‘*Warm Mix Additive* that also function as an antistripping Additive’

*Patents pending*
Akzo Nobel Rediset™ wmx Solutions
Main Focus

- Reducing mix and paving temperatures
  - To improve mix workability

- Addressing moisture damage in warm-mix
  - Inefficient aggregate drying at lower temp.,
  - Low temperatures being pushed to extreme limits

- Ensuring Cost effective solution
Mechanism of Moisture Damage
Adhesion and Cohesion
Moisture Damage

• Adhesion failure
  – Water has a higher affinity compared to asphalt
  – Asphalt cannot bond to aggregate with a wet surface

• Cohesion failure
  – Inclusion of water within asphalt will weaken its cohesive strength
Moisture Damage Survey*
Do You Treat HMA for Moisture Damage?

*Tim Aschenbrenner, Moisture Damage Symposium, San Diego, 2003
Akzo Nobel Rediset™ wmx Solutions

• Testing at NCAT
  – Densification, Moisture Damage

• Texas Hamburg Wheel Tracking Tests

• PG test results with warm-mix additive

• Function of Rediset™ wmx additives

• Field Trial, Chico, CA
Compaction Test Results - NCAT Vibratory Compactor

PG 76-22 Asphalt
Superpave coarse graded granite mix (12.5 mm max)
# Moisture Sensitivity Test Results - NCAT

Tensile Strength Ratio *

<table>
<thead>
<tr>
<th>Warm-Mix Additive</th>
<th>Conditioned Tensile Strength psi</th>
<th>Unconditioned Tensile Strength psi</th>
<th>Tensile Strength Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>WMX 7001</td>
<td>74.7</td>
<td>79.4</td>
<td>0.94</td>
</tr>
<tr>
<td>WMX 7002</td>
<td>74.2</td>
<td>83.7</td>
<td>0.89</td>
</tr>
</tbody>
</table>

* Compacted at 270°F

PG 76-22 Asphalt
Superpave coarse graded granite mix
(12.5 mm max)
Moisture Sensitivity Test Results - NCAT
Hamburg Wheel Tracking Test*

<table>
<thead>
<tr>
<th>Mix Type</th>
<th>Air Voids, %</th>
<th>Comp. Temp., F</th>
<th>Strip. Infl. Point, cycles</th>
<th>Total Rutting @ 10,000 cycles, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>WMX 7001 #1</td>
<td>7.2</td>
<td>270</td>
<td>&gt; 10,000</td>
<td>5.15</td>
</tr>
<tr>
<td>WMX 7001 #2</td>
<td>7.0</td>
<td>270</td>
<td>&gt; 10,000</td>
<td>6.62</td>
</tr>
<tr>
<td>WMX 7002 #1</td>
<td>7.0</td>
<td>270</td>
<td>&gt; 10,000</td>
<td>4.73</td>
</tr>
<tr>
<td>WMX 7002 #2</td>
<td>7.0</td>
<td>270</td>
<td>&gt; 10,000</td>
<td>3.77</td>
</tr>
</tbody>
</table>

* Compacted at 270°F
PG 76-22 Asphalt
Superpave coarse graded granite mix
(12.5 mm max)
## Texas Hamburg Wheel Tracking Test

*APAC 76-22  Asphalt*

<table>
<thead>
<tr>
<th>Material ID</th>
<th>Comp. Temp.</th>
<th>Additive %</th>
<th>% Air Voids</th>
<th>Cycles to failure</th>
<th>Deform, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control + LAS</td>
<td>300 F</td>
<td>0.75</td>
<td>0.71</td>
<td>&gt;20,000</td>
<td>&lt;12.5</td>
</tr>
<tr>
<td>WMX 7001-A</td>
<td>250 F</td>
<td>2.0</td>
<td>6.8</td>
<td>29,900</td>
<td>12.32</td>
</tr>
<tr>
<td>WMX 7002-B</td>
<td>250 F</td>
<td>2.0</td>
<td>6.8</td>
<td>29,975</td>
<td>12.40</td>
</tr>
</tbody>
</table>

*Type D Surface, Design #7-MMD-05*

Hamburg Test Temp 50 C

A= Added to binder

B= Added to aggregate mix
# Hamburg Wheel Tracking Test

**Lime comparison – PaveTex**

Note: Lime % of mix vs Rediset™ WMX % binder

Mix Composition: BR 710 Ty D
5.2% Alon Big Springs PG 70-28

<table>
<thead>
<tr>
<th>Material ID</th>
<th>Mix Type</th>
<th>Additive, %</th>
<th>Test Temp, °C</th>
<th>Cycles To Failure</th>
<th>Deform, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>D</td>
<td>0.0</td>
<td>50</td>
<td>18,177</td>
<td>12.50</td>
</tr>
<tr>
<td>Hydrated Lime</td>
<td>D</td>
<td>2.0</td>
<td>50</td>
<td>20,000</td>
<td>3.50</td>
</tr>
<tr>
<td>WMX 7019</td>
<td>D</td>
<td>2.0</td>
<td>50</td>
<td>20,000</td>
<td>2.93</td>
</tr>
<tr>
<td>WMX 7020</td>
<td>D</td>
<td>2.0</td>
<td>50</td>
<td>20,000</td>
<td>3.50</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>25,000</th>
<th>30,000</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.19</td>
<td>3.41</td>
</tr>
<tr>
<td></td>
<td>3.50</td>
<td>3.66</td>
</tr>
</tbody>
</table>
Hamburg Wheel Tracking Test
Lime comparison – PaveTex
Note: Lime at 2% mix vs Rediset™ at 2% binder

Rut Depth at ~20,000 Cycles

- Control
- Hydrated Lime
- WMX 7019
- WMX 7020
### PG Testing Results

<table>
<thead>
<tr>
<th>Test</th>
<th>PG 76-22</th>
<th>PG 76-22 + 2% WMX 7001</th>
<th>PG 76-22 + 2% WMX 7002</th>
</tr>
</thead>
<tbody>
<tr>
<td>G*/Sin d (kPa) @ 76º C</td>
<td>1.17</td>
<td>1.05</td>
<td>1.03</td>
</tr>
<tr>
<td>RTFOT G*/Sin d (kPa) @ 76ºC</td>
<td>2.49</td>
<td>2.27</td>
<td>2.25</td>
</tr>
<tr>
<td>BBR Creep Stiffness, S, @ -12º C</td>
<td>185</td>
<td>144</td>
<td>140</td>
</tr>
<tr>
<td>BBR, Slope m-Value @ -12º C</td>
<td>0.316</td>
<td>0.342</td>
<td>0.344</td>
</tr>
<tr>
<td>Original Binder, Phase Angle @ 76º C, Degrees</td>
<td>73.8</td>
<td>70.20</td>
<td>72.0</td>
</tr>
</tbody>
</table>
Rediset™ wmx

- Solid Additive – Pastilles
- Added to the asphalt
- Also can be added to the mix at the hot-mix plant
Rediset\textsuperscript{TM} wmx Function
Improve mix workability

- Reduce viscosity of asphalt and hot-mix
- Reduce surface tension of asphalt
- Easier to coat the aggregate and easier to compact
  - Reduce mix and compaction temperatures
Rediset™ wmx - Function
Increase resistance to moisture damage

- Rediset™ modified asphalt has higher affinity to the aggregate compared to water
- Displaces water from the aggregate surface and form bonds
- Acts as a bridge holding asphalt and aggregate together
- Bonds resistant to the action of water
- Additive increases cohesive strength of asphalt
Warm-Mix Trial
Chico, CA - November 13, 2007

• Kent’s Oil
  Sacramento, CA

• Baldwin Contracting
  Company, Inc
  Chico, CA

• Knife River Companies

• Akzo Nobel Surface
  Chemistry LLC

AKZO NOBEL
Warm Mix Trial at Chico, CA

<table>
<thead>
<tr>
<th>300°F Control Mix</th>
<th>240°F Warm Mix</th>
<th>270°F Warm Mix</th>
</tr>
</thead>
<tbody>
<tr>
<td>64-10 Asphalt</td>
<td>64-10 Asphalt + 2% Rediset™ WMX</td>
<td>64-10 Asphalt + 2% Rediset™ WMX</td>
</tr>
</tbody>
</table>

1. Pug mill Amps
2. Field Densities
3. Qualitative assessment of fumes
Kent’s Oil
Blending into the asphalt tank
Reviewing plans for the trial
Tack Coat
Control Room
Warm Mix
Windrow paving
Paving 240°F Mix (Average Temp.)
Compaction
After first pass of roller
Control 300°F Mix
240° F and 300° F Mixes
# Pug mill Amperage

<table>
<thead>
<tr>
<th>Average Mix Temp.,</th>
<th>240°F</th>
<th>270°F</th>
<th>300°F (Control)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pug mill Amps</td>
<td>135-140</td>
<td>120-125</td>
<td>120-125</td>
</tr>
</tbody>
</table>
Density measurements
# Warm Mix Trial Chico, California

## % Relative Compaction

CT 308A Method

<table>
<thead>
<tr>
<th>Type of Mix</th>
<th>Core Density (bulk)</th>
<th>%RC Rice</th>
</tr>
</thead>
<tbody>
<tr>
<td>240°F Mix (Ave.) Rediset™ WMX 2%</td>
<td>2.319</td>
<td>91.9%</td>
</tr>
<tr>
<td>270°F Mix (Ave.) Rediset™ WMX 2%</td>
<td>2.329</td>
<td>92.3%</td>
</tr>
<tr>
<td>300°F Mix (Ave.) Control</td>
<td>2.275</td>
<td>90.2%</td>
</tr>
</tbody>
</table>

*PG 64-10 Asphalt Mix*
**Warm Mix Trial Chico, California**

% Relative Compaction
ASTM D2726 Method

<table>
<thead>
<tr>
<th>Type of Mix</th>
<th>Core Density (bulk)</th>
<th>%RC Rice</th>
</tr>
</thead>
<tbody>
<tr>
<td>240°F Mix (Ave.) Rediset™ WMX 2%</td>
<td>2.327</td>
<td>92.2%</td>
</tr>
<tr>
<td>270°F Mix (Ave.) Rediset™ WMX 2%</td>
<td>2.339</td>
<td>92.7%</td>
</tr>
<tr>
<td>300°F Mix (Ave.) Control</td>
<td>2.286</td>
<td>90.6%</td>
</tr>
</tbody>
</table>

PG 64-10 Asphalt Mix
All Three Mixes
Warm Mix Trial at Chico
Main Observations

1. Pug mill Amperage
   - 270°F mix similar to that of the control mix (300)

2. Field Densities
   - Better % relative compaction compared to the control

3. Qualitative assessment of fumes
   - Considerable reduction in fumes, almost no fumes with the 240°F mix
     
Wider workability window and ease of mixing and compaction
Rediset™ wmx solutions
Distinctive features

1. Directly addresses the issue of moisture sensitivity
2. Moisture not introduced into the mix
3. Low temperature flexibility of asphalt enhanced
4. Formulated to suit a wide spectrum of aggregates
5. Binder and pavement cores can be analyzed for Rediset™ wmx additives
Rediset™ wmx solutions
Other warm-mix benefits

1. Reduction of asphalt fumes
2. Reduce fuel costs
3. Ease of mixing and compaction reduce operational costs
4. Reduce age hardening of the binder (ingredients also function as anti-oxidants)
5. Paving in non-attainment areas, cool weather paving, extend paving season, longer hauls
6. Global concept addressing aggregate quality variability
Warm Mix Trial at Chico
Baldwin Contracting Company comments

“…..extremely positive characteristics at significantly less than standard mixing and placement temperatures”

“At lower temperatures studied in this trial (240F and 270F) compaction efforts were minimized to achieve desired densities … substantial impact on placement costs ….. Could in fact increase the durability and life of the paved surface.”

“…operational costs including those incurred by fuel consumption should be lowered”
Questions?