ARC Update on Warm Mix Research
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Presented to
Manitoba, Infrastructure and Transportation
Materials Engineering Branch
Central Lab, 1181 Portage Avenue Annex
Winnipeg, Manitoba
March 17, 2009
ARC Subtask E1c-1: Effect of WMA Additives

• Progress Update
  – Binder Properties
    ▪ Viscosity
    ▪ Performance Grade
  – Mixture Workability
    ▪ Compaction Curves
    ▪ Workability Indices
Effect on Viscosity: PG64-22

PG64-22 Viscosity vs. Shear Rate

Change in η due to additive, relatively small.

Change in η due to temperature

PG64 Control
Sasobit - 2%
Surfactant - 0.5%
Effect on Viscosity: PG76-22

PG76-22 Viscosity vs. Shear Rate

- Change in $\eta$ due to temperature.
- Change in $\eta$ due to additive relatively small.

PG76 Control
- Sasobit - 2%
- Surfactant - 0.5%
Effects of WMA Additives:
HT PG Grade ($G^*/\sin\delta$)

2% Sasobit - One Grade Bump

0.5% Surfactant - One Grade Lower
Effects of WMA Additives: HT PG Grade (MSCR)

MSCR $J_{nr}$ Results - RTFO Binder

- Sasobit shows much higher stress sensitivity
Effects of WMA Additives: LT PG Grade

**Temperature -12°C**

- **Stiffness at 60 sec, MPa**
  - Control: PG64-22, PG76-22
  - Sasobit 2%: PG64-22, PG76-22
  - Surfactant 0.5%: PG64-22, PG76-22

- **m-value**
  - Control: PG64-22, PG76-22
  - Sasobit 2%: PG64-22, PG76-22
  - Surfactant 0.5%: PG64-22, PG76-22
Mixture Workability

- **Mix Design**
  - NMAS: 19.0 mm/Gradation: Fine /AC: 5.4%

- **Binder Grades**
  - PG64-22-and polymer-modified PG76-22

- **Evaluation Criteria**
  - Compaction Curves and Air Voids
  - Workability indices
    - Construction Densification Index (CDI)
    - Construction Force Index (CFI)
Mixture Workability - CDI

- **CDI Based on Compaction Curves:**
  - Area under the %Gmm vs. Gyration Curve from Nini – 92% Gmm. Densification after paver to field compaction.
  - Lower CDI relates to better workability.
Mixture Workability - CFI

- CFI Based on Force Measured by PDA Plate:
  - Pressure Distribution Analyzer (PDA) allow for calculation of resistive forces in the mix during compaction ($w$)
  - CFI calculated as the area under the Resistive Force ($w$) vs. Gyration curve
Mixture Workability – 600KPa

- No noticeable effects of WMA Additives.
- Additives allow mixes at 90°C to attain density of control mix at 135°C.
Mixture Workability – 300KPa

Densification Curves for PG64: 300 kPa, 90°C

% Gmm

Gyrations

HMA
Mineral-Based
Surfactant
135 HMA Control
Mixture Workability – CDI- 600KPa

- Little difference between mixes until 90°C compaction temperatures.
- WMA has significantly lower % Air Voids.
- CDI shows similar trends. WMA much more workable at 90°C than HMA.
- CDI of WMA 66% lower.

PG 76-22 Voids Analysis - 600 kPa, N=21 Gyraisons

% Air Voids for HMA ~ 1% Higher

PG76: CDI vs. Temperature - 600 kPa

66% Reduction for WMA
Mixture Workability – CDI- 300KPa

PG 64: CDI vs. Temperature - 300 kPa

- HMA
- Mineral-Based
- Surfactant

Temperature vs. CDI for different materials at 300 kPa.
Mixture Workability - CFI

- Construction Force Index
  - Force measurements are consistent – WMA additive requires less force to reach the same level of compaction.
# Moving Forward – Binder

<table>
<thead>
<tr>
<th>Binder</th>
<th>PG Grade</th>
<th>ZSV</th>
<th>UW-Madison Tack Test</th>
<th>G*/sinδ (HT °C)</th>
<th>MSCR (HT°C)</th>
<th>G*sinδ (IT °C)</th>
<th>BYET (IT °C)</th>
<th>BBR (LT+10°C)</th>
<th>SENB (LT+10°C)</th>
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<td>Neat L</td>
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<td>✓</td>
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<tr>
<td>Neat H+ 2% Sasobit</td>
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✓ = Test completed  
X = Test is planned
### Moving Forward – Workability

<table>
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<tr>
<th>Gradation</th>
<th>Pressure [kPa]</th>
<th>Comp. Temp. [°C]</th>
<th>Control</th>
<th>Mineral Based Additive</th>
<th>Surfactant</th>
<th>Foaming</th>
<th>Sasobit</th>
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✓ = Test completed  
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Testing of Field Mixtures
Field Projects in WI – 2008

![Graph showing final density percentage versus total roller passes for WMA and HMA materials.]

- **Final Density, %**
- **Total Roller Passes, n**

Legend:
- WMA
- HMA
# Field Mixes – with RAP

<table>
<thead>
<tr>
<th>Aggregate</th>
<th>HMA - Design</th>
<th>HMA - UW</th>
<th>WMA - 30% QC</th>
<th>WMA-40%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compaction Temp (F)</td>
<td>275</td>
<td>275</td>
<td>215</td>
<td>221</td>
</tr>
<tr>
<td>Nini - 7</td>
<td>91.2%</td>
<td>90.4%</td>
<td>92.0%</td>
<td>93.8%</td>
</tr>
<tr>
<td>Ndes - 60</td>
<td>96.1%</td>
<td>95.4%</td>
<td>97.0%</td>
<td>98.3%</td>
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<tr>
<td>Nmax- 75</td>
<td>96.6%</td>
<td>95.8%</td>
<td>N/A*</td>
<td>N/A*</td>
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<tr>
<td>VMA</td>
<td>14.10</td>
<td>12.86</td>
<td>12.30</td>
<td>11.00</td>
</tr>
</tbody>
</table>

*WMA QC samples were compacted to Ndes.
Summary / Wish List

• WMA works at lower temps
  – Density is not a good measure
  – Better use densification indicators

• Project should include true control
  – HMA @ same temps as WMA
  – Enough materials
  – Good recording of temp, roller passes and sampling
Thank you!

• For giving us the opportunity
• For the warm reception to talk about warm asphalt
• Getting us to visit Winnipeg during our spring break!