Reducing Paving Emissions Through the Use of Warm Mix Technology

J. Keith Davidson P. Eng.
McAsphalt Industries Limited

Congres Annual - Bitume Quebec
Trois-Rivieres March 18-20, 2007
Presentation Outline

- Introduction
- Processes
- Evotherm
- Trials
- Results
- Conclusions
- Future
Introduction

What is Warm Asphalt

Road mix that can be mixed and placed at lower temperatures than conventional hot mix while maintaining the original physical properties
Introduction

Why Warm Mix Asphalt

- IARC
- Kyoto Treaty
- Naphthalene & PAH Emissions
- Particulate Emissions
- Increased Activism
- Rising Energy Costs
- Higher Temperature Trends
- Regulatory & Permitting
- Odors

Lower Temperatures are Needed!
Warm Mix Processes

- WAM Foam – Shell/Kolo-Veidekke
- Sasobit – Sasol – Fisher-Tropsch Wax
- Aspha-min - Eurovia - Zeolite
- Low Energy Asphalt (LEA) - France
- Evotherm - MeadWestvaco
Evotherm - Technology

- Chemical additive package
- Used at 0.5 – 1%
- Delivered as a high-residue emulsion

Optimized to deliver
- Mixing
- Coating
- Workability
- Compaction
- Adhesion
Evotherm - Technology

- Compatible with HMA operations
- Produced using traditional drum or batch plants
- Paved with conventional equipment
- Openly available to end-users; no licensing
Evotherm – Materials & Design

- Drop-in to HMA job mix formula
- Both Marshall & SHRP designs employed
- Moisture resistant
- Volumetrics comparable to HMA
Evotherm – Materials & Design

- Standard PG-, visc-, & pen-graded binders
  - Modified & unmodified

- Limestone & silicate mineralogies
  - Dense & coarse gradations
  - Binder & surface courses
  - Lime compatible
Evotherm Trials

- Canada
  - Aurora, Calgary, Ramara, London
- United States
  - 12 locations throughout US
- France
- Switzerland
- China
  - Beijing
## Temperature Comparisons

<table>
<thead>
<tr>
<th>Location</th>
<th>Mixing Temperature</th>
<th>Compaction Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HMA</td>
<td>Evootherm</td>
</tr>
<tr>
<td>Aurora</td>
<td>150</td>
<td>125</td>
</tr>
<tr>
<td>Calgary</td>
<td>150</td>
<td>120</td>
</tr>
<tr>
<td>Ramara</td>
<td>150</td>
<td>125</td>
</tr>
<tr>
<td>London</td>
<td>150</td>
<td>135</td>
</tr>
</tbody>
</table>
Evotherm - Plant
Evotherm Laydown Temperatures

Prior to Rolling

After Initial Breakdown
Compaction Data

- Compaction Specifications Met
- No issues achieving Compaction
- Compaction has been achieved as low as 72 °C
<table>
<thead>
<tr>
<th>Sample</th>
<th>PGAC-Emulsion</th>
<th>Emulsion Residue</th>
<th>Recovered PGAC HL8</th>
<th>Spec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tests on Original AC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rotational Viscosity @ 135°C, Pa.s @ 165°C</td>
<td>0.321</td>
<td>0.325</td>
<td>NA</td>
<td>3.0 max</td>
</tr>
<tr>
<td>Dynamic Shear Rheometer. G*/Sin δ, kPa, @ 52°C @ 58°C @ 64°C</td>
<td>1.270</td>
<td>1.28</td>
<td>NA</td>
<td>1.0 min</td>
</tr>
<tr>
<td>Dynamic Shear Rheometer. G*/Sin δ, kPa, @ 52°C @ 58°C @ 64°C</td>
<td>0.580</td>
<td>0.59</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>RTFO Residue (AASHTO T240)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass Change, %</td>
<td>0.251</td>
<td>0.371</td>
<td>NA</td>
<td>1.0 max</td>
</tr>
<tr>
<td>Dynamic Shear Rheometer. G*/Sin δ, kPa, @ 52°C @ 58°C @ 64°C</td>
<td>3.030</td>
<td>2.58</td>
<td>4.00</td>
<td>2.2 min</td>
</tr>
<tr>
<td>Dynamic Shear Rheometer. G*/Sin δ, kPa, @ 52°C @ 58°C @ 64°C</td>
<td>1.340</td>
<td>1.15</td>
<td>1.77</td>
<td></td>
</tr>
<tr>
<td>RTFO Residue (AASHTO T240)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass Change, %</td>
<td>0.251</td>
<td>0.371</td>
<td>NA</td>
<td>1.0 max</td>
</tr>
<tr>
<td>Dynamic Shear Rheometer. G*/Sin δ, kPa, @ 52°C @ 58°C @ 64°C</td>
<td>3.030</td>
<td>2.58</td>
<td>4.00</td>
<td>2.2 min</td>
</tr>
<tr>
<td>Dynamic Shear Rheometer. G*/Sin δ, kPa, @ 52°C @ 58°C @ 64°C</td>
<td>1.340</td>
<td>1.15</td>
<td>1.77</td>
<td></td>
</tr>
<tr>
<td>PAV Residue (AASHTO R18) °C</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Dynamic Shear Rheometer. G*/Sin δ, kPa, @ 52°C @ 58°C @ 64°C</td>
<td>3333</td>
<td>3433</td>
<td>4758</td>
<td>5000 max</td>
</tr>
<tr>
<td>Dynamic Shear Rheometer. G*/Sin δ, kPa, @ 52°C @ 58°C @ 64°C</td>
<td>5107</td>
<td>5347</td>
<td>6938</td>
<td></td>
</tr>
<tr>
<td>Bending Beam Rheometer Creep Stiffness @ -12°C, MPa</td>
<td>89.0</td>
<td>73.3</td>
<td>99.4</td>
<td>300 max</td>
</tr>
<tr>
<td>@ -18°C, MPa</td>
<td>195.0</td>
<td>179.0</td>
<td>210.5</td>
<td></td>
</tr>
<tr>
<td>@ -24°C, Mpa</td>
<td>439.0</td>
<td>469.0</td>
<td>456.0</td>
<td></td>
</tr>
<tr>
<td>Slope, m-value @ -12°C, MPa</td>
<td>0.364</td>
<td>0.385</td>
<td>0.356</td>
<td>0.300 min</td>
</tr>
<tr>
<td>@ -18°C, Mpa</td>
<td>0.318</td>
<td>0.333</td>
<td>0.315</td>
<td></td>
</tr>
<tr>
<td>@ -24°C, Mpa</td>
<td>0.269</td>
<td>0.268</td>
<td>0.262</td>
<td></td>
</tr>
<tr>
<td>PGAC Temperature Range (BBR Basis)</td>
<td>59.8-30.2</td>
<td>59.2-31.2</td>
<td>62.4-29.7</td>
<td>60.5-29.5</td>
</tr>
<tr>
<td>PGAC Temperature Range (Direct Tension)</td>
<td>59.8-29.1</td>
<td>59.2-27.6</td>
<td>62.4-28.5</td>
<td>60.5-28.4</td>
</tr>
<tr>
<td>Penetration @ 25°C, 100g, 5 sec</td>
<td>121</td>
<td>118</td>
<td>49</td>
<td>77</td>
</tr>
</tbody>
</table>
# Recovered Penetration

<table>
<thead>
<tr>
<th>Location</th>
<th>Mix</th>
<th>Original</th>
<th>Mix Type</th>
<th>% Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>HMA</td>
<td>WMA</td>
</tr>
<tr>
<td>Aurora</td>
<td>HL8/3</td>
<td>118</td>
<td>105</td>
<td>11.02</td>
</tr>
<tr>
<td>Calgary</td>
<td>B Mix</td>
<td>163</td>
<td>138</td>
<td>15.34</td>
</tr>
<tr>
<td>Ramara</td>
<td>HL4</td>
<td>124</td>
<td>81</td>
<td>107</td>
</tr>
<tr>
<td>London</td>
<td>HL8R15</td>
<td>116</td>
<td>49</td>
<td>77</td>
</tr>
<tr>
<td></td>
<td>HL3R15</td>
<td>121</td>
<td>45</td>
<td>81</td>
</tr>
</tbody>
</table>
Emissions Testing - London
Stack Emissions - Ramara

- CO2 * 10: 46% reduction
- CO: 63% reduction
- NOx: 58% reduction
- SO2: 41% reduction

Pinchin Environmental
Stack Emissions Reduced Compared to HMA Controls

Indianapolis, July 6, 2005

ATP, Inc.
Fumes at Paver

Indianapolis, July 6, 2005
Performance Testing – Ramara Trial

- CPATT – University of Waterloo
- Cores & Loose Mix
- Warm Mix Asphalt
- Hot Mix Asphalt
- Resilient Modulus
- Dynamic Modulus
Performance Testing

- **Resilient Modulus**
- Measure of the mix stiffness related to fatigue and thermal cracking
- Run over four temperatures (0, 5, 10, 22 °C)
Performance Testing

**Dynamic Modulus**

- Measure of stiffness of mixture at high temperature (Rutting)
- At intermediate temperature (Fatigue)
- Repetitive compressive load applied to sample at specified temperatures at various loading frequencies
Performance Testing

- The test data shows that for both the warm mix (WMA) and hot mix (HMA) the resilient modulus and dynamic modulus were statistically the same based on Analysis of Variance.
Evotherm Benefits

- Reduced exposure to fumes
- Decreased emissions at HMA plant
- Savings in energy
- Extended haul distances
- Quicker return to traffic
- Improved compaction
- Higher RAP incorporation
- Less Aging of mix
- Longer service life
CONCLUSIONS FROM TRIALS

- Mixes designed according to SHRP & Marshall
- Reduced fuel consumption
- Plant gas and particulate emissions lowered significantly
- Worker fume exposure reduced
- Lower temperature mixes workable at paver
- Field densities easily within specification
- Jointing excellent
Summary

• Applicable to wide variety of aggregate & binders
• Suitable for use with modified binders (SBR, SBS, EVA to date in lab work)
• Excellent moisture resistance observed (90-100% is routine)
• Field work showed no production or construction difficulties
• Thin lifts possible, good feathering and hand work
• In-service performance has been excellent to date
RESEARCH & FUTURE WORK

Evotherm

- Dynamic & shear modulus to be established
- Beam fatigue testing
- High RAP Content mixes
- Low temperature cracking
- Life cycle cost & remaining service life analysis
- Additional trials & demos
- Other mix types (SMA, OGFC, etc.)
Future Trials

2007

• 5–7 within Canada

• Number of trials in United States/Worldwide
Thank You

Questions