Impact of Aging on Cracking Behavior of Asphalt Mixtures

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Asphalt pavements undergo aging during mixing and compaction, and over the service life.

- Short term aging (mixing and compaction)
- Long term aging (pavement service life)

Aging effects:

- Increase of stiffness
- Decrease of relaxation
- Increase of brittleness

More cracking susceptibility
Primary Objective

• To evaluate how the cracking properties of mixtures evolve with aging

Motivation

• AASHTO R30 is the current standard for aging in United States, there are several deficiencies that have been well documented:
  — Not sufficient to reflect the field aging in long term
  — Aging gradient in radial and vertical directions
Project Overview

• NHDOT Research Project 26962O
• 10 plant mixed, lab compacted mixtures
  – Binders: PG 58-28, PG 52-34
  – Aggregate: 12.5 mm NMAS
  – 20 and 30% RAP, 20% RAP/RAS
• Binder, Mixture and Field Core testing
- Short-term aging condition
  - Plant production
- Long-term aging condition
  - 5 days, 95 °C, loose mix (NCHRP 9-54)
  - 12 days, 95 °C, loose mix (NCHRP 9-54)
  - 24-hour, 135 °C, loose mix (Asphalt Institute)
Laboratory Testing

- Complex Modulus Testing: AASHTO T 342
  - $|E^*|$ and $\delta$ master curve
  - Higher $E^*$ and lower $\delta \Rightarrow$ more potential for cracking
Laboratory Testing

- Uniaxial Cyclic Direct Tension Testing (AASHTO TP 107)
  - Mixture cracking performance
  - Damage Characteristics Curve (C – S), Fatigue Failure Criterion ($G^R - N_f$)
Laboratory Testing

- Semi-Circular Bend (SCB) Test (AASHTO TP 124)
  - Flexibility Index ($FI = \frac{G_f}{\text{Slope at inflection point}}$)

\[ G_f = \frac{\text{Work}}{\text{Fracture Surface Area}} \]

\[ \text{FST} = \frac{G_f}{\text{Fracture Strength}} \]

\[ FI = \frac{G_f}{\text{Slope at Inflection Point}} \]
LVE Characteristics (PG 52-34, 12.5, 30% RAP mix)

Results: E* Example

- Higher $|E^*|$ and lower $\delta$ for LTOA mixtures;
- Horizontal and vertical shift in $\delta$ master curve shape
Results:

$|E^*| \text{ ratio}$

$E^*$ (12 days LTOA) / $E^*$ (STOA)

Frequency (Hz)

$|E^*| \text{ ratio ranges between 1 to 6; Lower ratio at very high & very low freq., highest ratio around 0.01 Hz.}$
• Higher FI for 5 days aged mixes than 12 days and 24 hr.
• The FI of 5 day aged mixes is not sensitive to RAP
• Similar integrity for STOA and 5 days LTOA, but high levels of aging make significant difference.

Results: Fatigue Properties (C-S)
This fatigue failure criterion does not seem to be very sensitive to aging for these mixtures.

A different criteria, $D^R$ has been now proposed by NCSU, results for $D^R$ are following similar trends as the fracture properties.
• All levels of long term aging made significant effect on LVE properties (\(|E^*|\) and \(\delta\)).
• 24 hour (135°C) and 12 days (95°C) aging levels create statistically similar effects on LVE properties, but not on fracture and fatigue properties.
• Fracture resistance decreases as the aging level changes from 5 to 12 days; no evident trend between the fracture properties of 24 hour and 12 days.
• High levels of aging (24 hr at 135°C and 12 days at 95°C) contribute to a significant reduction in “pseudo stiffness” of RAP/RAS mixtures, indicating the higher rate of damage growth that can result in more cracking potential.

Conclusions
Performance modelling of study sections and comparisons with field performance

Testing and analysis of cores from pavements that have aged in the field.

Development of new thresholds for available cracking parameters with the effect of aging.
   — Including use of mix Glover-Rowe parameter

Exploration of interdependence of LVE, fracture and fatigue changes with ageing.
Aging Effect: LVE vs. Fracture Parameters

- DOT Control 0.22 RBR [T(18.29)]
- Recycled 0.31 RBR [T(22.22)]
- Recycled 0.31 RBR (PG 52-34) [T(28.36)]
- Recycled 0.31 RBR (1.2%) V2 [T(12.84)]

- Virgin
- DOT Control 0.15 RBR
- Recycled 0.3 RBR
- Recycled 0.3 RBR (2%) T2
- Recycled 0.3 RBR (2%) A2

- DOT Control 0.22 RBR [T(18.29)]
- Recycled 0.31 RBR [T(22.22)]
- Recycled 0.31 RBR (PG 52-34) [T(28.36)]
- Recycled 0.31 RBR (1.2%) V2 [T(12.84)]
- Recycled 0.31 RBR + 5.5% V2 (58-28)
- Recycled 0.5 RBR + 9% V2 (58-28)

- DOT Control 0.33 RBR (0.4%) WMA
- Recycled 0.41 RBR (0.8%) T2
- Recycled 0.41 RBR (0.8%) T2 (0.25%) WMA
- Recycled 0.41 RBR (8%) T2
- Recycled 0.5 RBR (10%) T2
Thank you for your attention!

Questions / Comments?

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## Mixtures table

<table>
<thead>
<tr>
<th>Binder PG Grade</th>
<th>NMSA (mm)</th>
<th>%Recycled Binder Replacement (% RAP/ % RAS)</th>
<th>STOA</th>
<th>LTOA</th>
</tr>
</thead>
<tbody>
<tr>
<td>58-28</td>
<td>12.5</td>
<td>18.9 (18.9/0)</td>
<td>Complex Modulus and Fatigue results only. (No SCB testing)</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>18.5 (7.4/ 11.1)</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td></td>
<td>28.3 (28.3/ 0)</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>52-34</td>
<td>12.5</td>
<td>18.9 (18.9/0)</td>
<td>Complex Modulus and Fatigue results only. (No SCB testing)</td>
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