NCHRP Project 9-61

Short- and Long-Term Binder Aging Methods to Accurately Reflect Aging in Asphalt Mixtures

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Research Team

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Outline

• Objectives
• Project Tasks
• Work Completed
• What’s Next
Objectives

• Evaluate AASHTO 240, AASHTO R 28 and alternatives

• Recommend improvements
  – New procedure
  – Modifications to existing procedures

• Calibrate the improved procedures to accurately simulate aging
  – Mixture production, transport, and placement
  – Service life of the pavement
NCHRP 9-61 Is Not!

- A study of binder rheology
- A study of binder chemistry
- A study to relate chemical and rheological properties of binders
- A study to recommend improved specification criteria
Approach

- Task 1. Evaluate and Select Methods
- Task 2. Prepare Experimental Plans
- Task 3. Prepare Interim Report
- Task 4. Conduct and Analyze Experiments
- Task 5. Perform Industry Impact Assessment
- Task 6. Prepare Methods in AASHTO Format
- Task 7. Prepare Final Report
How Much Binder?

• Only a few grams if you use 4 mm DSR
  – Probably not realistic at this time

• M 320 or M 332 without direct tension
  – 35 g for verification
  – 65 g for grading

• M 320 or M 332 with Modified DENT? (per 9-59)
  – 75 g for verification
  – 105 g for grading

• M 320 or M 332 with LAS? (per 9-59)
  – 40 g for verification
  – 70 g for grading
What is Target Age for Long-Term?

- Consensus that R 28 (20 hour PAV) is not severe enough
- Research now using 40 hour PAV
- Limited field data equating either 20 or 40 hour PAV to field properties
  - SHRP A 369: 20 hr PAV ~ 4 to 8 years
  - Erskine, et al. 2012: 40 hr PAV ~ 8 years
  - AAPTP Project 06-01: No change to R 28
  - WRI Fundamental Properties of Asphalts and Modified Asphalts III : ALF, and AZ
  - Braden Smith
Analysis of LTPP SPS 8 Sites

• New pavements on roads with limited truck traffic
• Two sections
  – 4 in AC on 8 in of aggregate base
  – 7 in AC on 12 in of aggregate base
• 15 sites constructed
• Distresses monitored every 1 to 2 years
Transverse Cracking in SPS 8 Sections

Length of Transverse Cracks, m vs. Pavement Age, yrs

- AR
- CA
- MS
- NM
- NC
- MO
- NY
- OH
- WI
Practice Related T 240
Conditioning Issues

• Uniformity of the film and how well it is renewed is viscosity dependent
• Some modified binders tend to crawl out of the bottle
• Shape of the bottle makes recovery of the binder and cleaning difficult
• Procedure does not address WMA
Short-Term Alternates

- Modified German Rotating Flask
- Stirred Air Flow Test
- Universal Simple Aging Test
- Rotating Cylinder Ageing Test
- Ageing Profile Test
Short-Term Considerations

• Quantity of binder
• Number of binders per run
• Conditioning time
• Improves film uniformity
• Eliminates crawling from container
• Suitable for crumb rubber binders
• Simulate HMA and WMA temperatures
• Improves binder recovery
• Standard available
• Equipment availability
• Equipment cost
• Training cost
Short-Term Selections

• Modifications to t 240 made in the U.K. Ageing Profile Test

• Thicker Film USAT
  – Around 0.8 mm rather than 0.3 mm to increase yield
AAC-1 @ 163 °C for 85 min

![Graph showing G*/sinδ at 58°C, kPa vs. Thickness, mm. The graph compares AAC-1 Pan Aged, RTFOT, and Original samples.](image-url)
AAF-1 @ 163 C for 85 min

Graph showing the relationship between thickness (mm) and $G*/\sin\delta$ at 64°C, kPa for AAF-1 Pan Aged, RTFOT, and Original samples.
Practice Related R 28
Conditioning Issues

• Conditioning is not severe enough
• Service life that is simulated is not well defined
Long-Term Alternates

- Rotating Cylinder Ageing Test
- Ageing Profile Test
- Universal Simple Aging Test
- Extended Time PAV
- Thinner Film PAV
- Increased Temperature PAV
- Mixing in PAV
  - Ultrasonic
  - Resonant Acoustic
Long-Term Considerations

- Quantity of binder
- Number of binders per run
- Conditioning time
- Conditioning temperature
- Atmosphere (air vs oxygen)
- Pressure
- Correlated to field aging
- Standard available
- Equipment availability
- Equipment cost
- Training cost
# Long-Term Selection

- **Thinner Film PAV**

<table>
<thead>
<tr>
<th>Film Thickness, mm</th>
<th>Surface Area Required, cm²</th>
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<tbody>
<tr>
<td></td>
<td>Verification (75 g assumed)</td>
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<tr>
<td>3.18</td>
<td>233</td>
</tr>
<tr>
<td>1.59</td>
<td>465</td>
</tr>
<tr>
<td>0.8</td>
<td>925</td>
</tr>
<tr>
<td>0.3</td>
<td>2467</td>
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</table>
Example PAV Pan for 0.8 mm Film
Proposed Phase 2 Experiments

- Short-Term Final Selection
- Short-Term Calibration
- PAV Thickness, Time, Temperature
- Long-Term Calibration
- Sensitivity Study
Short-Term Selection

• Make final selection of short-term procedure
  – Thin film aging (0.8 mm)
  – UK mixing screw
  – NCHRP 9-61 improved mixing screw

• Compare binder conditioning procedures to binder recovered from short-term oven aged mixtures
  – NCHRP 9-52 recommendations
    • HMA 2 hours at 135 °C
    • WMA 2 hours at 116 °C
## Short-Term Selection

<table>
<thead>
<tr>
<th>Aging Methods</th>
<th>Neat PG 52-34</th>
<th>Polymer (Terpolymer) PG 64-34</th>
<th>Neat PG 64-22</th>
<th>Polymer (SBS) PG 76-22</th>
<th>GTR ASTM D 6114</th>
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<tbody>
<tr>
<td></td>
<td>WMA</td>
<td>HMA</td>
<td>WMA</td>
<td>HMA</td>
<td>WMA</td>
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<tr>
<td>AASHTO T 240</td>
<td>X X</td>
<td>X X</td>
<td>X X</td>
<td>X X</td>
<td>X X</td>
</tr>
<tr>
<td>UK Mixing Screw</td>
<td>X X</td>
<td>X X</td>
<td>X X</td>
<td>X X</td>
<td>X X</td>
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<tr>
<td>NCHRP 9-61 Mixing Screw</td>
<td>X X</td>
<td>X X</td>
<td>X X</td>
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<td>X X</td>
</tr>
<tr>
<td>Static Thin Film (0.8 mm)</td>
<td>X X</td>
<td>X X</td>
<td>X X</td>
<td>X X</td>
<td>X X</td>
</tr>
<tr>
<td>Recovered, NCHRP 9-52 Oven Aging</td>
<td>X X</td>
<td>X X</td>
<td>X X</td>
<td>X X</td>
<td>X X</td>
</tr>
</tbody>
</table>

**Response variables:**
- High temperature continuous grade
- Master curves
- CS+SO
- GPC for modified binders
Short-Term Calibration

- Calibrate the selected procedure (varying conditioning time) to reproduce properties of binder recovered from short-term conditioned loose mix
- NCHRP 9-52 recommendations
  - HMA 2 hours at 135 °C
  - WMA 2 hours at 116 °C
- High Temperature Continuous Grade
## Short-Term Calibration

<table>
<thead>
<tr>
<th>Mix Temp</th>
<th>Binder Type</th>
<th>Low Temp Grade</th>
<th>Binder Properties</th>
<th>Aging Index</th>
<th>Mix Properties</th>
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<tr>
<td></td>
<td></td>
<td></td>
<td>19 mm</td>
<td>9.5 mm</td>
<td>SMA</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Sandstone</td>
<td>Limestone</td>
<td>Diabase with Limestone Filler</td>
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<tr>
<td>WMA</td>
<td>Neat</td>
<td>-34 or -28</td>
<td>Low</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>High</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-22 or -16</td>
<td>Low</td>
<td>X</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>High</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Modified</td>
<td>-34 or -28</td>
<td>Low</td>
<td>X</td>
<td>X</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>High</td>
<td>X</td>
<td>X</td>
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<tr>
<td></td>
<td></td>
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<td>Low</td>
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<td>X</td>
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<td></td>
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<td></td>
<td>-22 or -16</td>
<td>Low</td>
<td>X</td>
<td>X</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td>High</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
PAV Thickness, Time, Temperature

• Investigate how to reasonably simulate more aging using the PAV
• Vary thickness, time, temperature
• Compare rheological and chemical properties to recovered binders from ARC Arizona (hot, 16 yrs) and Minnesota (cold, 11 yrs) sections
• Binder master curves, carbonyl + sulfoxide
ALF Master Curves

- 6.5 mm 96 Month + 8 Month Accelerated
- 6.5 mm 96 month
- 19 mm 96 month
- 48.5 mm 96 month
- 61.5 mm 96 month

Reduced Frequency, rad/sec

$G^*$, Pa

Advanced Asphalt Technologies, LLC

“Engineering Services for the Asphalt Industry”
# ARC AZ and MN Binders

<table>
<thead>
<tr>
<th>Site</th>
<th>Grade</th>
<th>Source</th>
<th>Modification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arizona US 93</td>
<td>PG 76-16</td>
<td>WTI/WTS blend</td>
<td>Airblown</td>
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<tr>
<td></td>
<td>PG 76-16</td>
<td>Venezuelan</td>
<td>N/A</td>
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<tr>
<td></td>
<td>PG 76-16</td>
<td>Rocky Mountain Blend</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>PG 76-16</td>
<td>Canadian Blend</td>
<td>N/A</td>
</tr>
<tr>
<td>Rochester, MN</td>
<td>PG 58-34</td>
<td>Canadian Blend</td>
<td>Terpolymer</td>
</tr>
<tr>
<td></td>
<td>PG 58-28</td>
<td>Canadian Blend</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>PG 58-28</td>
<td>Middle East Blend</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>PG 58-28</td>
<td>Venezuelan Blend</td>
<td>N/A</td>
</tr>
</tbody>
</table>
# Partial Factorial

<table>
<thead>
<tr>
<th>Temp, C</th>
<th>Thickness, mm</th>
<th>Time, hrs</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td>90</td>
<td>3.18</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>1.59</td>
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</tr>
<tr>
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<td>0.80</td>
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<tr>
<td>100</td>
<td>3.18</td>
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<td>0.80</td>
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<td>110</td>
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<td>1.59</td>
<td>X</td>
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<tr>
<td></td>
<td>0.80</td>
<td></td>
</tr>
</tbody>
</table>

Response surface experiment
Process improvement experiments
Output of Thickness, Time, Temperature Experiment

- Film thickness
- Conditioning time
- Range of useable temperatures
Long-Term Calibration

• Using thickness and time from the previous experiment, vary the conditioning temperature to determine conditioning temperature that reproduces the properties of binder recovered from field cores

• Binder master curves, carbonyl + sulfoxide
Example

The graph illustrates the change in log $\omega_c$ with respect to conditioning temperature ($C$) for different aggregate sizes. The blue line represents a 75 mm aggregate, while the red line represents a 6 mm aggregate. The graph shows the relationship between the change in log $\omega_c$ and the conditioning temperature, highlighting how the properties of asphalt change with temperature and aggregate size.
Available Original Binders and Cores From LTPP
Age

Age, Years

Section Number

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Regression Analysis of Conditioning Temperatures

• Factors
  – Climate
  – Age
  – Depth in pavement
  – Air voids
  – Binder volume

• Use regression model to recommend final lab conditioning temperatures
Sensitivity Study

• M 320 and M 332 Grade several binders
  – Current T 240 and R 28
  – Improved procedures developed in NCHRP 9-61
  – Materials with proven performance
  – Newer materials
  – 8 to 10 binders

• Information for the Industry Assessment