Application of Warm Mix Asphalt in China

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Research Institute of Highway (RIOH)
Ministry of Transport, PRC
Research Institute of Highway (RIOH)

- Affiliated to Ministry of Transport, China
- Government Funded National Highway R&D Center
- Drafter or producer of National Highway Specifications
- Policy councilor of Highway Technology
- National Test Labs to evaluate pavement materials
- Education and Training Center for Advanced Highway Technical Personnel
Proving ground

- 2.4 square km
- Test roads 28.6km
Research Institute of Highway (RIOH)

- Specialized laboratories
  - Real car crash laboratory
  - Automobile emissions laboratory
  - Engine Laboratory
  - Vehicle Laboratory
  - Auto warranty equipment laboratory
  - Intelligent Transportation System Laboratory
  - Road and Bridge Engineering Laboratory
• Key laboratories of MOT
  – Road structure & materials
  – Bridge Detection & Reinforcement
Key Laboratory of Road Structure & Material
Ministry of Communications, PRC

Key Laboratory of Bridge Detection &
Reinforcement Technology
Ministry of Communications, PRC

China National Center for Quality Supervision
and Inspection of Roads & Bridges
Main Topics

• Overview of Warm Mix Technologies in China
• Performance of WMA
• Major applications
• Challenge
• Summary
Overview of Warm Mix Technologies in China

• Primary WMA options
  – Aspha-Min
  – WAM-Foam
  – Sasobit *
  – Evotherm *
  – Local products *
  – ......
    • Active in China

• More than 90 percent of WMA projects used **Evotherm** warm mix asphalt in China
WMA History in China

- Lab evaluation and road trial since 2005
- 2006, research project on WMA funded by MOT
- 2007, low temp. paving trial; preparing local specification
- 2008, first WMA local specification published
- 2009, application on key projects
- 2010, WMA generally accepted
WMA Local Specifications in China

- Hebei – 2008
- Beijing – 2009
- Qinghai – 2009
- Jiangxi – 2010
- Shanghai – 2011


- Total consumption in 2010: 135 million tons
Main Topics

• Overview of Warm Mix Technologies in China
• Performance of WMA
  – Binder
  – Mix
• Major applications
• Challenge
• Summary
Performance of WMA---Binder

• Additive: influence on the binder
  – Compare asphalt with asphalt+Evootherm DAT
  – Compare PMA with PMA+Evootherm DAT

• Mixing: aging at different mixing temp.
  – WMA: 100°C\120°C
  – HMA: 140°C\160°C\180°C
## Asphalt

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Asphalt</th>
<th>Asphalt+Evotherm DAT</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEN(100g,5s), 25°C</td>
<td>0.1mm</td>
<td>80.5</td>
<td>79.3</td>
<td>80 ~ 100</td>
</tr>
<tr>
<td>PI</td>
<td></td>
<td>-0.22</td>
<td>-0.16</td>
<td>-1.5 ~ +1.0</td>
</tr>
<tr>
<td>Ductility, 15°C</td>
<td>cm</td>
<td>&gt;100</td>
<td>&gt;100</td>
<td>≥100</td>
</tr>
<tr>
<td>Softening point, $T_{R&amp;B}$</td>
<td>°C</td>
<td>50.3</td>
<td>55.1</td>
<td>≥45</td>
</tr>
<tr>
<td>Viscosity, 135°C</td>
<td>Pa.s</td>
<td>0.538</td>
<td>0.521</td>
<td>---</td>
</tr>
</tbody>
</table>

**After TFOT**

<table>
<thead>
<tr>
<th>Item</th>
<th>%</th>
<th>68.4</th>
<th>62.9</th>
<th>≥57</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEN ratio, 25°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PI</td>
<td>-0.22</td>
<td>0.91</td>
<td></td>
<td>---</td>
</tr>
<tr>
<td>Ductility, 15°C</td>
<td>cm</td>
<td>52.7</td>
<td>37.9</td>
<td>≥20</td>
</tr>
<tr>
<td>Softening point, $T_{R&amp;B}$</td>
<td>°C</td>
<td>55.9</td>
<td>55.3</td>
<td>---</td>
</tr>
</tbody>
</table>
## SBS PMA

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>PMA</th>
<th>PMA+Evotherm DAT</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEN(100g,5s), 25°C</td>
<td>0.1mm</td>
<td>73.2</td>
<td>72.8</td>
<td>60-80</td>
</tr>
<tr>
<td>PI</td>
<td>---</td>
<td>0.15</td>
<td>0.17</td>
<td>≥-0.4</td>
</tr>
<tr>
<td>Ductility, 5°C</td>
<td>cm</td>
<td>44.5</td>
<td>42.1</td>
<td>≥30</td>
</tr>
<tr>
<td>Softening Point, $T_{R&amp;B}$</td>
<td>ºC</td>
<td>73.7</td>
<td>74.4</td>
<td>≥55</td>
</tr>
<tr>
<td>Viscosity, 135 ºC</td>
<td>ºC</td>
<td>1.5</td>
<td>1.38</td>
<td>≤3</td>
</tr>
<tr>
<td>Segregation</td>
<td>%</td>
<td>2.1</td>
<td>2.0</td>
<td>≤2.5</td>
</tr>
<tr>
<td>Elastic Recovery, 25°C</td>
<td>cm</td>
<td>88.3</td>
<td>88.9</td>
<td>≥65</td>
</tr>
<tr>
<td>After TFOT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight loss</td>
<td>%</td>
<td>-0.14</td>
<td>-0.02</td>
<td>absolute value ≤1.0</td>
</tr>
<tr>
<td>PEN ratio, 25°C</td>
<td>%</td>
<td>70.2</td>
<td>71.6</td>
<td>≥60</td>
</tr>
<tr>
<td>Ductility, 5°C</td>
<td>cm</td>
<td>25.7</td>
<td>24.2</td>
<td>≥20</td>
</tr>
</tbody>
</table>
Viscosity (Pa·s) vs. Temp. (°C)

- Asphalt
- Asphalt + Evotherm

Range of Compaction Temp
Range of Mixing Temp
Performance of WMA---Binder

• Additive:
  – influence on the binder (modified or not)

Less, No change!
Performance of WMA---Binder

• Additive: influence on the binder
  – Compare asphalt with asphalt+Evotherm DAT
  – Compare PMA with PMA+Evotherm DAT

• Mixing: aging at different mixing temp.
  – WMA: 100°C\120°C
  – HMA: 140°C\160°C\180°C
# Binder Aging

<table>
<thead>
<tr>
<th>Performance</th>
<th>Virgin Asphalt</th>
<th>Extracted from WMA</th>
<th>Extracted from HMA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>100°C</td>
<td>120°C</td>
</tr>
<tr>
<td>PEN /0.1mm</td>
<td>86.7</td>
<td>56.5</td>
<td>46.5</td>
</tr>
<tr>
<td>Viscosity at 135°C/ (Pa.s)</td>
<td>0.540</td>
<td>0.800</td>
<td>0.860</td>
</tr>
</tbody>
</table>
Binder Aging

Graph showing the relationship between temperature (Temp/°C) and PEN (0.1mm)
Binder Aging

Viscosity at 135°C (Pa.s)

Temp/ °C

100 120 140 160 180 200
Performance of WMA---Mix

• Mixing:
  – aging at different mixing temp.

WMA: Less aging!
Performance of WMA---Mix

• WMA 1: PEN=90, AC-13
• WMA 2: SBS PMA, SMA-13

• Specification Test
• Fatigue Test
## Performance of WMA---Mix

Performance of different AC-13 mixtures

<table>
<thead>
<tr>
<th>Performance</th>
<th>PEN=90</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HMA</td>
</tr>
<tr>
<td>Marshall stability/kN</td>
<td>13.3</td>
</tr>
<tr>
<td>Flow value/mm</td>
<td>2.55</td>
</tr>
<tr>
<td>Retained marshall stability /%</td>
<td>83.3</td>
</tr>
<tr>
<td>Tensile strength ratio /%</td>
<td>81.5</td>
</tr>
<tr>
<td>Rutting dynamic stability /(times/mm)</td>
<td>1294</td>
</tr>
<tr>
<td>Permeability /( ml/min)</td>
<td>40</td>
</tr>
</tbody>
</table>

AC-13, Asphalt Concrete, dense gradation
Nominal Maximum Aggregate Size is 13.2mm
### Performance of WMA---Mix

#### Performance of different SMA-13 mixtures

<table>
<thead>
<tr>
<th>Performance</th>
<th>SBS modified asphalt</th>
<th>HMA with modifier</th>
<th>WMA with modifier</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marshall stability/kN</td>
<td>8.7</td>
<td>7.4</td>
<td>≥6.0</td>
<td></td>
</tr>
<tr>
<td>Flow value/mm</td>
<td>3.9</td>
<td>4.0</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>Retained marshall stability /%</td>
<td>96.7</td>
<td>97.0</td>
<td>≥80</td>
<td></td>
</tr>
<tr>
<td>Tensile strength ratio /%</td>
<td>88.1</td>
<td>92.4</td>
<td>≥80</td>
<td></td>
</tr>
<tr>
<td>Rutting dynamic stability (times/mm)</td>
<td>5 131</td>
<td>5 384</td>
<td>≥3 000</td>
<td></td>
</tr>
<tr>
<td>Schellenberg binder drainage test /%</td>
<td>0.06</td>
<td>0.05</td>
<td>≤0.1</td>
<td></td>
</tr>
<tr>
<td>Cantabro test /%</td>
<td>3.1</td>
<td>3.0</td>
<td>≤15</td>
<td></td>
</tr>
</tbody>
</table>
Fatigue test

• Strain control
  – Asphalt: 150\300\450 \(\mu\varepsilon\)
  – PMA: 200\400\600 \(\mu\varepsilon\)

• Temp. = 15°C

• Frequency = 10 HZ

• Sine wave
Performance of WMA---Mix

AC-13 Fatigue Properties

<table>
<thead>
<tr>
<th>System</th>
<th>unit</th>
<th>strain (με)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>150</td>
</tr>
<tr>
<td>HMA</td>
<td>cycles</td>
<td>441872</td>
</tr>
<tr>
<td>WMA</td>
<td>cycles</td>
<td>530696</td>
</tr>
<tr>
<td>Percent Increase</td>
<td>%</td>
<td>20.1</td>
</tr>
</tbody>
</table>

AC-13, Asphalt Concrete, dense gradation
Nominal Maximum Aggregate Size is 13.2mm
Performance of WMA---Mix

SMA-13 Fatigue Properties

<table>
<thead>
<tr>
<th>System</th>
<th>unit</th>
<th>strain (με)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>200</td>
</tr>
<tr>
<td>HMA</td>
<td>cycles</td>
<td>599424</td>
</tr>
<tr>
<td>WMA</td>
<td>cycles</td>
<td>1145464</td>
</tr>
<tr>
<td>Percent Increase</td>
<td>%</td>
<td>91.1</td>
</tr>
</tbody>
</table>
Performance of WMA---Mix

• Meeting the specification and to be similar to HMA

• More durable according to fatigue test
Main Topics

• Overview of Warm Mix Technologies in China
• Properties of WMA
• **Major applications**
  – Tunnel
  – Low temp. construction
  – High RAP incorporation
• Challenge
• Summary

Green Value

Engineering Benefits
WMA Applications in China

Green Value

• Asphalt paving jobs in long tunnels

• Asphalt paving jobs in dense population urban zone

• Binding with Crumb Rubber Asphalt to reduce odors and emissions
WMA Applications in China - Tunnel

• Tunnel – Hell of asphalt paving
• So Breathless, Smoky and Hot! >50°C
WMA Applications in China - Tunnel

• Paving with WMA – Back to life

Tunnel paving under Yangzi River in Shanghai

• Good air quality, easy operation
WMA Applications in China --- urban zone

- Milestone projects in Beijing – 2008 WMA for Olympic projects
WMA Applications in China
---urban zone

• Milestone projects in Beijing – 2009 WMA for Resurfacing Chang’an Avenue for 60 yrs Anniversary of National Events
WMA Applications in China
---Binding with CRMA

- Hot CRMA paving
- Mixing temperature >180°C

- CRMA WMA paving
- Mixing temperature 140 - 150°C

‘Almost eliminate’ odor
Reduced exposure to fume
WMA Applications in China

Engineering Benefits

• Longer Compaction Window
  – Compaction performance
  – Ambient air temp. (0-10°C)

• High RAP incorporation (Warm Recycling Process)
VV at different compaction temp.

- **WMA**
- **HMA**
WMA Applications in China
--- low temp. Paving

- Location: Qinghai Prov.
- Air temperature 0~5°C
- Altitude above sea level 4000m
- Field air voids 6.5%
- Pen 90, NMAS=13.2mm
- Laying temperature :135°C
WMA Applications in China
--- Low temperature paving

- Location: Hebei Province North to Beijing
- Air temperature -5°C
- Strong wind, 6m/s
- PEN=90, NMAS=13.2mm
- Laying temperature 135°C
WMA Applications in China
--- High RAP incorporation

**RAP Heating**

- Heating drum for RAP
- Aging seriously
## WMA Applications in China --- High RAP incorporation

<table>
<thead>
<tr>
<th></th>
<th>RAP temp., °C</th>
<th>New aggregate temp., °C</th>
<th>Mixing temp., °C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>30% RAP HCPR</strong></td>
<td>120</td>
<td>200</td>
<td>170</td>
</tr>
<tr>
<td><strong>30% RAP WCPR</strong></td>
<td>Ambient</td>
<td>190</td>
<td>130</td>
</tr>
<tr>
<td><strong>50% RAP WCPR</strong></td>
<td>80</td>
<td>200</td>
<td>135</td>
</tr>
</tbody>
</table>
## Tests on recovered asphalt

<table>
<thead>
<tr>
<th>Type</th>
<th>Viscosity (@135°C, cp)</th>
<th>PEN (0.1mm)</th>
<th>Softening Point (°C)</th>
<th>Ductility (@15°C, cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25% Hot recycling</td>
<td>1150</td>
<td>29.3</td>
<td>58.8</td>
<td>7.8</td>
</tr>
<tr>
<td>45% Warm recycling</td>
<td>990</td>
<td>31.0</td>
<td>57.7</td>
<td>9.6</td>
</tr>
<tr>
<td>RAP binder</td>
<td>-</td>
<td>23.5</td>
<td>61.2</td>
<td>1.1</td>
</tr>
<tr>
<td>Hot mixture</td>
<td>752</td>
<td>42.2</td>
<td>53.9</td>
<td>20.5</td>
</tr>
<tr>
<td>Warm mix asphalt</td>
<td>619</td>
<td>50.2</td>
<td>51.7</td>
<td>&gt;100</td>
</tr>
<tr>
<td>Virgin asphalt</td>
<td>425</td>
<td>68.2</td>
<td>48.0</td>
<td>&gt;100</td>
</tr>
</tbody>
</table>
## Test results for mixture

<table>
<thead>
<tr>
<th>Type</th>
<th>Marshall stability (KN)</th>
<th>TSR (%)</th>
<th>Rutting Test (times/mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25% Hot recycling</td>
<td>8.5</td>
<td>88.0</td>
<td>2197</td>
</tr>
<tr>
<td>45% Warm recycling</td>
<td>7.1</td>
<td>96.4</td>
<td>2573</td>
</tr>
</tbody>
</table>
WMA Applications in China  
--- High RAP incorporation

35% RAP WMA APPLIED IN HEIBEI PROVINCE  
PEN=90 , mixing temp.=110~130°C  
Air voids <7%
Main Topics

- Overview of Warm Mix Technologies in China
- Properties of WMA
- Major applications
- Challenge
- Summary
The challenge

• Cost
  – More money needed
  – Contractor is reluctant (economic benefit is more important; only special condition: tunnel)
  – Government push (budget added, pay for the green value)
The challenge

Design method

– Construction Temp.

• HMA: V-T curve
• WMA: N/A
The challenge

Design method

– Compaction

• HMA: Marshall & SGC

• WMA: Marshall doesn’t work sometimes; SGC?
Main Topics

• Overview of Warm Mix Technologies in China
• Properties of WMA
• Major applications
• Challenge
• Summary
Summary

• Green benefits
  – Less emissions, energy saving
• Proven Performance (Lab and field)
  – Less aging, better fatigue and compaction, etc.
• Trends
  – Research and application keep going
Acknowledgement

• MeadWestvaco(China)
THANK YOU!

Questions and suggestions?

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