Evaluating Permanent Deformation In HMA Containing RAP By Considering The Effect Of Silo Storage Time

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Outline

- Introduction
  - Recycled Asphalt Pavement
  - Diffusion and Blending
- Hypothesis and Objective
- Methodology
- Test Result
- Conclusions
○ Economic and Environmental benefits
○ +20% ➔ softer virgin binder may be needed

Zaumanis, 2013
- HMA containing RAP typically enhances rutting resistance
- However, incomplete blending between virgin and aged binder was presumed to create regions that are more susceptible to the rutting in the mixture
“Diffusion is the process by which matter is transported from one part of a system to another as a result of random molecular motion”

(Crank, 1975)

- Literature indicates that two factors can have significant impacts on blending process between aged and new binders in HMA-RAP: time and temperature

- As the temperature rises, the average speed at which the molecules are moving increases exponentially (Arrhenius law)
Introduction: Diffusion
Introduction: Diffusion

Binder A  Binder B
Introduction: Diffusion

Binder A + Binder B → Blended Binder
Hypothesis

- Partial blending occurs during mixing and full blending might happen over time
- Time-temperature effect of the silo-storage can optimize the blending
- Better blending would lead to better durability
Objective

- Determine the suitable storage duration to accelerate diffusion and enhance binder blending in HMA RAP mixes without causing significant aging to the (virgin) binder.

- Evaluating rutting resistance of HMA RAP mixes by considering the time-temperature effect during mixing and silo-storage.
- No blending
  - bleeding and rutting problems
- Partial blending
  - can be accelerated by using rejuvenators
- Total blending
  - fatigue cracking, stripping and low temperature cracking problems

**Introduction:**

**Diffusion**

RAP binder and virgin binder blending scenarios (Moghaddam et al., 2016)
Methodology

Sample Collection from Miller Group

- HL-3 & HL-8 at (0, 1, 4, 8, 12 hrs) time intervals
  
  
  On-site compaction for stiffness test
  
  Loose mixtures for rutting test

  Storing at 7 °C until the day of testing/compaction

  Curing time = 14 days before cutting and coring

  Curing time = 14 days before compaction

  Complex Modulus Test
  
  Hamburg Wheel Tracking Test

Results and Analysis
### Methodology

<table>
<thead>
<tr>
<th>Mix type</th>
<th>% RAP</th>
<th>% AC</th>
<th>% Virgin AC</th>
<th>% RAP AC</th>
<th>Virgin AC grade</th>
<th>NMAS (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HL-3</td>
<td>15</td>
<td>5</td>
<td>4.4</td>
<td>0.6</td>
<td>PG 58-28</td>
<td>13.2</td>
</tr>
<tr>
<td>HL-8</td>
<td>30</td>
<td>4.7</td>
<td>3.5</td>
<td>1.2</td>
<td>PG 52-34</td>
<td>19</td>
</tr>
</tbody>
</table>
Methodology

Complex Modulus Test
○ The triplicate Ø100×150H mm cylinder complex modulus specimens were prepared for each silo time by cutting and coring the compacted HMA samples.

○ The test specimens were subjected to a repetitive, compressive sinusoidal load.
○ Each specimen was examined at six loading frequencies (0.1, 0.5, 1.0, 5.0, 10.0, 2 and 25 Hz) and five temperatures (-10, 4, 21.1, 37, and 54.4 °C).
Hamburg Wheel Tracking Test

- Quadruplicate Ø150×63H mm cylinder specimens were created for 0 and 12 hours storage mixes with 7 ± 0.5% air content.

- The specimens were tested in wet condition at 50°C by using hard rubber wheels.

- Linear Variable Differential Transducers (LVDT) device was used to measure the depth of the impression of the wheel (rutting depth).
Methodology

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HL-3 & HL-8 at (0, 1, 4, 8, 12 hrs) time intervals

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Curing time = 14 days before compaction

Complex Modulus Test
Hamburg Wheel Tracking Test

Results and Analysis
Complex Modulus Test

For HL-3 mixes, a noticeable change is observed in the stiffness of mix samples collected after 8 and 12 hours of silo storage, particularly at higher temperatures/low frequencies.
Complex Modulus Test

For the HL-8 mixes, the significant reduction in the stiffness is only found for the 12 hours samples.
Hamburg Wheel Tracking Device (HWTD) Test

- The 12-hrs specimens for HL-3 and HL-8 mixtures tend to exhibit a slightly better resistance to rutting.

Hamburg Rutting Results for HL-3 and HL-8

Average Rut Depth and Standard Division of the Mixes
Conclusions

- There was no significant change in the complex modulus values of all the samples that were collected at 0, 1 and 4 hours of silo storage.
- A decrease in the stiffness was observed in the HL-3 samples collected after 8 hours of silo storage.
- The change in the rheology for HL-8 mixture was only present in samples stored for 12 hours.
- Despite the fact that the rutting resistance has improved by only 1.1 time for the 12-hrs samples as compared with the 0-hrs samples, these results are promising and suggest more samples to be analyzed to draw more solid conclusions.
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