MTE Experiences with Performance Testing

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FHWA Mix ETG

Fall River, MA

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Discussion Points

• Overview

• Summary of Performance Test Efforts
  – DCT Test
  – SCB Test: I-FIT and Jc

• Challenges
  – Standardization
  – Implementation & Setting Limits

• Next Steps
Performance Testing Experiences - MTE

• WI & MN: High recycle projects on state highways or county roads.
  – Internally developed specification that includes Hamburg, SCB, DCT.

• Iowa: Surface mixes and Interlayer
  – State specifications for Hamburg and Beam Fatigue

• BMD Approach
  – WI & MN: Tier 3. Volumetric requirements remain, mix expected to meet or exceed the performance of a conventional mix.
Disc Shaped Compact Tension (DCT) Test

Thermal Cracking Resistance

Measured Load (kN)

CMOD(fit) (mm)

Fracture Energy = Area Under Curve to

Binder 2
Binder 1
Test Implementation - DCT
Procedure and Specification

Test Procedure

• Temperature: LT PG + 10°C
• Aging: AASHTO R30 Short Term
  – Long term aging done for research.
• Air voids: Design + 3%
• Detailed procedures in place for conditioning time and duration samples can be held at low temps.

Specification

- Previous iterations included a min. fracture energy of 690 J/m²
- MTE draft specification compares to a conventional mix.

<table>
<thead>
<tr>
<th>Traffic Level/PG Grade</th>
<th>Fracture Energy (J/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Level 2-3/PG XX-34</td>
<td>400</td>
</tr>
<tr>
<td>Traffic Level 4-5/PGXX-34</td>
<td>450</td>
</tr>
</tbody>
</table>
Test Implementation – DCT

Evaluation #1 – Effect of Mix Design Factors

Factors Studied

- Binder Replacement (RAP): 15%, 30%, 50%
- Aging: Short Term (4 hrs @ 135C), Long Term (12 hrs @ 135C)
- Polymer Modification: PG 58S-34, PG 58V-34

Recovered Binder Data

<table>
<thead>
<tr>
<th>PBR</th>
<th>PG 58-34 (LT Continuous Grade - 34.9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>-32.7</td>
</tr>
<tr>
<td>30</td>
<td>-30.6</td>
</tr>
<tr>
<td>50</td>
<td>-27.7</td>
</tr>
</tbody>
</table>

Max Deviation from Plan Grade (°C) 6.3

Results

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Peak Load (kN)</th>
<th>Time at Peak Load (secs)</th>
<th>Fracture Energy (J/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>3.27</td>
<td>7.58</td>
<td>542</td>
</tr>
<tr>
<td>Range</td>
<td>0.23</td>
<td>0.38</td>
<td>43</td>
</tr>
<tr>
<td>Std Dev</td>
<td>0.08</td>
<td>0.15</td>
<td>15.67</td>
</tr>
<tr>
<td>COV</td>
<td>2.5%</td>
<td>2.0%</td>
<td>2.9%</td>
</tr>
</tbody>
</table>

Bahia et. al, WHRP 15-04 Study (3)
## Test Implementation – DCT

### Evaluation #1 – Effect of Mix Design Factors

<table>
<thead>
<tr>
<th>Factor</th>
<th>General Trend</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Peak Load</td>
</tr>
<tr>
<td>Increase PBR</td>
<td>PG 58-28: No trend.</td>
</tr>
<tr>
<td></td>
<td>PG 58-34: No trend.</td>
</tr>
<tr>
<td>Increase Aging</td>
<td>PG 58-28: Increase (0.06 kN)</td>
</tr>
<tr>
<td></td>
<td>PG 58-34: Decrease (0.05 kN)</td>
</tr>
<tr>
<td>Use of Modification</td>
<td>PG 58-28: Increase (0.26 kN)</td>
</tr>
<tr>
<td></td>
<td>PG 58-34: Increase (0.08 kN)</td>
</tr>
</tbody>
</table>

*Highlight = Inconsistent Trend Between Binder Grades*

Bahia et. al, WHRP 15-04 Study (3)
Test Implementation – DCT

Evaluation #2 – Aging and Aggregate Type

Gravelite
• LAR @ 500 = 18.3
• Fracture Energy (12 hr) = 551 J/m²

Limestone
• LAR @ 500 = 32.0
• Fracture Energy (12 hr) = 360 J/m²

• Factor driving fracture energy depends on aggregate type.
• Hard aggregate = Mastic Failure.
• Soft Aggregate = Coarse aggregate fracture.

Refer to TRB Paper by Braham (2001)
Test Implementation – DCT

Evaluation #2 – Aging and Aggregate Type

- Limestone Aggregate: LAR @ 500 = 32%
- Gravel Aggregate: LAR @ 500 = 15%
- All aging was loose mix at 135°C
Test Implementation – DCT
Evaluation #3 – MnDOT Report

Figure 2.1: Map of project locations across Minnesota.

DCT Pilot Study Summary of Results

Fracture Energy (J/m²)

- TH56 (Mix Design)
- TH56 (Adjusted)
- TH56 (Mix Design Correct Binder)
- TH310 (Mix Design Correct Binder)
- TH310 Production (Unadjusted, with RAP)
- TH310 Production (Adjusted, without RAP)
- TH10 (Mix Design)
- TH10 (Production Mix)
- TH69 (Unadjusted production)
- TH69 (Adjusted production)
- TH371 (Mix Design)
Test Implementation – DCT

Observations and Discussion

• Recent discussion has suggested reducing fracture energy requirements from initial targets:
  – Benefits: Accommodates “soft” aggregates such as limestone.
  – Risks: If hard aggregate is used there is potential that an inferior mix (i.e. high binder replacement or low binder content) would still pass specification limit.

• Implications of changing/eliminating aggregate sources.

• **Recommended Action:** Universal limit is not feasible. Compare to mixes of known performance.
Intermediate Temperature Cracking Test

• Test Methods Evaluated
  – ASTM D8044: LSU Procedure, 3 notch depths, 0.5 mm/min loading rate.
  – AASTHO TP 124: I-FIT, one notch depth, 50 mm/min loading rate.

• Factors Evaluated: Binder Replacement, Polymer Modification, Aging
Adjusting for a Northern Climate

• Test temperature was adjusted to PG Inter. Temp to account for use of softer grades in WI.

• Three independent studies:
  – WisDOT High RAM Pilot Program (AAPT 2015)
  – WHRP Performance Testing Feasibility Project (2016)

• Studies found the test was insensitive to the variables studied.

• Example of the localized development of these tests and potential complications in implementation.
SCB – D8044
ILS 1424 – Phase 1

• Three samples:

<table>
<thead>
<tr>
<th>Steel Sample</th>
<th>Plastic Sample</th>
<th>Plastic Sample w/notch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loading Rate</td>
<td>0.5mm/min</td>
<td>Loading Rate</td>
</tr>
<tr>
<td>Sampling Rate</td>
<td>10/sec</td>
<td>Sampling Rate</td>
</tr>
<tr>
<td>Load limit</td>
<td>500N, 1000N, 2500N</td>
<td>Load limit</td>
</tr>
<tr>
<td>Gage Length</td>
<td>127mm (5&quot;)</td>
<td>Gage Length</td>
</tr>
<tr>
<td>Temperature</td>
<td>Room Temperature</td>
<td>Temperature</td>
</tr>
<tr>
<td>Pre-load</td>
<td>45± 10N</td>
<td>Pre-load</td>
</tr>
</tbody>
</table>

• 12 laboratories
SCB – D8044
ILS 1424 – Phase 1

Results to date from 6 laboratories

• Testing Devices
  1- AMPT
  1- MTS
  2 – Brovold
  1 – Instron
  1- IPC-Global
  1 - Instrotek

• Testing Fixtures
  7 – fixed rollers
  3 – rollers with springs
  1 – 36mm roller

<table>
<thead>
<tr>
<th>Material</th>
<th>x̅</th>
<th>r-COV%</th>
<th>R-COV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Validator</td>
<td>300</td>
<td>24.3</td>
<td>57.0</td>
</tr>
<tr>
<td>Plastic with notch</td>
<td>58</td>
<td>26.6</td>
<td>102.1</td>
</tr>
<tr>
<td>Plastic with notch</td>
<td>111</td>
<td>45.5</td>
<td>122.7</td>
</tr>
</tbody>
</table>

average 32.1 93.9
Results to date from 6 laboratories

- Testing Devices
  1- AMPT
  1- MTS
  2 – Brovold
  1 – Instron
  1- IPC-Global
  1 - Instrotek

- Testing Fixtures
  7 – fixed rollers
  3 – rollers with springs
  1 – 36mm roller
SCB-IFIT
Initial Evaluations

• Benefits
  – Identifies mixes that are too stiff.
  – Verifies design vs. production
  – Provides a relatively easy way to evaluate mix composition.

• Concerns
  – Repeatability
  – Polymer modification (Discussed in Fall 2017 meeting)
  – Aging
  – Refining limits.
SCB - IFIT

**RAP/RAS Content & Volumetrics**

<table>
<thead>
<tr>
<th>Mix Design</th>
<th>AB (%)</th>
<th>%AV at Ndes</th>
<th>VMA</th>
<th>VFA</th>
<th>RCY AB (%)</th>
<th>ABR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>RAP</td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td>RAS</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Total</td>
<td></td>
</tr>
<tr>
<td>N50</td>
<td>5.8</td>
<td>3.6</td>
<td>15.1</td>
<td>73.5</td>
<td>1.2</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20.3</td>
<td>14.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>34.3</td>
<td></td>
</tr>
<tr>
<td>N70</td>
<td>5.9</td>
<td>3.5</td>
<td>15.3</td>
<td>73.9</td>
<td>0.6</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.6</td>
<td></td>
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<tr>
<td></td>
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<td></td>
<td></td>
<td>9.6</td>
<td>0</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9.6</td>
<td></td>
</tr>
</tbody>
</table>

**Differences**

- Aggregate structure
- Recycled products and ABR values for mix designs:
  - N50 has 34% PBR, 40% of the binder replacement is from RAS.
SCB I-FIT
Effect of PBR - Flexibility Index

Histogram of Flexibility Index
Normal

<table>
<thead>
<tr>
<th>Mix Type</th>
<th>N50</th>
<th>N70</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>5.730</td>
<td>13.56</td>
</tr>
<tr>
<td>StDev</td>
<td>2.564</td>
<td>4.895</td>
</tr>
<tr>
<td>N</td>
<td>32</td>
<td>32</td>
</tr>
</tbody>
</table>

Main Effects Plot for Slope Ratio
Fitted Means

Mean of Slope Ratio

Base Binder  Modification  Mix Type

PG S8-26  PG S6-22  None  S100  S170  S85  N50  N70
## SCB I-Fit

### Potential Benefits to Monitor Production

<table>
<thead>
<tr>
<th>Factors</th>
<th>Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mix Design Variables</strong></td>
<td></td>
</tr>
<tr>
<td>Aggregate Source:</td>
<td>Granite, Gravel, Limestone</td>
</tr>
<tr>
<td>Mix Traffic Level</td>
<td>Medium Traffic and High Traffic</td>
</tr>
<tr>
<td><strong>Production Variables</strong></td>
<td></td>
</tr>
<tr>
<td>Asphalt Binder Content</td>
<td>Design – 0.3%, Design, Design + 0.3%</td>
</tr>
<tr>
<td>P200 Content</td>
<td>Design -2%, Design, Design + 2%</td>
</tr>
</tbody>
</table>
### SCB I-Fit

**Potential Benefits to Monitor Production**

<table>
<thead>
<tr>
<th>Factors</th>
<th>Flexibility Index</th>
<th>Post-Peak Slope</th>
<th>Fracture Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mix Type/Modification</td>
<td>P-value</td>
<td>P-Value</td>
<td>P-value</td>
</tr>
<tr>
<td>Aggregate Source</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.054</td>
</tr>
<tr>
<td>Asphalt Binder Content</td>
<td>0.001</td>
<td>0.176</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>P200 Content</td>
<td>0.124</td>
<td>0.475</td>
<td>0.001</td>
</tr>
</tbody>
</table>

- Results presented for HT-V-28 mix, similar for medium traffic unmodified design.
### SCB I-FIT Concerns

**Repeatability – Single Lab**

<table>
<thead>
<tr>
<th>Base Binder</th>
<th>Polymer</th>
<th>N50</th>
<th>N70</th>
</tr>
</thead>
<tbody>
<tr>
<td>PG 64-22</td>
<td>5160</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>5170</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>None</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>SBS</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

**Boxplot of Flexibility Index**

Four replicates tested for all mixes.
SCB I-FIT Concerns

Aging

- Is Flexibility Index a discriminating property on long term aged samples?
- Data represents ~12 designs. 4% AV and 3.0% Regressed AV contents.
SCB IFIT Concerns

Effects of Loading Rate and Aging

- After aging Flexibility Index values collapse due to stiffness effect.
Challenges

Standardization

- HMA acceptance based on volumetrics causes plenty of disputes due to multi-lab variability and differing practices.
- Adoption of even simple performance tests introduces more complexity.
- Have been successful in generating test procedures.
  - Need to understand precision and bias, ruggedness, etc.
- Assign testing responsibility and at what point in the process it will occur.
Challenges
Implementation Approach and Value Added

1. Maintaining current specifications and adding performance test requirements.
   a. Pro: Good for initial data gathering.

Long Term Outcomes
Change in specifications based on initial performance test results.

Or

BMD Approach #2: Relax volumetric criteria and add performance test requirements.
Challenges
One Size Does Not Fit All – Setting Limits

• Dense Graded Mixes
  – Surface Layers vs. Lower Layers
  – Mix Traffic Level
  – Should effects of load/moisture be combined?

• Specialty Mixes
  – Interlayer, Thinlay, SMA

• Example
  – Flexibility Index = 7.0 (Dense Graded Mix) or 20.0 (SMA).

• Different Tests may be better suited for different applications.
Next Steps

Ideal Process

1. Selection of Binder Grade and Binder Content

- Cracking (Compliance)
- Rutting (Stiffness)

2. Quality Assessment

- Aging Protocol?
- Aging Evaluation – Mixture or Binder?
- Moisture Damage
  - Which test?
Next Steps
Quality Assessment - Gaps

• **Moisture Damage**
  – Combined with Rutting by using wet Hamburg with very high # of passes.
  – Is specification promoting dry/stiff mixes?
  – Should effects of load/moisture be combined?

• **Aging/Durability**
  – Significant debate on which aging method to use and aging binder or mix.
  – Many index cracking tests have not been developed at the levels of aging currently under consideration.
  – Interim solution? Binder properties (i.e. $\Delta T_c$, G-R) have shown good correlation to field performance.
Remarks/Discussion Points

• There are benefits to single loading rate/single temperature tests, but they cannot solve all problems.
  – Evaluates the mix as a system & Provides a control for mix stiffness.

• A solution for aging resistance is still a major research need.
  – Accelerated load correlations indicate load associated cracking.

• States are looking for guidance on how to incorporate these tests into practice.
Thank You!

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References


