Heated Reclaimed Asphalt Pavement Material and Warm Mix Asphalt for Use in Recycled Hot Mix Asphalt

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Content

- Background
- Needs
- Objectives
- Materials
- Scope – mix, tests
- Results
- Discussion
- Conclusions and recommendations
Background

- Most of MDOT’s 21,000 miles of road systems consist of low to medium volume roads.
- MDOT has been experimenting with different types of recycled materials.
- Factors include cost, resistance to moisture, compactibility, effect of construction on traffic, opening delays and structural strength.
Recycling Options

- Both FDR and PMRAP processes use “old” materials
- PMRAP material is screened prior to blending - achieve particle size quality
- On projects that require significant realignment or grade change, PMRAP is the choice
- Needs three to seven days for curing, prior to the application of HMA overlay
Needs to Improve PMRAP

- Improve the dispersion of asphalt emulsion on the RAP and hence associated proprieties such as density and resistance to moisture
- Improve its compactibility
- Maintain a relatively low temperature in the mixing and compaction process to keep expenses at a relatively low level
- Shorten the waiting time prior to the application of HMA overlay
Objectives

• To evaluate several options and determine the most appropriate method of recycling

• Specifically the objectives were to compare workability, compactibility, stiffness and resistance to moisture damage
Concepts

• The following two concepts were selected for this experimental study:

• 1. Heating the RAP prior to mixing with the emulsion (MS2) in the PMRAP process

• 2. Using the RAP (with a PG 64-28 grade asphalt binder) at a lower mixing temperature, using the concept of Warm Mix Asphalt
Warm Mix Asphalt Additive-Sasobit

- Using a recycled HMA $\rightarrow$ superior mix
- Use of conventional mixing temperatures would lead to production problems
- If the proper use of Sasobit allows mixing and compaction at a relatively lower temperature, then the use of recycled HMA would provide an attractive alternative
- Key requirement is that good performance must be obtained
Scope

- Preparing different mixes with RAP (100 % RAP), compacting them and testing samples
- RAP material from Westbrook, Maine
- The RAP was tested for moisture and asphalt content as well as gradation
- Optimum content determined on the basis of density/voids
<table>
<thead>
<tr>
<th>Property</th>
<th>Sample</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture content</td>
<td>1</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2.1</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>1.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Average: 1.8</td>
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<tr>
<td>Asphalt Content</td>
<td>1</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>5.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Average: 5.5</td>
</tr>
<tr>
<td>Sieve Size, mm</td>
<td>Percent Passing</td>
<td>Percent Passing</td>
</tr>
<tr>
<td>----------------</td>
<td>----------------</td>
<td>----------------</td>
</tr>
<tr>
<td></td>
<td>Sample 1</td>
<td>Sample 2</td>
</tr>
<tr>
<td>37.5</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>25</td>
<td>94</td>
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<td>1.18</td>
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<td>0.6</td>
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<td>9</td>
<td>11</td>
</tr>
<tr>
<td>0.15</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>0.075</td>
<td>0.3</td>
<td>0.5</td>
</tr>
</tbody>
</table>
Materials

- A MS2 emulsion with a base grade of PG 64-28
- A PG 64-28 grade asphalt binder
- An initial optimum of 2 percent emulsion was selected.
<table>
<thead>
<tr>
<th>Mix</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAP+Emulsion at 60°C</td>
<td>Unheated RAP was mixed with Emulsion heated to 60°C; Two different mixes were produced – one with 2 % emulsion and the other with 3 % emulsion.</td>
</tr>
<tr>
<td>Heated RAP+Emulsion at 60°C</td>
<td>Two different mixes were produced – one with RAP and Emulsion heated to 60°C and the other with RAP heated to 110°C and the emulsion to 60°C.</td>
</tr>
<tr>
<td>Heated RAP+Asphalt Binder+1.5% Sasobit- 125°C</td>
<td>Both asphalt binder and RAP were heated to 125°C, and 1.5 % Sasobit was mixed with the asphalt before mixing it with the RAP; 2 % asphalt binder was used.</td>
</tr>
<tr>
<td>Heated RAP+Asphalt Binder+1% Sasobit- 125°C</td>
<td>Both asphalt binder and RAP were heated to 125°C, and 1% Sasobit was mixed with the asphalt before mixing it with the RAP; 2 % asphalt binder was used.</td>
</tr>
<tr>
<td>Heated RAP+Asphalt Binder-150 °C</td>
<td>Both RAP and Asphalt binder were heated to 150°C, and then mixed at 2 % asphalt content.</td>
</tr>
</tbody>
</table>
Mix RAP and emulsion/asphalt/sasobit mix in 15 kg buckets

Test one bucket at intervals of 15 minutes for workability for 2 hours

Take three 2,000 gram samples and compact to 50 gyrations – note bulk specific gravity

Lay the mix in the mold and spread evenly in the mold with a spreader

Note thickness after every 10 passes

Compact with a vibratory roller until thickness does not change significantly with roller passes (thickness does not decrease more than 1/4 inch (6 mm) after 10 passes)

• Test for in-place stiffness
• If possible take core samples of the material for testing – bulk specific gravity, resilient modulus and indirect tensile strength
Workability

- Torque tester built and evaluated on the basis of results reported in Reference NCAT Report 03-03.
- Torque needed to move a paddle through a mix inside a bucket at different times after mixing - higher the torque lower is the workability.
- Found to be sensitive to the NMAS and the temperature.
- Paddle was rotated through 12 kg batch -- one full circle using the torque wrench -- repeated three more times.
- Repeated different times after mixing, and the temperature of the mix was noted at each reading.
- The torque values were converted to a “workability” by multiplying the inverse of the average torque by 1,000.
Compactibility

- Slabs were compacted by partitioning a 2.7 m by 0.9 m mold, and using a vibratory roller.
- Each slab - 0.9 m long, 0.9 m wide and 0.125 m thick.
- Roller assembly -- 0.45 m diameter by 0.9 m steel drum with a 8.9 kN 50/60Hz electric vibrator mounted inside it.
- The sides of the mold were marked for reading thickness during compaction.
\[ \log(CBR) = 2.20 - 0.71 \times (\log(DCP))^{1.5} \]

\[ M = 10 \times CBR \]
2% Emulsion

![Graph showing temperature and workability for 2% emulsion over time.]

3% Emulsion

![Graph showing temperature and workability for 3% emulsion over time.]

Solid line → workability
RAP-60°C+3% Emulsion

RAP-110°C+3% Emulsion

Solid line → workability
Gyratory Compacted Samples

Mix

- RAP-150C + 2% AC-150oC
- RAP-125C+ 2% AC+1%Sasobit-125oC
- RAP-125C+ 2% AC+1.5%Sasobit-125oC
- RAP-110oC+3%Emulsion
- RAP-60C+3%Emulsion
- 3% emulsion
- 2 % emulsion

Coefficient of Variation , % of Bulk Specific Gravity
Samples Cored from Slabs

Mix

- RAP-150C + 2% AC-150oC
- RAP-125C+ 2% AC+1% Sasobit-125oC
- RAP-125C+ 2% AC+1.5% Sasobit-125oC
- RAP-110oC+3% Emulsion

Coefficient of Variation, % of Bulk Specific Gravity

Samples Cored from Slabs
**Resilient Modulus**

- 2% Emulsion
- 3% Emulsion
- RAP 110C
- Sasobit 1.5%
- Sasobit 1%
- HMA

**In-Place Seismic Modulus**

- RAP 110C
- Sasobit 1.5%
- Sasobit 1%
- HMA

Diff. colors ➔ statistically significant difference
Dry Tensile Strength

- RAP 110C: 300 kPa
- Sasobit 1%: 600 kPa
- HMA: 1200 kPa

Conditioned Tensile Strength

- RAP 110C: 400 kPa
- Sasobit 1%: 700 kPa
- HMA: 1200 kPa

Diff. colors → statistically significant difference
Sasobit 1.5 % versus 1 %

- Moduli of the samples from RAP+1.5% Sasobit are lower than the moduli of the samples from RAP+1%
- RAP+1.5% Sasobit cores showed cracks on the surface.
- Cracks were formed most likely during the compaction of the slab, due to fall in temperature and increase in stiffness of the mix.
- Most likely, the mix would have produced superior results if the compaction was completed above 115°C.
Conclusions

- Heating the RAP prior to mixing with emulsion improves workability, compactibility and stiffness of the mix.
- For emulsion mixes, RAP heated to 110°C produced mixes with significantly better properties than mixes with unheated RAP, at similar emulsion content.
- The heated RAP mix shows lower variability in bulk specific gravity and better stiffness and strength.
Conclusions

- Use of Sasobit with asphalt binder at a mixing temperature of 125°C produced mixes with workabilities and compactibilities that are lower but close to those of a mix with neat asphalt binder, mixed at 150°C.
- No significant difference was found between stiffness and retained strength values of asphalt binder mixes with and without Sasobit.
- The dispersion of the asphalt binder is suspected to improve with the use of Sasobit at lower temperatures.
Conclusions

• For a mixing temperature of 125°C, the use of 1% Sasobit, in terms of total asphalt, provided a mix with better properties, compared to a mix with 1.5% Sasobit. However, the mix with 1.5% Sasobit showed much better workability.

• There seems to be a significant advantage in using heated RAP and/or Sasobit in reducing temperature for using asphalt binder in recycling of HMA.
Recommendations

• A field project to evaluate emulsion and Sasobit mixes along with HMA should be initiated.

• The use of heated RAP (110°C) with emulsion, and 1 % and 1.5 % Sasobit with asphalt binder are recommended.
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Thank You!