Evaluation of Warm Asphalt Technologies

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Why Warm Asphalt?

Research by Stroup-Gardiner and Lange at AU Indicates increased emissions with increased temp.
Why Warm Asphalt?

• Reduce production and laydown temperatures
• Reduce emissions
• Reduce energy costs
• Reduce aging of binder
• Other Possible Benefits:
  – Cool weather paving (extend season)
  – Compaction aid for stiff mixes

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 – Shell/Kolo Veidekke
- Zeolite – Eurovia/Hubbard Construction
- Sasobit – Sasol Int./Moore and Munger
- Evotherm – MeadWestvaco
- Low Energy Asphalt - Fairco
- New Products under development
WAM-Foam

• Two Phase addition of asphalt
  – Aggregate coated with “soft” asphalt
  – Hard asphalt foamed to mix with pre-coated aggregate
  – Soft asphalt controls minimum placement temperature
  – Material placed as low as 80 C (176 F), 50 – 60 C (90 – 108 F) reduction
  – Requires plant modification for foaming, estimated at $50,000 - $70,000. No additional costs thereafter
  – Special asphalt feeds may be required
WAM Foam Installation in Hot Mix Asphalt Plant

2000

Courtesy of Shell/Kolo Veidekke
Zeolite

- Zeolites are crystalline hydrated aluminum silicates
- When the Zeolite is heated, it gives up its internal moisture, approximately 21% by weight, microscopically foaming the asphalt
- Aspha-min is typically added at 0.3% by TWM
Granulated aspha-min®
Sasobit®/Sasoflex

- Fischer-Tropsch synthetic waxes – Sasobit
  - Produced from gasification of coal or natural gas feed stocks
  - Added to binder or directly into mix
  - Can incorporate an SBS modifier using special cross-linking agent (Sasoflex)
  - Does not require high-shear blending
  - May negatively impact low temperature properties
Sasobit®

31 degree F reduction in compaction temperature
## Sasobit Binder Tests

<table>
<thead>
<tr>
<th></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>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Modifier</strong></td>
<td>None</td>
<td>None</td>
<td>2.5% Sasobit®</td>
<td>4% Sasoflex</td>
<td>None</td>
<td>4% Sasoflex</td>
</tr>
<tr>
<td><strong>Test Temp., °C</strong></td>
<td>58</td>
<td>64</td>
<td>64</td>
<td>70</td>
<td>76</td>
<td>76</td>
</tr>
<tr>
<td><em><em>Original DSR, G</em>/sin δ, kPa</em>*</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><em><em>RTFO DSR, G</em>/sin δ, kPa</em>*</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><strong>Test Temp., °C</strong></td>
<td>19</td>
<td>25</td>
<td>25</td>
<td>28</td>
<td>31</td>
<td>31</td>
</tr>
<tr>
<td><strong>PAV DSR. G*sinδ, kPa</strong></td>
<td>4138</td>
<td>3554</td>
<td>2906</td>
<td>2448</td>
<td>1059</td>
<td>2635</td>
</tr>
<tr>
<td><strong>Test Temp., °C</strong></td>
<td>-18</td>
<td>-12</td>
<td>-12</td>
<td>-12</td>
<td>-12</td>
<td>-12</td>
</tr>
<tr>
<td><strong>BBR Creep Stiffness (S), MPa</strong></td>
<td>248</td>
<td>208</td>
<td>164</td>
<td>153</td>
<td>165</td>
<td>251</td>
</tr>
<tr>
<td><strong>BBR m-value</strong></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>
Evotherm®

- Emulsion – approximately 70% binder residue
- Chemical package provides mixing, coating, workability, compaction and adhesion (e.g. anti-stripping agents)
- Some steam liberated upon mixing
L.E.A’s sequential mixing

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

PHASE 2
- 170°C
- 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
Product Evaluations

- Evaluate Warm Asphalt Technologies for U.S. Paving Practices
  - Compaction
  - Quick “turn-over” to traffic
  - Rutting
  - Resilient modulus (for pavement design)
  - Moisture damage
- Products Evaluated
  - Aspha-min zeolite
  - Sasobit
  - Evotherm
How Do You Measure Compaction in Lab?

- Superpave gyratory compactor is not sensitive to reduced temperature – control mix produces the same voids.
- Field Compaction, Marshall and Vibratory (PTI) Compaction sensitive to temperature/workability changes.
Samples mixed 35F above compaction temperature
Limestone

![Graph showing the relationship between VMA and Air Voids for different additives.](image)

- **VMA, %**
- **Air Voids, %**

- **Additives:**
  - Control
  - Zeolite
  - Sasobit
  - Evotherm

- **Legend:**
  - Diamonds: Control
  - Purple: Zeolite
  - Green: Sasobit
  - Crosses: Evotherm

**190F**
APA Rut Testing
APA Rut Depth for PG 64-22 - Granite
## Comparison of Additives to Hot Mix Produced at 300F

<table>
<thead>
<tr>
<th></th>
<th>Air Voids</th>
<th>Resilient Modulus</th>
<th>APA Rutting</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>265</td>
<td>230</td>
<td>265</td>
</tr>
<tr>
<td>None</td>
<td>=</td>
<td>=</td>
<td>=</td>
</tr>
<tr>
<td></td>
<td>(0.8895)</td>
<td>(0.1161)</td>
<td>(0.9695)</td>
</tr>
<tr>
<td>Zeolite</td>
<td>=</td>
<td>&gt;</td>
<td>=</td>
</tr>
<tr>
<td></td>
<td>(0.2250)</td>
<td>(0.0122)</td>
<td>(0.9968)</td>
</tr>
<tr>
<td>Sasobit</td>
<td>&gt;</td>
<td>&gt;</td>
<td>=</td>
</tr>
<tr>
<td></td>
<td>(0.0006)</td>
<td>(0.0059)</td>
<td>(1.0000)</td>
</tr>
<tr>
<td>Evotherm</td>
<td>&gt;</td>
<td>&gt;</td>
<td>=</td>
</tr>
<tr>
<td></td>
<td>(0.0000)</td>
<td>(0.0001)</td>
<td>(0.9801)</td>
</tr>
</tbody>
</table>
Moisture Susceptibility
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></td>
</tr>
</tbody>
</table>

* Dry Strength 17.5 psi, wet strength 16.5 psi
Field Sections

More than ten U.S. sections to date
World wide in dense-grade, SMA and OGFC
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
# Evotherm Test Sections

**November 2005**

<table>
<thead>
<tr>
<th>N2</th>
<th>N1</th>
<th>E9</th>
</tr>
</thead>
<tbody>
<tr>
<td>1”</td>
<td>19.0 mm NMAS w/ Evotherm PG 67-22</td>
<td>22</td>
</tr>
</tbody>
</table>

- N2: HMA Control PG 67-22
- N1: Evotherm PG 67-22 + 3% Latex
- E9: Evotherm PG 67-22

**9.5 mm NMAS**

<table>
<thead>
<tr>
<th>1”</th>
<th>19.0 mm NMAS w/ Evotherm PG 67-22</th>
</tr>
</thead>
<tbody>
<tr>
<td>2”</td>
<td>19.0 mm NMAS w/ Evotherm PG 67-22</td>
</tr>
</tbody>
</table>

\[ N_{design} = 80 \]

for all mixes

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For all mixes, the design notation is 80.
Evotherm Wearing Course with Latex

Mix Produced 7:00 PM

Mix Loaded out 1:30 PM – next day

Mix held in silo at 240°F overnight

Mix Placed at 3:15 PM

Traffic Returned at 5:00 PM
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
Missouri N\textsubscript{design} VTM

Average of six samples
Missouri APA Rut Depth

Average of six samples

![Bar chart showing APA Rut Depth for different compaction temperatures and materials. The chart compares Control, Sasobit, and Evotherm treatments with and without reheating.]
Missouri TSR

Average of six samples

Compcation Temperature F

Control
Sasobit
Evotherm

Compacted Hot
Reheated

NA
What Have We Learned?

• WMA additives improve compaction, both in the lab and in the field
• In the lab, rutting increases with lower temperatures – may not translate to the field
• Moisture, trapped in the aggregates and introduced into the mix, still a concern. Long-term affects unclear. Can mitigate effect in lab.
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?
Vision?

- Started with: Is it possible? – Yes!
- Tool for the toolbox
  - Compaction aid for stiff mixes
  - Extend paving season (cold weather)
  - Allow longer haul distances
  - Address emissions and odor concerns in limited urban areas
- A future solution to changes in emissions or worker exposure requirements, *if necessary*
Thanks!

For More Information:

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