Update on Results of Simple Durability Tests on Mixes from the FHWA ALF Experiment and Plans for the MnROAD-NCAT Partnership to Validate Cracking Tests
Performance Test Development

Need

Develop Test Method, Prototype Equipment

Establish Performance Relationship

Draft Test Method

Robust Validation of Procedure and Criteria

Commercial Equipment Specification, First Article Equipment

Ruggedness Refine Critical Aspects

Round-Robin Testing Precision and Bias

Training

Engineering Practice
Evaluation of Simple Mix Tests to Assess Cracking Resistance

- The objective is to determine if results of selected tests correlate with observed cracking performance using 10 mixtures from the 2013 FHWA ALF experiment.
- Cracking tests selected that are reasonably quick to conduct and could possibly used for mix design and QA testing.
Facility Overview
ALF Loading Conditions

• Controlled 20°C @ 20mm
• Loading only one direction
• Lateral Wander
• 425 Super Single Tire
• 100 psi inflation
• 14,200 lb load
• ~4-inch thick asphalt
• ~22-inch thick agg base
Mixes in Current FHWA ALF Experiment

<table>
<thead>
<tr>
<th>Lane</th>
<th>WMA Type</th>
<th>RAP BR (%)</th>
<th>RAS BR (%)</th>
<th>Virgin Binder PG</th>
<th>Prod. Temp. (F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>n/a</td>
<td>0</td>
<td>0</td>
<td>64-22</td>
<td>285</td>
</tr>
<tr>
<td>2</td>
<td>foam</td>
<td>40</td>
<td>0</td>
<td>58-28</td>
<td>240</td>
</tr>
<tr>
<td>3</td>
<td>n/a</td>
<td>0</td>
<td>20</td>
<td>64-22</td>
<td>285</td>
</tr>
<tr>
<td>4</td>
<td>chem.</td>
<td>20</td>
<td>0</td>
<td>64-22</td>
<td>240</td>
</tr>
<tr>
<td>5</td>
<td>n/a</td>
<td>40</td>
<td>0</td>
<td>64-22</td>
<td>285</td>
</tr>
<tr>
<td>6</td>
<td>n/a</td>
<td>20</td>
<td>0</td>
<td>64-22</td>
<td>285</td>
</tr>
<tr>
<td>7</td>
<td>n/a</td>
<td>0</td>
<td>20</td>
<td>64-22</td>
<td>240</td>
</tr>
<tr>
<td>8</td>
<td>n/a</td>
<td>40</td>
<td>0</td>
<td>58-28</td>
<td>285</td>
</tr>
<tr>
<td>9</td>
<td>foam</td>
<td>20</td>
<td>0</td>
<td>64-22</td>
<td>240</td>
</tr>
<tr>
<td>11</td>
<td>chem.</td>
<td>40</td>
<td>0</td>
<td>58-28</td>
<td>240</td>
</tr>
</tbody>
</table>

- All lanes were built to a target of 4 inches of asphalt mix. Testing of the lanes began in Fall 2013 and is expected to be completed in Fall 2015.
Cracking Performance Measured...
As-Built vs. Perfect Construction (thin)

Average = “Perfect”

Asphalt Thickness

Base Stiffness
Tests Conducted

<table>
<thead>
<tr>
<th>Test</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cantabro</td>
<td>ASTM D7064-08</td>
</tr>
<tr>
<td>SCB</td>
<td>LTRC method</td>
</tr>
<tr>
<td>IDT</td>
<td>NCAT</td>
</tr>
<tr>
<td>Overlay Tester</td>
<td>Tex-248-F modified by NCAT</td>
</tr>
</tbody>
</table>

- Test specimens were made from SGC samples compacted to $N_{\text{design}}$ (65 gyrations).
- Using $N_{\text{design}}$ specimens provides the quickest and simplest path to implementation for any of these durability “performance” tests.
- Sealed buckets of mix were reheated, weighed out, then brought back to the compaction temperature before SGC compaction.
Cantabro Test

- Primarily used for OGFC mixes
- One compacted specimen placed in LA Abrasion drum at a time
- No Steel Balls
- 300 drum revolutions
- Calculate mass loss
- Studies by Doyle and Howard
## Cantabro Results

<table>
<thead>
<tr>
<th>Group</th>
<th>Description</th>
<th>Avg. Cantabro Loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>40%RAP HMA 64-22 285</td>
<td>A</td>
</tr>
<tr>
<td>3</td>
<td>5%RAS HMA 64-22 285</td>
<td>A</td>
</tr>
<tr>
<td>8</td>
<td>40%RAP HMA 58-28 285</td>
<td>A B</td>
</tr>
<tr>
<td>7</td>
<td>5%RAS None 64-22 240</td>
<td>A B</td>
</tr>
<tr>
<td>2</td>
<td>40%RAP Foam 58-28 240</td>
<td>A B C</td>
</tr>
<tr>
<td>6</td>
<td>20%RAP HMA 64-22 285</td>
<td>A B C</td>
</tr>
<tr>
<td>4</td>
<td>20%RAP Chem 64-22 240</td>
<td>B C</td>
</tr>
<tr>
<td>9</td>
<td>20%RAP Foam 64-22 240</td>
<td>B C</td>
</tr>
<tr>
<td>1</td>
<td>No RAP or RAS 64-22 285</td>
<td>B C</td>
</tr>
<tr>
<td>11</td>
<td>40%RAP Chem 58-28 240</td>
<td>C</td>
</tr>
</tbody>
</table>

*Average COV = 19%*
Cantabro vs ALF Cracking

- 40% RAP HMA 64-22 285
- 5% RAS HMA 64-22 285
- 20% RAP Chem 64-22 240
- 20% RAP Foam 64-22 240
- 40% RAP Chem 58-28 240
- 0% RAP HMA 64-22 285
Cantabro Loss (%) vs ALF Passes to 20 feet of Cracking (thousands)

- 40% RAP HMA 64-22 285
- 5% RAS HMA 64-22 285
- 5% RAS None 64-22 240
- 20% RAP Chem 64-22 240
- 20% RAP Foam 64-22 240
- 40% RAP Chem 58-28 240
- 0% RAP HMA 64-22 285

Cantabro vs ALF Cracking
Modified Overlay Test

- Method modified by NCAT
  - Displacement = 0.381 mm
  - Cycle = 1 Hz
  - Failure = peak of normalized load x cycle
- Conducted in AMPT @ 25°C
- Triplicates
Overlay Test Results

Average COV = 32%

Lane 9 Results
3,880
3,893
8,094
13,687

Tukey Statistical Groupings

Royal Center for Asphalt Technology at Auburn University
Overlay Test vs ALF Cracking

- 20% RAP Foam 64-22 240
- 20% RAP Chem 64-22 240
- 40% RAP Chem 58-28 240
- 5% RAS HMA 64-22 285
- 40% RAP HMA 64-22 285
- 5% RAS None 64-22 240
- 0% RAP HMA 64-22 285
Semi-Circular Bend Test (LTRC)

- 50 mm thick specimens
- Ram rate = 0.5 mm/min.
- Notch depths of 38.1, 31.8, 25.4 mm
- Triplicates

![Graph showing the relationship between Specimen Notch Length (mm) and Area to Peak Load (kN-mm).]

\[ y = -0.0388x + 1.9336 \]
\[ R^2 = 0.70 \]
SCB Results

Average COV for Area to Peak Load = 27%
SCB-LTRC vs ALF Cracking

- 40% RAP Chem 58-28 240
- 40% RAP HMA 64-22 285
- 5% RAS None 64-22 240
- 5% RAS HMA 64-22 285
- 20% RAP Chem 64-22 240
- 20% RAP Foam 64-22 240
- 0% RAP HMA 64-22 285

ALF Passes to 20' of Cracking (thousands)

SCB-LTRC J_c (kJ/m³)
IDT Fracture Energy

- 50 mm thick specimens
- Ram rate = 50 mm/min.
- Temp. = 25°C
- Area under load vs. displ. at peak load
- Triplicates
IDT Fracture Energy Results

Average COV = 19%
IDT Fracture Energy vs ALF Cracking

- 40% RAP Chem 58-28 240
- 40% RAP HMA 64-22 285
- 5% RAS None 64-22 240
- 20% RAP Chem 64-22 240
- 5% RAS HMA 64-22 285
- 20% RAP Foam 64-22 240
- 0% RAP HMA 64-22 285

ALF Passes to 20' of Cracking (thousands) vs IDT Fracture Energy (J)
IDT FE Additional Analysis

- 50 mm thick specimens
- Ram rate = 50 mm/min.
- Temp. = 25°C
- Area under $\sigma$ vs. $\epsilon$ to post peak inflection point divided by slope at that point
IDT FE Additional Analysis

- 50 mm thick specimens
- Ram rate = 50 mm/min.
- Temp. = 25°C
- Area under σ vs. ě to post peak inflection point divided by slope at that point

\[
y = 0.0003x^6 - 0.0268x^5 + 0.8303x^4 - 11.238x^3 + 49.595x^2 + 122.61x - 8.435 \\
R^2 = 0.9988
\]

Inspired by IL-SCB method

\[
\text{Toughness} = \text{area calculated by integrating polynomial}
\]

\[
\text{Nflex factor} = \frac{\text{Toughness at inflection pt.}}{\text{slope at inflection pt.}}
\]
### IDT Nflex factor

#### Nflex Factor

<table>
<thead>
<tr>
<th>Description</th>
<th>Nflex Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>40%RAP Foam 58-28 240</td>
<td>130</td>
</tr>
<tr>
<td>20%RAP Foam 64-22 240</td>
<td>120</td>
</tr>
<tr>
<td>20%RAP Chem 64-22 240</td>
<td>120</td>
</tr>
<tr>
<td>40%RAP HMA 58-28 285</td>
<td>120</td>
</tr>
<tr>
<td>40%RAP Chem 58-28 240</td>
<td>120</td>
</tr>
<tr>
<td>No RAP or RAS 64-22 285</td>
<td>110</td>
</tr>
<tr>
<td>20%RAP HMA 64-22 285</td>
<td>100</td>
</tr>
<tr>
<td>5%RAS None 64-22 240</td>
<td>90</td>
</tr>
<tr>
<td>5%RAS HMA 64-22 285</td>
<td>80</td>
</tr>
<tr>
<td>40%RAP HMA 64-22 285</td>
<td>70</td>
</tr>
</tbody>
</table>

**Average COV = 11%**
IDT Nflex factor vs ALF Cracking

- 20% RAP Chem 64-22 240
- 40% RAP Chem 58-28 240
- 20% RAP Foam 64-22 240
- 0% RAP HMA 64-22 285
- 5% RAS None 64-22 240
- 40% RAP HMA 64-22 285
- 5% RAS HMA 64-22 285
Preliminary Observations

- The performance of the ALF sections is confounded by variations in thickness, base stiffness, and age at testing.
- The ALF mixes are ranked very differently by the five tests used in this study.
- The Overlay Test and the SCB test have poor repeatability.
- Nflex factor, Cantabro loss and the SCB J-intergral were able to statistically differentiate the virgin mix from some other mixes.
## Preliminary Assessment

<table>
<thead>
<tr>
<th>Test</th>
<th>Time(^1)</th>
<th>COV</th>
<th>Sens.</th>
<th>Corr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cantabro</td>
<td>40 min.</td>
<td>19%</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>Mod. OT</td>
<td>2 days</td>
<td>32%</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>SCB-LTRC</td>
<td>1.5 days(^2)</td>
<td>27%(^3)</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>IDT Nflex factor</td>
<td>4 hours</td>
<td>11%</td>
<td>A</td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) once Ndes specimens are cooled  
\(^2\) requires five SGC specimens  
\(^3\) COV of Work (area under load-def. curve)
Remaining Work

- Get cracking performance of remaining ALF lanes and analyze correlations between lab and field results
- Determine if there is a way to account for variations in layer thicknesses and base moduli
- Prepare final report
NCAT+MnROAD
Cracking Group Experiments
Project Objectives and Goals

- **Objective**: validate laboratory cracking tests by establishing correlations between the test results and measured cracking in real pavements (test sections)
- **Goals**: evaluate various tests based on:
  - Criteria related to field performance.
  - Practicality of the tests for mix design verification and quality control testing.
  - The ability to accommodate recycled materials, new and future additives, and mix combinations.
  - Cost-effectiveness
Top-Down Cracking Sections

Cracking Group sections
- 7 200-ft. sections
- each section instrumented

<table>
<thead>
<tr>
<th>Layer</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface Layer</td>
<td>1.5”</td>
</tr>
<tr>
<td>Intermediate Layer</td>
<td>2.25”</td>
</tr>
<tr>
<td>Base Layer</td>
<td>2.25”</td>
</tr>
<tr>
<td>Granular base</td>
<td>6”</td>
</tr>
<tr>
<td>Stiff track subgrade</td>
<td>infinite</td>
</tr>
</tbody>
</table>

HiMA mix
Tests for Assessing Cracking Resistance

NCAT will conduct these tests on both LMLC and PMLC samples that are aged and unaged.

Materials were sampled for complementary studies funded by sponsoring agencies. 99 buckets of mix sampled per test section.
## Cracking Group Sections

<table>
<thead>
<tr>
<th>Section</th>
<th>Surface Mix Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N2</td>
<td>Same as N1 with 95% in-place density</td>
</tr>
<tr>
<td>S5</td>
<td>Same as N1 with HiMA PG76-28E</td>
</tr>
<tr>
<td>S13</td>
<td>Arizona style asphalt-rubber mix</td>
</tr>
<tr>
<td>N1</td>
<td>20% RAP (0.19 binder ratio) PG 67-22</td>
</tr>
<tr>
<td>S6</td>
<td>35% RAP and PG 58-28</td>
</tr>
<tr>
<td>N5</td>
<td>Same as N1 except 0.5% low AC, low density</td>
</tr>
<tr>
<td>N8</td>
<td>20% RAP &amp; 5% RAS PG 67-22</td>
</tr>
</tbody>
</table>

Cracking expectation:
- low
- med.
- high

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*National Center for Asphalt Technology at Auburn University*
Instrumentation

- Instrumentation will be installed at the bottom of the asphalt base layer to:
  - check that structures initially respond similarly to load
  - assess when surface cracking impacts structural response
NCAT CG Experiment Status

- All sections have been built
- Currently organizing construction data and establishing baseline (0-time) field data
- Trafficking to begin Oct. 1
- Mix testing to commence Oct. 1
- Complete experiment within 3 year cycle
MnROAD - Cracking Group
Safer, Smarter, Sustainable Pavements through Innovative Research

Dave Van Deusen
Cracking Group Pooled Fund Meeting
Low-Temp Cracking Experiment

• Work plan developed
  – State sponsors review
  – mainline cells identified, plan to reconstruct cells
• Targeted performance property ranges
  – Nine sections proposed with varying ranges of:
    • Fracture energy
    • Binder replacement
## Candidate Mixtures
(revised based on August 27, 2015 sponsor meeting)

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>BINDER</th>
<th>POLYMER</th>
<th>RAP/RAS</th>
<th>NMAS</th>
<th>CRACK POTENTIAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mix w/ &gt;30% RAP &amp; softer AC</td>
<td>PG 52-34</td>
<td>Neat</td>
<td>30/0</td>
<td>12.5</td>
<td>Med/High</td>
</tr>
<tr>
<td>Typical surface mix</td>
<td>PG 58-28</td>
<td>Neat</td>
<td>20/0</td>
<td>12.5</td>
<td>Med/High</td>
</tr>
<tr>
<td>Typical surface mix</td>
<td>PG 58-34;</td>
<td>Yes</td>
<td>20/0</td>
<td>12.5</td>
<td>Low</td>
</tr>
<tr>
<td>Fine surface mix</td>
<td>PG 64-22;</td>
<td>Neat</td>
<td>0/0</td>
<td>9.5</td>
<td>Med/High</td>
</tr>
<tr>
<td>Typical surface mix</td>
<td>PG 64-22;</td>
<td>Neat</td>
<td>20/0</td>
<td>12.5</td>
<td>High</td>
</tr>
<tr>
<td>Mix w/ high RAP/RAS</td>
<td>PG 64-22;</td>
<td>Neat</td>
<td>25/5</td>
<td>12.5</td>
<td>High</td>
</tr>
<tr>
<td>Mix w/ high RAP/RAS</td>
<td>PG 64-28;</td>
<td>Yes</td>
<td>20/5</td>
<td>12.5</td>
<td>Med</td>
</tr>
<tr>
<td>Mix w/ cracking prone gradation</td>
<td>PG 64-28;</td>
<td>Yes</td>
<td>20/0</td>
<td>12.5</td>
<td>Med/High</td>
</tr>
</tbody>
</table>
Cracking Modes and Testing

- Types of cracking to be investigated
  - Low temperature is a “given”
  - Top-down very likely
  - Fatigue also possible

- Select appropriate post-construction testing
  - Low temp: SCB-IL, DCT-MN, SCB-MN
  - Top down, fatigue: Overlay Tester, BB Fatigue
  - ME Design: E*
  - Additional: BBR mix beams (related proposed study)
  - Loose mix, cores
  - Fracture energy test data analysis: both FE and FI
MnROAD Cracking Group Experiment Status

• Mix designs to commence soon, to be completed early Dec.
• Test sections to be built in 2016 construction season
• Monitoring of performance over several years using video-based automated pavement evaluation van (same as NCAT)
Thanks!