NCHRP 9-49A Project
Long-Term Field Performance of Warm Mix Asphalt Technologies
NCHRP Report 843

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Presented to the Asphalt Mixture ETG
Ames, IA

May 1st, 2017
Acknowledgements

• NCHRP 9-49A project
• Dr. Ed Harrigan and panel members
• Field work partners, Braun Intertec. Inc & Bloom Companies, LLC
• Statisticians from PSU and WSU
• State DOTs and local agencies
• Past NCHRP WMA project teams, universities, graduate students, ......
Outline

• Introduction & Objectives

• Project Scope and Research Approach

• Results
  • Transverse Cracking
  • Wheel-path Longitudinal Cracking
  • Rutting & Moisture Susceptibility

• Findings
Introduction

• Rapid growth in the use of WMA

• Limited research on long-term performance of WMA
  • How WMA compares with HMA in terms of specific performance
  • What are the critical material properties that could have significant impact on the long-term performance of WMA

• Better understanding of WMA technologies for full implementation
Research Objectives

• Investigate the long-term field performance of WMA as compared to its control HMA:
  - Transverse cracking
  - Wheel-path longitudinal cracking
  - Rutting and moisture damage

• Identify the material and engineering properties of WMA pavements that are significant determinants of their long-term field performance

• Recommend best practices for the use of WMA technologies.
Outline

• Introduction & Objectives
• Project Scope & Research Approach
• Results
  • Transverse Cracking
  • Wheel-path Longitudinal Cracking
  • Rutting & Moisture Susceptibility
• Findings
Project Scope

- 28 pavement projects
  - 22 in-service projects +1 HVS = 40 HMA-WMA pairs
    - ✓ 4-9 years service life
  - 5 newly constructed in 2011/2012 = 8 HMA-WMA pairs
- 3 WMA categories: organic, chemical, foaming

![Map of the United States with project locations marked.](image-url)
Scope: Project Distribution

WMA Type

No. of Projects

<table>
<thead>
<tr>
<th>Type</th>
<th>No. of Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic</td>
<td>12</td>
</tr>
<tr>
<td>Chemical</td>
<td>17</td>
</tr>
<tr>
<td>Foaming</td>
<td>18</td>
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</table>

Climate Zone

No. of Projects

<table>
<thead>
<tr>
<th>Zone</th>
<th>No. of Projects</th>
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<tbody>
<tr>
<td>Dry Freeze</td>
<td>6</td>
</tr>
<tr>
<td>Wet Freeze</td>
<td>10</td>
</tr>
<tr>
<td>Dry No-Freeze</td>
<td>4</td>
</tr>
<tr>
<td>Wet No-Freeze</td>
<td>8</td>
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</tbody>
</table>

Service Year

No. of Projects

<table>
<thead>
<tr>
<th>Year</th>
<th>No. of Projects</th>
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</thead>
<tbody>
<tr>
<td>(4,5)</td>
<td>11</td>
</tr>
<tr>
<td>(5,7)</td>
<td>10</td>
</tr>
<tr>
<td>(7,9)</td>
<td>7</td>
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</tbody>
</table>

Pavement Type

No. of Projects

<table>
<thead>
<tr>
<th>Type</th>
<th>No. of Projects</th>
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</thead>
<tbody>
<tr>
<td>Flexible</td>
<td>20</td>
</tr>
<tr>
<td>PCC or Cement Stabilized Base</td>
<td>8</td>
</tr>
</tbody>
</table>
Scope: Project Distribution

**Traffic (ESALs)**
- < 3 million: 18
- ≥ 3 million: 10

**Use of Anti-stripping**
- Yes: 12
- No: 12
- N/A: 4

**Use of RAP**
- Yes: 14
- No: 10
- N/A: 4
Research Approach

Selection of WMA Candidate Projects

Laboratory Characterization
- Volumetrics: aggregate gradation, AC, Gmm, Gmb
- Field cores
- Extracted binders

Field Characterization
- Field cores / plant mix
- Distress Survey: cracking (transverse, wheel-path longitudinal), rutting
- FWD test
Field Characterization: Two-Rounds of Distress Survey

Transverse Cracking

Sealed transverse crack
Residue of crack sealant
Sealed transverse crack

Reflective
Evotherm

[Images of reflective cracking]

Surface-initiated
Advera

[Images of surface-initiated cracking]

Underlying
Overlay

Overlay
Underlying
Observation:
• 2 to 4 feet away from the shoulder or centerline.
• Field cores indicate top-down fatigue cracks.
Field Characterization: Two-Rounds of Distress Survey

Rut Depth
Research Approach

Lab Test Results

Field Test Results

Data Analysis

Field Performance Comparison

Identification of Significant Determinants

Development of Performance Predictive Models

Conclusions & Recommendations
Outline

• Introduction & Objectives
• Project Scope and Research Approach
• Results
  • Transverse Cracking
  • Wheel-path Longitudinal Cracking
  • Rutting & Moisture Susceptibility
• Findings
1st-Round Field Transverse Cracking
HMA vs. WMA, Y 2011/2012

[Map of the United States with regions labeled as follows: Dry Freeze (3/6), Wet Freeze (5/10), Dry No-Freeze (1/4), Wet No-Freeze (5/8).]

[Bar chart showing the number of pairs as follows: H > W (5), H = W (29), H < W (1).]
1st Round Transverse Cracking
Comparison Among WMAs

- Chemical > Organic
- Chemical = Organic
- Chemical < Organic

Chemical > Foaming
- Chemical = Foaming
- Chemical < Foaming

Organic > Foaming
- Organic = Foaming
- Organic < Foaming

All technologies behave similarly in trans. cracking.
1st Round Field Transverse Cracking

Effect of Pavement Age

Transverse Crack Length, ft/200ft

Pavement Age, years

- HMA
- WMA
Effect of Aging on Pavement Performance

- Transverse Crack Length: ft/200ft
- Pavement Age, years
- High Temp. Increase, °C
- Month of Aging

- HMA
- WMA

- MN 169
- LA 116
2nd Round Field Transverse Cracking
HMA vs. WMA, Y 2014/2015

No. of Pairs

- H > W: 6
- H = W: 31
- H < W: 2

Map showing distribution across different regions:
- Dry Freeze
- Wet Freeze
- Dry No-Freeze
- Wet No-Freeze

Bar graph showing comparison:
- H > W: 6
- H = W: 31
- H < W: 2
2\textsuperscript{nd} Round Transverse Cracking
Y 2014/2015

**Dry Freeze**
- Foaming
- Chemical
- HMA
- Organic

**Wet Freeze**
- Chemical
- Organic
- HMA
- Foaming

**Dry Non-Freeze**
- Foaming
- HMA

**Wet Non-Freeze**
- Foaming
- Organic
- HMA
- Chemical
2nd Round Transverse Cracking
Effect of Pavement Age

Transverse Crack Length, ft/200ft

Pavement Age, years

TN SR 125
IA US 34
MT I-15
LA US 61

HMA
WMA
2nd Round Transverse Cracking
Comparison Among WMAs

Organic starts to show more cracks than Chemical and Foaming
Outline

• Introduction & Objectives
• Project Scope and Research Approach
• Results
  • Transverse Cracking
  • Wheel-path Longitudinal Cracking
  • Rutting & Moisture Susceptibility
• Findings
1st Round Wheel-path Longitudinal Cracking
HMA vs. WMA, 2011/2012

No. of Pairs

H > W | H = W | H < W
---|---|---
0  | 39  | 2

Map of the United States showing regions divided into categories:
- **Dry Freeze**: 0/6
- **Wet Freeze**: 2/10
- **Dry No-Freeze**: 0/4
- **Wet No-Freeze**: 6/8

Legend:
- ★ No Crack
- ★ Crack
1st Round Longitudinal Cracking
2011/2012

Dry Freeze

Dry Non-Freeze

Wet Freeze

Wet Non-Freeze
1st Round Wheel-path Longitudinal Cracking
Comparison Among WMAs

All technologies behave similarly in long. cracking
2nd Round Longitudinal Cracking
Y 2014/2015

Dry Freeze

- Foaming
- Chemical
- HMA
- Organic

Longitudinal Crack, ft./200ft.

Dry Non-Freeze

- Foaming
- HMA

Longitudinal Crack, ft./200ft.

Wet Freeze

- HMA
- Sasobit
- Evotherm

Longitudinal Crack, ft./200ft.

Wet Non-Freeze

- Foaming
- Organic
- Chemical

Longitudinal Crack, ft./200ft.
Organic starts to show more cracks than Chemical and Foaming.
2nd Round Wheel-path Longitudinal Cracking

Effect of Pavement Age

Wheel-path Longitudinal Crack Length, ft/200ft

Pavement Age, years

- HMA
- WMA
Outline

• Introduction & Objectives
• Project Scope and Research Approach
• Results
  • Transverse Cracking
  • Wheel-path Longitudinal Cracking
  • Rutting & Moisture Susceptibility
• Findings
Field Rutting Performance

- Rut depth is less than 1/16” for the 1st round survey;
- Use 2nd round survey results to compare;

![Map of the United States showing rutting performance](image)

- **Dry Freeze**: 5/6
- **Wet Freeze**: 9/10
- **Dry No-Freeze**: 1/4
- **Wet No-Freeze**: 8/8

![Bar chart showing rutting performance](image)

- H > W: 3
- H = W: 39
- H < W: 1

No. of Pairs
2nd Round Rut Depth
Y 2014/2015

Dry Freeze
- Foaming
- Chemical
- HMA
- Organic

Wet Freeze
- Chemical
- HMA
- Organic
- Foaming

Dry Non-Freeze
- Chemical
- Foaming
- HMA
- Organic

Wet Non-Freeze
- Foaming
- Organic
- HMA
- Chemical
2nd Round Rut Depth

Effect of Pavement Age

Pavement Age, years

Second-Round Rut Depth, in.

TN SR 125
WA SR 12

HMA
WMA
2nd Round Rut Depth
Comparison Among WMA

All technologies behave similarly in rut depth.
Moisture Susceptibility
Field Performance

• Moisture damage was not observed
  • Both WMA and HMA pavements
  • Consistent with NCHRP 9-49 findings
Moisture Susceptibility
Lab Hamburg Wheel Track Test Results

<table>
<thead>
<tr>
<th>Project</th>
<th>No. of Passes at SIP</th>
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<tr>
<td>MN</td>
<td>169</td>
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<tr>
<td>OH</td>
<td>841</td>
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<tr>
<td>PA</td>
<td>2012</td>
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<td>IL</td>
<td>147</td>
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<td>2006</td>
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<td>IA</td>
<td>34</td>
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<td>US</td>
<td>34</td>
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<td>NE</td>
<td>46</td>
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<td>TN</td>
<td>14</td>
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<td>SC</td>
<td>178</td>
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<td>MD</td>
<td>925</td>
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<tr>
<td>MO</td>
<td>Hall</td>
</tr>
<tr>
<td>MO</td>
<td>CC</td>
</tr>
<tr>
<td>MO</td>
<td>I-66</td>
</tr>
<tr>
<td>VA</td>
<td>FM</td>
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<td>TX</td>
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<td>LA</td>
<td>US</td>
</tr>
<tr>
<td>LA</td>
<td>3191</td>
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</table>

Projects
Red : No anti-strip agent
Black : W/ anti-strip agent
Green : Info not available
Relationship between Rutting and Cracking Performance
Dry Freeze Climatic Zone

Rutting Dominates
Relationship between Rutting and Cracking Performance
Dry Non-Freeze Climatic Zone

Not Conclusive

Rut Depth Versus Transverse Crack
- □ HMA
- △ WMA

Rut Depth Versus Long. Crack
- ○ HMA
- △ WMA
Relationship between Rutting and Cracking Performance
Wet Freeze Climatic Zone

Cracking Dominates
Relationship between Rutting and Cracking Performance

Wet Non-freeze Climatic Zone

Cracking & Rutting

Rut Depth Versus Transverse Crack
○ HMA
△ WMA

Rut Depth Versus Long. Crack
○ HMA
△ WMA
Outline

• Introduction & Objectives
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• Results
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  • Wheel-path Longitudinal Cracking
  • Rutting & Moisture Susceptibility
• Findings
Findings: Transverse Cracking

• *Transverse cracks* were found to initiate from the top surface of the pavement, but often overlapped with transverse cracks in existing asphalt layer
  • transverse cracking could be a combination of *thermal* and *reflective* cracking.

• *Transverse cracking performance* between HMA and WMA
  • *comparable* for the majority of HMA and WMA pavements
  • mostly seen in pavements with *four or more years* of age

• *Transverse cracking performance* among WMAs
  • short-term: comparable for the three WMA technologies
  • longer term: *chemical* and *foaming* appear to be comparable or better than *organic*
Findings: Wheel-path Longitudinal Cracking

• Cracks were found to initiate from surface of pavement
  • may be indicative of top-down fatigue cracking

• Performance comparison between HMA and WMA
  • comparable for the majority of HMA and WMA pavements
  • cracks start to develop mostly at age of 3-4 years; more cracking is seen with 6+ years.

• Performance among WMAs
  • short-term: comparable for the three WMA technologies
  • longer term: chemical and foaming appear to have comparable or better performance than organic
Findings: Rutting & Moisture Susceptibility

• Rutting performance between HMA and WMA pavements, and among WMA technologies is mainly comparable

• Field rut depth starts to build up as early as 3 years; and becomes more differentiable (more than 0.1”) with 6 or more years service.

• Based on field investigation, no moisture-related distress was found in both HMA and WMA pavements.

• Based on laboratory HWT test results, most of mixes without an anti-stripping agent exhibited SIPs

  • The use of anti-stripping agent may be beneficial overall for both HMA and WMA mixtures.
Findings: Overall

• **Distress distribution** appears to be climatic related.
  • Within dry freeze zone, rutting appears to be the major type of distress, regardless of HMA or WMA

• Within wet freeze zone, cracking appears dominant

• Within wet non-freeze zone, cracking and rutting can both happen.

**Effect of moisture on cracking?**
List of Publications


Thank You!
Any questions?
<table>
<thead>
<tr>
<th>Project</th>
<th>MT I-15</th>
<th>TN SR 125</th>
<th>IA US 34</th>
<th>TX FM 973</th>
<th>LA US 61</th>
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<tbody>
<tr>
<td><strong>Construction Year</strong></td>
<td>2011</td>
<td>2011</td>
<td>2011</td>
<td>2011</td>
<td>2012</td>
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<tr>
<td><strong>Warm Mix Type</strong></td>
<td>Sasobit, Evotherm DAT, Foaming</td>
<td>Evotherm 3G</td>
<td>Sasobit, Evotherm 3G</td>
<td>Evotherm 3G, Foaming</td>
<td>Sasobit, Evotherm 3G</td>
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<tr>
<td><strong>Design Thickness, in.</strong></td>
<td>2.5</td>
<td>1.25</td>
<td>1.5</td>
<td>2.0</td>
<td>2.0</td>
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<tr>
<td><strong>Traffic</strong></td>
<td>3 million ESALs (3,170 AADT, 26.3% truck)</td>
<td>0.39 million ESALs (3,470 AADT, 13% truck)</td>
<td>3 million ESALs (6,450 AADT, 10.9% truck)</td>
<td>3 million ESALs (11,300 AADT, 4.3% truck)</td>
<td>9 million ESALs (34,138 ADT, 14% truck)</td>
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<td><strong>Aggregate</strong></td>
<td>Siliceous</td>
<td>Gravel &amp; Sand</td>
<td>Limestone, Quartzite &amp; Sand</td>
<td>Gravel, Limestone &amp; Dolomite</td>
<td>Granite &amp; Limestone</td>
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<tr>
<td><strong>NMAS, in.</strong></td>
<td>3/4</td>
<td>1/2</td>
<td>1/2</td>
<td>3/4</td>
<td>1/2</td>
</tr>
<tr>
<td><strong>Asphalt Binder</strong></td>
<td>PG 70-28</td>
<td>PG 70-22</td>
<td>PG 58-28</td>
<td>PG 70-22</td>
<td>PG 76-22</td>
</tr>
<tr>
<td><strong>Anti-stripping Agent</strong></td>
<td>Hydrated Lime, 1.4%</td>
<td>ARR-MAZ, 0.3%</td>
<td>None</td>
<td>None</td>
<td>0.6%</td>
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<tr>
<td><strong>Polymer-modified</strong></td>
<td>SBS</td>
<td>Yes</td>
<td>None</td>
<td>N/A</td>
<td>SBS</td>
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<td><strong>Asphalt Content, %</strong></td>
<td>4.6</td>
<td>6.0</td>
<td>5.44</td>
<td>5.2</td>
<td>4.7</td>
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<tr>
<td><strong>Maximum Specific Gravity (G_{mm})</strong></td>
<td>HMA (2.458) Sasobit (2.466) Evotherm (2.459) Foaming (2.453)</td>
<td>HMA (2.352) Evotherm (2.355)</td>
<td>HMA (2.423) Sasobit (2.428) Evotherm (2.429)</td>
<td>HMA (2.406) Evotherm (2.405) Foaming (2.420)</td>
<td>HMA (2.464) Sasobit (2.468) Evotherm (2.464)</td>
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<tr>
<td><strong>RAP or RAS</strong></td>
<td>None</td>
<td>10% RAP</td>
<td>17% RAP</td>
<td>None</td>
<td>15% RAP</td>
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<tr>
<td><strong>Structure</strong></td>
<td>2.5&quot; overlay + 7&quot; existing HMA + 16.2&quot; base (non-stabilized) + infinite subgrade</td>
<td>1.25&quot; overlay + 8&quot; existing HMA + 7&quot; bituminous base + 6&quot; min. aggregate base + infinite subgrade</td>
<td>HMA &amp; Sasobit: 1.5&quot; overlay + 5&quot; existing HMA + 7&quot; PCC + subgrade Evotherm: 1.5&quot; overlay + 3&quot; existing HMA + 9&quot; PCC + subgrade</td>
<td>2&quot; overlay + 8&quot; existing HMA + 10&quot; base + 141.1&quot; subgrade (lean clay)</td>
<td>2&quot; overlay + 8&quot; existing HMA + 8&quot; PCC + 6&quot; cement-treated soil subgrade</td>
</tr>
<tr>
<td>Project</td>
<td>MD 925</td>
<td>MO Hall St.</td>
<td>MO Rte. CC</td>
<td>MN TH 169</td>
<td>OH SR 541</td>
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<td>--------</td>
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<td>-----------</td>
<td>-----------</td>
</tr>
<tr>
<td><strong>Warm Mix Type (content, %, by weight of binder)</strong></td>
<td>Sasobit</td>
<td>Sasobit (1.5); Evotherm ET; Aspha-min (0.3)</td>
<td>Evotherm DAT</td>
<td>Evotherm 3G</td>
<td>Sasobit (1.5); Evotherm ET (5.3 by mix); Aspha-min (0.3)</td>
</tr>
<tr>
<td><strong>Production Temp., °F</strong></td>
<td>HMA (310-350); Sasobit (270-310)</td>
<td>HMA (320); Sasobit (240); Evotherm (225); Aspha-min (275)</td>
<td>HMA (320); Evotherm (280-290)</td>
<td>HMA (300); Evotherm (265)</td>
<td>HMA (320); Sasobit (260); Evotherm (235); Asphamin (245)</td>
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<td><strong>Traffic (AADT)</strong></td>
<td>10,480</td>
<td>21,000</td>
<td>8618</td>
<td>12,600</td>
<td>650</td>
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<tr>
<td><strong>Aggregate</strong></td>
<td>N/A</td>
<td>Limestone</td>
<td>Steel Slag</td>
<td>Limestone</td>
<td>N/A</td>
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<tr>
<td><strong>NMAS, in.</strong></td>
<td>3/8</td>
<td>1/2</td>
<td>1/2</td>
<td>3/4</td>
<td>3/8</td>
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<tr>
<td><strong>Asphalt Binder</strong></td>
<td>64-22</td>
<td>70-22</td>
<td>64-22</td>
<td>58-28</td>
<td>70-22</td>
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<td><strong>Anti-stripping Agent</strong></td>
<td>None</td>
<td>ARR MAZ, 0.25%</td>
<td>Pave Bond Lite, 0.25%</td>
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<td>None</td>
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<tr>
<td><strong>Asphalt Content, %</strong></td>
<td>5.0</td>
<td>5.3</td>
<td>5.4</td>
<td>4.2</td>
<td>6.1</td>
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<td><strong>G_{mm}</strong></td>
<td>2.519</td>
<td>2.451</td>
<td>2.469</td>
<td>2.549</td>
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<td><strong>Sampling Date</strong></td>
<td>6/28/12</td>
<td>7/16-18/12</td>
<td>7/17/12</td>
<td>8/28/12</td>
<td>6/18/12</td>
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<tr>
<td><strong>RAP</strong></td>
<td>15%</td>
<td>10%</td>
<td>20%</td>
<td>N/A</td>
<td>15%</td>
</tr>
<tr>
<td><strong>Structure</strong></td>
<td>2&quot; + 5&quot; HMA + 8&quot; Macadam stone</td>
<td>1.75&quot; + 12&quot; PCC + 0-3&quot; base</td>
<td>3.75&quot; + 7&quot; PCC + 6&quot; base</td>
<td>2&quot; + 8&quot; HMA + 6&quot; base</td>
<td>1.25&quot; + 6.75&quot; HMA + 9&quot; granular base</td>
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In-service Projects – Wet Freeze Zone
<table>
<thead>
<tr>
<th>Project</th>
<th>SC US 178</th>
<th>TN SR 46</th>
<th>TX FM 324</th>
<th>LA 116</th>
<th>LA 3191</th>
<th>LA 3121</th>
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<tbody>
<tr>
<td><strong>Warm Mix Type</strong></td>
<td>Evotherm DAT</td>
<td>Sasobit, Evotherm DAT, Astec DBG, and Advera</td>
<td>Sasobit, Evotherm DAT, Rediset, Advera</td>
<td>Foam</td>
<td>Astec Foam</td>
<td>Evotherm 3G</td>
</tr>
<tr>
<td><strong>Production Temp., °F</strong></td>
<td>HMA (295); Evotherm (240)</td>
<td>HMA Danley (320-350); HMA Franklin (320-350); Sasobit (250); Evotherm DAT (240); Advera (250); DBG (260)</td>
<td>H (330); W (240)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td><strong>Traffic (AADT)</strong></td>
<td>3880</td>
<td>4440</td>
<td>1450</td>
<td>2600</td>
<td>ADT 200</td>
<td>ADT 400</td>
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<tr>
<td><strong>Aggregate</strong></td>
<td>N/A</td>
<td>Limestone</td>
<td>Limestone</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>NMAS, in.</strong></td>
<td>3/8</td>
<td>1/2</td>
<td>3/8</td>
<td>1/2</td>
<td>1/2</td>
<td>1/2</td>
</tr>
<tr>
<td><strong>Asphalt Binder</strong></td>
<td>64-22</td>
<td>70-22</td>
<td>64-22</td>
<td>70-22</td>
<td>70-22</td>
<td>70-22</td>
</tr>
<tr>
<td><strong>Anti-stripping Agent</strong></td>
<td>N/A</td>
<td>Franklin (AD-Here 77-00, 0.3%); Astec DBG (Pavegrip 650, 0.3%)</td>
<td>1% Lime</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td><strong>Asphalt Content, %</strong></td>
<td>H (5.3); W (5.4)</td>
<td>5.3</td>
<td>4.6</td>
<td>4.4</td>
<td>5.2</td>
<td>5.1</td>
</tr>
<tr>
<td><strong>G&lt;sub&gt;mm&lt;/sub&gt;</strong></td>
<td>H (2.460) W (2.463)</td>
<td>HMA Danley (2.428); Sasobit (2.411); Evotherm (2.410); Astec DBG (2.444); Advera (2.422); HMA Franklin (2.425)</td>
<td>HMA, Sasobit, Evotherm (2.508); Advera Rediset (2.498)</td>
<td>H (2.525) W (2.541)</td>
<td>H (2.453) W (2.486)</td>
<td>H (2.507) W (2.490)</td>
</tr>
<tr>
<td><strong>Sampling Date</strong></td>
<td>07/27/12</td>
<td>07/24/12</td>
<td>2/6-8/13</td>
<td>05/21/13</td>
<td>05/21/13</td>
<td>05/20/13</td>
</tr>
<tr>
<td><strong>RAP</strong></td>
<td>N/A</td>
<td>None</td>
<td>None</td>
<td>15</td>
<td>15</td>
<td>15, 30</td>
</tr>
<tr>
<td><strong>Structure</strong></td>
<td>2&quot; overlay + 5.7&quot; HMA + 7.1&quot; PCC + sand clay base</td>
<td>1.25&quot; overlay + 4.26&quot; HMA + 6&quot; crushed stone</td>
<td>1.5&quot; overlay + 5.7&quot; HMA + 10&quot; base</td>
<td>1.5&quot; overlay + 5&quot; HMA + 8.5&quot; base</td>
<td>2&quot; HMA + 6&quot; HMA + 7&quot; PCC</td>
<td>2&quot; overlay + 12&quot; cement-treated base</td>
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<tr>
<td>Project</td>
<td>WA I-90</td>
<td>WA SR 12</td>
<td>CO IH 70</td>
<td>NE US 14</td>
<td>NV</td>
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<td>----------</td>
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</tr>
<tr>
<td>Warm Mix Type</td>
<td>Sasobit</td>
<td>Aquablack</td>
<td>Sasobit (1.5% by mass of binder); Evotherm DAT (0.5% of binder); Advera (0.3% of mixture)</td>
<td>Advera, Evotherm DAT</td>
<td>Ultrafoam</td>
<td></td>
</tr>
<tr>
<td>Production Temp., °F</td>
<td>HMA (330), Sasobit (276)</td>
<td>HMA (325), Aquablack (275)</td>
<td>HMA (mixing 310, compaction 280); Sasobit (255, 235); Evotherm (250, 230); Advera (255, 235)</td>
<td>H (330), W (275)</td>
<td>H (330), W (275)</td>
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</tr>
<tr>
<td>Traffic (AADT)</td>
<td>13,000</td>
<td>6,550</td>
<td>30,000</td>
<td>2,140</td>
<td>5,000</td>
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<tr>
<td>Aggregate</td>
<td>Basalt</td>
<td>Basalt</td>
<td>Crushed River Rock</td>
<td>Limestone, Gravel</td>
<td>N/A</td>
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<tr>
<td>NMAS, in.</td>
<td>1/2</td>
<td>1/2</td>
<td>1/2</td>
<td>1/2</td>
<td>1/2</td>
<td></td>
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<tr>
<td>Asphalt Binder</td>
<td>76-28</td>
<td>64-28</td>
<td>58-28</td>
<td>64-28</td>
<td>64-28</td>
<td></td>
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<tr>
<td>Anti-stripping Agent</td>
<td>None</td>
<td>Superbond (0.25%)</td>
<td>Hydrated Lime (1% by mass of aggregate blend)</td>
<td>None</td>
<td>Hydrated Lime, 1.5%</td>
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</tr>
<tr>
<td>Asphalt Content, %</td>
<td>5.5</td>
<td>5.2</td>
<td>6.3</td>
<td>5.0</td>
<td>4.6</td>
<td></td>
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<tr>
<td>Gₘₘ</td>
<td>2.601</td>
<td>2.596</td>
<td>2.45</td>
<td>H-Adv (2.439), H-Evo (2.441)</td>
<td>2.451</td>
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<tr>
<td>Sampling Date</td>
<td>8/27/12</td>
<td>8/28/12</td>
<td>10/18/12</td>
<td>10/14/12</td>
<td>10/19/12</td>
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<tr>
<td>RAP, %</td>
<td>15-20</td>
<td>20</td>
<td>None</td>
<td>&lt;15</td>
<td>15</td>
<td></td>
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<tr>
<td>Structure</td>
<td>3&quot; overlay + 11.28&quot; HMA + 6.5&quot; base (HMA)/5&quot; base (Sasobit)</td>
<td>3&quot; overlay + 7.8&quot; HMA + 9&quot; base</td>
<td>2.5&quot; overlay + 10-11&quot; HMA</td>
<td>3&quot; overlay + 4&quot; HL slurry stabilization + 1.5&quot; existing asphalt + 4&quot; bit sand base</td>
<td>6&quot; HMA + 9&quot; aggregate base</td>
<td></td>
</tr>
</tbody>
</table>
# In-service Projects – Dry Non-Freeze Zone

<table>
<thead>
<tr>
<th>Project</th>
<th>TX SH 251</th>
<th>TX SH 71</th>
<th>CA HVS 3a</th>
<th>CA HVS 3b</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Warm Mix Type</strong></td>
<td>Astec DBG</td>
<td>Evotherm DAT</td>
<td>Gencor, Evotherm DAT, Cecabase</td>
<td>Sasobit, Advera, Astec DBG, Rediset</td>
</tr>
<tr>
<td><strong>Production Temp., °F</strong></td>
<td>H (310), W (270)</td>
<td>H (330), W (240)</td>
<td>HMA (320), Gencor (284), Evotherm (248), Cecabase (266)</td>
<td>HMA (335, 279), Sasobit (300,279), Advera (295,266), Astec DBG (295,257), Rediset (285,258)</td>
</tr>
<tr>
<td><strong>Traffic (AADT)</strong></td>
<td>2,300</td>
<td>57,000</td>
<td>HMA (74,000), Gencor (159,000), Evotherm and Cecabase (160,000)</td>
<td>HMA, Sasobit, Astec DBG and Rediset (160,000), Advera (50,000)</td>
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<tr>
<td><strong>Aggregate</strong></td>
<td>Limestone</td>
<td>Limestone</td>
<td>Granite</td>
<td>Reed</td>
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<tr>
<td><strong>NMAS, in.</strong></td>
<td>3/8</td>
<td>3/8</td>
<td>1/2</td>
<td>1/2</td>
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<tr>
<td><strong>Asphalt Binder</strong></td>
<td>70-22</td>
<td>76-22</td>
<td>64-16</td>
<td>64-16</td>
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<tr>
<td><strong>Anti-stripping Agent</strong></td>
<td>1% Akzo</td>
<td>0.8% Liquid</td>
<td>None</td>
<td>None</td>
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<tr>
<td><strong>Asphalt Content, %</strong></td>
<td>5.1</td>
<td>4.8</td>
<td>7.0</td>
<td>8.3</td>
</tr>
<tr>
<td><strong>G_{mm}</strong></td>
<td>H (2.45), W (2.4)</td>
<td>2.416</td>
<td>H (2.503)</td>
<td>H (2.505)</td>
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<tr>
<td><strong>Sampling Date</strong></td>
<td>2/5/13</td>
<td>2013</td>
<td>2012</td>
<td>2012</td>
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<tr>
<td><strong>RAP, %</strong></td>
<td>None</td>
<td>N/A</td>
<td>Rubber (18% of binder)</td>
<td>Rubber (18% of binder)</td>
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<tr>
<td><strong>Structure</strong></td>
<td>2.0&quot; overlay + 4.3&quot; HMA</td>
<td>2&quot; overlay + HMA</td>
<td>2.5&quot; gap-graded rubberized HMA + 2.5&quot; HMA + 15.6&quot; base</td>
<td>2.5&quot; gap-graded rubberized HMA + 2.5&quot; HMA + 15.6&quot; base</td>
</tr>
</tbody>
</table>