Characterization of Evotherm Warm Mix Binder

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Plant Mixing Temperature

- Harder the asphalt, higher the mixing temperature with Hot Mix
- Independent on the asphalt hardiness with Evotherm
  - The thin water film acts as the lubricant, as the curling stone slides on the ice
Emulsion based Warm Mix

- Significant reduction in CO, NO\textsubscript{x} and SO\textsubscript{2} emissions from stack

McAsphalt Trial in Oct. 4-5, 2005

<table>
<thead>
<tr>
<th></th>
<th>Plant Production</th>
<th>Aggregate</th>
<th>Asphalt</th>
<th>Compaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot Mix</td>
<td>155°C</td>
<td>155°C</td>
<td>145°C</td>
<td></td>
</tr>
<tr>
<td>Warm Mix</td>
<td>125°C</td>
<td>*95°C</td>
<td>85°C</td>
<td></td>
</tr>
</tbody>
</table>

* Emulsion temp.

<table>
<thead>
<tr>
<th></th>
<th>Av. Stack Gas Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot Mix</td>
<td>162°C</td>
</tr>
<tr>
<td>Warm Mix</td>
<td>121°C</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Fuel Oil Consumption Litres/Tonne</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot Mix</td>
<td>11.4</td>
</tr>
<tr>
<td>Warm Mix</td>
<td>5.2</td>
</tr>
</tbody>
</table>
Residue Recovery
Procedure for Warm Mix Asphalt Emulsion
## Temperature profile of emulsion based Warm Mix

<table>
<thead>
<tr>
<th>Location</th>
<th>Temp., °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixing temperature</td>
<td>130</td>
</tr>
<tr>
<td>Discharge temperature</td>
<td>100</td>
</tr>
<tr>
<td>In hopper of paver</td>
<td>97</td>
</tr>
<tr>
<td>Just behind the screed of paver</td>
<td>92</td>
</tr>
<tr>
<td>at edge of mat</td>
<td>87</td>
</tr>
<tr>
<td>at center of mat</td>
<td>92</td>
</tr>
<tr>
<td>After pneumatic roller</td>
<td>73</td>
</tr>
<tr>
<td>Pavement 4 hrs after lay down*</td>
<td>52</td>
</tr>
</tbody>
</table>

*25mm below the surface

**Recovery Procedure for Asphalt Emulsion Residue**

- Need to represent the mixing and paving conditions
Evotherm trial by McAsphalt

- Base asphalt had a penetration of 124 dmm at 25°C, 5s.
- Asphalt cement recovered from field core samples
  - Recovered AC from Hot Mix asphalt = 81 dmm (63% of original value)
  - Recovered AC from Warm Mix asphalt = 107 dmm (86% of original value)
- Less heat aging of asphalt cement at the mix plant
Residue recovery procedure

- **Dry the emulsion at 80°C for 20 hours**
  - 80g emulsion in a PAV pan (~ 50g residue)
  - Maintain stable polymer network

- **Recovered residue = Equivalent of RTFOT sample of the hot mix AC**
  - RTFOT simulate heat oxidation of AC at the hot mix plant

- **SHRP and other binder characterizations of recovered residue**
The new procedure closely simulate heat hardening of Evotherm warm AC as penetration values.
Residue recovery procedure

- Asphalt binder becomes brittle upon oxidation in the field
  - Reduce fatigue and cold fracture resistance of pavement
- PAV: Laboratory simulation of oxidative aging of asphalt binder
  - 100°C at 2.1MPa pressure for 20 hours
- Stable polymer network even after the PAV-aging
Before and After PAV (FTIR)

- Polymer modification does not prevent asphalt oxidation.
Oxidative Hardening (Base asphalt/Unmodified residue)

- Base asphalt shows sharp increase in complex modulus, $G^*$, after PAV
- Less significant hardening with Evotherm warm mix
- Base asphalt after RTFOT $\approx$ Evotherm warm mix after PAV
Modification with SBR latex-polymer reduces negative effects of hardened asphalt at wide temperature range.
Before and After PAV

- 7°C reduction in $T_g$ with 3% SBR latex polymer
- 5°C increase in $T_g$ after PAV, both unmodified and modified residues
Cold Fracture Resistance: Stiffness with BBR

- Improved Cold Fracture Resistance with Evotherm warm mix
- Base asphalt after RTFOT ≈ Evotherm warm mix after PAV
- All binder samples are after the PAV-aging.
- Even unmodified residue is lower creep stiffness than the base asphalt used to make the emulsion.
- SBR latex polymer further reduce the stiffness, thus maintain low temp. flexibility.
Fatigue Resistance under Repeated Stresses
Unmodified Binders

Base AC, after RTFOT
Unmodified Residue
Unmod. Res., after PAV

Base asphalt after RTFOT \(\approx\) Evotherm warm mix after PAV
Evotherm with 3.0% SBR latex maintains excellent fatigue resistance even after PAV --- Extended service life with >2% latex
4, 20, 44 and 94 hours PAV-aging

- FTIR for Chemistry
- DSR for rheological measurements
  - Binder samples were too brittle to do the BBR measurements after 44 hrs PAV-aging
Accelerated oxidative aging test (PAV)

McAsphalt PG58-28, Unmodified Evotherm Residue

McAsphalt PG58-28, 3% SBR Latex Modified Residue

SBR polymers remain even after 94 hrs PAV
SBR polymers remain even after 94 hrs PAV-aging
Reduced Oxidative hardening of SBR latex modified residue.
Pavement Longevity: McAsphalt in Canada

- Reduced Oxidative hardening of SBR latex modified residue, even after >20 years of service
Pavement Longevity: Shell China

- Reduced Oxidative hardening of SBR latex modified residue
- Consistent conclusion with 3 widely different asphalt
Conclusions

**Potential Pavement Longevity with Warm Mix System**
- Reduced oxidative hardening of asphalt binder during the mixing and paving processes

- D. Newcomb, the Vice President-Research & Technology, National Asphalt Pavement Association, states
  - “Binder aging is directly related to the production temperature of the mixture. The majority of binder hardening due to aging takes place in the hot-mix plant. If the plant temperature is reduced, the oxidative hardening of the binder will be reduced. Less hardening of the binder during construction could mean more flexibility and resistance to cracking in service. ---”
Reference

- Takamura, K., Road Materials and Pavement Design 9, 87-102 (2008)
Thank You for Your Attention