Development of Warm Mix Asphalt in North America

The Western Canada Pavement Workshop – 2010 Addition

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Warm Mix Asphalt (WMA) Technologies

- **Hot Mix Asphalt** 275-325°F  
  135°C-160°C

- **Warm Mix Asphalt** 250-275°F  
  120°C-135°C

- **Cold Mix Asphalt** 60°F  
  15°C
What is WMA?

• Allows a reduction in the temperatures at which asphalt mixes are produced and placed
  • Reduced viscosity at lower temps
    • Complete aggregate coating
  • Chemical package to promote coating of the aggregate
Why WMA?

- Potential Advantages**
  - Energy Savings
  - Decreased Emissions
    - Visible and Non-Visible
  - Decreased Fumes
  - Decreased Binder Ageing
  - Extended Paving Season
  - Compaction Aid
  - Increased RAP usage

**Advantages will only be realized by optimizing production operations and utilizing best practices
Lower Mix Production Temperature

Conventional: 151°C
ASTEC DBG: 126°C

Lower Field Compaction Temperature

Conventional: 137°C
ASTEC DBG: 112°C
Lower Thermal Segregation / More Uniform Compaction

Conventional SD: 6.68
ASTEC DBG Foam SD: 2.52

Lower Temperature Cooling Rate

Temperature (°C)

Time (min)

ASTEC DBG Foam
Conventional
# Lower Plant Emissions

<table>
<thead>
<tr>
<th></th>
<th>Conventional</th>
<th>ASTEC DBG Foam</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Carbon Dioxide (CO2)</strong> (CO2 (%))</td>
<td>10.9%</td>
<td></td>
</tr>
<tr>
<td><strong>Carbon Monoxide (CO)</strong> (CO (%))</td>
<td>10.4%</td>
<td></td>
</tr>
<tr>
<td><strong>Sulphur Dioxide (SO2)</strong></td>
<td>-</td>
<td></td>
</tr>
<tr>
<td><strong>Nitrogen Oxides (NOx)</strong></td>
<td>8.3%</td>
<td></td>
</tr>
</tbody>
</table>

# Higher Workability / Easier Compaction

![Graph showing workability comparison between ASTEC DBG and conventional methods.](image)

- **1 Pass Vibratory Steel Roller**
- **2 Pass Vibratory Steel Roller**
- **Neumatic Tire Roller**
- **Behind Paver**

The graph illustrates the percentage of MTD (Modified Tonnage Density) achieved with different compaction methods, demonstrating higher workability and easier compaction with ASTEC DBG Foam compared to conventional methods.
Why WMA?

- Potential Advantages**
  - Energy Savings
  - Decreased Emissions
    - Visible and Non-Visible
  - Decreased Fumes
  - Decreased Binder Ageing??
  - Extended Paving Season
  - Compaction Aid
  - Increased RAP usage??
  - Moisture Damage??

**Advantages will only be realized by optimizing production operations and utilizing best practices
WMA Investigation and Implementation Premise

- Although there are many factors driving the development and implementation of WMA technologies globally, in order for WMA to succeed, WMA pavements must have equal or better performance when compared to traditional HMA pavements.
Brief World History

- 1995 Preliminary Lab Experiments
- 1997 German Bitumen Forum
- 2000 First International Conference of Asphalt Pavements (Sydney)
- 2000 Second Euroasphalt and Eurobitume Congress (Barcelona)
- NAPA 2002 European Scan Tour
  - Germany & Norway
Brief US History

- NAPA Annual Meeting 2003
  - San Diego

- World of Asphalt 2004
  - Nashville

- WMA TWG 2005

- FHWA International Scan 2007

- International WMA Conference 2008
  - Nashville
WMA European Scan Tour

- Joint Program with FWHA, AASHTO, NCHRP & Industry
- Publication FWHA-PL-08-007
- Scan Final Report
  - pdf available at:

  http://international.fhwa.dot.gov/pubs/pl08007/index.cfm
Initial U.S. Research Partners

2004 - 2005

- U.S. Department of Transportation Federal Highway Administration
- NAPA StateAPA
- National Center for Asphalt Technology (NCAT) - Auburn University
- Asphalmn®
- EUROVIA
- Hubbard Construction Company
- Sasol®
- Evotherm®
- MeadWestvaco Business
How Many WMA Technologies are available in NA?
How Many WMA Technologies are available in NA?

Currently Twenty (20) Technologies Marketed and available in NA.
Technology Overview

- WAM-Foam
- Low Emission Asphalt
- Aspha-Min
- Advera
- Sasobit
- REVIX
- Evotherm
- Cecabase RT
- Thiopave
- Rediset WMX
- Lea-co
- Meeiker
- Ultrafoam GX
- Terex
- ACCU-SHEAR
- Aquablack
- Double Barrel
- Green

**FHWA does not endorse any particular proprietary product or technology.**
More to come …
Many other technologies are also used Internationally.
Warm Mix Asphalt (WMA) Technologies

- Technologies
  - Organic Additives
  - Chemical Additives
  - Foaming Process
    - Additives/Asphalt Binders
    - Mechanical Plant Modification

WMA Technical Working Group

- FHWA/NAPA sponsored
  - Formed in 2005

- Co-Chairs
  - Matthew Corrigan, FHWA
  - Ron White, Industry

- Represented
  - State DOT
  - State APA
  - NCAT
  - Hot Mix Asphalt Industry
  - AASHTO
  - Labor
  - NIOSH
WMA TWG Accomplishments

- www.warmmixasphalt.com
- Material Testing Framework
- Emission Testing Framework
- WMA Best Practices Document
- WMA Guide Spec for Highway Construction

Research Needs Identified
- Developed five (5) research statements
- Submitted through AASHTO to NCHRP
  - All projects highly ranked by SCOR
  - Total $2.9 million
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
DIVISION 400 FLEXIBLE PAVEMENTS

SECTION 401 HOT MIX ASPHALT (HMA) PAVEMENTS

401.01 Description
401.02 Material
401.03 Construction
401.04 Measurement
401.05 Payment
Warm Mix Asphalt (WMA) Guide  
Specification for Highway Construction  

DIVISION 400 - Asphalt Pavements and Surface Treatments  
SECTION 4XX - WARM MIX ASPHALT (WMA) PAVEMENTS

4XX.01 Description  
4XX.02 Material  
4XX.03 Construction  
4XX.04 Measurement  
4XX.05 Payment
The following references detail specifics related to plant modifications and operational changes in order to maximize the benefits of WMA production:


- Quality Improvement Series 126 (QIP 126),

- “Energy Conservation in Hot Mix Asphalt Production”

- Environmental Council 101 (EC-101),

- “Best Management Practices to Minimize Emissions During HMA Construction”
WMA Trials and Demonstrations

Mobile Asphalt Mixture Testing Laboratory (MAMTL)
WMA Trials and Demonstrations

Mobile Asphalt Mixture Testing Laboratory (MAMTL)
WMA Trials and Demonstrations
Canadian Experience

- **Maritime Provinces**
  - Sasobit, Advera, Evotherm

- **Eastern Canada**
  - Sasobit, Advera, Evotherm, HyperTherm, DBG System

- **Western Canada**
  - DBG System, HyperTherm, Sasobit, Evotherm, Ultrafoam, WAM, Thiopave

- Been placed on residential, collector and arterial freeways, primary highways, airports and heavy industrial/commercial applications
WCAN Canadian Experience

- Used primarily in Alberta and BC
  - Organic / Waxy Additives - Sasobit
  - Chemical Additives – Evotherm, HyperTherm
  - Foaming Process
    - Additives/Asphalt Binders - Advera
    - Mechanical Plant Modification – Astec DBG, Gencor Ultrafoam, WAM

- Vancouver Island
  - Evotherm, DBG System and HyperTherm

- BC Mainland
  - Sasobit, Thiopave, DBG System, HyperTherm

- Alberta Experience
  - Sasobit, Advera, Evotherm, DBG System, HyperTherm, Ultrafoam, WAM
Vancouver Experience - Update

- Presented at CTAA in Moncton in 2009

- DuraClime placed in September, 2007
  - North Vancouver Redi-mix entrance road
  - Coquitlam Sand & gravel pit access road

- Detailed evaluation performed to assess mix performance after two years in service
  - Surface distress evaluation
    - Edge cracking and raveling identified
    - No rutting evidenced
  - Laboratory testing
    - Bulk density, TS, RM, TSR, APA
    - Binder rheology testing DSR small amplitude oscillations and BBR repeated creep and recovery
    - Performance properties of mix similar to original lab mix properties
North Vancouver Redi-Mix Plant

DBG 15%RAP Surface Course Mix, DBG Virgin Binder Course Mix

Approx 750,000 ESAL’s
Coquitlam Sand & Gravel Pit

Wearing Course Mix DBG 50%RAP

During Construction

After Two Years Service

Approx 500,000 ESAL’s
Coquitlam Sand & Gravel Pit

Distresses Noted

Low Severity Ravelling

Pavement Edge Cracking
Calgary Study
Project Location

GARRISON GREEN
Project Location
Project Description

WMA Road Study

Objective: determine the performance of ASTEC and GENCOR water based (foaming) technology and HyperTherm (Iterchemica) chemical additive technology in WMA.

Asphalt Mixes:
- GENCOR Foam
- ASTEC Foam
- GENCOR HyperTherm
- GENCOR Conventional

Plant production evaluation (ASTEC – GENCOR)
- Quality / Volumetrics - AC/Gradation, AV, VMA, Moisture
- Aggregate / AC / Mix temperature
- Water concentration
- Emissions
- Baghouse temperatures

Laboratory evaluation
- Moisture susceptibility - TSR
- Rutting resistance – APA, Flow number
- Fatigue – Fatigue tests at different strain
- Low temperature – TSRST tests
- Complex Modulus
- Binder evaluation – Extracted & original

Evaluation of field laydown and compaction
- Temperature behind paver
- Cooling rate profile
- Thermal segregation
- Compaction profile - densities
- Texture - Visual inspection
- Cores – Stiffness, future evaluations
Temperature Cooling Rate

![Graph showing temperature cooling rate for different materials over time.](image)
Road Compaction Profile

- GENCOR Foam
- ASTEC DBG Foam
- GENCOR HyperTherm
- GENCOR Conventional

1 Pass Vibratory Steel Roller
2 Pass Neumatic Tire Roller
Final Vibratory Steel Roller

% of MTD

Behind Paver

Images of construction equipment and scenes.
Thermal Segregation

- GENCOR Conventional
- GENCOR Foam
- ASTEC DBG Foam
- GENCOR HyperTherm
Workability

[Graph showing workability data for different types of foam and hypertherm processes, with labels for Mix Temperature (°C) on the x-axis and Maximum Load (kN) on the y-axis. Legend includes GENCORE Foam, ASTEC DBG Foam, GENCOR HyperTherm, and GENCOR Conventional.]
# Plant Emissions

<table>
<thead>
<tr>
<th></th>
<th>GENCOR Foam</th>
<th>ASTEC DBG Foam</th>
<th>GENCOR HyperTherm</th>
<th>GENCOR Conventional</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO (mg/m³)</td>
<td>1449</td>
<td>308</td>
<td>1471</td>
<td>1702</td>
</tr>
<tr>
<td>NO (mg/m³)</td>
<td>16</td>
<td>17</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>NOX (mg/m³)</td>
<td>25</td>
<td>26</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>SO2 (mg/m³)</td>
<td>3.0</td>
<td>0.0</td>
<td>0.0</td>
<td>2.0</td>
</tr>
<tr>
<td>CO2 (%)</td>
<td>2.7</td>
<td>2.8</td>
<td>2.7</td>
<td>3.0</td>
</tr>
<tr>
<td>CO (%)</td>
<td>0.12</td>
<td>0.08</td>
<td>0.12</td>
<td>0.13</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>GENCOR Foam</th>
<th>ASTEC DBG Foam</th>
<th>GENCOR HyperTherm</th>
<th>GENCOR Conventional</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO (mg/m³)</td>
<td>~</td>
<td>82</td>
<td>13.53</td>
<td>~</td>
</tr>
<tr>
<td>NO (mg/m³)</td>
<td>~</td>
<td>~</td>
<td>~</td>
<td>~</td>
</tr>
<tr>
<td>NOX (mg/m³)</td>
<td>~</td>
<td>~</td>
<td>~</td>
<td>~</td>
</tr>
<tr>
<td>SO2 (mg/m³)</td>
<td>~</td>
<td>~</td>
<td>~</td>
<td>~</td>
</tr>
<tr>
<td>CO2 (%)</td>
<td>10.0</td>
<td>8.33</td>
<td>10.0</td>
<td>~</td>
</tr>
<tr>
<td>CO (%)</td>
<td>9.62</td>
<td>38.46</td>
<td>7.69</td>
<td>~</td>
</tr>
</tbody>
</table>
Mix Hot Storage

- Sealed laboratory samples
- Samples compacted by using Marshall (25 & 50 Blows) and SG compactors
Mix Hot storage - Silos

- Stability
- Time (day)
- GENCOR Foam 50 Blows
- ASTEC Foam 50 Blows
- GENCOR Foam 25 Blows
- ASTEC Foam 25 Blows
## Moisture Susceptibility

### TSR Tests (%) on Plant Produced Mix

<table>
<thead>
<tr>
<th></th>
<th>Dry</th>
<th>60°C Soak</th>
<th>Freeze / Thaw</th>
<th>TSR (60°C)</th>
<th>TSR (Freeze / Thaw)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GENCOR Conventional</td>
<td>482.5</td>
<td>399.6</td>
<td>433.7</td>
<td>82.8</td>
<td>89.9</td>
</tr>
<tr>
<td>GENCOR Foam</td>
<td>416.8</td>
<td>337.5</td>
<td>408.2</td>
<td>81.0</td>
<td>97.9</td>
</tr>
<tr>
<td>GENCOR HyperTherm</td>
<td>385.5</td>
<td>397.8</td>
<td>410.2</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>ASTEC Foam</td>
<td>468.6</td>
<td>411.5</td>
<td>447.1</td>
<td>87.8</td>
<td>95.4</td>
</tr>
</tbody>
</table>

### Mix Moisture (%) During Mix Manufacturing

<table>
<thead>
<tr>
<th></th>
<th>GENCOR Conventional</th>
<th>GENCOR HyperTherm</th>
<th>ASTEC Foam</th>
<th>GENCOR Conventional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mix Moisture</td>
<td>0.10</td>
<td>0.10</td>
<td>0.12</td>
<td>0.10</td>
</tr>
</tbody>
</table>
Texture

- Tight surface
- Few aggregates uncoated identified for future evaluation
Final Appearance / GENCOR Foam
Ongoing National Research

- NCHRP 9-43 “Mix Design Practices for Warm Mix Asphalt” $500,000

- NCHRP 9-47A “Engineering Properties, Emissions, and Field Performance” $900,000

- NCHRP 9-49 “Long Term Field Performance of Warm Mix Asphalt Technologies”
  - Phase I, Moisture Susceptibility
  - Phase II, Long-Term Performance
Future WMA Specifications

- Emphasis on Performance
  - Asphalt Mixture Performance Tester (AMPT)
    - Flow Number (Fn), mixture rutting
    - Dynamic Modulus (E*), mixture stiffness
    - Cyclic Tension – Compression, fatigue cracking
  - IDT Creep and Strength
    - fatigue and thermal cracking
  - Hamburg wheel tracking
  - Moisture Susceptibility Testing
written summary of WMA @
http://www.fhwa.dot.gov/pavement/asphalt/wma.cfm
Thank You!

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bob.forfylow@lafarge-na.com