Laboratory Evaluation of High Binder Replacement with Recycled Asphalt Shingles (RAS) for a Low N-Design Asphalt Mixture

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Outline

- RAS Background
- Research Methodology and Objectives
- Sample Preparation and Materials
- Experimental Program
- Results and Analysis
- Summary and Conclusions
Recycled Shingles in Illinois

- Recycled asphalt shingles (RAS) are considered as a valuable supplement in HMA
- Potential for savings in paving projects and environmental benefits
- Current use of RAS in Illinois\(^1\):
  - 3,234 tons in IDOT projects
  - 4,440 tons in City of Chicago projects
  - 14,054 tons in Tollway projects
  - US total estimated: 701,000 tons in 2009 and 1,099,000 tons in 2010 (Hansen, 2012-NAPA survey)

Lippert and Brownlee (2012) – Use of RAS in IL

Why RAS?

- The composition of RAS (good stuff in RAS)
- Sufficient RAS supply in the market

<table>
<thead>
<tr>
<th>Material</th>
<th>% by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coating filler (limestone or fly ash)</td>
<td>32-42</td>
</tr>
<tr>
<td>Granules (painted rocks and slag)</td>
<td>28-42</td>
</tr>
<tr>
<td>Asphalt binder</td>
<td>16-25</td>
</tr>
<tr>
<td>Back dust (limestone and sand)</td>
<td>3-6</td>
</tr>
<tr>
<td>Fibers (paper, cotton rag, fiberglass)</td>
<td>2-15</td>
</tr>
</tbody>
</table>
Major Concerns with RAS

- Highly oxidized asphalt binder
  - Poor relaxation potential (usually characterized by m-value)
  - High PG Grades 100-150
- Low temperature cracking resistance due to brittleness of hardened binder
- Fatigue performance at intermediate temperatures when used at large quantities

Research Objectives and Methodology

- The objective is to evaluate the effects of RAS on the critical performance properties of asphalt mixture

- A laboratory experimental program was conducted to assess fracture, fatigue, modulus, and permanent deformation characteristics of an asphalt mixture at high binder replacement levels
Mix Designs with RAS

- Mix design initially contained 7.5% RAS and 37.5% RAP (N30 at 2.0% air voids)
- Different versions of the mix were produced with varying percentages of RAS

<table>
<thead>
<tr>
<th>Mix Design*</th>
<th>Coarse RAP (%)</th>
<th>Fine RAP (%)</th>
<th>RAS (%)</th>
<th>ABR(%)</th>
<th>Binder Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5% RAS</td>
<td>20.0</td>
<td>22.5</td>
<td>2.5</td>
<td>48</td>
<td>PG46-34</td>
</tr>
<tr>
<td>5.0% RAS</td>
<td>20.0</td>
<td>20.0</td>
<td>5.0</td>
<td>56</td>
<td>PG46-34</td>
</tr>
<tr>
<td>7.5% RAS</td>
<td>20.0</td>
<td>17.5</td>
<td>7.5</td>
<td>64</td>
<td>PG46-34 and PG58-28</td>
</tr>
</tbody>
</table>

*All mix designs were prepared and initially tested by S.T.A.T.E Testing

Experimental Program

- Complex Modulus Test
- Hamburg Wheel Track
- Semi Circular Bending Beam
- Texas Overlay Test
- Disc Compact Tension
- Push-pull Test
Specimen Preparation

- Gyratory compacted lab specimens and field cores were used
- Target air voids were achieved within 3-5 number of gyrations

Hamburg Wheel Track (AASHTO T324-11)

- Rutting results were all passing the IDOT criteria (mix designs were acceptable)
- RAS (as expected) improved the rutting resistance
Complex Modulus Testing
(AASHTO TP62-03)

- Complex modulus testing were conducted for all lab compacted mixes to evaluate:
  - Stiffness of the mixes with RAS

<table>
<thead>
<tr>
<th>Test Temperature (°C)</th>
<th>Test Frequency (Hz)</th>
<th>Mixes</th>
</tr>
</thead>
<tbody>
<tr>
<td>-10</td>
<td>0.1, 0.5, 1, 1.5, 10, 25</td>
<td>All Lab Compacted Mixes</td>
</tr>
<tr>
<td>4</td>
<td>0.1, 0.5, 1, 1.5, 25</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>0.1, 0.5, 1, 1.5, 10, 25</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>0.1, 0.5, 1, 1.5, 10, 25</td>
<td></td>
</tr>
</tbody>
</table>

High Temperature
Slow Loading Speed

Low Temperature
High Loading Speed

RAS Effect
Complex Modulus Testing

RAS kicks in @ high temperatures

Low Temperature Fracture

- Test temperatures are 0 and −12°C
- Two types of fracture tests were conducted

Area under the curves = Fracture energy
Fracture Test Results

- Comparable results for lab and field cores at -12°C
- PG46-34 appears to be working well with 7.5% RAS

Fatigue Tests

- Cyclic loads or displacements until failure at or around room temperature

Texas Overlay

Push-pull
Texas Overlay Tester

- Texas overlay tester (aka TTI overlay test) was designed to measure reflective cracking resistance (Lytton and his co-workers)
- Cyclic displacements of 0.025 in at 0.1 Hz until specimens are fully broken

Texas overlay tests were conducted at TXDOT.

Texas Overlay Test Results

Initial loads are the footprints of stiffness

Significant reduction in failure cycles with RAS
Push-pull Test Results

- Developed late 2000s by Richard Kim and his co-workers at North Carolina State University
- The main purpose is to characterize damage in asphalt concrete with repeated load applications
- Cyclic displacements generate uniaxial tension and compression in the specimen
- Tests are usually conducted at temperatures from 10 to 20°C and various strain levels (100 to 500 microstrains)

Push-pull Test Matrix

- A rigorous test matrix was conducted at different strain levels and temperatures

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>ID #</th>
<th>Air Voids</th>
<th>Microstrain</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5% RAS PG 46-34</td>
<td>1</td>
<td>5.1</td>
<td>250</td>
<td>20</td>
</tr>
<tr>
<td>2.5% RAS PG 46-34</td>
<td>2</td>
<td>4.7</td>
<td>350</td>
<td>20</td>
</tr>
<tr>
<td>2.5% RAS PG 46-34</td>
<td>3</td>
<td>4.5</td>
<td>350</td>
<td>20</td>
</tr>
<tr>
<td>5.0% RAS PG 46-34</td>
<td>1</td>
<td>5.9</td>
<td>150</td>
<td>15</td>
</tr>
<tr>
<td>5.0% RAS PG 46-34</td>
<td>2</td>
<td>3.0</td>
<td>250</td>
<td>20</td>
</tr>
<tr>
<td>5.0% RAS PG 46-34</td>
<td>3</td>
<td>4.1</td>
<td>250</td>
<td>20</td>
</tr>
<tr>
<td>5.0% RAS PG 46-34</td>
<td>4</td>
<td>2.8</td>
<td>350</td>
<td>20</td>
</tr>
<tr>
<td>5.0% RAS PG 46-34</td>
<td>5</td>
<td>5.6</td>
<td>350</td>
<td>20</td>
</tr>
<tr>
<td>7.5% RAS PG 46-34</td>
<td>1</td>
<td>3.9</td>
<td>150</td>
<td>15</td>
</tr>
<tr>
<td>7.5% RAS PG 46-34</td>
<td>2</td>
<td>5.1</td>
<td>250</td>
<td>20</td>
</tr>
<tr>
<td>7.5% RAS PG 46-34</td>
<td>3</td>
<td>5.4</td>
<td>250</td>
<td>20</td>
</tr>
<tr>
<td>7.5% RAS PG 46-34</td>
<td>1</td>
<td>5.8</td>
<td>350</td>
<td>20</td>
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<td>7.5% RAS PG 46-34</td>
<td>2</td>
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<td>350</td>
<td>20</td>
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<td>3.7</td>
<td>150</td>
<td>15</td>
</tr>
</tbody>
</table>
Test Results
20°C (68°F) & 250 microstrains

- Calculate the decrease (damage) in modulus at every cycle
- 2.5% RAS survived more than 100,000 cycles
- 7.5% RAS and PG58-28 are not working very well (insufficient bumping?)

Fatigue Curves for RAS Mixes

- When data is sufficient, fatigue curves can be developed
- Some correlation was noticed between complex modulus parameters and fatigue
- Further research and more testing is needed to develop reliable fatigue curves

Calculate number of cycles to failure for a given microstrain
Summary and Remarks

- Permanent deformation resistance of the mixtures was improved in the presence of RAS
- Stiffness tests were reflecting the presence of RAS in the mix
- Fatigue life appears to be a problem with increasing RAS
  - 2.5% RAS and PG 46-34 showed the best performance in fatigue and fracture tests
- The improvement in performance and cracking resistance was noticeable when simply binder type was changed from PG 58-28 to PG 46-34

Acknowledgements

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- ICT staff and students