HMA Field Cracking and Performance Test

David L. Lippert, PE
Sustainability Implementation Engineer

December 12, 2017
Acknowledgements

University of Illinois at Urbana-Champaign

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Murphy Pavement Technology, Inc.

Abbas Butt and Satish Gundapuneni
Engineering & Research International, Inc.

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Illinois Department of Transportation
Disclaimer

This presentation is partly based upon work in progress under project:

ICT-R27-161- CONSTRUCTION AND PERFORMANCE MONITORING OF VARIOUS ASPHALT MIXES

Project Chair: James S. Trepanier

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CONSTRUCTION AND PERFORMANCE MONITORING OF VARIOUS ASPHALT MIXES IN ILLINOIS: 2015 INTERIM REPORT

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Research Report No. FHWA-ICT-15-009
A report of the findings of ICT-R27-161
CONSTRUCTION AND PERFORMANCE MONITORING OF VARIOUS ASPHALT MIXES
Illinois Center for Transportation
February 2016

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UTILIZING LAB TESTS TO PREDICT ASPHALT CONCRETE OVERLAY PERFORMANCE

Prepared By
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Research Report No. FHWA-ICT-xx-xxx

A report of the findings of
ICT PROJECT R27-161
CONSTRUCTION AND PERFORMANCE MONITORING OF VARIOUS ASPHALT MIXES

http://ict.illinois.edu/
Focus on Cracking

- Thermal Cracking (Full Depth HMA)
- Block Cracking (All HMA)
- Reflective Cracking (Composite)
Outline

• Construction Project Review
• Crack Performance
• Pavement Profile
• Analysis
• Findings
• Conclusions
• Recommendations
Construction Project Review
Region 1/ District 1 Projects
# 2013 Let TRA Projects

## April 26, 2013 Letting Projects

<table>
<thead>
<tr>
<th>Map ID/Construction Year</th>
<th>Project Description</th>
<th>Net Length (mi.)</th>
<th>Net Mix Details</th>
<th>ABR %</th>
<th>RAS %</th>
<th>RAP %</th>
<th>Virgin PG</th>
<th>Surface Tons</th>
</tr>
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<tbody>
<tr>
<td>A /2013</td>
<td>26th Street (Chicago Heights) from Western Ave to East End Ave 137 L62</td>
<td>2.0</td>
<td>N50 TRA&lt;sup&gt;2&lt;/sup&gt; 60L62-137M</td>
<td>60</td>
<td>4.6</td>
<td>51</td>
<td>52-28</td>
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<td>B /2013</td>
<td>Harrison Street (Hillside) from IL 38/Roosevelt Rd. to Wolf Rd. 338 N67</td>
<td>1.1</td>
<td>N50 TRA&lt;sup&gt;2&lt;/sup&gt; 60N67-338K</td>
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<td>C /2013</td>
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<td>D /2013</td>
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1. Total recycle asphalt (100% recycled aggregate with high ABR)  
2. Percent of mixture that contributes to the indicated ABR%  
   Note: Maximum 5% RAS allowed in total mix by specification
# 2014/2015 Monitoring Projects

## June 13, 2014 Letting Projects

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<tr>
<th>Map ID/Construction Year</th>
<th>Project Description</th>
<th>Net Length (mi.)</th>
<th>Dir.</th>
<th>Mix Details</th>
<th>ABR %</th>
<th>RAS$^2$ %</th>
<th>RAP$^2$ %</th>
<th>Virgin PG</th>
<th>Surface Tons</th>
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<td>1 /2014</td>
<td>Crawford Ave/Pulaski Rd from 172nd to US Rt. 6</td>
<td>1.5</td>
<td>S</td>
<td>N70-30% ABR 60Y03-157M</td>
<td>29</td>
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<td>N</td>
<td>N70-15% ABR 60Y03-156M</td>
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<td>34</td>
<td>58-34</td>
<td>1,580</td>
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</table>

1. Total recycle asphalt (100% recycled aggregate with high ABR)
2. Percent of mixture that contributes to the indicated ABR%

Note: Maximum 5% RAS allowed in total mix by specification
Urban Bare PCC Detail

- AC Surface
  - Course 1.5 in
- IL 4.75 Level
  - Binder 0.75 in
- Milled Concrete
  - Taper 0.0 to 1.5 in
Rural Detail (Thick)

- IL 4.75 Level Binder 0.75 in
- PCC Base Course 9” +/-
- HMA Surface Course 1.5 in
- Remaining HMA After Milling - 3.5” +/-
- Existing HMA Base Widening
Urban Mill and Fill

HMA Surface Course 1.5 in
IL 4.75 Level Binder 0.75 in
Existing Pavement
Typical HMA Rehabilitation Designs
Rehabilitated Thick & Thin HMA/PCC/Bare PCC and Full Depth HMA

6-8” HMA

2.5-3” HMA

Old PCC

HMA
Plant Mix and Core Sample Testing
Testing

Binder PG Grading

Asphalt Content/Mix Verification

Moisture Damage (TSR)

Marshall Stability

Cantabro Loss

Texas Overlay

“Where Excellence and Transportation Meet”
Testing

Complex Modulus Test

Hamburg Wheel Track

Semi Circular Bending Beam

Flow Number

IDT Fracture / Creep Compliance

Beam Fatigue

“Where Excellence and Transportation Meet”
## Summary of Testing

<table>
<thead>
<tr>
<th>Test</th>
<th>Specification</th>
<th>Field Core</th>
<th>Plant Mix</th>
<th>Laboratory</th>
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<td>2013 Let</td>
<td>2014 Let</td>
<td>2013 Let</td>
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<td>G\textsubscript{mm}</td>
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<td>Complex modulus</td>
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<td>Beam fatigue</td>
<td>AASHTO T-321-14</td>
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<td>Performance-graded asphalt binder</td>
<td>AASHTO M 320</td>
<td>Binder sample from Plant</td>
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</table>
Crack Performance
Crack Surveys

• Conducted by BMPR – Lead Joe Vespa
• Survey sheets provided to ICT
  • Translated into spreadsheets
  • Summary/analysis/graphs
2013 Let Projects

Distress Summary
26th Street - 137 L62

<table>
<thead>
<tr>
<th>2014</th>
<th>2015</th>
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</thead>
<tbody>
<tr>
<td><img src="image1" alt="Distressed Centerline Joint" /></td>
<td><img src="image2" alt="M &amp; H Transvers Cracking" /></td>
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<td><img src="image3" alt="Distressed Centerline Joint" /></td>
<td><img src="image4" alt="M &amp; H Transvers Cracking" /></td>
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2016

2017
Harrison Street – 338 N67

<table>
<thead>
<tr>
<th>Year</th>
<th>Description</th>
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<tr>
<td>2014</td>
<td>Alligator Cracking</td>
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<tr>
<td>2015</td>
<td>H Transverse Cracking</td>
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<tr>
<td>2016</td>
<td>H Centerline Distress</td>
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<td>2017</td>
<td></td>
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</table>

"Where Excellence and Transportation Meet"
Richards Street – 138 P70

<table>
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<th>Year</th>
<th>Condition</th>
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<td>2014</td>
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<tr>
<td>2015</td>
<td>L, M, H Transverse Cracking</td>
</tr>
<tr>
<td>2016</td>
<td></td>
</tr>
<tr>
<td>2017</td>
<td></td>
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</table>
Wolf Road – 306 M30

<table>
<thead>
<tr>
<th>Year</th>
<th>Description</th>
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</thead>
<tbody>
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<td>2014</td>
<td>L, M Transverse Cracking</td>
</tr>
<tr>
<td>2015</td>
<td></td>
</tr>
<tr>
<td>2016</td>
<td></td>
</tr>
<tr>
<td>2017</td>
<td></td>
</tr>
</tbody>
</table>
Cracking Progression

Harrison St, Richards St, 26th St & Wolf Rd
Transverse Joints and Cracking
Linear Feet/1000 Lane Feet

Survey/Section

Pre Overlay | Post Overlay | 1st Spring | 2nd Spring | 3rd Spring | 4th Spring

0 | 2 | 2 | 4 | 3 | 3

Linear Feet/1000 Lane Feet

0 | 200 | 400 | 600 | 800 | 1000

High | Med | Low

Pre Overlay | Post Overlay | 1st Spring | 2nd Spring | 3rd Spring | 4th Spring

138 P70 | 138 P70 | 138 P70 | 138 P70 | 138 P70 | 138 P70
137 L62 | 137 L62 | 137 L62 | 137 L62 | 137 L62 | 137 L62

“Where Excellence and Transportation Meet”
Centerline Cracking

Harrison St, Richards St, 26th St & Wolf Rd
Centerline Cracking
Linear Feet/1000 Centerline Feet

Survey/Section
Pre Overlay | Post Overlay | Spring 2014 | Spring 2015 | Spring 2016 | Spring 2017
137 N67 | 137 N67 | 137 N67 | 137 N67 | 137 N67 | 137 N67
306 P70 | 306 P70 | 306 P70 | 306 P70 | 306 P70 | 306 P70
HFD HOL Rch 26S WLF | HFD HOL Rch 26S WLF | HFD HOL Rch 26S WLF | HFD HOL Rch 26S WLF | HFD HOL Rch 26S WLF | HFD HOL Rch 26S WLF

“Where Excellence and Transportation Meet”
Main Observations (2013 Projects)

• Richards (non-RAS) and Wolf Road
  • Transverse cracking at lower severity
  • Wolf Road average slab length ~11’
    • Many slabs – little movement – less severity

• 26th Street severe centerline problems

• Harrison and Richards Alligator Cracking

• Harrison: extensive early transverse cracking and higher severity sooner than other projects (Mix 338 N67, FI = 1)
2014 Let Projects

2014 Construction
Crawford/ Pulaski - 157 Y03/ 156 Y03

Omission 1
Sta. 18+88 to 26+30
Omission 2
Sta. 84+18 to 96+05

81BT147M
35% ABR
PG 70-28

Paved 1020
Paved Last
Paved 1016

Level binder not placed in outer 6’ of lane

Thin AC Overlay

Bare PCC
Crawford/ Pulaski - 157 Y03/ 156 Y03

- Milled to Bare PCC - Deep Grooves
- Highly Distressed Joints
- Zebra Tack on LB
- No Lev B. Outside 6'
- Lev B. “Shadow” in Surface
US 52 (IL 53 to Laraway Rd) - 140 Y02/ 159 Y02

4 Lane “Thick” Overlay of PCC

“Thin” Intersection Area Broken Out

2-Lane “Thick” Rural Cross-Section

“Where Excellence and Transportation Meet”
**US 52 (IL 53 to Laraway Rd) - 140 Y02/ 159 Y02**

- **Deep Milling Grooves**
- **Good Lev B. Prime**
- **1' Narrow Lev B.**
- **Surface Crack at Edge of Lev B.**
2014 Let Projects

2015 Construction
Washington St. - 177 Y04/ 159 Y04

“Thin” 5 Lane Bare PCC

Thick – 6 In AC/ 8 In PCC Stab.

Thick – 6 In AC/ 8 In PCC Stab.
Washington St. - 177 Y04/ 159 Y04

Milled Layer Debonding

Milled PCC - Lev Bind

Surface Paving

Level Binder Lane Paved Second, June 1, 2015
Level Binder Lane Paved First, May 29, 2016

4.75 Level Binder Mix: M169M

“Where Excellence and Transportation Meet”
Washington St. Leveling Binder

I-FIT FI = 7
Laydown 5/29/15
Photo 6/9/15

4.75 Leveling Binder
0.75-Inch
PG 70-28
AC: 8.0%
ABR: 29%
RAP: 24%
RAS: 4.9%
US 52 (Laraway to Gougar) - 185 N08

Rural Cross-Section

Thick 8.25 in AC
US 52 (Laraway to Gougar) - 185 N08

More Uniform Milling

Some Debonding

1' Narrow Lev B.
US 52 (Gougar to 2nd St.) - 185 N07

Rural
Thick 8.25 in AC

Urban

"Where Excellence and Transportation Meet"
US 52 (Gougar to 2nd St.) - 185 N07

Uniform Milling

Level Binder

Surface Paving
Construction Observations

• 2014 milling operations could be improved upon (deep grooves from new teeth in worn head). – enforce existing specifications or adopt finer mill texture?

• 2015 milling operation adequate

• Tack coat adequate – with limited zebra stripes.

• Plan patching and cracking filling quantities were adequate.
2014 Let Projects
2014 Construction Distress Summary
Transverse Joints and Cracking

Crawford Ave./Pulaski Rd.
Transverse Joints and Cracking
Linear Feet/1000 Lane Feet

Survey/Section

Pre Overlay
1st Spring
2nd Spring
3rd Spring

Thick
Med
Thin

High

Med

Low

Survey/Section

0 200 400 600 800 1000 1200
Linear Feet/1000 Lane Feet

0 5 156 Y03 S1
157 Y03 S1
156 Y03 S2
157 Y03 S2
156 Y03 S3
157 Y03 S3
156 Y03 S1
157 Y03 S1
156 Y03 S2
157 Y03 S2
156 Y03 S3
157 Y03 S3

“Where Excellence and Transportation Meet”
Centerline Cracking

Crawford Ave./Pulaski Rd.
Centerline Cracking
Linear Feet/1000 Lane Feet

Survey/Section

Pre Overlay
1st Spring
2nd Spring
3rd Spring

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<th>Year</th>
<th>Section</th>
<th>Pre Overlay</th>
<th>1st Spring</th>
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<tr>
<td>2017</td>
<td>S2</td>
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2014 Let Projects

2015 Construction Distress Summary
Transverse Joints and Cracking

US 52 (IL 53 to Laraway)
Transverse Joints and Cracking
Linear Feet/1000 Lane Feet

Survey/Section

Pre Overlay
1st Spring
2nd Spring
3rd Spring

Linear Feet/1000 Lane Feet

Thick
Thin

High
Med
Low

0
200
400
600
800
1000
1200

140 Y02 S1
159 Y02 S1
159 Y02 S2
159 Y02 S3
140 Y02 S1
140 Y02 S2
159 Y02 S3
140 Y02 S1
159 Y02 S1
140 Y02 S2
159 Y02 S3
140 Y02 S1
140 Y02 S2
159 Y02 S3
140 Y02 S1
159 Y02 S1
140 Y02 S2
159 Y02 S3
Centerline Cracking

US 52 (IL 53 to Laraway)
Centerline Cracking
Linear Feet/1000 Lane Feet

Survey/Section
Pre Overlay | 1st Spring | 2nd Spring | 3rd Spring

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<tr>
<td>2002</td>
<td>140 Y02 S1, 159 Y02 S1, 159 Y02 S2, 140 Y02 S3</td>
</tr>
</tbody>
</table>

Legend:
- Red: High
- Yellow: Med
- Green: Low
Main Observations (2014 Let & Constructed Projects)

• Transverse cracking similar by project more than segment or different mixes on a project.

• Higher amount of transverse cracking on Crawford/Pulaski “thin” project.
  • 157 (SB) – ABR 30% w/PG58-28, RAS 5%
  • 156 (NB) – ABR 15% w/PG64-22, RAS 2.5%

• Lower amount of transverse cracking on US 52 (Y02) project “thick” and “thin” segments.
  • 140 (EB) – ABR 30% w/PG58-28, RAS 3.1%
  • 159 (WB) – ABR 29% w/PG58-28, No RAS

• Raveling/Weathering/Segregation on nearly all project measured in 1st spring after construction on US 52.

• Fewer distresses at lower severity than 2013 projects.
2014 Let Projects

2015 Construction Distress Summary
US 52 (Laraway to Gougar N08)
US 52 (Gougar to 2nd N07)
Washington St.

• Sec 1 (Thin)

• Sec 2 (Thick)
Transverse Joints and Cracking

US 52 (Laraway to Gougar, Gougar to 2nd St) & Washington St
Transverse Joints and Cracking
Linear Feet/1000 Lane Feet

Survey/Section

Pre Overlay

185 N08 S2
185 N07 S2
177 Y04 S1
159 Y04 S2
159 Y04 S2
185 N08 S2
185 N07 S2
177 Y04 S1
177 Y04 S2
159 Y04 S2
159 Y04 S2
185 N08 S2
185 N07 S2
177 Y04 S1
177 Y04 S2
159 Y04 S2
159 Y04 S2
185 N08 S2
185 N07 S2
177 Y04 S1
177 Y04 S2
159 Y04 S2
159 Y04 S2

1st Spring

Thick 5
Thick 7
Thick 10
Thin 7
Thin 10

2nd Spring

Linerar Feet/1000 Lane Feet

0 200 400 600 800 1000 1200

High
Med
Low

"Where Excellence and Transportation Meet"
Centerline Cracking

US 52 (Laraway to Gougar, Gougar to 2nd St) & Washington St
Centerline Cracking
Linear Feet/1000 Lane Feet

Survey/Section

Pre Overlay 1st Spring 2nd Spring

Linear Feet/1000 Lane Feet

High Med Low

185 185 177 159 159 185 185 177 159 177 159 185 185 177 159 177 159
N08 N07 Y04 Y04 Y04 Y04 Y07 Y04 Y04 Y04 Y04 Y07 Y04 Y04 Y04 Y04 Y04
S2 S2 S1 S2 S2 S2 S2 S1 S2 S2 S2 S1 S1 S2 S2 S1 S2
Main Distress Observations (2014 Let Projects)

• “Thin” overlays reflecting cracks/joints quickly
  • West end Washington
  • Crawford/ Pulaski

• “Thick” overlays (not removed by milling) reduces transverse cracking
  • US 52 sections
  • Washington St. Segment 2

• 2015 TRA mixes performing much better than 2013 TRA mixes (thus far)
Pavement Profile
High Speed Inertial Profiler

- IDOT tested pre-overlay
- ERI tested post-overlay
  - After Construction
  - 1st Winter Frozen
  - Annually thereafter
  - 2016 Spring and Fall
  - Spring 2017 – Final run

Data collected:
Roughness: International Roughness Index, in/mi
Rutting: Five point (each wheel path), in
IRI/Rutting

2014 Illinois Interstate IRI

Post-Construction
- US 52 Y02
- Crawford Y03
- Washington Y04

Typical New Interstate Construction
IRI before and after Overlay

\[ y = 0.9873x - 119.27 \]
\[ R^2 = 0.7477 \]
Profile Trend Observations

• IRI in the **right** wheel path **higher** than left wheel path.

• **Annual increase** in IRI **higher** in right wheel path

• **Little difference by mix** for both IRI and rutting - rutting **low thus far**

• **Initial IRI could be smoother** – Requires spec changes
Analysis
Flexibility Index vs Transverse Cracking
All Projects After Winter

- **1st Winter**
  \[ y = -171.2 \ln(x) + 368.19 \]
  \[ R^2 = 0.5854 \]

- **2nd Winter**
  \[ y = -213.9 \ln(x) + 526.21 \]
  \[ R^2 = 0.6509 \]

- **3rd Winter**
  \[ y = -237.5 \ln(x) + 666.35 \]
  \[ R^2 = 0.7387 \]

- **4th Winter**
  \[ y = -194.4 \ln(x) + 617.4 \]
  \[ R^2 = 0.9958 \]

**IDOT Proposed Min 8.0**
Typical I-FIT Test Result

- Secant Modulus
- Peak Load
- Slope at Inflection Point (m)
- Work of Fracture ($W_f$)
- Critical Displacement ($u_1$)
- Final Displacement ($u_{\text{final}}$)
3D-BMD for PMLC
(Balanced Mix Design)
CRS Analysis
CRS after 2nd Winter

CRS After 2nd Winter

<table>
<thead>
<tr>
<th>Mix/Project/Segment</th>
<th>2013 Let</th>
<th>2014 Let</th>
</tr>
</thead>
<tbody>
<tr>
<td>338 N67 HOL</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>338 N67 HFD</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>138 P70 RDS</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>306 M30 WLF</td>
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<td>5</td>
</tr>
<tr>
<td>157 Y03 S1 C/P</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>156 Y03 S2 C/P</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>157 Y03 S3 C/P</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>140 Y02 S1 US$2</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>159 Y02 S1 US$2</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>140 Y02 S2 US$2</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>159 Y02 S2 US$2</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>185 N08 US$2</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>185 N07 US$2</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>177 Y04 S1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>177 Y04 S2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

“Thin” ◯ “Thick” ☐
Moving from FI average of 6 to 9 (Min 8) on slope of 0.3 gains 0.9 CRS points = ~ 2-3 years of life
Main CRS Observations

• 2013 (N50) TRA projects performed worse at any given time.
  • After 4 years nearly same CRS as pre-construction on Harrison – Mix 338 N67 (FI = 1.6)
• Wolf Road (2013 let– No RAS and N70 ) performed similar to 2014 let projects
• “Thin”/”Thick” CRS trends are different, but not as strong as transverse cracking trends
Findings
Overall Study Findings

• Projects that left an AC layer of 3.5 in or more in place after milling resulted in less cracking in the new overlay.

• The highest FI in the study, over 10, was the result of soft-binder (PG 58-34) and moderate ABR rate (30%) - Washington Street project.

• Increase FI values correlated to higher Condition Rating Survey (CRS) values as the pavement aged and therefore longer pavement life.

• The Texas overlay test did not correlate to transverse-cracking development in the first four years.

• Pavement rutting is well within values that would be expected for the pavements under study.
Findings (Continued)

• For the 2013 let TRA projects, pavement distress, (types, extent, and severity) is developing sooner than for the comparison project on Wolf Road.
  • TRA with 37 to 60% ABR, while Wolf Road project has 20% ABR with no RAS.

• The TRA projects on US 52 (60N07 and 60N08) are performing much better than the TRA projects constructed in 2013, which correlates to FI of the AC mixture and pavement families.

• Alternatives to the “mill and fill” approach of pavement rehabilitation such as hot or cold in-place recycling should be considered where appropriate in order to obtain the benefits of reduced cracking of the “thick” pavement family.
Conclusions
CONCLUSIONS

- The Illinois Flexibility Index Test (I-FIT) and resulting flexibility index (FI) can be used on plant sampled laboratory compacted AC mixtures to characterize the potential of transverse cracking in pavements.
- Transverse cracking initiation and propagation are influenced by both the AC mixture characteristics and pavement family.
- The regression analysis of FI and transverse cracking indicates that transverse cracking can be reduced in both thin- and thick-pavement families by using AC with a minimum FI of 8.
- Low FI values and thin-AC overlays of PCC pavement, may result in high amounts of reflective cracking early in the overlay life. i.e. Harrison Street mix 338.
CONCLUSIONS (cont.)

• The use of polymer asphalt-binder (PG 70-28) in the 4.75 level binder with approximately 30% ABR (RAP/RAS) resulted in FI values similar to the surface AC mixes in this study. Limited use for controlling reflective cracking.
Recommendations
Recommendations

• I-FIT should be adopted for use as a specification requirement in AC mixture design and/or production.

• The proposed Flexibility Index (FI) value of 8.0 by IDOT should be adopted.

• Balance mix design should be used and explore the 3D balance mix design.

• Use of virgin aggregates rather than all recycled aggregates, would result in better production control of the AC mix and less absorption which would reduce cost of TRA mixes.
Thank You