Long-Life Asphalt Pavements for the 21st Century

WARM MIX ASPHALT TECHNOLOGY

Northeast Asphalt User/Producer Group

2008 Annual Meeting
October 9, 2008
Atlantic City, NJ

warmmixasphalt.com
Acknowledgements:

John D’Angelo - FHWA

FHWA Mobile Asphalt Testing Laboratory Program
  Chuck Paugh – Project Manager
  Jagan Gudimettla – Mixture Project Engineer
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  Joshua Thompson – Mix Technician
  David Heidler – Binder Technician
  Darnel Jackson – Binder Technician

also FHWA Turner Fairbank Highway Research Center
  Nelson Gibson, Scott Parobeck, Frank Davis

NCHRP project 09-43
  Advanced Asphalt Technologies, LLC
Although there are many factors driving the development and implementation of WMA technologies globally, in order for WMA to succeed in the U.S., WMA pavements must have equal or better performance when compared to traditional HMA pavements.
How Many WMA Technologies are Available in the U.S.?
How Many WMA Technologies are Available in the U.S.?

Currently 12 Technologies Marketed and Available in the U.S.
WMA Trials and Demonstrations
Interstate 70, Dillon, CO

70 miles West of Denver, CO

Elevation
8,800 – 11,100 Feet
East Entrance, Yellowstone, WY

Yellowstone National Park

Shoshone National Forest

End project

Begin project

85 km To Cody, WY

Entrance Fees

Yellowstone and Grand Teton National Parks

- Vehicle Permit: $60.00
- Motorcycle Permit: $20.00
- Snowmobile Permit: $40.00
- Park Annual Pass: $10.00
- Emergency Vehicle Pass: $30.00
- Commercial Truck Vehicle: $100.00
- Individuals over 65 with Disability: Free
- Individuals with Handicapped Vehicles: Free
# MAMTL Trailer WMA Projects

## Warm Mix Asphalt Projects

<table>
<thead>
<tr>
<th>Location</th>
<th>Mix Design</th>
<th>Lab Compaction Level, Gyrations</th>
<th>Base Binder Grade</th>
<th>Technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hall St., St. Louis, MO</td>
<td>12.5mm Superpave</td>
<td>100</td>
<td>PG 70-22</td>
<td>Aspha-Min Evotherm Sasobit</td>
</tr>
<tr>
<td>I-70, Dillon, CO, West of Eisenhower Tunnel</td>
<td>9.5mm Superpave</td>
<td>75</td>
<td>PG 58-28</td>
<td>Advera Evotherm Sasobit</td>
</tr>
<tr>
<td>East Entrance Road, Yellowstone National Park, WY</td>
<td>19mm Hveem</td>
<td>75</td>
<td>PG 58-34</td>
<td>Advera Sasobit</td>
</tr>
</tbody>
</table>

Mobile Asphalt Mixture Testing Laboratory
Objective

- Evaluate the effects of three Warm Mix process namely Sasobit, Aspha-Min and Evotherm on M320-Table 2 Performance Grade
- To Compare the Performance Grades of Warm Mix processes with the base asphalt used in preparing warm mix asphalts
Hall Street, St. Louis, MO

<table>
<thead>
<tr>
<th>Base</th>
<th>M320 Continuous Performance Grade</th>
<th>M320, Table 2 Performance Grade</th>
<th>Additive Rate, by wt of binder</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>70.9 – 24.8</td>
<td>70 - 22</td>
<td></td>
</tr>
<tr>
<td>w/ Sasobit</td>
<td>76.5 – 22.8</td>
<td>76 - 22</td>
<td>1.5%</td>
</tr>
<tr>
<td>w/ Aspha-Min</td>
<td>72.4 – 24.6</td>
<td>70 - 22</td>
<td>5.26%</td>
</tr>
<tr>
<td>Evotherm (recovered per ASTM D 6934)</td>
<td>66.6 – 26.7</td>
<td>64 - 22</td>
<td></td>
</tr>
</tbody>
</table>
Hall Street, St. Louis, MO
PG Comparison - Evotherm

BASF Method

-23.3
-25.9
-26.6
-26.7

70.1
68.2
67.6
66.6

Asphalt Binders
### I-70, Dillon, CO

<table>
<thead>
<tr>
<th></th>
<th>M320 Continuous Performance Grade</th>
<th>M320, Table 2 Performance Grade</th>
<th>Additive Rate, by wt of binder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>59.9 – 30.3</td>
<td>58 – 28</td>
<td></td>
</tr>
<tr>
<td>Sasobit</td>
<td>64.2 – 29.2</td>
<td>64 – 22</td>
<td>1.5%</td>
</tr>
<tr>
<td>Aspha-Min</td>
<td>61.1 – 30.9</td>
<td>58 – 28</td>
<td></td>
</tr>
<tr>
<td>Advera</td>
<td>60.7 – 30.4</td>
<td>58 - 28</td>
<td>4.33%</td>
</tr>
<tr>
<td>Evotherm</td>
<td>No Data Obtained Due to Schedule</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### East Entrance Rd, Yellowstone, WY

<table>
<thead>
<tr>
<th></th>
<th>M320 Continuous Performance Grade</th>
<th>M320, Table 2 Performance Grade</th>
<th>Additive Rate, by wt. of binder</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Base</strong></td>
<td>60.2 – 34.1</td>
<td>58 – 28</td>
<td></td>
</tr>
<tr>
<td><strong>Sasobit</strong></td>
<td>65.1 – 32.0</td>
<td>64 – 28</td>
<td>1.5%</td>
</tr>
<tr>
<td><strong>Advera</strong></td>
<td>61.2 – 33.2</td>
<td>58 – 28</td>
<td>5.2%</td>
</tr>
</tbody>
</table>
Findings

- Sasobit – increase of one high temp. PG grade
- Aspha-Min - no effect on PG grade
- Evotherm
  - recovered at BASF, no effect on the PG grade
  - recovered from the stored emulsion, reduced by one high temp. PG grade
Findings

- Emulsion recovery processes had no effect on the PG. The PGs from all three recovery methods were found to be the same.
- ASTM D6934 was found to be the quickest and easiest process to recover the Evotherm residue from emulsion.
Objectives

- When should WMA performance specimens be tested
- What are the effects of reheating on WMA performance test properties

Approach

- Immediate Compaction / Immediate Testing
- Immediate Compaction / Delayed Testing
- Reheated Compaction and Testing
St. Louis Paving Schedule

- Control (12.5mm PG 70-22) – 5/17/06
- Sasobit – 5/18/06
- Sasobit – 5/19/06
- Evotherm – 5/22/06
- Evotherm – 5/23/06
- Aspha-Min – 5/25/06
Sampling

- Truck bed ≈ every 2 hours of production
  - Volumetric
    - $P_b$ – Ignition
    - $G_{mm}$
    - $G_{mb}$
- Immediate Testing
  - $E^*$ and $F_n$ next day after manufacture
  - TSR and Hamburg (TFHRC)
Sampling

- Truck bed ≈ every 2 hours of production
  - Volumetric
    - $P_b$ – Ignition
    - $G_{mm}$
    - $G_{mb}$

- Delayed Testing
  - $E^*$ and $F_n$ testing 2-3 weeks after manufacture
  - TSR and Hamburg (TFHRC)
**Sampling**

- Reheated compaction and testing conducted by TFHRC
- 1~2 tons mixture
  - 15 – 5 gallon buckets
  - SPT; TSR; Hamburg
- *Nelson Gibson - TFHRC*
Sampling

- Reheated compaction and testing conducted by TFHRC
- 1~2 tons mixture
  - 15 – 5 gallon buckets
  - SPT; TSR; Hamburg
- *Nelson Gibson - TFHRC*
Superpave Gyratory Compactor

366 specimens fabricated over 6 days
Dynamic Modulus ($E^*$)

- Test Temperatures
  - 4.4° C (40° F)
  - 21.1° C (70° F)
  - 37.8° C (100° F)
  - 54.4° C (130° F)

- Frequencies
  - 0.1, 0.5, 1, 5, 10, 25 Hz
Master Curve – Arrenhius Fit

Reduced Time, sec

E*, ksi

25 Hz  5 Hz  1 Hz  0.1 Hz

4.4° C  21.1° C  37.8° C  54.4° C

Fit
Hall Street, St. Louis, MO
Control Mixture

E*, MPa

- Immediate
- Delayed
- Reheated

Reduced Time, sec
Hall Street, St. Louis, MO
Sasobit Mixture

Reduced Time, sec

$E^*$, MPa

- Immediate-280 F
- Delayed-280 F
- Reheated-280 F
- Immediate-240 F
- Delayed-240 F
- Reheated-240 F
Hall Street, St. Louis, MO
Evotherm Emulsion Mixture

- Immediate-280 F
- Delayed-280 F
- Reheated-280 F
- Immediate-240 F
- Delayed-240 F
- Reheated-240 F

Reduced Time, sec

$E^*$, MPa
Hall Street, St. Louis, MO
Immediately Compacted – Immediately Tested

Control Mix
Sasobit 280°F
Sasobit 240°F
Evotherm 280°F
Evotherm 240°F
Aspha-Min 280°F
Hall Street, St. Louis, MO
Immediately Compacted – Delayed Testing

- Control Mix
- Sasobit 280°F
- Sasobit 240°F
- Evotherm 280°F
- Evotherm 240°F
- Aspha-Min 280°F

Reduced Time, sec

E*, MPa
Hall Street, St. Louis, MO
Reheated Compaction – Delayed Testing

- Control Mix
- Sasobit 280°F
- Sasobit 240°F
- Evotherm 280°F
- Evotherm 240°F
- Aspha-Min 280°F

Reduced Time, sec

$E^*$, MPa
I-70, Frisco, CO

Reduced Time, sec

E*, MPa

Control Mix
Advera
Sasobit
E. Entrance Rd, Yellowstone, WY
Pb - 5.3%, Mix Design Replication

Reduced Time, sec

E*, MPa

Control Mix
Advera
Sasobit
E. Entrance Rd, Yellowstone, WY
Average WMA Production

Reduced Time, sec

$E^*$, MPa
Flow Number, $F_n$

Test Temperatures

- LTTPBind, Version 3.1 Software
- Site pavement temperature @ 50% Reliability
  - Pavement Temperature
  - Pavement Temperature + 6° C
  - Pavement Temperature - 6° C
Flow Number, $F_n$

Hall Street, St. Louis, MO

- Test Temperatures
  - 46°C (115°F)
  - 52°C (126°F)
  - 58°C (136°F)

- Loading
  - 600 kPa – Deviator Stress
  - 0 kPa – Confining Pressure
Flow Number, Fn

Immediate and Delayed Test Specimens

Flow Number, cycles

- 46° C
- 52° C
- 58° C

- Control
- SasoBit T1
- SasoBit T2
- Evotherm T1
- Evotherm T2
- Aspha - Min

Flow Number, cycles
Flow Number, $Fn$

I-70 - Frisco, CO

- **Test Temperatures**
  - $36^\circ$ C ($97^\circ$ F)
  - $42^\circ$ C ($108^\circ$ F)
  - $48^\circ$ C ($118^\circ$ F)

- **Loading**
  - $689$ kPa (100 psi) – Deviator Stress
  - $69$ kPa (10 psi) – Confining Pressure
I-70 Flow Number, \( F_n \)

![Flow Number Graph]

- **36° C**
- **42° C**
- **48° C**

- **Control**
- **Advera**
- **Sasobit**
- **Evotherm**

Flow Number, cycles
Findings

- Immediate vs. Delayed Testing
  - Evotherm & Aspha-Min
    - Performance testing - delayed after specimen manufacture
  - Sasobit
    - Performance testing can be conducted immediately after specimen manufacture
CDOT Hamburg History:
75 gyration mixtures typically fail Hamburg, but fail primarily due to plastic flow rutting rather than stripping/moisture damage

CONTROL
9.46 mm

ADVERA
9.79 mm

*Data and Photos are Courtesy of CODOT
I-70 Hamburg Sasobit

CONTROL
17.31 mm

SASOBIT
10.49 mm

*Data and Photos are Courtesy of CODOT
I-70 Hamburg Evotherm

CONTROL
10.10 mm

Evotherm
14.86 mm

*Data and Photos are Courtesy of CODOT
Control - 3.82 mm and 4.00 mm
Advera - 3.80 mm and 3.25 mm
Sasobit - 3.28 mm and 2.60 mm

*All the testing was performed at 40°C wet and reported at 20,000 passes.
Implementation Challenges

- Multiple WMA technologies (with more to come)
- Mix Design Procedures
  - Conditioning temperature
  - Binder ageing procedures
  - Effects of reheating specimens
  - Laboratory equipment for foamed asphalt
- Moisture Sensitivity
- Performance
  - Equal or better than HMA!!
- Specification Requirements
WMA Technical Working Group (TWG)

- FHWA / NAPA sponsored
- Co-Chairs
  - Matthew Corrigan, FHWA
  - Ron White, Industry
- Represented
  - State DOT
  - State APA
  - NCAT
  - AASHTO
  - Labor
  - NIOSH
  - Hot Mix Asphalt Industry
WMA TWG Accomplishments

- www.warmmixasphalt.com
- Material Testing Framework
- Emission Testing Framework
- WMA Best Practices Document
- Research Needs Identified
  - Developed three (3) research statements
  - Submitted through AASHTO to NCHRP
    - All projects highly ranked by SCOR
    - Total $1.4 million
- WMA Guide Spec for Highway Construction
NCHRP Project 09-43

“Mix Design Practices for Warm Mix Asphalt”

$500,000.00

Principal Investigator:
Dr. Ramon Bonaquist,
Advanced Asphalt Technologies, LLC

Completion Date: March 2010

http://www.trb.org/TRBNet/ProjectDisplay.asp?ProjectID=977
NCHRP Project 09-43

- Address the increasingly wide range of WMA technologies and processes
- Design Mixtures Based on AASHTO M323
  - Materials Selection
  - Volumetric Design
  - Moisture Damage and Rutting
  - Coating, Workability, Compactability
- Develop AASHTO Standard Practice
  - Modified AASHTO R35 for WMA
  - Short Term Conditioning
    - 2 hours at compaction temperature
UMass Workability Device
### Key Differences Volumetric Design

<table>
<thead>
<tr>
<th>Item</th>
<th>HMA AASHTO R35</th>
<th>WMA Proposed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixing &amp; Compaction</td>
<td>Viscosity</td>
<td>Coating Workability Compactability</td>
</tr>
<tr>
<td>Temperatures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specimen Preparation</td>
<td>Standard</td>
<td>Process specific Short-term aging</td>
</tr>
<tr>
<td>Optimum Binder Content</td>
<td>AASHTO M323 Volumetrics</td>
<td>AASHTO M323 Volumetrics</td>
</tr>
<tr>
<td>Moisture Sensitivity</td>
<td>AASHTO T283</td>
<td>AASHTO T283</td>
</tr>
<tr>
<td>Rutting Resistance</td>
<td>None</td>
<td>Flow Number Test</td>
</tr>
</tbody>
</table>
Performance Testing

- Flow Number Test (Fn) – Rutting Resistance
  - based on Design ESALs
- Dynamic Modulus (E*)
- Fatigue Cracking
- Thermal Cracking

Binder Performance Grade

- High Grade increase based on production temp
- Ageing Index (AI) at high PG temp
  \[
  \frac{(G*/\sin \delta)_{RTFOT}}{(G*/\sin \delta)_{Tank}}
  \]
NCHRP Project 09-47

“Engineering Properties, Emissions, and Field Performance”

$900,000.00

Principal Investigator: Asphalt Institute

Completion Date: not to exceed 42 months

http://www.trb.org/TRBNet/ProjectDisplay.asp?ProjectID=1625
WMA TWG Submissions for Future NCHRP Research Projects

- WMA TWG Research Needs Statements
  - Moisture Sensitivity of Warm Mix Asphalt Technologies
  - Short Term Ageing of WMA Binders During Production
  - Long Term Field Performance of Warm Mix Asphalt Technologies
  - Differences between Field Produced WMA and HMA Volumetric Properties
Laboratory Evaluation: Wax Additives in Warm-Mix Asphalt Binder

Evaluate the effect of wax additives on physical properties and characteristics of asphalt binders and their subsequent performance in mixtures.
Asphalt – One (1)

- Lion Oil PG64-22 Eldorado, AR Refinery

Wax Additives – Nine (9)

- Non-Paraffin Wax Additives

Aggregates

- Vulcan Barin Quarry Granite, Columbus, GA

Mix Design

- 12.5mm Dense Graded SuperPave Gyratory
  - ~5.5% Binder
  - ~7.0% Air Voids
Fourier Transform Infra-Red Spectroscopy
- Gel Permeation Chromatography
- Glass Transition (Tg)
- Branching
- Physical Hardening (32 days saturation at -12°C) Bending Beam Rheometry
  - Testing at 1, 2, 4, 8, 16 and 32 Days
- Multi-Step Creep Recovery (MSCR)
- Binder Stress Sweep Fatigue
- Additional testing … etc.
Warm Mix Asphalt: Best Practices

Quality Improvement Series (QIP) 125
- Stockpile Moisture Management
- Burner Adjustments and Efficiency
- Aggregate Drying and Baghouse Temperatures
- Drum Slope and Flighting
- Combustion Air
- RAP usage
- Placement Changes
**WMA European Scan Tour**

- Joint Program w/ FHWA, AASHTO, NCHRP and Industry
- Publication FHWA-PL-08-007
- Scan Final Report
- Electronic copy .pdf available at warmmixasphalt.com
Matthew Corrigan, P.E.
Mobile Asphalt Laboratory Program Manager
Warm Mix Asphalt Program Manager

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