Short- and Long-Term Performance of Modified SMA Produced with WMA Additives

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Warm Mix Asphalt

- Technology that reduces production temp
  - WMA: 212-280°F
  - HMA: 300-350°F
- WMA expected to perform equal or better than HMA/SMA with enhanced sustainability
- Three main techniques
  - Organic additives
  - Chemical additives
  - Foaming process
WMA Additives

**Organic**
- Lowers binder viscosity at temp > 90°C
- Fine crystalline nature increases binder stiffness
- Sasobit used in this study

**Chemical**
- Works at agg./binder microscopic interface to reduce friction forces, ~185-284°F
- Evotherm (emulsion) used in this study

**Foaming**
- Small amount of water is injected into hot asphalt binder
- Steam expands binder volume to reduce viscosity

Motivation of the Study

- Illinois Tollway have used SMA widely in their expressway within Chicago area
- Apply WMA to heat-sensitive mixture (polymer or GTR modified) designed for heavy traffic volume

**Main objective**
Determine short-term performance of warm-SMA via laboratory performance testing and field evaluation
2010 Field Test Sections

- I-355 Southbound
  - Driving lane
  - MP 21 ¾
  - 3” overlay on top of JPCP
  - Control and Sasobit SMA

- I-355 Northbound
  - Driving lane
  - MP 26 ¼
  - 3” overlay on top of JPCP
  - Control and Evotherm (emulsion) SMA

- I-90 Westbound
  - Genoa Road Ramp
  - Foamed asphalt SMA (cold day construction, ~40°F)

Material Characterization
SMA with WMA Additive

Control SMA Volumetrics

<table>
<thead>
<tr>
<th>N\text{des}</th>
<th>N\text{MAS}</th>
<th>Asphalt Content</th>
<th>G\text{mb}</th>
<th>G\text{mm}</th>
<th>Air void</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td>12.5 mm</td>
<td>6.2%</td>
<td>2.440</td>
<td>2.529</td>
<td>3.5%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mix</th>
<th>Binder</th>
<th>Fine FRAP</th>
<th>RAS</th>
<th>Compaction Temperature (°F)</th>
<th>Warm mix additive (% of binder)</th>
<th>AC (%)</th>
<th>VMA (%)</th>
<th>VFA (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control SMA</td>
<td>PG 64-22 12% GTR</td>
<td>8%</td>
<td>N/A</td>
<td>305</td>
<td>N/A</td>
<td>6.2</td>
<td>15.7</td>
<td>77.7</td>
</tr>
<tr>
<td>Evotherm (chemical) WMA-SMA</td>
<td>PG 64-22 12% GTR</td>
<td>8%</td>
<td>N/A</td>
<td>260</td>
<td>0.5%</td>
<td>6.2</td>
<td>15.7</td>
<td>77.7</td>
</tr>
<tr>
<td>Sasobit (wax) WMA-SMA</td>
<td>PG 70-22 SBS modified</td>
<td>5%</td>
<td>5%</td>
<td>260-280</td>
<td>1.5%</td>
<td>6.0</td>
<td>16.0</td>
<td>78.1</td>
</tr>
<tr>
<td>Foamed SMA</td>
<td>PG 64-22 12% GTR</td>
<td>13%</td>
<td>N/A</td>
<td>260</td>
<td>1.0%</td>
<td>6.0</td>
<td>15.7</td>
<td>77.7</td>
</tr>
</tbody>
</table>

Testing Suite

- Conducted at 77°F with varying load frequencies to obtain |E*|
- Conducted at 86°F until 20,000 cycles to obtain rut depth
- Conducted at 77°F with loading rate of 0.5 in/min to obtain IDT strength
- Conducted at 10°F with CMOD control of 0.028 in/min to obtain work of fracture
Fast Track Testing

Curing Time: 3, 6, 12 hrs; 1, 3 and 7 days

Dynamic Modulus Test Results

- Control and WMA chemical additive (Evotherm) followed the same increasing trend
- WMA wax additive (Sasobit) and foamed WMA experienced modulus increase but converged towards control SMA modulus at 7 days
Hamburg Wheel Track Test Results

- Compared to the modulus trends, control and Evotherm SMAs had the similar rutting resistance.
- Sasobit and foamed warm-SMAs resulted in lower rut depths.

IDT Strength Test Results

- Control and warm with chemical additive (Evotherm) SMAs resulted in similar IDT strength.
- WMA with wax additive (Sasobit) and foamed warm-SMAs resulted in higher strength values.
Fracture energy for the control SMA was greater than all warm-SMAs.

WMA with wax additive (Sasobit) resulted in lowest energy values during various curing times.

In-Situ Modulus

Surface modulus obtained using a Light-Weight Deflectometer (LWD)
LWD Results

Warm SMA had lower surface temperature than the control SMA but with similar cooling rates.

Expected increasing moduli as temperature decreased; at same modulus, warm SMA has lower temperature.

Surface Temperature

- WMA chemical additive resulted in 15% lower surface temperature than control
- WMA wax additive and control SMAs converged to the same surface temperature
Surface Modulus Variation

- WMA chemical additive resulted in 33% higher modulus
- WMA wax additive led to 25% lower modulus at relatively close temperatures

Early Opening Time

Use of surface modulus as opening time criterion between control and warm SMAs

Nearly an hour difference between the control and warm SMAs
Test Section Evaluation

I-355 SB Test Section (Sasobit)

I-355 Southbound
- SMA with Sasobit warm-mix additive
- Constructed in September 2010 over JPCP
- Milepost 21 ¾
- Lane 1 (innermost)
- 2010 ADT = 55,070 (1,391,499 ESALs)
I-355 SB Test Section (Sasobit)

- SMA with Sasobit WMA
- Constructed at Lane 1 (innermost)

2010

2012

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I-355 SB Test Section (Sasobit)

- SMA with Sasobit WMA
- Constructed at Lane 1 (innermost)

- Low severity reflective cracks
- Low severity centerline deterioration

2010

2012

2014

Notice the reflective cracks through warm-SMA?

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I-355 SB Test Section (Sasobit)

- SMA with Sasobit WMA
- Constructed at Lane 1 (innermost)

2010

2012

2014

2015

2016

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I-355 SB Test Section (Sasobit)

- SMA with Sasobit WMA
- Constructed at Lane 1 (innermost)

2010

- Low severity reflective cracks
- Low severity centerline deterioration

2012

- Reflective crack width > 0.25 inch
- Medium severity centerline deterioration

2014

- Same distress and severity levels as in 2014 evaluation

2015

- Increase severity and frequency of distresses
- Mid-lane longitudinal cracking

2016

Sasobit SMA Performance

Warm SMA overlay on top of JPCP

CRS declined by 30% over 7 years
I-355 SB Test Section

Evaluation Notes
✓ Sasobit SMA
✓ Reflection cracks
✓ Centerline deterioration
✓ Overlaid patch reflective cracks
✓ Longitudinal cracks (mid-lane)

CRS (2017) = 6.82

First major rehab of section since the section was constructed in 2010

I-355 NB Test Section (Evotherm)

Similar to SB section, first major rehab in 2018

Aug 2010 Construction
2012 Low-severity reflective cracks

2014 Medium-severity reflective cracks, Centerline deterioration
2015 Medium-severity reflective cracks, CL deterioration with spalling

2016 Reflective crack width > 0.25 in, Centerline deterioration with spalling, Longitudinal cracking (mid-lane)
Evotherm SMA Performance

Sasobit and Evotherm SMA sections performed similarly

CRS declined by 31% over 7 years

I-355 NB Resurfacing

Evaluation Notes
✓ Evotherm SMA
✓ Reflection cracks
✓ Centerline deterioration
✓ Overlaid patch reflective cracks

CRS (2017) = 7.18
I-90 Genoa Ramp Test Section

November 2010 Construction

2016 ADT = 4,600

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I-90 WB Ramp Resurfacing

Evaluation Notes

2018 Distresses
✓ Block cracks
✓ Alligator cracks
✓ Joint reflection cracks
✓ Centerline deterioration

CRS (2018) = 6.26

Ramp evaluation completed every 3 years

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Energy Consumption

<table>
<thead>
<tr>
<th>Item</th>
<th>Reduction due to WMA</th>
</tr>
</thead>
<tbody>
<tr>
<td>GHG (mt)</td>
<td>32.7%</td>
</tr>
<tr>
<td>CO (g/ton)</td>
<td>8.63%</td>
</tr>
<tr>
<td>VOC (g/ton)</td>
<td>69.42%</td>
</tr>
<tr>
<td>NOx (g/ton)</td>
<td>51.3%</td>
</tr>
<tr>
<td>SO2 (g/ton)</td>
<td>19.64%</td>
</tr>
</tbody>
</table>

Summary

- In general, warm-SMA showed comparable performance with control SMA
- Lab and field data suggested that pavement w/ warm SMA may be open to traffic earlier, wherein threshold is needed.
- Heavily trafficked expressway sections with warm-SMA had eight years of service life
- Incorporating GTR, RAP, and RAS should be carefully evaluated for optimized use
Acknowledgements

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Thank You

Any Question?