NCAT Pavement Test Track
at Auburn University

- WMA, Thin Surfaces, and Polymer
Warm Mix Asphalt

• WMA definitions
  – asphalt mix produced with special technologies at temperatures 30 to 70°F lower than typical HMA
  – Asphalt mix produced at temps below 275 F

• Lower temperatures result in...
  – Less energy to produce asphalt mixes thus reduced cost
  – Fewer emissions from asphalt plants
  – Less fumes and odors for paving crew and neighbors
  – Better workability at lower temperatures
  – Cold weather paving
Potential WMA Density Benefit

- Some contractors use WMA primarily for a density benefit.
- Data from NCHRP 9-47A indicates WMA test sections have only an average density 0.17% higher than companion HMA sections.
- In a typical PWL specification, even that small improvement can impact the density pay factor and translate to a benefit of up to $1 per ton.
Plant Concerns with Initial use of WMA

- Lower production temperatures could lead to:
  - Less efficient burner operation
  - Incomplete drying of the virgin aggregates
  - Condensation in the baghouse
  - Increase amperage on motors
WMA Research on the NCAT Test Track

- 2009 full-depth sections
  - Control HMA (all virgin materials)
  - MeadWestvaco Evotherm DAT WMA
  - Astec Foamed Asphalt WMA
  - 50% RAP HMA
  - 50% RAP WMA
Full-Depth
WMA and Control Test Sections

<table>
<thead>
<tr>
<th>Layer</th>
<th>NMAS</th>
<th>Binder Grade</th>
<th>Target Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface</td>
<td>9.5 mm</td>
<td>PG 76-22</td>
<td>32 mm</td>
</tr>
<tr>
<td>Intermediate</td>
<td>19.0 mm</td>
<td>PG 76-22</td>
<td>70 mm</td>
</tr>
<tr>
<td>Base</td>
<td>19.0 mm</td>
<td>PG-67-22</td>
<td>76.2 mm</td>
</tr>
</tbody>
</table>

The same mix designs were used for HMA and WMA mixes of the same layer.
All mixes were fine-graded.
HD Video vs Infrared
HMA vs WMA\textsubscript{foam} vs WMA\textsubscript{additive}
<table>
<thead>
<tr>
<th>Property</th>
<th>Control</th>
<th>WMA-F</th>
<th>WMA-A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant Mix Temp. °C</td>
<td>168</td>
<td>135</td>
<td>121</td>
</tr>
<tr>
<td>Pb, %</td>
<td>6.1</td>
<td>6.1</td>
<td>6.4</td>
</tr>
<tr>
<td>Pbe, %</td>
<td>5.4</td>
<td>5.5</td>
<td>5.7</td>
</tr>
<tr>
<td>Lab Air Voids, %</td>
<td>4.0</td>
<td>3.3</td>
<td>3.4</td>
</tr>
<tr>
<td>Vol. of Eff. Binder, %</td>
<td>12.5</td>
<td>12.7</td>
<td>13.3</td>
</tr>
<tr>
<td>Rec. Binder Grade</td>
<td>81.7 - 24.7</td>
<td>82.0 - 25.7</td>
<td>80.3 - 25.7</td>
</tr>
<tr>
<td>In-place Density, %</td>
<td>93.1</td>
<td>92.3</td>
<td>93.7</td>
</tr>
</tbody>
</table>
Back-calculated AC Modulus vs. Temp.

**WMA sections 7-10% lower stiffness than HMA**

### Back-calculated Exponential Formulas for AC Modulus

<table>
<thead>
<tr>
<th>Material</th>
<th>$k_1$</th>
<th>$k_2$</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>9051</td>
<td>-0.034</td>
<td>0.98</td>
</tr>
<tr>
<td>WMA-F</td>
<td>7554</td>
<td>-0.033</td>
<td>0.98</td>
</tr>
<tr>
<td>WMA-A</td>
<td>8217</td>
<td>-0.034</td>
<td>0.97</td>
</tr>
</tbody>
</table>

**Exponential Formulas**

$$AC 	ext{ Modulus, ksi} = k_1 e^{-k_2 (T - 90)}$$
Critical Strain vs. Temperature

No Statistical Difference between WMA and HMA sections
# Updated Field Performance

<table>
<thead>
<tr>
<th>Section</th>
<th>15 Million ESALs</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cracking % of Lane Area</td>
<td>Rutting (mm)</td>
</tr>
<tr>
<td>Control HMA</td>
<td>2%</td>
<td>9 mm</td>
</tr>
<tr>
<td>WMA – Foam</td>
<td>11%</td>
<td>12 mm</td>
</tr>
<tr>
<td>WMA – Additive</td>
<td>18%</td>
<td>14 mm</td>
</tr>
<tr>
<td>50% RAP HMA</td>
<td>0%</td>
<td>4 mm</td>
</tr>
<tr>
<td>50% RAP WMA</td>
<td>3%</td>
<td>5 mm</td>
</tr>
</tbody>
</table>
HIGH POLYMER MIXTURES
Perpetual Pavements on Soft Clays
Perpetual Pavements on Soft Clays

N8 Strain = 21.487e^{0.0335\times\text{Temperature}}
R^2 = 0.96

N9 Strain = 11.496e^{0.0298\times\text{Temperature}}
R^2 = 0.9217

Mid-Depth Temperature, F
Tensile Microstrain

N8 N9
Terminal Crack Map (10 million ESALs)
Rehabilitation with 125 mm Mill/Inlay
Placement of Fabric Interlayers
Initial Distresses (2.7 million ESALs)
More Distresses (3.4 million ESALs)
Terminal Distresses (3.8 million ESALs)
Forensic Coring
1st Rehab after 4.0 million ESALs
2009 Group Experiment (+)

<table>
<thead>
<tr>
<th>Conventional Dense HMA</th>
<th>Permeable Surface on Dense HMA</th>
<th>High RAP % HMA</th>
<th>High RAP % Warm Mix</th>
<th>Foamed Warm Mix</th>
<th>Additized Warm Mix</th>
<th>Thiopave Warm Sulfur</th>
<th>Thiopave Warm Sulfur</th>
<th>Kraton Modified Mix</th>
<th>TLA Modified Mix</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 inches</td>
<td>7 inches</td>
<td>7 inches</td>
<td>7 inches</td>
<td>7 inches</td>
<td>7 inches</td>
<td>7 inches</td>
<td>7 inches</td>
<td>6.76 inches</td>
<td>7 inches</td>
</tr>
<tr>
<td>6 inches DGAB</td>
<td>6 inches DGAB</td>
<td>6 inches DGAB</td>
<td>6 inches DGAB</td>
<td>6 inches DGAB</td>
<td>6 inches DGAB</td>
<td>6 inches DGAB</td>
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<td>6 inches DGAB</td>
<td>6 inches DGAB</td>
</tr>
<tr>
<td>Stiff Subgrade</td>
<td>Stiff Subgrade</td>
<td>Stiff Subgrade</td>
<td>Stiff Subgrade</td>
<td>Stiff Subgrade</td>
<td>Stiff Subgrade</td>
<td>Stiff Subgrade</td>
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<td>Stiff Subgrade</td>
<td>Stiff Subgrade</td>
</tr>
</tbody>
</table>

Private Sector Funding

National Center for Asphalt Technology
at Auburn University
Effect of High Polymer Inlay

Average of Date:

Backcalculated AC Modulus, ksi:

Test Date:

2\textsuperscript{nd} Rehab after 5.6 million ESALs

Now with over 11 million ESALs!
Implementation in Alabama

- Cracking on new construction on US-280
- Pending structural failure on I-59
- Rutting under heavy traffic on US-231
Can I build Thinner?

- Yes!
- Reduced pavement thickness from 178 mm to 146 mm
- Still no cracking in thin pavement
- Better fatigue
- Better rutting
THIN LIFT MIXTURES
Background

• Cost of mix materials is increasing
• “Screenings” stockpiles are accumulating
• Small NMAS mixes are used for light traffic
• Disproportionally high increase in binder cost

• Can “screenings” mixes support heavy traffic?
• Can neat asphalt produce polymer performance?
2003 NCAT Pavement Test Track

N4 – 9.5 mm NMA Grv/Lms/Sand

W6 – 4.75 mm NMA Lms/Grv/Sand

S5 – 12.5 mm NMA Grv/Lms/Sand
4.75 NMAS Mix in West Curve
“W6” Construction in 2003

Laboratory Diary

General Description of Mix and Materials
Design Method: Superpave
Compactive Effort: 50 gyrations
Binder Performance Grade: 70-22
Modifier Type: SBS
Aggregate Type: Lms/Grv/Smld
Gradation Type: ARZ

Construction Diary

Relevant Conditions for Construction
Completion Date: Thursday, August 21, 2003
24 Hour High Temperature (F): 88
24 Hour Low Temperature (F): 68
24 Hour Rainfall (in): 0
Lift type: Surface
Planned Mill / Lift Thickness (in): 0.8

Plant Configuration and Placement Details
Component: Asphalt Content (Plant Setting)
Sieve Size: 100
Design: 100
QQ: 100

Component: Cherokee Limestone
Sieve Size: 3/4"
Design: 100
QQ: 100

Component: Guntown Crushed Gravel
Sieve Size: 1/2"
Design: 100
QQ: 100

Component: Mississippi Natural Sand
Sieve Size: 3/8"
Design: 100
QQ: 100

Component: Hydrated Lime
Sieve Size: No. 4
Design: 99
QQ: 96

Component: Asphalt Content
Sieve Size: No. 8
Design: 72
QQ: 75

Component: Asphalt Content
Sieve Size: No. 16
Design: 43
QQ: 50

Component: Asphalt Content
Sieve Size: No. 30
Design: 30
QQ: 35

Component: Asphalt Content
Sieve Size: No. 50
Design: 18
QQ: 22

Component: Asphalt Content
Sieve Size: No. 100
Design: 11
QQ: 15

Component: Asphalt Content
Sieve Size: No. 200
Design: 8.0
QQ: 11.3

Asphalt Content: 7.5
Pit Bulk Gravity: 2.314
TMD (Rice): 2.411
Avg Air Voids: 4.0
Avg VMA: 16

General Notes:
1) Mixes are referenced by quadrant (E = East, N = North, W = West, and S = South), section number (sequential) and sublot;
2) Sections are listed in the order they appear on the Track beginning with E2 and continuing counterclockwise to E1;
3) The total research thickness of all structual study sections (N1 through N8) ranges from 3/4 to 4 inches by design;
4) The total HMA thickness of all structual study sections (N1 through N8) ranges from 5 to 6 inches by design;
5) ARZ, TRZ, and BRZ refer to gradations intended to pass above, through and below the restricted zone, respectively;
6) SMA and OGFC refer to stone matrix asphalt and open-graded friction course, respectively.
Rutting

Average Rut Depth (mm) vs. Traffic Accumulation (ESALs)

- Average Rut Depth: 4.75, 9.5, 12.5
- Traffic Accumulation Range: 0 to 22,500,000 ESALs
Roughness

![Graph showing roughness over traffic accumulation](image-url)
Durability

\[ y = 1 \times 10^{-8}x + 0.1908 \]
\[ R^2 = 0.8871 \]

\[ y = 2 \times 10^{-8}x + 0.3174 \]
\[ R^2 = 0.8095 \]

\[ y = 7 \times 10^{-9}x + 0.3731 \]
\[ R^2 = 0.6398 \]

Mean Texture Depth (mm)
Traffic Accumulation (ESALs)

4.75 9.5 12.5
4.75 NMAS Mix Appearance
Comments on 4.75 NMAS Mix

• Section has performed extremely well
• High cost / ton due to polymer binder content
  – Lower cost / SY due to low placement rate
• Need lower cost / ton with same performance
  – Two screenings stockpiles and neat asphalt
THANK YOU!