Team members

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• Butch Heidler

Their efforts on the projects and their presentation support are greatly appreciated.
FHWA MATT Program

- Mobile Asphalt Testing Trailer (MATT)
- AASHTO Accredited
- Superpave™ Technology
  - Test
  - Evaluate
  - Refine
  - Improve
  - Implement
FHWA MATT’s Involvement

- Address National Pavement Issues
  - Interaction with Transportation Partners
    - FHWA Division Offices and Resource Center
    - State DOTs and Industry
    - ETG’s and TWG’s
  - Technical Support on National Initiatives
    - Hot Mix Asphalt (HMA)
    - Warm Mix Asphalt (WMA)
    - Reclaimed Asphalt Pavement (RAP)
    - Reclaimed Asphalt Shingles (RAS)
    - Ground Tire Rubber (GTR)
  - Pavement ME™ (previously Mechanistic-Empirical Pavement Design Guide - MEPDG)
Outline

• Challenges
  – Fatigue cracking
  – Thermal cracking
  – Aging (Conditioning)

• Use of different parameters
  – Low temperature cracking
  – $\Delta T_c$
  – Master Curve
  – Glover-Rowe parameter

• Summary of Findings
Binder New Parameter ($\Delta T_c$)

- $\Delta T_c$ is the difference between the critical low temperature determined by stiffness and relaxation criteria from BBR test
  - $\Delta T_c = S \text{ critical temp} - m \text{ critical temp}$
- As an asphalt binder ages, $\Delta T_c$ value becomes more negative
  - Indicating a loss of relaxation properties
- Important parameter related to asphalt binder durability
Christensen-Anderson model used
• Project Location:
  – Wisconsin

• Production of HMA mixes with various content of recycled materials:
  – Recycled Asphalt Pavement (RAP): 13 to 40 percent of total mix
  – Recycled Asphalt Shingles (RAS): 3 to 6 percent of total mix
  – Binders
    ✓ PG 52-24
    ✓ PG 58-28
    ✓ PG 58-34
    ✓ Additives: SBS, WMA
# Mix Designs

<table>
<thead>
<tr>
<th>Mix 9</th>
<th>Mix 9.5</th>
<th>Mix 10</th>
<th>Mix 12</th>
<th>Mix 13</th>
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<tbody>
<tr>
<td>RAP = 32%</td>
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<tr>
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<td>PG 58-28</td>
<td>PG 58-28</td>
<td>PG 52-34</td>
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<td>PG 52-34</td>
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<tr>
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<td>VA = 3.5%</td>
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<tr>
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<td>Pb = 2.7%</td>
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<table>
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<tr>
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<th>Mix 5</th>
<th>Mix 6</th>
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<td>RAP = 33%</td>
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<td>RAP = 33%</td>
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<tr>
<td>RAS = 6%</td>
<td>RAS = 6%</td>
<td>RAS = 4%</td>
<td>RAS = 4%</td>
<td>RAS = 4%</td>
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<td>ABR = 0.50</td>
<td>ABR = 0.50</td>
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<tr>
<td>VA = 3.5%</td>
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<td>VA = 3.5%</td>
<td>VA = 3.5%</td>
<td>VA = 3.5%</td>
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<tr>
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<td>Pb = 2.45%</td>
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<tr>
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<td>No additive</td>
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</tr>
</tbody>
</table>

Notes:
1. ABR = Asphalt Binder Replacement
2. Warm mix additive used for rejuvenation purpose only
As-recovered Binder Results

BBR Low Temperature

- **Effect on Cracking**
  - ABR has an effect on Critical Cracking Temp and the effect is nearly linear
  - $\Delta T_c$ for the recovered binder is getting more negative when the ABR increases
As-recovered Binder Results

*Master Curve*

- **Effect of increasing ABR**
  - The master curves become flatter
  - Similar to effect of aging
Conditioned Binder Results

Master Curve

- Conditioning effect
  - The master curves become flatter
  - $R$ increasing and $\omega_c$ decreasing
• **ABR increasing similar to more conditioning**
  
  – The master curves become flatter
  
  – Master curves for the as-recovered binders are flatter than the master curve for PG 58-28 binder after 20 hrs PAV
• **Effect of Long Term Conditioning**
  
  – Extended PAV conditioning decreases $\Delta T_c$ approximately 3.5 °C
  – The difference between 20 and 40 hrs conditioning remains relatively constant as the ABR increases.
Cracking Susceptibility

Glover-Rowe parameter

- **Effect of increasing ABR**
  - The Glover-Rowe parameter increases
  - After standard PAV, the recovered binder from all mixtures exceed the recommended limit for the onset of damage (except the lowest ABR)!
Summary of Findings I

- For the recycled materials used, $\Delta T_c$ decreases at the rate of about 0.2 °C per percent ABR.

- The rate of change of the Glover-Rowe parameter with PAV condition time increases with increasing ABR.

- For extended PAV conditioning, binders becoming highly m-value controlled.

- Master curve becomes more flat as conditioning increases or ABR % increases.
• Project Location:
  – Arizona

• Open Graded Friction Course (OGFC) mixtures:
  – Three different Terminal blended Asphalt Rubbers
  – Hybrid Binders: GTR + SBS
    ✓ PG70-22 TR+ (contains 8 % of GTR)
    ✓ PG70-22 TR+ SBS (8 % GTR + 2 % SBS; solubility limit of 97%)
    ✓ PG70-22 TR+ S92 (8 % GTR + 2 % SBS; solubility limit of 92%)
### Long Term Conditioning

**Low Temperature Cracking**

<table>
<thead>
<tr>
<th>Asphalt Binder</th>
<th>PAV Cond Time, (hr)</th>
<th>AASHTO M 320 Table 1, (°C)</th>
<th>AASHTO M 320 Table 2, (°C)</th>
<th>ABCD, (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PG 70-22 TR+</td>
<td>20</td>
<td>-28.8</td>
<td>-29.5</td>
<td>-26.6</td>
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<tr>
<td>PG 70-22 TR+</td>
<td>40</td>
<td>-24.5</td>
<td>-24.8</td>
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<tr>
<td>PG 70-22 TR+ (S 92)</td>
<td>20</td>
<td>-32.0</td>
<td>-31.8</td>
<td>-32.3</td>
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<tr>
<td>PG 70-22 TR+ (S 92)</td>
<td>40</td>
<td>-26.0</td>
<td>-26.7</td>
<td>-31.0</td>
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<tr>
<td>PG 70-22 (SBS)</td>
<td>20</td>
<td>-30.9</td>
<td>-29.7</td>
<td>-30.5</td>
</tr>
<tr>
<td>PG 70-22 (SBS)</td>
<td>40</td>
<td>-23.0</td>
<td>-27.8</td>
<td>-29.4</td>
</tr>
</tbody>
</table>

- Reasonable agreement between the three measurements for 20 hrs PAV conditioning.
- The ABCD is less sensitive than the other two to conditioning time.
- Doubling PAV time:
  - 0.9 °C ↑ of cracking temp (ABCD)
  - 6.1 °C ↑ of cracking temp (Table 1)
  - 3.9 °C ↑ of cracking temp (Table 2)
### Long Term Conditioning

#### Intermediate grade & $\Delta T_c$

<table>
<thead>
<tr>
<th>AsphaltBinder</th>
<th>PAV Conditioning Time, (hr)</th>
<th>AASHTO M 320 Table 1 Intermediate Temperature Continuous Grade, (°C)</th>
<th>AASHTO M 320 Table 1 $\Delta T_c$, (°C)</th>
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</thead>
<tbody>
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<td>20</td>
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<td>PG 70-22 (SBS)</td>
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<td>PG 70-22 (SBS)</td>
<td>40</td>
<td>19.9</td>
<td>-8.4</td>
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</table>

- The low temperature grade becomes much more **m-value** controlled for 40 hrs vs. 20 hrs PAV conditioning.
- The $\Delta T_c$ parameter dropped **lower than -5.0 °C** for the PG 70-22 TR+ (S 92) and the PG 70-22 (SBS) after extended PAV conditioning.
- These changes indicate that the in-service aging will likely be greater for the PG 70-22 TR+ (S 92) and PG 70-22 (SBS).
Long Term Conditioning

Master Curve - PG 70-22 TR+ (S 92)

More conditioning causes the master curves become flatter with $R$ increasing and $\omega_c$ decreasing.
Long Term Conditioning

Glover-Rowe Parameter

- After 40 hrs of PAV conditioning, all binders have Glover-Rowe parameters above the recommended limit for the onset of cracking.
- The slope for these binders is about 5 kPa per hr of PAV conditioning over the first 20 hr increasing to about 16 kPa per hr for extended PAV conditioning.
• For extended PAV conditioning, binders becoming highly \textit{m-value} controlled.

• The master curves became \textit{flatter} (increasing R value and decreasing $\omega_c$) with \textit{increased laboratory} conditioning.

• \textit{40 hrs PAV} conditioning may \textit{better differentiate} between different materials.
Mobile Asphalt Pavement Materials Lab
  – Site Visits
  – Field Data/Testing/Evaluation
  – Use/Demo Emerging Test Devices
  – POC: Matthew Corrigan
Thank You!!

FHWA’s Mobile Asphalt Testing Trailer
Office of Asset Management, Pavement, and Construction

www.fhwa.dot.gov/pavement/asphalt