The “Other” HMA Test

101st THE
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Engineer of Tests
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The “Other” HMA Test for Flexible Pavements

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special acknowledgements to:

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& Jim Trepanier

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ICT - Testing Protocols to Ensure Mix Performance w/ High RAP and RAS
HMA Pavement Failures

- Rutting
Solution – a Performance Test
Solution – a Performance Test

Does this test duplicate traffic and conditions?
Solution – a Performance Test

Does this test duplicate traffic and conditions?
• It has steel wheels, not rubber!
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Does this test duplicate traffic and conditions?
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• The wheels go forward …. and backward on the sample.
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Does this test duplicate traffic and conditions?
• It has steel wheels, not rubber!
• The wheels go forward …. and backward on the sample.
• The test occurs in a 50° C water bath.
Solution – a Performance Test

Does this test duplicate traffic and conditions?
• It has steel wheels, not rubber!
• The wheels go forward …. and backward on the sample.
• The test occurs in a 50°C water bath.
• It takes less than a day …. to simulate 15 years……
Solution – a Performance Test

Does this test duplicate traffic and conditions?
• It has steel wheels, not rubber!
• The wheels go forward …. and backward on the sample.
• The test occurs in a 50° C water bath.
• It takes less than a day …. to simulate 15 years……
• It’s not based on a fundamental property.
Solution – a Performance Test

Does this test duplicate traffic and conditions?
• It has steel wheels, not rubber!
• The wheels go forward …. and backward on the sample.
• The test occurs in a 50° C water bath.
• It takes less than a day …. to simulate 15 years……
• It’s not based on a fundamental property.
• And …. 
Solution – a Performance Test

It’s an Accurate Indicator, Not a Flawed Simulator
HMA Pavement Failures

- Rutting
- Cracking
HMA Pavement Failures

- Rutting
- Cracking
  - Reflective
HMA Pavement Failures

- Rutting
- Cracking
  - Reflective
  - Thermal (Cold Weather)
HMA Pavement Failures

- Rutting
- Cracking
  - Reflective
  - Thermal (Cold Weather)
  - Fatigue
Where Do We Need to Focus?
Where Do We Need to Focus?

- Asphalt Binder
2. Elastic vs. Viscoelastic Response

2.2. Material Models

Behavior of Prony Series

- **Delayed Elastic Response**, \( f(D_1, t) \)
- **Steady State Creep**, Slope = \( f(\eta) \)
- **Initial Elastic Response**, \( f(D_0) \)

Transportation Research Board Webinar Organized by:
AFK 56(1): Sub committee on advanced models to understand behavior and performance of asphalt mixtures
AFK 50: Committee on characteristics of asphalt paving mixtures to meet structural requirements
Could There be a Single Solution?
Challenges

- SuperPave was developed for neat materials.
- More recycled materials are being used in HMA – less virgin components – especially PG asphalts in the final mix.
- Currently, some recycled materials are allowed by method specifications intended to limit the risk of cracking by ABR limits and grade bumping, not actual mix performance.
- Fatigue cracking issue: stiffer mixes with high ABR may exhibit early fatigue cracking.
- Thermal/Block cracking issue: stiffer mixes have reduced relaxation potential.
Challenges (RAP/RAS)

- RAP AC can be hard or soft – depends on project(s) milled
- RAP aggregates may be siliceous or carbonate
- Shingle asphalt (*PG 112+02) is much harder than paving grades
- Counteracting various hard recycled binders with virgin PG binder becomes arbitrary
- Neat asphalt blending with RAP and RAS for final mix is not understood
Test Method Selection Criteria

- Practical $$
- Quick turnaround
- Correlation to independent tests and engineering intuition
- Significant and meaningful spread in test output
- Correlation to field performance
Mixture Tests Available

Beam Fatigue Test

Push-pull Fatigue

DCT (ASTM D7313)

SCB (AASHTO TP105)

Texas Overlay Test
Mixture Tests Available

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- Beam Fatigue Test
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Semi-Circular Bending Test

- Relies on simple three point bending
- Easy specimen preparation
- Can use AASHTO T283 equipment *
- Repeatable
Research Approach

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material Source</td>
<td>Plant Mixes, Lab-Mixes, Field Cores</td>
</tr>
<tr>
<td>N-Design</td>
<td>N30, N50, N70, N80, N90</td>
</tr>
<tr>
<td>Nominal Maximum Aggregate Size</td>
<td>4.75 mm, 9.5 mm, 12.5 mm, 19.0 mm</td>
</tr>
<tr>
<td>Recycled Materials</td>
<td>RAP, RAS, Recycled Concrete, and Steel Slag</td>
</tr>
<tr>
<td>Asphalt Binder Ratio</td>
<td>0 to 60</td>
</tr>
<tr>
<td>RAP Content (%)</td>
<td>0 to 53</td>
</tr>
<tr>
<td>RAS Content (%)</td>
<td>0 to 8.5</td>
</tr>
</tbody>
</table>

- **Assessment of variety of plant mixes, lab designed mixes, and field cores**
- **Correlation to other tests (modulus and fatigue)**
- **Theoretical and numerical evaluation**
FEM Results

- FEM simulations of N80-25 mix
Fracture Process Zone
Fracture Process Zone

<table>
<thead>
<tr>
<th>N90 Control (0% RAS)</th>
<th>N90 30% ABR (7% RAS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-12°C @ 0.7 mm/min</td>
<td>-12°C @ 0.7 mm/min</td>
</tr>
<tr>
<td>25°C @ 50mm/min</td>
<td>25°C @ 50mm/min</td>
</tr>
</tbody>
</table>

Images show microstructural changes under different conditions.
SCB Fracture Results

N90 lab mix design (30%ABR)
Fracture Energy = 1780 J/m²
Slope = -2.87 kN/mm
Critical displacement = 2.19 mm

N90 lab mix design (control)
Fracture Energy = 1790 J/m²
Slope = -1.59 kN/mm
Critical displacement = 2.84 mm
Establishment of Test Temperature and Loading Rate

- SCB fracture test results at -12°C
- Limited data spread
Establishment of Test Temperature and Loading Rate

- SCB fracture energy results for the same mixes at 25 °C using displacement control at 50 mm/min
- Significant spread in fracture energy
A comparison of low temperature and intermediate temperature (25°C) SCB test results indicate the suitability test to discriminate mixes.

25 °C and 50 mm/min loading rate were selected.
SCB Fracture Results

- Flexibility Index calculated for two lab design (N90) mixes w/ and w/o ABR (30% ~ 7% RAS):

Flexibility Index (Fl) = A*G_F /m
SCB Fracture Results

- Flexibility Index calculated for two lab design (N90) mixes w/ and w/o ABR (30% ~ 7% RAS):

![Graph showing load vs. displacement for two N90 lab mix designs with and without ABR.]

- **N90 lab mix design (30% ABR)**
  - Fracture Energy = 1780 J/m²
  - Slope = -2.87 kN/mm
  - Critical displacement = 2.19 mm

- **N90 lab mix design (control)**
  - Fracture Energy = 1790 J/m²
  - Slope = -1.59 kN/mm
  - Critical displacement = 2.84 mm
Development of Flexibility Index

- **A theoretically-supported flexibility index (FI)**

\[
\text{Flexibility Index (FI)} = A \times G_F / m
\]

- sse = 629
- \( R^2 = 0.88 \)
Development of Flexibility Index

- A theoretically-supported flexibility index (FI)

\[ G_F \times \frac{\text{initial slope}}{\text{strength}^2 \times \text{post peak slope}} \]

**Graph:**
- x-axis: Flexibility Index
- y-axis: Approximate Crack Velocity (mm/sec)
- sse = 679
- \( R^2 = 0.87 \)
Development of Flexibility Index

- A theoretically-supported flexibility index (FI)

\[ GF \times \frac{1}{1000} \]

\( sse = 1973 \)
\( R^2 = 0.61 \)
Flexibility Index calculated for selected plant mixes

- N50 60% ABR (P1): 4.4
- N50 29% ABR (P2): 4.8
- N70 29% ABR (P3): 3.0
- N30 37% ABR (P4): 3.2
- N70 6% ABR (P5): 0.6
- N90 6% ABR (P6): 5.0
- N50 0% ABR (P7): 12.2


**FI - Plant Mixes**

<table>
<thead>
<tr>
<th>Mix ID</th>
<th>PG</th>
<th>RAP (%)</th>
<th>RAS (%)</th>
<th>ABR (%)</th>
<th>AC (%)</th>
<th>VMA (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(P5)</td>
<td>N70-6</td>
<td>64-22</td>
<td>10</td>
<td>-</td>
<td>6</td>
<td>6.1</td>
</tr>
<tr>
<td>(P9)</td>
<td>N50-60</td>
<td>52-28</td>
<td>42</td>
<td>6</td>
<td>59</td>
<td>5.6</td>
</tr>
<tr>
<td>(P11)</td>
<td>N70-50</td>
<td>58-28</td>
<td>30</td>
<td>5</td>
<td>48</td>
<td>6.0</td>
</tr>
<tr>
<td>(P12)</td>
<td>N80-25</td>
<td>70-28</td>
<td>8</td>
<td>5</td>
<td>26</td>
<td>6.1</td>
</tr>
<tr>
<td>(P7)</td>
<td>N50-0</td>
<td>64-22</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>5.9</td>
</tr>
</tbody>
</table>
FI (with SF): Field Cores

Increasing cracking potential

Type I
Type II
Type III

Flexibility Index (FI) - Field Cores
## FI Categorization & Implementation

- **Draft Categorization of Mixes Using Flexibility Index and Threshold**

<table>
<thead>
<tr>
<th>Mix Category</th>
<th>Mix Type Based on Flexibility Index (FI)</th>
<th>Potential Actions and Remedies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unacceptable Mix</td>
<td>Type III (&lt;2.0)</td>
<td>Reject mix due to high early cracking potential. Redesign the mix.</td>
</tr>
<tr>
<td>Inferior Mix</td>
<td>Type II (≤2.0-4.0)</td>
<td>Mix susceptible to cracking. Use the mix only in temporary application or redesign.</td>
</tr>
<tr>
<td>Acceptable Mix</td>
<td>Type I (≤4.0-10.0¹)</td>
<td>Accept the mix. Mix is expected to perform adequately. Use the mix in surface overlay or typical pavement applications.</td>
</tr>
</tbody>
</table>

*Lab-compacted mix having FI > 10 is considered high performance mix.*
Low Temperature Cracking
-40°C Low in-service temperatures

Fatigue Cracking/Service Temperature
-20°C Intermediate in-service temperatures

Permanent Deformation
20°C

40°C High Temperatures
Owner Concerns

- We don’t know where asphalts originate
- We don’t know what is added to asphalts
- We don’t know what is in recycled materials
- We don’t know what happens when sources of asphalt and aggregate change
- We don’t know what damage occurs during production in various plants
- We need a mix cracking performance test
The Other HMA Test
The Other HMA Performance Test
The Other HMA *Performance* Test

- With the Hamburg Wheel to minimize rutting probability ....
The Other HMA Performance Test

- With the Hamburg Wheel to minimize rutting probability ....

- The SCB reduces risk to the owner of premature pavement cracking
  - It is simple and scientifically sound
  - Can test gyratory specimens or field cores
  - The Flexibility Index can discriminate between good and poor performing mix
  - More validation is underway*