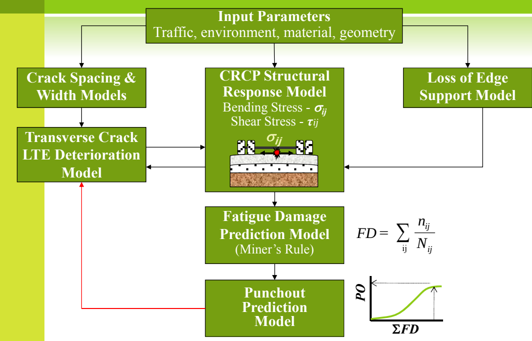
Punchout Mechanism: Top-Down Cracking



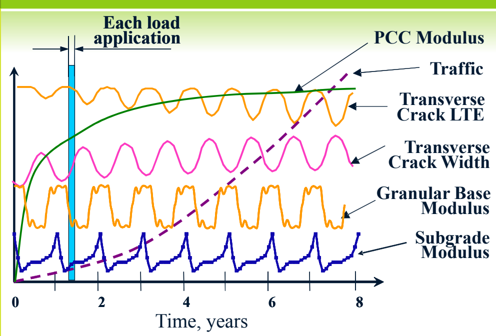
AASHTO Pavement ME Basic Design Process

- Mechanistic-empirical CRCP Design process
  - Design inputs
    - Pavement layers, materials, climate, traffic
  - Predict crack spacing and width
  - Cumulative damage analysis - incremental
    - Calculating slab tensile stresses
      - Climate and traffic
    - Monthly fatigue (punchout) damage
    - Crack deterioration model
  - Predicts punchouts and smoothness
  - Final CRCP thickness determined

Mechanistic-Empirical Punchout Modeling Approach



Design Parameters Over CRCP Life



Models in AASHTO Pavement ME Unique to CRCP

- Transverse Crack Spacing Model
  - e.g., mean of 48 inches
- Transverse Crack Width Model
  - Varies monthly and increases over time
- Crack Deterioration Model
  - Load Transfer Efficiency
- Edge support erosion model
  - Empirical based on base type
- Edge Punchout Model
- IRI Model

Main CRCP Design Elements for Pavement Engineer

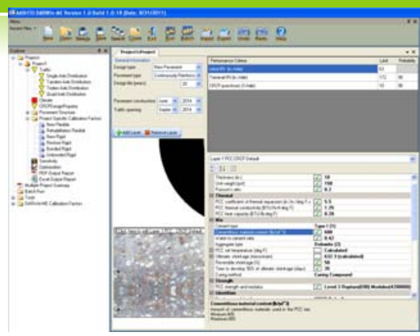
- Longitudinal steel design (e.g., #6 @ ρ=0.75%)
- Base / subbase design (friction, erodibility)
- Shoulder / edge support design
- Concrete properties design
- Construction timing & climate effects

- Slab thickness determination (90-95% reliability)
  - Punchout limit ≤ 10/mile
  - IRI limit ≤ 172 in./mile

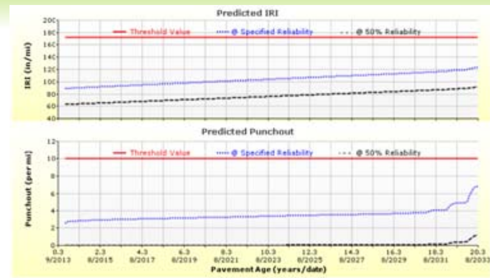
Key Design Factors Considered in AASHTO Pavement ME

1. Slab thickness
2. Concrete: strength, CTE, ultimate shrinkage
3. Reinforcement: % steel, depth in slab
4. Slab supporting layers: friction & loss of support
5. Truck axle type & loading & wander
6. Axial Temperature Movements and Curling
7. Transverse crack spacing as a function of pavement design parameters & base friction
8. Changes in transverse crack width and crack load transfer over service life
9. Development of edge punchouts during service life

AASHTO Pavement ME Input Screen



AASHTO Pavement ME CRCP Output Screen



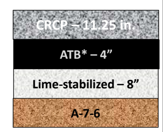
CRCP Performance Sensitivity in AASHTO Pavement ME

- Most sensitive design inputs:
  - Slab thickness
  - Concrete -strength, CTE, shrinkage
  - Steel content and depth
  - Shoulder type
  - Base type/ Friction / Erodibility
  - Heavy truck volume
  - Other sensitive variables
    - Construction Month, surface absorptivity, built-in curling

**From past sensitivity studies

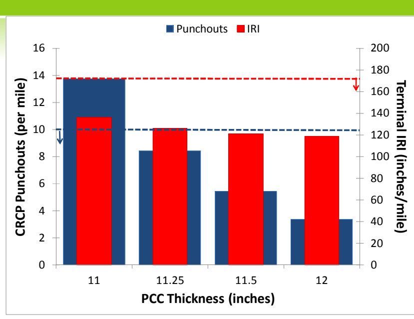
Chicago, IL Sensitivity Example

- High volume highway in Chicago, IL
- AADTT = 20,000
  - 103 million design ESALs
- Asphalt shoulder
- MOR = 650 psi, w/c = 0.42
- Base/slab friction coefficient =7.50
- Steel content = 0.7% @ 3.5 inches
- *AASHTO Pav't ME Level 3 defaults*
- *AASHTO 1993 = 14 in.*



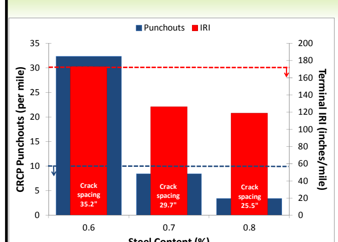
*ATB=asphalt treated base

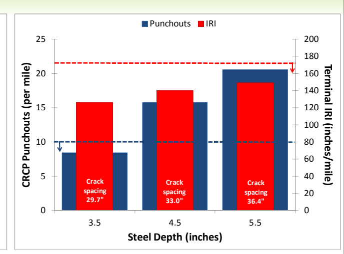
PCC Thickness Sensitivity Chicago, IL



Punchouts → control design (11.25")

Steel Content & Depth Sensitivity Chicago, IL

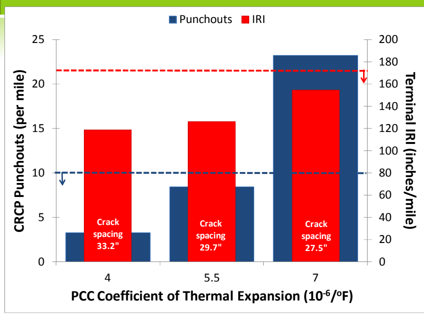




Punchouts → control design (≥0.7%)

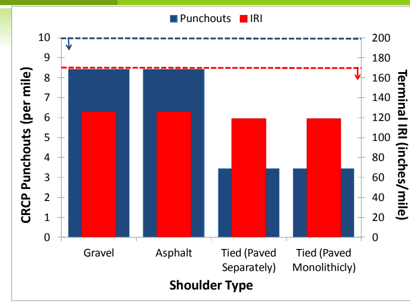
Punchouts → control design (3.5")

CTE Sensitivity Chicago, IL



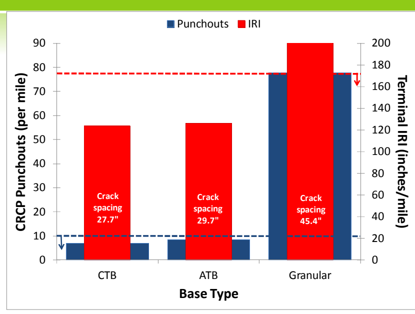
Higher CTE concrete leads to significant increases in punchouts and IRI

Impact of Shoulder Type Chicago, IL



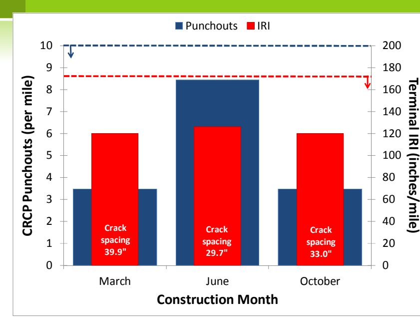
Concrete shoulder reduces distress development

Base Type / Friction / Erosion Chicago, IL



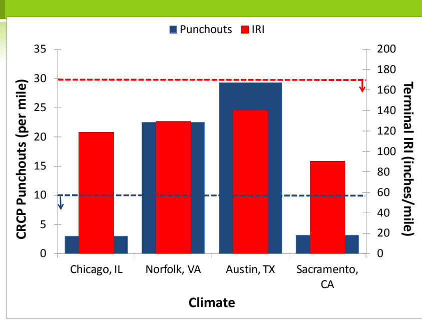
Stabilized bases show significantly better CRCP performance

Construction Month Sensitivity Chicago, IL



Summer season shows highest level of distress → wider crack openings

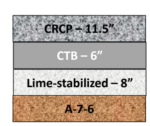
Climatic Effects on CRCP Design



Climate has impact crack spacing/width and punchout development

Dallas Sensitivity Example

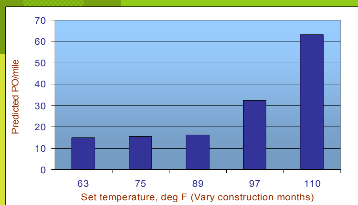
- High volume highway in Dallas, TX
  - AADTT = 20,000
  - Asphalt shoulder
  - MOR = 650 psi, w/c = 0.42
  - Base/slab friction coefficient =7.50
  - Steel = 0.675% @ mid-depth*
  - *AASHTO Pav't ME Level 3 defaults*

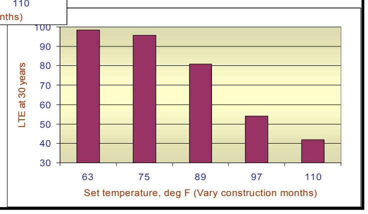


- AASHTO 1993 = 14 in.

CRCP = 12 inch for steel mid-depth
CRCP = 11.5 inch @ 3.5 inch

Impact of Construction Temp: MEPDG



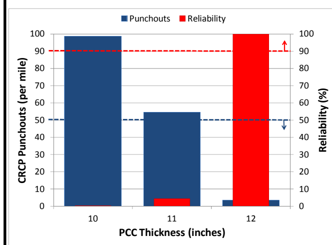


Section: Texas CRCP
Climate: Dallas-FTW
Traffic: 40 million trucks
Design Life: 30 years

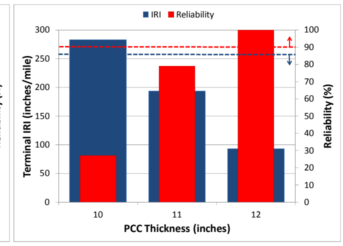
RAO, ARA 2011

PCC Thickness Sensitivity Dallas, TX

Punchouts



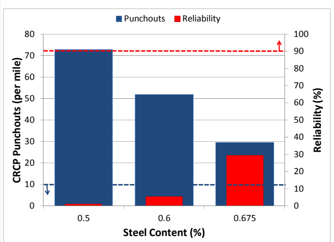
IRI



PCC Thickness is extremely sensitive variable for CRCP performance

Steel Percentage Sensitivity Dallas, TX

Punchouts



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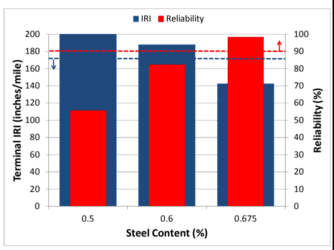
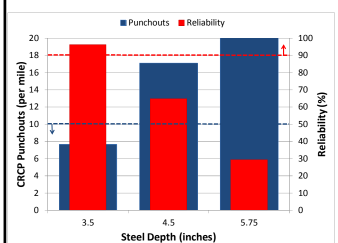


Extremely sensitive parameter for thickness design of CRCP

Steel Depth Sensitivity Dallas, TX

Punchouts



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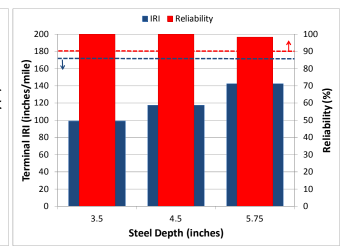
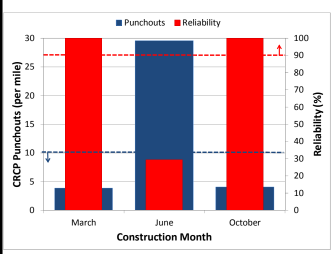


Punchouts → controls design (3.5" steel depth shows large reduction in punchouts)

Construction Month Sensitivity Dallas, TX

Punchouts



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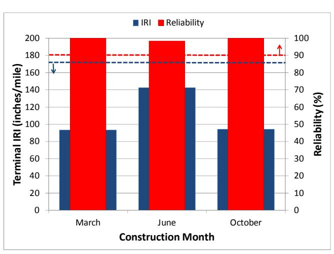
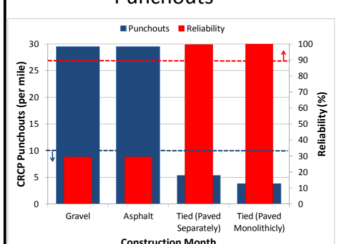


Summer season shows highest level of distress → wider crack openings

Shoulder Type Sensitivity Dallas, TX

Punchouts



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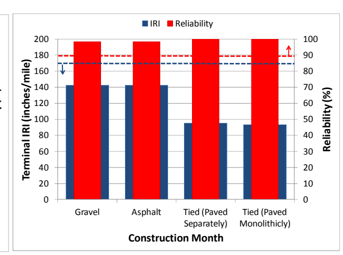

Tied PCC shoulder (separate or monolithic) shows significant performance increase

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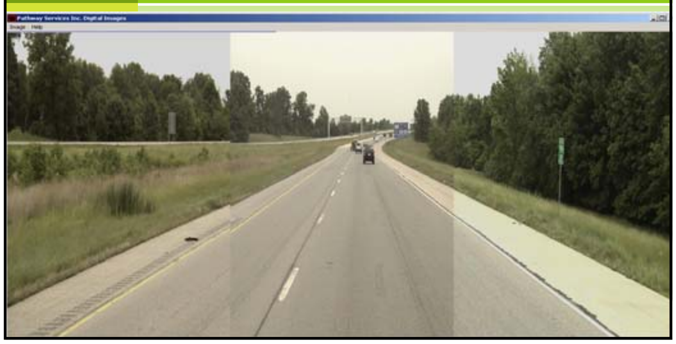
j7 NONE OF these percentages passed for the design?
jeff, 7/25/2012

I-57/I-64 Overlay Case Study

- 9.4 centerline miles of existing CRCP
- AADTT = 17,391
- 3 - 12 ft lanes each direction
- 10 ft & 12 ft concrete shoulders
- Investigate CRCP unbonded overlay of existing CRCP
  - Milling options vs. rubblization
  - JPCP & HMA alternative

Poor Section I-57/I-64 NB

Good Section I-57 NB

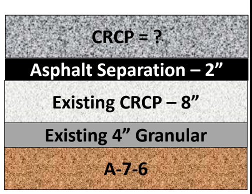


CRCP Unbonded Overlay AASHTO Pavement ME Inputs

- 20-year design life
  - Charleston-Mattoon, IL Climate
- ESALs
  - 80×10^6 approx. (AADTT=17,400)
- A-7-6 soil type
  - k=200 psi/in
- Tied concrete shoulder
  - 50% LTE
- CRCP Steel properties
  - 3.5-inch depth, #6, 0.70%

CRCP Overlay Designs using AASHTO Pavement ME

- Reconstruct project with CRCP = 11 in.
- Unbonded CRCP w/ existing CRCP = 9 in.
- *Unbonded CRCP w/ rubblized existing CRCP = 10.5 in.*
- *Unbounded JPCP w/ existing CRCP = 9 to 10 in.*



I-57 / I-64 Mt. Vernon (2011-2012)

- Mill existing HMA overlay
- Primarily RUBBLIZE existing 8-inch CRCP
- Place 3-inch HMA interlayer
- **10.5-in. CRCP overlay w/ 0.7% steel**
  - #6 bars @ 5¼ inch spacing

Comparisons with Other Design Methods

- Many other design methods are equivalency methods from a modified AASHTO JPCP/JRCP design
- Different failure criteria used so may not always match previous design method results
- Not rooted in prediction of CRCP failure mechanisms

CRCP ME Design Summary

- AASHTO Pavement ME is significant advance for design of economical, long-life CRCP
  - New CRCP and CRCP Overlays
- Designer has input control for pavement layer and materials, traffic, and local climate
- Failure criteria:
  - Punchouts and IRI
  - Subbase erosion
- CRCP Design thickness sensitivity:
  - climate, shoulder type, strength, base type, steel content and position, and construction month.

Acknowledgments

- CRSI / FHWA
- Drs. M.I. Darter and C. Rao

- AASHTO. (2008). *Mechanistic-Empirical Pavement Design Guide, A Manual of Practice*, Washington DC.
- Applied Research Associates (2003*). Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures, Appendix LL: Punchouts in Continuously Reinforced Concrete Pavements,* NCHRP 1-37A.
- Roesler, J.R. and Hiller, J. (2013), *Continuously Reinforced Concrete Pavement: Design Using the AASHTO Pavement ME Design Program*, ACPT TechBrief, USDOT/FHWA, FHWA-HIF-13-027, 11 pp.
- Roesler, J.R. and Hiller, J. (2013), *Continuously Reinforced Concrete Pavement: Design Using the AASHTOWare Pavement ME Design Procedure*, USDOT/FHWA, FHWA-HIF-13-025, 34 pp.

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j8 I am not sure the purpose of this.
jeff, 7/25/2012