Combining WMA Technologies with Mixtures Containing RAP

J. Richard Willis, Randy C. West, Jason Nelson, Adam Taylor, & Kristoffer Leatherman

National Center for Asphalt Technology
Presentation Overview

- Background
- Objectives and Scope
- Test Results
  - Binder Characterization
  - Mixture Stiffness
  - Moisture Damage
  - Rutting
  - Cracking
- Conclusions
Background

- Synergistic advantages of combining RAP and WMA
  - Combined environmental benefits
  - Cost savings
  - Cancelling affect of negative aspects of WMA and RAP
    - Increased potential of rutting with WMA
    - Incomplete aggregate drying in WMA
    - Requiring softer binder grade for high RAP
Objective

- Characterize how incorporating WMA technologies in RAP mixtures affects binder and mixture performance properties
Scope

- 4 field projects (Southeast and Midwest US)
  - 4 HMA-RAP mixtures
  - 6 WMA-RAP mixtures
- NCAT Pavement Test Track
  - 2 HMA-RAP mixtures
  - 2 WMA-RAP Mixtures
- Laboratory characterization
  - Binder grade, mixture stiffness, rutting, cracking, and moisture damage resistance
<table>
<thead>
<tr>
<th>Location</th>
<th>WMA Technology</th>
<th>RAP %</th>
<th>NMAS mm</th>
<th>AC %</th>
<th>$V_a$ %</th>
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<td>1.9</td>
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<tr>
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<td>Rediset</td>
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<td>1.6</td>
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<td>19.0</td>
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<td>Evotherm DAT</td>
<td>50</td>
<td>19.0</td>
<td>4.6</td>
<td>4.1</td>
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</tbody>
</table>
Binder Characterization
Binder Characterization

- Mixtures from Test Track, Daytona, FL and Macon, GA
- Binder extracted using TCE
- Binder recovered with rotary evaporator
- Performance grades of binders using AASHTO R 29
## Binder Performance Grades

<table>
<thead>
<tr>
<th>Location</th>
<th>WMA</th>
<th>True Grade</th>
<th>Performance Grade</th>
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<td>None</td>
<td>75.5 – 22.6</td>
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<tr>
<td></td>
<td>Astec DBG</td>
<td>71.8 – 24.0</td>
<td>70-22</td>
</tr>
<tr>
<td><strong>Macon, GA</strong></td>
<td>None</td>
<td>75.3 – 24.5</td>
<td>70-22</td>
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<td></td>
<td>Evotherm 3G</td>
<td>74.9 – 23.9</td>
<td>70-22</td>
</tr>
<tr>
<td></td>
<td>Rediset</td>
<td>75.4 – 24.5</td>
<td>70-22</td>
</tr>
<tr>
<td></td>
<td>Cecabase</td>
<td>77.9 – 27.8</td>
<td>76-22</td>
</tr>
<tr>
<td><strong>Test Track – Surface Mix</strong></td>
<td>None</td>
<td>87.8 – 15.4</td>
<td>82-10</td>
</tr>
<tr>
<td></td>
<td>Astec DBG</td>
<td>83.8 – 17.7</td>
<td>82-16</td>
</tr>
<tr>
<td><strong>Test Track – Base Mix</strong></td>
<td>None</td>
<td>95.0 – 12.8</td>
<td>94-10</td>
</tr>
<tr>
<td></td>
<td>Astec DBG</td>
<td>88.7 – 14.1</td>
<td>88-10</td>
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</tbody>
</table>
Mixture Stiffness
E* Testing Methodology

- AASHTO TP 62-07
- Temperatures
  - 4.4, 21.1, 37.8, and 54.4 °C
- Frequencies
  - 25, 10, 5, 1, 0.5, 0.1 Hz
- Confinement: Varied
- Target Strain: 100με
Daytona, FL

Confinement = 20 psi

Daytona - HMA

Daytona - DBG

Log Frequency (Hz)

E (ksi)
Confinement = 20 psi

Macon, GA

E (ksi)

Log Frequency (Hz)

Macon - HMA
Macon - 3G
Macon - Rediset
Macon - Cecabase
Unconfined Test Results

- Royal - HMA
- Royal - DAT
- Royal - Advera

E (ksi) vs Log Frequency (Hz)
Orlando, FL

Unconfined Test Results

Log Frequency (Hz)

E (ksi)

Orlando - Gencor
Orlando - HMA
NCAT Test Track

Unconfined Test Results

Reduced Frequency (Hz)

E* (ksi)

9.5 mm HMA-RAP
9.5 mm WMA-RAP
19.0 mm HMA-RAP
19.0 mm WMA-RAP

Unconfined Test Results

NCAT Test Track
Moisture Susceptibility
AASHTO T283

- All mixtures tested
- Plant-produced field-compacted mix
- Air voids: 7 ± 0.5%
- 1 freeze-thaw cycle
- Minimum TSR: 0.80
Test Results

- WMA-RAP mixtures had lower tensile strengths than HMA-RAP
  - Conditioned: Paired t-test ($\alpha = 0.05, p = 0.006$)
  - Unconditioned: Paired t-test ($\alpha = 0.05, p = 0.04$)
- Three WMA-RAP mixtures fail TSR
  - All were foaming technology
- No statistical difference between HMA-RAP and WMA-RAP TSR values
  - Paired t-test ($\alpha = 0.05, p = 0.14$)
Hamburg

- Plant-produced, field-compacted
- AASHTO T324
- Temperature: 50°C
- Air voids: 7 ± 1%
- Load: 158 ± 1 lbs
- Stripping inflection point > 5000 cycles
  - TX, CO, and UT
  - IL more stringent when using stiffer binders
Test Results

- Eleven mixtures were tested
  - 4 mixtures did not meet the minimum stripping inflection point
    - All 3 mixtures from Royal, NE
    - Cecabase from Macon, GA
- No statistical difference between HMA and WMA
  - Paired t-test ($\alpha = 0.05$, $p = 0.21$)
Moisture Damage Summary

- WMA mixtures were generally less resistant to moisture damage than control HMA mixtures
- TSR and Hamburg results are contradictory

<table>
<thead>
<tr>
<th>Mixture</th>
<th>TSR Results</th>
<th>Hamburg Results</th>
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</thead>
<tbody>
<tr>
<td>Orlando Gencor</td>
<td>Fail</td>
<td>Pass</td>
</tr>
<tr>
<td>Macon Cecabase</td>
<td>Pass</td>
<td>Fail</td>
</tr>
<tr>
<td>Royal Evotherm DAT</td>
<td>Pass</td>
<td>Fail</td>
</tr>
<tr>
<td>Royal Advera</td>
<td>Pass</td>
<td>Fail</td>
</tr>
<tr>
<td>Test Track Surface DBG</td>
<td>Fail</td>
<td>Pass</td>
</tr>
</tbody>
</table>
Rutting Susceptibility
Asphalt Pavement Analyzer

- AASHTO TP 63-07
- Temperature: 64°C
- Load: 100 lbs
- Pressure: 100 psi
- Average rut depth @ 8000 cycles
- Criterion:
  - Rut depth < 5.5 mm
Test Results

- No statistical differences between HMA-RAP and WMA-RAP rut depths
  - Paired $t$-test ($\alpha = 0.05, p = 0.13$)
- Four mixtures do not pass criterion
  - Daytona: Astec DBG
  - Orlando: Control and Gencor
  - Test Track: Astec DBG
- 5/8 of WMA mixtures passed criterion
Hamburg

- Plant-produced, field-compacted
- AASHTO T324
- Temperature: 50°C
- Air voids: 7 ± 1%
- Load: 158 ± 1 lbs
- Rut Depth @ 20,000 passes < 10 mm
  - CO, TX, UT
  - IL < 12.5 mm
Test Results

• No statistical difference between rut depths of WMA and control mixtures
  • Paired t-test ($\alpha = 0.05, \ p = 0.30$)
• 4/7 of WMA mixtures did not pass Hamburg requirement
  • Orlando Gencor, Macon Rediset, and Test Track DBG surface passed
Rutting Summary

- APA and HWTD test results contradict each other

<table>
<thead>
<tr>
<th>Mixture</th>
<th>APA Results</th>
<th>Hamburg Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orlando HMA</td>
<td>Fail</td>
<td>Pass</td>
</tr>
<tr>
<td>Orlando Gencor</td>
<td>Fail</td>
<td>Pass</td>
</tr>
<tr>
<td>Macon 3G</td>
<td>Pass</td>
<td>Fail</td>
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<tr>
<td>Macon Cecabase</td>
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<td>Fail</td>
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<tr>
<td>Royal Evotherm DAT</td>
<td>Pass</td>
<td>Fail</td>
</tr>
<tr>
<td>Royal Advera</td>
<td>Pass</td>
<td>Fail</td>
</tr>
<tr>
<td>Test Track DBG*</td>
<td>Fail</td>
<td>Pass</td>
</tr>
</tbody>
</table>

*Known performance
Cracking
Bending Beam Fatigue Testing

- AASHTO T321
- Air voids: 7 ± 1.0%
- Temperature: 20 °C
- Frequency: 10 Hz
- 3-6 beams tested
  - Strain range: 200 – 800 με
- Failure: 50% stiffness reduction

Beam Fatigue Apparatus
Beam Fatigue Results

Macon, GA, 800 με

Daytona, FL, 600 με
Beam Fatigue Results

Orlando, FL

NCAT Test Track

![Graph showing fatigue results for HMA and Gencor in Orlando, FL.]

- HMA: 200 με, 400 με
- Gencor: 400 με

![Graph showing fatigue results for HMA-RAP and WMA-RAP in NCAT Test Track.]

- HMA-RAP: 200 με, 400 με
- WMA-RAP: 800 με
Beam Fatigue Results

- In most cases, WMA improves fatigue resistance of recycled mixtures
- Strain level is very important
- Test Track mixes fatigue endurance limits
  - HMA–RAP = 58 microstrain
  - WMA–RAP = 99 microstrain
- Large variability of results
Conclusions

- Most WMA technologies decreased high and low true binder grade
- WMA decreases mixture stiffness by 5 to 40%
- Tensile strengths decrease with WMA
- TSR and Hamburg results contradict each other
- APA and Hamburg results contradict each other
- Fatigue performance equal or better with WMA
Recommendations

- Need to determine appropriate rutting and moisture tests for WMA-RAP mixtures
- Lab results should be considered with suspicion since field results are almost always positive
Acknowledgments

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Questions?