Warm Mix Asphalt

Technical Working Group Meeting

Marriott Hunt Valley Inn
Baltimore, MD
Dec. 12-13, 2007

Federal Highway Administration
Office of Pavement Technology
Warm Mix Asphalt Characterization

Binder Properties

Mixture Properties
Acknowledgements

Matt Corrigan – Program Manager

Jagan Guddimettla – Mix Project Engineer
Satish Belagutti – Binder Project Engineer
Raj Dongré – DLS, Inc
Justin Tesch – Mix Tech
Joshua Thompson – Mix Tech
David Heidler – Binder Tech
Darnel Jackson – Binder Tech

also:

TFHRC Group
Nelson Gibson
Scott Parobeck
Frank Davis
# Projects

## Warm Mix Asphalt Projects

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<th>Mix Design</th>
<th>Lab Compaction Level, gyrations</th>
<th>Base Binder Grade</th>
<th>Technologies</th>
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<tr>
<td>Hall St, St. Louis, MO</td>
<td>12.5mm Superpave</td>
<td>100</td>
<td>PG 70-22</td>
<td>Aspha-Min, Evotherm, Sasobit</td>
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<td>I-70 w of Eisenhower Tunnel, Frisco, CO</td>
<td>9.5mm Superpave</td>
<td>75</td>
<td>PG 58-28</td>
<td>Advera, Evotherm, Sasobit</td>
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<tr>
<td>E Entrance Rd, Yellowstone National Park, WY</td>
<td>19mm Hveem</td>
<td>75</td>
<td>PG 58-34</td>
<td>Advera, Sasobit</td>
</tr>
</tbody>
</table>

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Federal Highway Administration  
*Office of Pavement Technology*
FHWA Power Chart
12.5 mm Superpave, MO 0672

Sieve Size Raised to 0.45 Power

Percent Passing

JMF
Maximum Density Line
PCS
Binder Characterization
Objective

• Evaluate the effects of three Warm Mix process namely Sasobit, Aspha-Min and Evotherm on M320-Table 2 Performance Grade

• To Compare the Performance Grades of Warm Mix processes with the base asphalt used in preparing warm mix asphalts
Study Approach

• Experiment Design
  – Base Asphalt PG 70-22
  – Base Asphalt + 1.5% Sasobit
  – Base Asphalt + 5.26% Aspha-Min
  – Evotherm – (emulsion)
<table>
<thead>
<tr>
<th>Additive</th>
<th>M320 Continuous Performance Grade</th>
<th>M320, Table 2 Performance Grade</th>
<th>Additive Rate, by wt of binder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>70.9 – 24.8</td>
<td>70 - 22</td>
<td></td>
</tr>
<tr>
<td>Sasobit</td>
<td>76.5 – 22.8</td>
<td>76 - 22</td>
<td>1.5%</td>
</tr>
<tr>
<td>Aspha-Min</td>
<td>72.4 – 24.6</td>
<td>70 - 22</td>
<td>5.26%</td>
</tr>
<tr>
<td>Evotherm - recovered</td>
<td>66.6 – 26.7</td>
<td>64 - 22</td>
<td></td>
</tr>
<tr>
<td>(ASTM D 6934)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Hall St, St. Louis, MO

- Base Asphalt: PG 70.9, Low Temperature -24.8
- Sasobit: PG 76.5, Low Temperature -22.8
- Aspha-min: PG 72.4, Low Temperature -24.6
PG Comparison - Evotherm

- Continuous PG
  - High Temperature
  - Low Temperature

<table>
<thead>
<tr>
<th>Asphalt Binders</th>
<th>BASF Method</th>
<th>BASF Method - FHWA</th>
<th>British</th>
<th>ASTM D6934</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>70.1</td>
<td>68.2</td>
<td>67.6</td>
<td>66.6</td>
</tr>
<tr>
<td></td>
<td>-23.3</td>
<td>-25.9</td>
<td>-26.6</td>
<td>-26.7</td>
</tr>
</tbody>
</table>
## I-70, Frisco, CO

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<tr>
<th>Additive</th>
<th>M320 Continuous Performance Grade</th>
<th>M320, Table 2 Performance Grade</th>
<th>Additive Rate, by wt of binder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>59.9 – 30.3</td>
<td>58 – 28</td>
<td></td>
</tr>
<tr>
<td>Sasobit</td>
<td>64.2 – 29.2</td>
<td>64 – 22</td>
<td>1.5%</td>
</tr>
<tr>
<td>Aspha-Min</td>
<td>61.1 – 30.9</td>
<td>58 – 28</td>
<td></td>
</tr>
<tr>
<td>Advera</td>
<td>60.7 – 30.4</td>
<td>58 - 28</td>
<td>4.33%</td>
</tr>
<tr>
<td>Evotherm</td>
<td>NO DATA</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M320 Continuous Performance Grade</td>
<td>M320, Table 2 Performance Grade</td>
<td>Additive Rate, by wt of binder</td>
</tr>
<tr>
<td>-------</td>
<td>----------------------------------</td>
<td>---------------------------------</td>
<td>--------------------------------</td>
</tr>
<tr>
<td>Base</td>
<td><strong>60.2 – 34.1</strong></td>
<td><strong>58 – 28</strong></td>
<td></td>
</tr>
<tr>
<td>Sasobit</td>
<td><strong>65.1 – 32.0</strong></td>
<td><strong>64 – 28</strong></td>
<td><strong>1.5%</strong></td>
</tr>
<tr>
<td>Advera</td>
<td><strong>61.2 – 33.2</strong></td>
<td><strong>58 – 28</strong></td>
<td><strong>5.2%</strong></td>
</tr>
</tbody>
</table>
Findings

- Sasobit – increase of 1 high temp grade
- Aspha-Min - no impact on PG grade
- Evotherm - recovered at BASF, no effect on the PG
- Evotherm - recovered from the stored emulsion was reduced by one grade
Findings

• Emulsion recovery processes had no effect on the PG. The PGs from all three recovery methods were found to be the same.

• ASTM D6934 was found to be the quickest and easiest process to recover the Evotherm residue from emulsion.
Mixture Characterizations
Objectives

• When should performance specimens be tested
• What are the effects of reheating on performance test properties

• Approach
  – Immediate Testing
  – Delayed Testing
  – Reheated Testing
St. Louis Paving Schedule

- **Control** (12.5mm PG 70-22) – 5/17/06
- **Sasobit** – 5/18/06
- **Sasobit** – 5/19/06
- **Evoetherm** – 5/22/06
- **Evoetherm** – 5/23/06
- **Aspha-Min** – 5/25/06
Sampling

- **IMMEDIATE Testing**
  - Next day after manufacture
- **Truck bed** ≈ every 2hrs of production
  - Volumetric
    - Pb – Ignition
    - Gmm
    - Gmb
  - SPT; TSR; Hamburg
Sampling

• DELAYED Testing
  – 2-3 weeks after manufacture

• Truck bed ≈ every 2 hrs of production
  – Volumetric
    • Pb – Ignition
    • Gmm
    • Gmb
  – SPT; TSR; Hamburg
Sampling

- REHEATED (TFHRC)
- 1~2 tons
  - 15 – 5 gallon buckets
  - SPT; TSR; Hamburg
- *Nelson Gibson - TFHRC*
SGC

- 6 nights - 366 specimens
Dynamic Modulus (E*)

- Test Temperatures
  - 4.4° C (40° F)
  - 21.1° C (70° F)
  - 37.8° C (100° F)
  - 54.4° C (130° F)

- Frequency Sweep
  - 0.1, 0.5, 1, 5, 10, 25 Hz
Master Curve – Arrenhius Fit

- 25 Hz
- 5 Hz
- 1 Hz
- 0.1 Hz

Temperature Points:
- 4.4° C
- 21.1° C
- 37.8° C
- 54.4° C

Frequency Points:
- 0.1 Hz
- 1 Hz
- 5 Hz
- 25 Hz

Reduced Time, sec

E*, ksi

Fit
**E* - Master Curve**

Hall St, St. Louis, MO

![Graph showing E* vs. Reduced Time, with different control conditions: Immediate, Delayed, and Reheated. The graph includes logarithmic scales for both axes, ranging from 1E-09 to 1E+05 for Reduced Time and from 10 to 1E+05 for E*, MPa. The legend indicates the different control conditions.](image-url)
E* - Master Curve

Hall St, St. Louis, MO

Reduced Time, sec

E*, MPa

Sasobit - Immediate
Sasobit - Delayed
Sasobit - Reheated
E* - Master Curve

Hall St, St. Louis, MO

Reduced Time, sec

E*, MPa

- Aspha-Min - Immediate
- Aspha-Min - Delayed
- Aspha-Min - Reheated
E* - Master Curve

I-70, Frisco, CO

- Control Mix
- Advera
- Sasobit
E* - Master Curve

E. Entrance Rd, Yellowstone, WY
Pb - 5.3%, Mix Design Replication

Reduced Time, sec

E*, MPa

Control Mix
Advera
Sasobit
E* - Master Curve

E. Entrance Rd, Yellowstone, WY
Average WMA Production

Reduced Time, sec

E*, MPa

Control Mix • Advera
Sasobit


10 100 1000 10000 100000

1.E+05 1.E+03 1.E+01 1.E+03 1.E+05
Flow Number, Fn

- Test Temperatures
  - LTTPBind, Version 3.1 Software
  - Site pavement temperature @ 50% Reliability
    - Pvmnt Temp, ± 6° C
Flow Number, F_n

Hall Street, St. Louis, MO

- Test Temperatures
  - 46º C (115º F)
  - 52º C (126º F)
  - 58º C (136º F)

- Loading
  - 600 kPa – Deviator Stress
  - 0 kPa – Confining Pressure
Flow Number, Fn

Immediate and Delayed Test Specimens

Flow Number, cycles

46° C  52° C  58° C
Flow Number, Fn

Immediate and Delayed Test Specimens

Total Cycles @ 5% Strain

46° C
52° C
58° C
Flow Number, $F_n$

I-70 - Frisco, CO

- **Test Temperatures**
  - $36^\circ C$ (97$^\circ$ F)
  - $42^\circ C$ (108$^\circ$ F)
  - $48^\circ C$ (118$^\circ$ F)

- **Loading**
  - $689$ kPa (100 psi) – Deviator Stress
  - $69$ kPa (10 psi) – Confining Pressure
Flow Number, $F_n$

- Control
- Advera
- Sasobit
- Evotherm

Temperature Conditions:
- 36° C
- 42° C
- 48° C
Flow Number, $F_n$

![Bar chart showing Flow Number for different temperatures and materials. The x-axis represents the materials: Control, Advera, Sasobit, and Evotherm. The y-axis represents the total cycles at 5% strain. The chart shows the number of cycles for each material at 36°C, 42°C, and 48°C, with bars in blue, purple, and yellow respectively.](chart.png)
Flow Number, $F_n$

**East Entrance Rd - Yellowstone, WY**

- Test Temperatures
  - $46^\circ \text{C} \ (115^\circ \text{F})$
  - $52^\circ \text{C} \ (126^\circ \text{F})$
  - $58^\circ \text{C} \ (136^\circ \text{F})$

- Loading
  - $689 \text{ kPa} \ (100 \text{ psi})$ – Deviator Stress
  - $69 \text{ kPa} \ (10 \text{ psi})$ – Confining Pressure
Flow Number, Fn
Findings

• Immediate vs Delayed Testing
  – Evotherm & Aspha-Min
    • Performance testing - delayed after specimen manufacture
  – Sasobit
    • Performance testing can be conducted immediately after specimen manufacture
Questions

Courtesy of the FHWA Mobile Asphalt Laboratories