NCHRP 9-43
Mix Design Practices for Warm Mix Asphalt

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Acknowledgements

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  – University of Wisconsin – Madison
  – Western Research Institute
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• Agencies and Contractors
Outline

• Brief Overview of NCHRP Project 9-43
• NCHRP Project 9-43 Conclusions
• NCHRP Project 9-43 Products
• Review of the Proposed Appendix to AASHTO R35
• What to Expect When Using the Appendix
• Additional Research
Objective

- To adapt laboratory mixture design and analysis procedures to WMA
  - Compatible with HMA procedures
  - Address wide range of warm mix processes
    - Current
    - Future
Approach

Preliminary Procedure
- Focus

Phase I Experiments
- Reheating
- Binder Grade
- RAP
- Short-Term Conditioning
- Workability

Revised Procedure

Phase II Experiments
- Expanded RAP Mixing
- Laboratory Mix Design
- Field Validation
- Limited Fatigue

Final Procedure
- Draft Appendix to AASHTO R35
Major Conclusion 1

• WMA can be designed with only minor changes to AASHTO R35
  - Specimen fabrication procedures
  - Coating and compactability in lieu of viscosity based mixing and compaction temperatures
  - WMA design is challenging for plant foaming process
Major Conclusion 2

• For mixtures using the same aggregates and binders and having binder absorption equal to or less than 1 percent
  – Volumetric properties of WMA and HMA are very similar
    • Supports current practice
  – Compactability, moisture sensitivity, and rutting resistance may be different when designed as WMA compared to HMA
    • Supports need for design procedure
Major Conclusion 3

- Fatigue properties of HMA and WMA are very similar
NCHRP 9-43 Products

• NCHRP Report 691
   – http://www.trb.org/Main/Blurbs/165013.aspx

• Recommended Draft Appendix to AASHTO R35, *Special Mixture Design Considerations and Methods for Warm Mix Asphalt (WMA)*

• Commentary to the Draft Appendix

• Training Materials for the Draft Appendix
   – NHI Web-Course ~ Oct/Nov 2011
1. Equipment for Designing WMA
2. WMA Process Selection
3. Binder Grade Selection
4. RAP in WMA
5. Process Specific Specimen Fabrication Procedures
6. Evaluations
   • Coating
   • Compactability
   • Moisture Sensitivity
   • Rutting Resistance
7. Adjusting the Mixture to Meet Specification Requirements.
Additional Equipment

Mechanical Mixer

Low Shear Mixer

Laboratory Foaming
WMA Process Selection

• WMA mix design requires the producer to select
  – WMA process
  – Planned production temperature
  – Planned compaction temperature

• Laboratory specimen fabrication

• Producer should consider
  – Past performance and technical support
  – Cost
  – Useful temperature range
  – Production rates
  – Modifications
Binder Grade Selection

- Use same grade as HMA
RAP

- RAP Does Mix at WMA Temperatures

![Graph showing the measured to Hirsch estimated fully blended dynamic modulus at 68°F, 1.0 Hz versus short-term conditioning time for different asphalt mixtures. The graph includes data points for HMA 280/255, HMA 248/230, WMA 248/230, WMA 230/212, and no RAP.]
RAP in WMA

- High temperature grade of RAP $\leq$ planned compaction temperature
WMA Design Categories

Additive Added to the Binder

Additive Added to the Mixture

Wet Aggregate Mixtures

Foamed Asphalt Mixtures
Specimen Fabrication

• Short-Term Conditioning
  – 2 hours at Planned Compaction Temperature

• Compactive Effort and Volumetric Criteria
  – Same as HMA
Coating

• Evaluate coating per AASHTO T195
  - Separate coarse aggregates
    • 9.5 mm sieve for NMAS 12.5 mm and larger
    • 4.75 mm sieve for NMAS 9.5 and smaller
    • Min 200 particles
    - \[ \text{% Coated Particles} = \left( \frac{\text{# of Fully Coated Particles}}{\text{Total # of Particles}} \right) \times 100\% \]
  • \( \geq 95 \) percent
Compactability

- Compact 2 specimens to $N_{\text{design}}$ at the planned compaction temperature
  - Compute gyrations to 92 % of Gmm
- Compact 2 specimens to $N_{\text{design}}$ at 30 °C below the planned compaction temperature
  - Compute gyrations to 92 % of Gmm

$$\text{Ratio} = \frac{(N_{92})_{T-30}}{(N_{92})_T} \leq 1.25$$
Moisture Sensitivity and Rutting Resistance

• **AASHTO T283**
  - Tensile strength ratio >= 0.80 with no visual stripping

• **Rutting resistance**
  - Flow number, **AASHTO T79**

<table>
<thead>
<tr>
<th>Traffic Level, Million ESALs</th>
<th>Minimum Flow Number</th>
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<tr>
<td>&lt;3</td>
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<tr>
<td>3 to &lt; 10</td>
<td>30</td>
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<tr>
<td>10 to &lt; 30</td>
<td>105</td>
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<tr>
<td>≥ 30</td>
<td>415</td>
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Adjusting the Mixture to Meet Specifications

- Coating
- Compactability
- Moisture Sensitivity
- Rutting Resistance
  - Change binder grade
  - Add RAP
  - Increase filler content
  - Decrease VMA
  - Increase $N_{\text{design}}$

Consult WMA Technology Supplier
## Comparison of HMA and WMA Properties

<table>
<thead>
<tr>
<th>No.</th>
<th>Mixture Identification</th>
<th>Process</th>
<th>HMA</th>
<th>WMA A</th>
<th>WMA B</th>
<th>WMA C</th>
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<tr>
<td>N\textsubscript{design}</td>
<td>Aggregate Absorption</td>
<td>RAP</td>
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<td>1</td>
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<td>320/310</td>
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<td>270/260</td>
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<tr>
<td>4</td>
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<tr>
<td>6</td>
<td>100</td>
<td>Low</td>
<td>No</td>
<td>320/310</td>
<td>270/260</td>
<td>225/215</td>
</tr>
</tbody>
</table>

Paired t-test WMA-HMA
Design Binder Content

Binder Absorption 0.5 to 1.0 %

Average Difference in Design Binder Content, wt. %

WMA Process A  WMA Process B  WMA Process C
Binder Absorption

WMA Process A  WMA Process B  WMA Process C

Average Difference in Binder Absorption, wt %

-0.35  -0.30  -0.25  -0.20  -0.15  -0.10  -0.05  0.00  0.05  0.10
Compactability

WMA Process A
WMA Process B
WMA Process C

Average Difference in Gyration Ratio, %

Without RAP
25 Percent RAP
Moisture Sensitivity

WMA Process A  WMA Process B  WMA Process C

Average Difference in Tensile Strength Ratio, %
On-Going WMA Research

• NCHRP 9-47A, *Properties and Performance of Warm Mix Asphalt Technologies*

• NCHRP 9-49, *Performance of WMA Technologies: Stage I -- Moisture Susceptibility*

• NCHRP 9-49A, *Performance of WMA Technologies: Stage II -- Long-Term Field Performance*
Questions

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