Warm Mix Asphalt Evaluation Protocol

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Why Warm Asphalt?

- Reduce production and laydown temperatures
- Reduce emissions
- Reduce energy costs
- Reduce aging of binder
- **Other Benefits:**
  - Cool weather paving (extend season)
  - Compaction aid for stiff mixes
  - Reduce bumps from pre-existing crack sealant

While achieving the same or better density!
What is Warm Mix Asphalt?

Several processes have been developed to improve mixture workability allowing lower production and laydown temperatures:

- WAM Foam – Kolo Veidekke
- Zeolite – Eurovia/Hubbard Construction
- Sasobit – Sasol International/Sasol Americas
- Evotherm – MeadWestvaco
- Low Energy Asphalt - Fairco
- New Products under development
L.E.A’s sequential mixing

**PHASE 1**
- 120°/150°C
- Dry, hot coarse aggregates

**PHASE 2**
- 170°C
- Hot asphalt
- Coarse aggregates are coated by all the asphalt

**PHASE 3**
- Moisture from fine aggregates triggers asphalt foaming

**PHASE 4**
- Foamed asphalt encapsulates fine aggregates
- 100°C

**PHASE 5**
- Thermal equilibrium reached
- All aggregates uniformly coated
- 90°C

Courtesy of Fairco
How does an Agency know whether a new WMA additive/process or any new asphalt additive will perform?
By using a robust evaluation protocol based on performance testing
How can a WMA product effect performance?

- Binder properties
- Mix design
- Rutting performance
- Cracking potential
  - Fatigue
  - Low Temperature
- Moisture damage
- Field Compaction
Specific Concerns

• Does the WMA improve field compaction (their purpose)?
• If the aging of the binder is reduced due to lower production temperatures, is rutting more likely?
• If WMA improves field compaction, when does that improvement end, e.g. what happens if you dump traffic on the road at 6:00 AM while it is still hot?
Specific Concerns (Continued)

• Is moisture damage more likely if the aggregates are not completely dry due to lower temperatures?
• Will a wax additive increase the likelihood for low temperature cracking?
• Is mixture stiffness (modulus) reduced by decreased aging of the binder?
NCAT, with the assistance of Dr. Mary Stroup-Gardiner from AU, developed an evaluation protocol to address these questions.

A separate standardized field data collection/evaluation protocol has been developed by the FHWA/NAPA Warm Mix Asphalt TWG.
Evaluate Potential for Low Temperature Cracking

- Low temperature cracking potential is primarily related to the binder properties.
- Used AASHTO MP-1A to evaluate low temperature cracking potential.
- Probably overly conservative if product used to reduce production temperatures.
- Lower production temperature $\rightarrow$ reduced aging of the binder $\rightarrow$ reduced stiffness for some period of time.
- Superpave IDT test included in field evaluation protocol on reheated material.
## Sasobit Binder Tests

<table>
<thead>
<tr>
<th>Test</th>
<th>PG 58-28 Base</th>
<th>PG 64-22 Control</th>
<th>PG 64-22 Sasobit®</th>
<th>PG 70-22 Sasoflex</th>
<th>PG 76-22</th>
<th>PG 76-22 Sasoflex</th>
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</thead>
<tbody>
<tr>
<td>Modifier</td>
<td>None</td>
<td>None</td>
<td>2.5% Sasobit®</td>
<td>4% Sasoflex</td>
<td>None</td>
<td>4% Sasoflex</td>
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<tr>
<td>Test Temp., °C</td>
<td>58</td>
<td>64</td>
<td>64</td>
<td>70</td>
<td>76</td>
<td>76</td>
</tr>
<tr>
<td>Original DSR, G*/sin δ, kPa</td>
<td>1.015</td>
<td>1.815</td>
<td>1.790</td>
<td>2.689</td>
<td>1.290</td>
<td>1.461</td>
</tr>
<tr>
<td>RTFO DSR, G*/sin δ, kPa</td>
<td>2.781</td>
<td>3.868</td>
<td>3.950</td>
<td>4.548</td>
<td>3.096</td>
<td>2.682</td>
</tr>
<tr>
<td>Test Temp., °C</td>
<td>19</td>
<td>25</td>
<td>25</td>
<td>28</td>
<td>31</td>
<td>31</td>
</tr>
<tr>
<td>PAV DSR, G*sin δ, kPa</td>
<td>4138</td>
<td>3554</td>
<td>2906</td>
<td>2448</td>
<td>1059</td>
<td>2635</td>
</tr>
<tr>
<td>Test Temp., °C</td>
<td>-18</td>
<td>-12</td>
<td>-12</td>
<td>-12</td>
<td>-12</td>
<td>-12</td>
</tr>
<tr>
<td>BBR Creep Stiffness (S), MPa</td>
<td>248</td>
<td>208</td>
<td>164</td>
<td>153</td>
<td>165</td>
<td>251</td>
</tr>
<tr>
<td>BBR m-value</td>
<td>0.316</td>
<td>0.317</td>
<td>0.306</td>
<td>0.328</td>
<td>0.315</td>
<td>0.292</td>
</tr>
</tbody>
</table>
Evaluate Effect on Mix Design

- Chose a virgin mix design with a granite aggregate used by a contractor supplying one of the additives
  - Original mix design was $N_{design} = 125$
  - Coarse graded
- Replicated mix design with limestone aggregate
- Aged and compacted samples at 190, 230, 265 and 300°F, samples mixed 35°F higher temperature
Samples mixed 35°F above compaction temperature
Measuring Field Compactability

- Not SGC – Constant shear device
- Constant stress device better simulates a roller in the field
  - Rolling wheel compactor
  - PTI vibratory compactor
- NCAT used vibratory compactor since we did not have a rolling wheel
- Used vibratory compactor to produce performance specimens since density effects performance
Modulus

• Stiffness of HMA input for M-E pavement design

• Dynamic modulus
  – Recommended for field evaluation protocol
  – Preparing samples in field without reheating can be hit or miss

• Resilient modulus
  – Diametral test used in NCAT’s laboratory evaluations
  – Testing variability can mask differences
Test Samples for SPT Tests

150 mm tall by 100 mm diameter, cored from SGC
Rutting Susceptibility

• **Simple Performance Test**
  – Repeated load permanent deformation
  – Field protocol recommends testing at climatic high temperature - 6°, e.g. 64 – 6 = 58°C and 600 kPa

• **Torture Test**
  – Asphalt Pavement Analyzer at climatic high temperature
  – Hamburg Test
## Comparison of Additives to Hot Mix Produced at 300F

<table>
<thead>
<tr>
<th></th>
<th>Air Voids</th>
<th></th>
<th>Resilient Modulus</th>
<th></th>
<th>APA Rutting</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>265</td>
<td>230</td>
<td>265</td>
<td>230</td>
<td>265</td>
<td>230</td>
</tr>
<tr>
<td>None</td>
<td>=</td>
<td>=</td>
<td>=</td>
<td>=</td>
<td>=</td>
<td>&lt;</td>
</tr>
<tr>
<td></td>
<td>(0.8895)</td>
<td>(0.1161)</td>
<td>(0.9695)</td>
<td>(0.9969)</td>
<td>(0.3071)</td>
<td>(0.0002)</td>
</tr>
<tr>
<td>Zeolite</td>
<td>=</td>
<td>&gt;</td>
<td>=</td>
<td>=</td>
<td>&lt;</td>
<td>&lt;</td>
</tr>
<tr>
<td></td>
<td>(0.2250)</td>
<td>(0.0122)</td>
<td>(0.9968)</td>
<td>(0.9391)</td>
<td>(0.0025)</td>
<td>(0.0420)</td>
</tr>
<tr>
<td>Sasobit</td>
<td>&gt;</td>
<td>&gt;</td>
<td>=</td>
<td>=</td>
<td>=</td>
<td>=</td>
</tr>
<tr>
<td></td>
<td>(0.0006)</td>
<td>(0.0059)</td>
<td>(1.0000)</td>
<td>(0.8911)</td>
<td>(0.9926)</td>
<td>(0.9752)</td>
</tr>
<tr>
<td>Evotherm</td>
<td>&gt;</td>
<td>&gt;</td>
<td>=</td>
<td>=</td>
<td>&lt;</td>
<td>&lt;</td>
</tr>
<tr>
<td></td>
<td>(0.0000)</td>
<td>(0.0001)</td>
<td>(0.9801)</td>
<td>(0.9987)</td>
<td>(0.9833)</td>
<td>(0.0087)</td>
</tr>
</tbody>
</table>
Strength Gain

- WMA materials improve compaction
- What happens, if anything, if you open roadway to traffic while WMA is still hot?
- Basically looking at a change in binder properties with time
- For example, true emulsion mixes will “cure” to a higher strength
- Indirect tensile strength sensitive to binder stiffness
Strength Gain Experiment

Zeolite Strength Gain

<table>
<thead>
<tr>
<th></th>
<th>Tensile Strength, psi</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2 Hours</strong></td>
<td>120</td>
</tr>
<tr>
<td><strong>4 Hours</strong></td>
<td>120</td>
</tr>
<tr>
<td><strong>2 Hours + 1 Day</strong></td>
<td>100</td>
</tr>
<tr>
<td><strong>2 Hours + 3 Days</strong></td>
<td>100</td>
</tr>
<tr>
<td><strong>2 Hours + 5 Days</strong></td>
<td>100</td>
</tr>
</tbody>
</table>

- **Warm**
- **Control**
Moisture Susceptibility

- Laboratory moisture susceptibility tests typically performed on oven dry aggregates
- Lower production temperatures used in WMA may result in incomplete drying of aggregates
- Need to simulate field conditions in laboratory
- For field trials, samples prepared in the field without reheating
Simulating a Drum Plant
Failure Modes

Adhesive

Cohesive
# Granite TSR

<table>
<thead>
<tr>
<th>Additive</th>
<th>Dry Aggregate 300F</th>
<th>SSD+ in Bucket Mixer at 250F</th>
<th>Bucket Mixer With Anti-Strip</th>
<th>Anti-Strip Agent</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMA</td>
<td>0.97</td>
<td>1.16</td>
<td>0.86</td>
<td>0.75% LOF 6500</td>
</tr>
<tr>
<td>Zeolite</td>
<td>0.81</td>
<td>0.67</td>
<td>0.87</td>
<td>1.5% Lime</td>
</tr>
<tr>
<td>Sasobit</td>
<td>0.68 (250F)</td>
<td>0.71</td>
<td>0.94*</td>
<td>0.4% Magnabond</td>
</tr>
<tr>
<td>Evotherm</td>
<td>NA</td>
<td>0.96</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

* Dry Strength 17.5 psi, wet strength 16.5 psi
# Granite Hamburg Stripping Inflection Point

<table>
<thead>
<tr>
<th>Additive</th>
<th>SSD+ in Bucket Mixer at 250°F</th>
<th>Bucket Mixer With Anti-Strip</th>
<th>Anti-Strip Agent</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMA</td>
<td>6500*</td>
<td>NA</td>
<td>0.75% LOF 6500</td>
</tr>
<tr>
<td>Zeolite</td>
<td>3975</td>
<td>8500*</td>
<td>1.5% Lime</td>
</tr>
<tr>
<td>Sasobit</td>
<td>3450</td>
<td>&gt;10,000</td>
<td>0.4% Magnabond</td>
</tr>
<tr>
<td>Evotherm</td>
<td>&gt;10,000</td>
<td>NA</td>
<td>Evotherm</td>
</tr>
</tbody>
</table>

* One of two samples did not have striping inflection point in 10,000 cycles
Thoughts on Moisture Susceptibility

- Many do not “trust” TSR test
- Hamburg is severe alternative
- If mixtures pass Hamburg, they should perform in the field
- Environmental conditioning system and SPT for future?
Field Sections

Numerous U.S. sections to date
World wide in dense-grade, SMA and OGFC
Seeing is Believing!
Orlando, FL - 2004

Hot Mix 314 F
Aspha-min Mix 254 F

138.1 pcf
138.5 pcf
MD SMA Sasobit Trial
Capital Beltway - 2005
OGFC with Sasobit
Beijing, China - 2005

• Breakdown - 95°C (203°F)
• Finish - 75°C (167°F)

Courtesy of Don Watson
APA Rut Depth, mm

- Wearing Control
- Wearing PG 67-22 Evotherm
- Wearing PG 67-22 Evotherm with 3% Latex
The Lab/Field Disconnect
Evotherm Field Rut Depths - NCAT Test Track

Rut Depths after 500,000 ESALs

- PG 67-22 Control
- Evotherm PG 67-22
- Evotherm PG 67-22 w/ 3% Latex

Rut Depth, mm
Elements for Field Trials

- Samples of raw materials
- Mix Design
  - Aggregate properties
- Traffic
- Volumetric properties
  - Without reheating (contractor)
  - Reheated (agency)
- Performance tests
  - Rutting – APA and SPT
  - $E^*$
  - TSR and/or Hamburg
  - Fatigue (should be better)
  - Low Temperature IDT
- In-place density
  - Bond strength
  - Change in density with time
Average of six samples
Missouri APA Rut Depth

Average of six samples

Burner Fuel?
Missouri TSR

Average of six samples

Compacted Hot

Reheated
Things We Need to Go Forward

- Larger trials – Ongoing!
- A robust product evaluation protocol – Draft Developed!
- Better understanding of effect on rutting and moisture damage – Lab vs. Field
- Procedures for mix design and QC/QA (Do they need to be different?)
- A way for Agencies to specify
  - Temperature reduction?
  - Binder grade?
The Bottom Line

What ever we add to HMA or however we decide to make HMA differently, we need a means to evaluate the change to ensure that it will give us equal or better performance.

- Accurate and precise performance tests we are confident in
- Timely results
- User friendly
- Relationship between the test results and field performance
- Relationship between reduced field performance and cost
Thanks!

For More Information:

www.ncat.us
NCAT 05-04 Aspha-min
NCAT 05-06 Sasobit
NCAT 06-02 Evotherm