Evaluation of Laboratory Performance Tests for Fatigue Cracking of Asphalt Pavements

FHWA Cooperative Study at Asphalt Institute
• Principal Investigator
  • Mike Anderson, Asphalt Institute

• Evaluation of current cracking performance tests
Several factors affect fatigue cracking of asphalt pavements:

- Asphalt, aggregate, and their interactions
- Pavement structure
- Material aging, hardening, and embrittlement
- Traffic and environmental loads
- Moisture damage
- Additives, recycles materials
- Healing and relaxation properties of asphalt
Several tests have been developed by different research institutions.

- Various geometries
- Various analysis method
- For different applications
  - Bottom-up cracking
  - Thermal cracking
  - Top-down cracking
  - Reflective cracking
Objective

• To assist with deployment of a fatigue cracking test that is:
  • Sensitive properties of mix components
  • Sensitive to mixture aging
  • Repeatable and reproducible
  • Easy to implement
  • Practical, low cost
Plan

• An experimental study to examine various cracking tests
• Evaluate capability of the tests in discerning the factors of interest
• Evaluation on practicality and ease of use
Primary Factors

• Asphalt grade
• Mix properties
• Load range (test strains/stresses)
• Asphalt aging and hardening
• RAP/RAS content
• Warm-mix additives
# Initial Testing Plan

<table>
<thead>
<tr>
<th>Test</th>
<th>Test Temperature</th>
<th>Test Strain / Load Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-Point Bending Beam Fatigue</td>
<td>20°C</td>
<td>400 &amp; 600 με</td>
</tr>
<tr>
<td>AMPT Push/Pull Fatigue (S-VECD)</td>
<td>19°C</td>
<td>TBD</td>
</tr>
<tr>
<td>Indirect Tensile Strength (IDT)</td>
<td>25°C &amp; 4°C</td>
<td>12.5 mm/min</td>
</tr>
<tr>
<td>Disk-Shaped Compact Tension [DC(t)]</td>
<td>-12°C</td>
<td>1 mm/min</td>
</tr>
<tr>
<td>Texas Overlay</td>
<td>25°C</td>
<td>TBD</td>
</tr>
<tr>
<td>Dissipated Creep Strain Energy (DSCE)</td>
<td>TBD</td>
<td>Standard Methods</td>
</tr>
<tr>
<td>Semi-Circular Bending (SCB)</td>
<td>25°C</td>
<td>0.5 mm/min</td>
</tr>
</tbody>
</table>
Phase 1 Testing Plan

• Lab Standard Mix

• Aging:
  • 4-hour loose mix aging at 135°C
  • 24-hour loose mix aging at 135°C
Why 24 Hour Loose Mix Aging

• Buttlar work in IL
• AAPTP non-load associated cracking study
• KY RAP/ RAS study
4-Point Bending Beam Fatigue

4-point bending beam fatigue (1950’s / SHRP)
KY Density Study Findings

Density Matters

Can use lab beam fatigue device to better understand pavement cracking potential.

\[ y = -1650 \ln(x) + 23848 \]

\[ R^2 = 0.9254 \]
Beam Fatigue

ASTM D4760 4-point Flexural Fatigue
Cycles*Stiffness Analysis
15°C Test Temperature

\[ y = 4 \times 10^{19} x^{-5.5091} \]
\[ R^2 = 0.9725 \]

\[ y = 2 \times 10^{16} x^{-5.421} \]
\[ R^2 = 0.9786 \]

- 4-hour Conditioning @ 135°C, 15°C test
- 24-hour Conditioning @ 135°C, 15°C test
Beam Fatigue

ASTM D4760 4-point Flexural Fatigue
Cycles*Stiffness Analysis
20°C Test Temperature

Test Strain (Î¼ε)

Cycles to Failure (Nf)

4-hour Conditioning @ 135°C, 20°C test
24-hour Conditioning @ 135°C, 20°C test

y = 1E+17x^-2.454
R² = 0.9905

y = 4E+19x^-3.463
R² = 0.9679
Beam Fatigue

Multiple Strain Comparison
ASTM D4760 4-point Flexural Fatigue
Cycles*Stiffness Analysis
20°C Test Temperature

- 4-hour Conditioning @ 135°C, 20°C test
- 24-hour Conditioning @ 135°C, 20°C test

<table>
<thead>
<tr>
<th>Strain Level</th>
<th>Average Cycles to Failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 με</td>
<td>1,208,484</td>
</tr>
<tr>
<td>600 με</td>
<td>55,835</td>
</tr>
<tr>
<td></td>
<td>26,232</td>
</tr>
</tbody>
</table>
Beam Fatigue

Multiple Strain Comparison
ASTM D4760 4-point Flexural Fatigue
Cycles*Stiffness Analysis
15°C Test Temperature

<table>
<thead>
<tr>
<th>Strain Level</th>
<th>4-hour Conditioning @ 135°C, 15°C test</th>
<th>24-hour Conditioning @ 135°C, 15°C test</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 με</td>
<td>939,728</td>
<td>270,518</td>
</tr>
<tr>
<td>600 με</td>
<td>22,026</td>
<td>13,058</td>
</tr>
</tbody>
</table>
AMPT Push/Pull Fatigue (S-VECD)
Indirect Tensile Strength (IDT)

• ASTM D 6931
• Related AASHTO T322

• Rate of Movement: 12.5 mm/min
Indirect Tensile Strength (IDT)

IDT Average Peak Strengths at 25°C

IDT Peak Strengths, kN

- 4-hour Conditioning @ 135°C, 25°C test
- 24-hour Conditioning @ 135°C, 25°C test
Indirect Tensile Strength (IDT)

IDT Average Peak Strengths at 4°C

IDT Peak Strengths, kN

- 5.0
- 10.0
- 15.0
- 20.0
- 25.0
- 30.0
- 35.0
- 40.0
- 45.0

4-hour Conditioning @ 135°C,...
Disk-Shaped Compact Tension [DC(t)]

- ASTM D 7313
- Rate of Movement: 1 mm/min
Disk-Shaped Compact Tension [DC(t)]

Average Fracture Energy, -12°C

Fracture Energy from CMOD, J/m²

- 4-hour Conditioning @ 135°C
- 24-hour Conditioning @ 135°C
Texas Overlay
Semi-Circular Bending (SCB)
<table>
<thead>
<tr>
<th>Test</th>
<th>Cost – saw/coring not included</th>
<th>Sample Prep.</th>
<th>Perform Test</th>
<th>Data Analysis</th>
<th>Speed of Test (3x)-conditioning not included</th>
<th>Sensitive to Aged (24hr) vs. Unaged (4hr) Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-Point Bending Beam Fatigue</td>
<td>$50,000</td>
<td>3-trim 4x</td>
<td>2</td>
<td>2-normalized cycles</td>
<td>3-24 hours</td>
<td></td>
</tr>
<tr>
<td>AMPT Push/Pull Fatigue (S-VECD)</td>
<td>$10,000 to $15,000 to upgrade</td>
<td>5-trim 2x, core, glue</td>
<td>5</td>
<td>5-specialized software</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indirect Tensile Strength (IDT)</td>
<td>0 – could use TSR device at 25°C</td>
<td>1-trim 1x</td>
<td>1</td>
<td>1-direct reading</td>
<td>10 min.</td>
<td></td>
</tr>
<tr>
<td>Disk-Shaped Compact Tension [DC(t)]</td>
<td>$ to upgrade AMPT</td>
<td>5-trim 2x, cut, core (2 samples)</td>
<td>2</td>
<td>3-area under curve</td>
<td>30 min</td>
<td></td>
</tr>
<tr>
<td>Texas Overlay</td>
<td>$ to up to upgrade AMPT</td>
<td>1-trim 1x</td>
<td>2</td>
<td>1-cycles to failure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dissipated Creep Strain Energy (DSCE)</td>
<td>?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Semi-Circular Bending (SCB)</td>
<td>&amp; to upgrade AMPT</td>
<td>2-trim 2x</td>
<td>2</td>
<td>3-area under curve</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Conclusions

• None at this time
Phase 1 Test Plan

• Test devices: 7
• Binder:
  • PG 64-22
• Aggregates:
  • Virgin mix
  • 9.5 mm NMAS, dense mix
• Aging:
  • 4-hour loose mix aging at 135°C
  • 24-hour loose mix aging at 135°C
Phase 2 Test Plan

• Test devices: 7
• Binder:
  • PG 64-22, 76-22, 58-34
• Aggregates:
  • Virgin mix, RAP/RAS
  • 9.5 mm NMAS, dense mix; 12.5mm
• Aging:
  • 4-hour loose mix aging at 135°C
  • 24-hour loose mix aging at 135°C
Phase 2 Test Plan

• Other suggestions from Mix ETG:
  • Add ALF mixture to validate
  • Possible DOT mixtures
Thank you