Performance Characteristics of Asphalt Rubber Mixtures Containing RAP and Warm Mix Asphalt Technology

Presented By:
Professor Walaa S. Mogawer, PE
University of Massachusetts Dartmouth
Highway Sustainability Research Center (HSRC)
Acknowledgements

The following people have been instrumental in completing the research presented here:

Dr. Ramon Bonaquist, P.E. – Advanced Asphalt Technologies, LLC

Mr. Mike Rousell - UMass Dartmouth HSRC

Mr. Alexander Austerman - UMass Dartmouth HSRC

Mr. John Grieco - MassDOT

Mr. Ed Naras – MassDOT

Mr. Mike Nichols - Aggregate Industries

Mr. Mark Gabriel – All States Asphalt, Inc.

Mr. Chris Strack – Sonneborn, Inc.
**Project Scope - Green Design**

- Recycled Asphalt Pavement
- Warm Mix Asphalt Technology - Wax Based
- 12.5mm Asphalt Rubber Mixture
- Crumb Rubber from Waste Tires

2010 NEAUPG Fall Meeting
Saratoga Springs, NY
**Project Objectives**

1. Design a 12.5mm asphalt rubber mixture with and without a high RAP content and repeat these mixture designs with the addition of a WMA technology.

2. Measure the effect of high RAP content, WMA technology, and reduced mixing and compaction temperatures associated with the WMA technology on the dynamic modulus (measure of mixture stiffness) of the mixtures.

3. Measure the cracking resistance of the mixtures using the Overlay Tester.
Project Objectives

4. Evaluate the low temperature cracking resistance of the mixtures using a simple performance test known as the Asphalt Concrete Cracking Device (ACCD).

5. Measure the moisture susceptibility of the mixtures using the Hamburg Wheel Tracking Device.

6. Compare the test data to determine if the asphalt rubber mixtures incorporating RAP and WMA technology perform the same or better than the same mixtures without RAP and WMA technology.
Experimental Plan

Asphalt Rubber (AR) Binder

12.5mm Asphalt Rubber Mixture

Reclaimed Asphalt Pavement (RAP)

Virgin Aggregates

Control Mixture [No RAP]

25% RAP Mixture

Control Mixture + WMA Technology

25% RAP + WMA Technology

Mixtures Prepared without WMA Technology
Mix: 177°C (351°F)
Age/Compact: 154°C (309°F)

Mixtures Prepared with WMA Technology
Mix: 160°C (320°F)
Age/Compact: 141°C (286°F)

Performance Testing

WMA Technology 1.0% SonneWarmix

2010 NEAUPG Fall Meeting
Saratoga Springs, NY
Experimental Plan (cont’d)

Performance Testing

- Mixture Stiffness
  Dynamic Modulus $|E^*|$ Testing
- Moisture Susceptibility
  Hamburg Wheel Tracking Device (HWTD)
- Cracking Resistance
  Overlay Tester
- Low Temperature Cracking
  Asphalt Concrete Cracking Device (ACCD)

2010 NEAUPG Fall Meeting
Saratoga Springs, NY
Asphalt Rubber (AR) Binder

- AR binder obtained from regional supplier and utilized for all mixture designs.

- AR binder fabricated with a PG58-28 base binder incorporating 17% rubber.

- AR binder conformed to requirements of ASTM D 6114 Type II specification.

- Mixing [177°C (351°F)] and compaction [154°C (309°F)] temperatures based on manufacturer recommendations.
Warm Mix Technology

- Waxed based additive known as SonneWarmix™.

- SonneWarmix™ added at a dosage rate of 1.0% by weight of total binder (Virgin +RAP).

- Mixture incorporating the warm mix technology were fabricated with approximately a 30°F reduction in mixing temperature as compared to the mixture without the technology.
RAP

- RAP was obtained from same contractor that supplied the virgin aggregates.

- RAP average binder content = 4.99% (AASHTO T308 - Ignition)
12.5mm mixture developed in accordance with Arizona DOT specification Section 413 “Asphaltic Concrete (Asphalt Rubber).”

Mixture designs completed so that gradations were consistent with control mixture.

Mixtures compacted in SGC to $N_{design} = 75$ Gyrations.

40% RAP mixture initially attempted but did not meet required volumetric properties. RAP content subsequently reduced to 25% for remainder of mixture designs.
## Mixture Gradations

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Control</th>
<th>25% RAP</th>
<th>ADOT Specification Section 413</th>
<th>ADOT Production Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>19.0mm</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>±4</td>
</tr>
<tr>
<td>12.5 mm</td>
<td>92.6</td>
<td>92.3</td>
<td>80-100</td>
<td>±4</td>
</tr>
<tr>
<td>9.5 mm</td>
<td>65.4</td>
<td>66.2</td>
<td>65-80</td>
<td>±4</td>
</tr>
<tr>
<td>4.75 mm</td>
<td>33.9</td>
<td>33.1</td>
<td>28-42</td>
<td>±4</td>
</tr>
<tr>
<td>2.36 mm</td>
<td>20.3</td>
<td>19.5</td>
<td>14-22</td>
<td>±3</td>
</tr>
<tr>
<td>1.18 mm</td>
<td>13.5</td>
<td>14.2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>0.600 mm</td>
<td>9.3</td>
<td>10.4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>0.300 mm</td>
<td>6.2</td>
<td>6.9</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>0.150 mm</td>
<td>4.1</td>
<td>4.3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>0.075 mm</td>
<td>2.9</td>
<td>3.0</td>
<td>0-2.5</td>
<td>±1</td>
</tr>
</tbody>
</table>
## Mixture Volumetrics

<table>
<thead>
<tr>
<th>Properties</th>
<th>Control</th>
<th>25% RAP</th>
<th>Control + 1% WMA</th>
<th>25% RAP + 1% WMA</th>
<th>ADOT Specification Section 413</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Binder Content, %</td>
<td>8.0</td>
<td>8.0</td>
<td>8.0</td>
<td>8.0</td>
<td>-</td>
</tr>
<tr>
<td>Binder from RAP, %</td>
<td>0</td>
<td>1.26</td>
<td>0</td>
<td>1.26</td>
<td>-</td>
</tr>
<tr>
<td>Virgin Binder Added, %</td>
<td>8.0</td>
<td>6.74</td>
<td>8.0</td>
<td>6.74</td>
<td>-</td>
</tr>
<tr>
<td>Air Voids, %</td>
<td>5.8</td>
<td>2.6</td>
<td>5.9</td>
<td>4.7</td>
<td>5.5±1.0%</td>
</tr>
<tr>
<td>VMA, %</td>
<td>21.9</td>
<td>19.0</td>
<td>22.0</td>
<td>20.9</td>
<td>19% min.</td>
</tr>
<tr>
<td>VFA, %</td>
<td>73.7</td>
<td>86.5</td>
<td>73.3</td>
<td>78.0</td>
<td>-</td>
</tr>
<tr>
<td>Binder Absorbed, %</td>
<td>0.73</td>
<td>0.86</td>
<td>0.73</td>
<td>0.77</td>
<td>0 -1.0%</td>
</tr>
<tr>
<td>Dust to Binder Ratio</td>
<td>0.40</td>
<td>0.42</td>
<td>0.40</td>
<td>0.41</td>
<td>-</td>
</tr>
</tbody>
</table>

2010 NEAUPG Fall Meeting
Saratoga Springs, NY
Percent Binder Replacement

- Estimates how much aged (RAP) binder can potentially be imparted to the mixture.
- Method assume 100% blending of aged and virgin binder.
- Method takes into account differences in binder content between different RAP stockpiles.

\[
\text{% Binder Replaced} = \frac{(\text{% Binder in the RAP}) \times (\text{% RAP in Mixture})}{\text{Total % Binder in Mixture}}
\]
### Percent Binder Replacement

<table>
<thead>
<tr>
<th>Properties</th>
<th>25% RAP</th>
<th>25% RAP + 1% WMA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target Mixture Binder Content %</td>
<td>8.0</td>
<td>8.0</td>
</tr>
<tr>
<td>Average Mixture Binder Content % (By Ignition)</td>
<td>7.80</td>
<td>7.63</td>
</tr>
<tr>
<td>Binder in RAP, %</td>
<td>4.99</td>
<td>4.99</td>
</tr>
<tr>
<td>RAP in Mixture by Weight, %</td>
<td>25.0</td>
<td>25.0</td>
</tr>
<tr>
<td>Total RAP Binder in Mixture, %</td>
<td>1.25</td>
<td>1.25</td>
</tr>
<tr>
<td>Virgin Binder Replaced with RAP Binder</td>
<td>16.0%</td>
<td>16.4%</td>
</tr>
</tbody>
</table>

2010 NEAUPG Fall Meeting
Saratoga Springs, NY
Mixture Stiffness - Dynamic Modulus

Conducted to determine changes in mixture stiffness due to incorporation of RAP and/or the WMA Technology.

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>4°C</td>
<td>10 Hz, 1Hz, 0.1Hz</td>
</tr>
<tr>
<td>20°C</td>
<td>10 Hz, 1Hz, 0.1Hz</td>
</tr>
<tr>
<td>40°C</td>
<td>10 Hz, 1Hz, 0.1Hz, 0.01Hz</td>
</tr>
</tbody>
</table>

Asphalt Mixture Performance Tester (AMPT)

2010 NEAUPG Fall Meeting
Saratoga Springs, NY
Cracking Evaluation - Overlay Test

- Test Temperature = 15°C (59°F)
- Test Termination at 1,200 cycles or 93% Load reduction
- Testing in accordance with Tex-248-F
<table>
<thead>
<tr>
<th>Mixture</th>
<th>Average OT Cycles to Failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>351</td>
</tr>
<tr>
<td>25% RAP</td>
<td>43</td>
</tr>
<tr>
<td>Control + 1% WMA</td>
<td>275</td>
</tr>
<tr>
<td>25% RAP + 1% WMA</td>
<td>64</td>
</tr>
</tbody>
</table>
Low Temperature Cracking — Asphalt Concrete Cracking Device (ACCD)

- Utilized to evaluate impact of RAP and WMA on low temperature cracking resistance of mixture

- Operates on principal of accumulation thermal stress until failure (crack)

- Cooling rate of 10ºC/hr

2010 NEAUPG Fall Meeting
Saratoga Springs, NY
## ACCD Results

### Mixture vs. ACCD Cracking Temperature

<table>
<thead>
<tr>
<th>Mixture</th>
<th>ACCD Cracking Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>-37.3°C (-35.1°F)</td>
</tr>
<tr>
<td>25% RAP</td>
<td>-38.8°C (-37.8°F)</td>
</tr>
<tr>
<td>Control + 1% WMA</td>
<td>-35.0°C (-31.0°F)</td>
</tr>
<tr>
<td>25% RAP + 1% WMA</td>
<td>-35.8°C (-32.4°F)</td>
</tr>
</tbody>
</table>
Moisture Susceptibility – Hamburg Wheel tracking device (HWTD)

- HWTD testing conducted in accordance with AASHTO T324

- Water temperature of 50°C (122°F) during testing

- Test duration of 20,000 cycles

2010 NEAUPG Fall Meeting
Saratoga Springs, NY
Stripping Inflection Point (SIP)
# HWTD Results

## Mixture Stripping Inflection Point

<table>
<thead>
<tr>
<th>Mixture</th>
<th>Stripping Inflection Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>NONE</td>
</tr>
<tr>
<td>25% RAP</td>
<td>NONE</td>
</tr>
<tr>
<td>Control + 1% WMA</td>
<td>NONE</td>
</tr>
<tr>
<td>25% RAP + 1% WMA</td>
<td>NONE</td>
</tr>
</tbody>
</table>
CONCLUSIONS

Mixtures incorporating asphalt rubber binder, RAP up to 25% and a WMA technology were able to be designed to meet the gradation and volumetric requirements.

Mixtures incorporating up to 40% RAP were attempted but did not exhibit the target volumetric properties.

The Overlay Test results indicated that mixtures incorporating RAP were more susceptible to cracking as compared to the control mixtures.
CONCLUSIONS

- The low temperature cracking results suggested that the incorporation of 25% RAP in the asphalt rubber mixtures did not have negative impact on the low temperature cracking resistance of the mixtures as compared to the control.

- The moisture susceptibility results indicated that none of the mixtures tested had potential for moisture damage as all mixture passed the HWTD test.
CONCLUSIONS

- Overall the results suggest that the combination of 25% RAP, asphalt rubber, and WMA technology can be utilized without negatively impacting the performance of the mixture.

- The use of RAP contents over 25% for these types of mixtures requires further study.
Thank you!