Effect of WMA Additives on Binders Workability and Performance

Hussain U. Bahia, Andrew Hanz and Pouya Temourpour

2nd International Warm Mix Asphalt Conference
St. Louis, Missouri, October 12, 2011
Background and Scope

Warm Mix Additives should improve binders workability without negatively affecting performance

1. Binder Workability
   a) Lower Viscosity, b) better Lubricity

2. Binder Performance
   a) Reduced Aging: could result in less rutting resistance but more cracking resistance.
   b) Change adhesion/ Cohesion, as related to moisture resistance.
Methods Used

• Impacts of WMA Additives on Workability
  – Asphalt Binder Viscosity – *Rotational Viscometer*
  – Asphalt Binder Lubricity – *New DSR Test*

• Binder Performance Impacts
  – All temperature regimes (HT, IT, LT)
  – Standard (LVE) and Advanced Test Methods
  – Adhesion/Cohesion – *Bitumen Bond Strength Test*
Impacts of WMA Additives on Workability
**Effects on Viscosity – PG64-22**

*Finding: Effect is small and Shear rate is not important*

![Viscosity vs. Shear Rate Graph](image)

- **PG64 Control**
- **Sasobit - 2%**
- **Surfactant -0.5%**

Change in $\eta$ due to additive, relatively small.

Change in $\eta$ due to temperature:
- 95°C
- 110°C
- 130°C
Conventional Analysis of Friction and Wear – Striebeck Curve

Boundary – Asperities cause friction

Mixed (Partial Contact) – Friction decrease as fluid pushes asperities apart.

Hyrdodynamic (No Contact) – Friction increase due to viscous drag.

Asphalt Lubricity Test - How do we test it?

Schematic

Fixture for DSR
Asphalt Lubricity Test

- **Torque** is monitored under constant **normal force and speed**. The coefficient of friction ($\mu$) is obtained from the normal force and torque measured.

\[
\mu = C \times \frac{T}{P \times d}
\]

- Where:
  - $C = 2.842$ – Value of constant for the four ball testing fixture geometry, $T$ = Torque (N), $P$ = Normal Force (N), $d$ = diameter (m)
Experimental Design - Materials

• **Four Warm Mix Additives:**
  - One **surfactants:** (@2 %),
  - One **wax-based** additive: (2%)
  - Two **foaming** processes: (0.3% by wt. of mix) and Lab Foaming (1.5% H₂O)

• **Two base binders:**
  - **Unmodified** PG64-22 and
  - **SBS** modified PG 76-22
New Test Method “Asphalt Lubricity Test” – Initial Results – 50 RPM

- Effect of Additive ~0 to -10% (PG 64), -10 to -15% (PG76)
- Effect of Binder ~-20 to -25%
Effects on Aggregate Coating

\[ \Delta T = 30^\circ \text{degC} \]

40% More coating

Neat 76-22
Impacts of WMA Additives on Moisture Damage
BBS Testing Apparatus

PATTI Quantum Gold

Graded Scale for Air Flow Control
BBS Stub Geometry

- Rough Surface to prevent interface failure.
- Machined edge to control film thickness.
Data Acquisition System

- Data Acquisition System allows for measurement of force and loading rate.
- Electronic Storage of vs. Time for further analysis.
- Files Transfer to Excel.

BBS Test Description

- **Two functions**
  - Characterize the strength of the bond (POTS)
  - Assess failure mode (cohesive vs. adhesive)
- **Offset potential effects of WMA on moisture damage due to production temperature or un-dried aggregates**
## BBS Test Experimental Design

<table>
<thead>
<tr>
<th>Factor</th>
<th>Levels</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Binder Grade</td>
<td>2</td>
<td>PG 64-22</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PG 76-22 (SBS)</td>
</tr>
<tr>
<td>WMA Additive Type</td>
<td>2</td>
<td>Rediset</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Advera</td>
</tr>
<tr>
<td>Aggregate Type</td>
<td>2</td>
<td>Granite</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rhyolite</td>
</tr>
<tr>
<td>Conditioning</td>
<td>2</td>
<td>Dry</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wet (96 hrs@40 °C)</td>
</tr>
<tr>
<td>Aggregate Application Temp.</td>
<td>2</td>
<td>105 °C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>145 °C</td>
</tr>
</tbody>
</table>
Results – Ratio of Wet /Dry Strength
PG 64 Binder

- Effect of Application Temp: Not Important, and some additives improve moisture resistance.

![Graph showing bond strength ratio for different applications and temperatures.](image)
Results – Ratio of Wet /Dry Strength
PG 76 Binder

- Rediset offsets the effect of lower temperature
Impacts of WMA Additives on Asphalt Binder Performance
Comparison of Aging Devices

RTFOT (Standard)

Thin Film Method

- Isolate effects of oxidation.
- Procedure Development.
  - Calibrated based on equivalency to standard aging method.
  - Reduce film thickness to reduce aging time.

Aging = f(temp., viscosity)

Aging = f(temp.)
Evaluation of High Temperature Performance

• Factors Impacting Performance

• Both impacted by:
  ▪ Asphalt Binder Source
  ▪ Presence of WMA Additive
WMA additives can reduce aging
Effect is significant for some additives
Sensitivity of Performance Grade to Aging Temperature- *PG grade needs adjustment*
Slope of Change in HT Grade vs. Aging Index

\[ \Delta T = \frac{(-\Delta PG/A)/(AI-1)^B}{ } \]

Where:
\( \Delta T \) = Maximum allowable change in production temperature due to WMA
\( \Delta PG \) = User Specified allowable change in HT PG Grade
\( A \) = Model Coefficient
\( AI \) = Aging Index
\( B \) = Model Coefficient
**Evaluation of Performance – MSCR Test**

*Reduced aging could cause less resistance to rutting*

<table>
<thead>
<tr>
<th>Material</th>
<th>Jnr @3.2 kPa</th>
<th>Ratio of Jnr = 110°C/163°C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PG 64-22</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>4.50</td>
<td>2.01</td>
</tr>
<tr>
<td>2% Rediset</td>
<td>7.12</td>
<td></td>
</tr>
<tr>
<td>8% Advera</td>
<td>4.82</td>
<td></td>
</tr>
<tr>
<td>4% Sasobit</td>
<td>3.05</td>
<td></td>
</tr>
<tr>
<td><strong>PG 76-22</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>0.75</td>
<td>3.00</td>
</tr>
<tr>
<td>2% Rediset</td>
<td>0.71</td>
<td></td>
</tr>
<tr>
<td>8% Advera</td>
<td>0.57</td>
<td></td>
</tr>
<tr>
<td>4% Sasobit</td>
<td>0.87</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
- Reduced aging could cause less resistance to rutting.
- The table above compares the Jnr values at different temperatures for different materials, with the ratio of Jnr at 110°C to 163°C calculated for each material.
Fatigue Parameter Results – $G*\sin\delta$

- Reduction in $G*\sin\delta$ indicates that fatigue performance improves with use of Rediset and other WMA additives.
Fatigue Parameter Results – $G^*\sin\delta$

PG 76 – 22
Low Temperature Performance – Estimated S(60)

<table>
<thead>
<tr>
<th></th>
<th>100.0</th>
<th>150.0</th>
<th>200.0</th>
<th>250.0</th>
<th>300.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>64-22</td>
<td>189.0</td>
<td>166.3</td>
<td>187.8</td>
<td>207.9</td>
<td>227.2</td>
</tr>
<tr>
<td>Neat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>64-22 +2</td>
<td>227.2</td>
<td>184.2</td>
<td>201.8</td>
<td>234.6</td>
<td></td>
</tr>
<tr>
<td>Rediset</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>64-22 +8</td>
<td>245.8</td>
<td>209.5</td>
<td>219.5</td>
<td>258.8</td>
<td></td>
</tr>
<tr>
<td>Advera</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>64-22 +4</td>
<td>245.8</td>
<td>209.5</td>
<td>219.5</td>
<td>258.8</td>
<td></td>
</tr>
<tr>
<td>Sasobit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>76-22</td>
<td>227.2</td>
<td>184.2</td>
<td>201.8</td>
<td>234.6</td>
<td></td>
</tr>
<tr>
<td>Neat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>76-22 +2</td>
<td>227.2</td>
<td>184.2</td>
<td>201.8</td>
<td>234.6</td>
<td></td>
</tr>
<tr>
<td>Rediset</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>76-22 +8</td>
<td>245.8</td>
<td>209.5</td>
<td>219.5</td>
<td>258.8</td>
<td></td>
</tr>
<tr>
<td>Advera</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>76-22 +4</td>
<td>245.8</td>
<td>209.5</td>
<td>219.5</td>
<td>258.8</td>
<td></td>
</tr>
<tr>
<td>Sasobit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TFA 110

TFA 163
Low Temperature Performance – Estimated $m(60)$

<table>
<thead>
<tr>
<th></th>
<th>TFA 110</th>
<th>TFA 163</th>
</tr>
</thead>
<tbody>
<tr>
<td>64-22 Neat</td>
<td>0.327</td>
<td>0.283</td>
</tr>
<tr>
<td>64-22 +2 Rediset</td>
<td>0.336</td>
<td>0.299</td>
</tr>
<tr>
<td>64-22 +8 Advera</td>
<td>0.328</td>
<td>0.330</td>
</tr>
<tr>
<td>64-22 +4 Sasobit</td>
<td>0.320</td>
<td>0.319</td>
</tr>
<tr>
<td>76-22 Neat</td>
<td>0.283</td>
<td>0.262</td>
</tr>
<tr>
<td>76-22 +2 Rediset</td>
<td>0.317</td>
<td>0.294</td>
</tr>
<tr>
<td>76-22 +8 Advera</td>
<td>0.308</td>
<td>0.290</td>
</tr>
<tr>
<td>76-22 +4 Sasobit</td>
<td>0.281</td>
<td>0.272</td>
</tr>
</tbody>
</table>
Summary of Findings - I

- WMA vary in their effects on binder properties.
- Workability & Lubricity
  - Marginal reduction in viscosity at 135 C
  - Better lubricity is detected - could be the main effect.
  - Better aggregates coating for most additives.
Summary of Findings- II

- **Binder performance properties**
  - Effects on moisture resistance depends on binder and additive.
  - Significant reduction in aging due to lower temps
    - Effects on rutting resistance are not favorable. Need to consider adjusting PG grade
    - Effects on fatigue resistance could be favorable
    - Effects on thermal cracking resistance are favorable with the exception of the wax additive.
Thank you for your time!

Authors would like to acknowledge

• The support from the Asphalt Research Consortium – WRI and FHWA.

• Financial support of MARC partners

Hussain U. Bahia
bahia@engr.wisc.edu