Low-Temperature Performance Testing of Asphalt Mixtures

AASHTO TP-125: Use of Bending Beam Rheometer for Asphalt Mixtures

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Asphalt Mixture Properties

• Existing tests for asphalt mixtures’ low-temperature mechanical properties:
  • Indirect Tensile test (IDT)
  • Thermal Stress Restraint Specimen test (TSRST)
• Tests are not used on a regular basis
  • Equipment
  • Materials
  • Complexity
Bending Beam Rheometer

- Normally used in binder grading
- Researches at University of Utah and University of Minnesota have shown that the modified BBR test, adopted from the AASHTO BBR binder test, is valid for asphalt mixtures
  - Can overcome some adoption difficulties
- Recently voted as AASHTO TP 125 Provisional Standard
Development Challenges

- Specimen Preparation
  - Easily obtained from SGC or Cores
- Representative Volume Element
  - Are beams too small to test mixtures?
- Repeatability
  - Within lab and between labs
- Relation to Performance
  - Field observations
Sample Preparation

From SGC samples or field cores

12.7 mm x 6.35 mm x 127 mm
± 0.25 mm tolerance
Span of BBR = 101.6 mm
Cutting

Commercial tile saw with asphalt blade

12.7 mm x 6.35 mm x 127 mm (width x thickness x length)
± 0.25 mm tolerance
Span of BBR = 101.6 mm
Is beam size adequate?

• Composite theory
  – In materials having spatial disorder with no microstructural periodicity (Asphalt Concrete) the stress, strain, or energy field is averaged over domain
• Approach not valid for strength (fracture) of material
• BBR measures Flexural Creep Modulus
**Aggregate to Beam-size Ratio**

Beam size cannot change

<table>
<thead>
<tr>
<th>Mixture Size</th>
<th>NMAS/Width Ratio</th>
<th>NMAS/Thickness Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.75-mm</td>
<td>~ 1/3</td>
<td>~ 3/4</td>
</tr>
<tr>
<td>9.5-mm</td>
<td>~ 3/4</td>
<td>~ 1.5/1</td>
</tr>
<tr>
<td>12.5-mm</td>
<td>~ 1/1</td>
<td>~ 2/1</td>
</tr>
</tbody>
</table>

4.75-mm Mixture
- NMAS / Width Ratio ~ 1/3
- NMAS / Thickness Ratio ~ 3/4

9.5-mm Mixture
- NMAS / Width Ratio ~ 3/4
- NMAS / Thickness Ratio ~ 1.5/1

12.5-mm Mixture
- NMAS / Width Ratio ~ 1/1
- NMAS / Thickness Ratio ~ 2/1
Visual Analysis

- 13 Different Areas Within Each Mixture
  - Each area cropped and magnified
- Statistical analysis confirmed equal amounts of aggregate between scaled images of mixtures
Statistical Analysis

• Homogeneity of variances
  – Equal variances across sample groups
• If creep modulus data sets for all mixtures have equal variances, then the beams with dimensions of 12.7-mm x 6.35-mm x 127-mm meet RVE requirements.
• 12.5-mm NMAS introduce no more variability in BBR testing than a scaled equivalent 4.75-mm NMAS mixture.

• **Large aggregates do not create outliers within data sets.**
Variability of Results

• Even though the BBR Test has been shown to be valid, there is no standardized specification.
  – Ruggedness Study
  – Precision – Bias Statement
• The repeatability of the test must be understood.
  – The reproducibility of the BBR test across labs
  – The effect of time interval on material's low-temperature properties (steric hardening)
Experiment

- 60 beams were cut from 3 asphalt mixture pucks
- 40 beams were chosen at random from these 60 beams
  - 20 beams for University of Utah Lab, 20 beams for UDOT Lab
- Each lab’s set of 20 specimens was divided into 4 groups of 5 beams to run each group at different time intervals
  - 2 days since cutting
  - 3 days since cutting
  - 1 week since cutting
  - 2 weeks since cutting
Results

Stiffness

m-value
Relation to field performance

- 7 State Roads
- Deep pavements, constructed within 3 years
- Low-temperature required binder grade = \(-28^\circ C\)
# Mixture Test Results

## Same Binder Grade

<table>
<thead>
<tr>
<th>Project</th>
<th>Creep Modulus @ 60s Min PG + 10°C (MPa)</th>
<th>m-Value @ 60s</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR 48</td>
<td>10 605</td>
<td>0.155</td>
</tr>
<tr>
<td>SR 68</td>
<td>4 416</td>
<td>0.183</td>
</tr>
<tr>
<td><strong>SR 71</strong></td>
<td>9 232</td>
<td><strong>0.126</strong></td>
</tr>
<tr>
<td>SR 111</td>
<td>10 234</td>
<td><strong>0.114</strong></td>
</tr>
<tr>
<td>SR 171</td>
<td>4 577</td>
<td>0.221</td>
</tr>
<tr>
<td><strong>SR 266</strong></td>
<td>6 955</td>
<td><strong>0.107</strong></td>
</tr>
<tr>
<td>SR 269</td>
<td>5 456</td>
<td>0.169</td>
</tr>
</tbody>
</table>
**Black Space Diagram**

*Field Sample Creep Modulus vs. m-Value @ 60s Min PG + 10°C*

- **Likely to Crack**
- **Not Likely to Crack**
June 13th, 2012 – No Visible Distresses
January 9th, 2013 – No Visible Distresses
Visible Cracking

SR 111

June 13, 2012 →

January 23, 2013 →
Performance Predictions

Field Sample Creep Modulus vs. m-Value
@ 60s Min PG + 10°C

- C13
- C14
- C16

Likely to Crack
Not Likely to Crack
Conclusions

• Binder testing alone is not sufficient to determine mixture performance
  – All mixtures used PG 64-28, but had varying creep moduli and m-Values

• BBR testing is practical
  – Coring, cutting, and testing at one temperature could be completed in one work day with ‘simple’ equipment

• BBR testing on mixtures is repeatable across labs

• BBR test results can be used to predict sections with potential for low temperature cracking
  – A specification to predict low-temperature performance of asphalt concrete must include the creep modulus and relaxation capacity
  – In Black Space, a possible thermal stress failure envelope could be developed

• Performance-related specification will allow for innovation
Questions?

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