Warm Mix Asphalt
Mix Design
Superpave and Marshall
CUPGA 2012 WORKSHOP

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Westin Bayshore, Vancouver BC

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Outline

- WMA Design References
- WMA vs. HMA Mix Design
- WMA Mix Design Specific Considerations
- WMA Laboratory Mix Design Equipment
- Preparation of WMA Mixtures
- WMA Additive Specific Procedures
- WMA Mixture Evaluation
- Marshall WMA Mix Consideration
- Closing Summary
WMA Mix Design References

- NCHRP 691 - Mix Design Practices for Warm Mix Asphalt
  - Outlines Research and Provides Draft Procedure
    - Draft Appendix to AASHTO R 35: Special Mixture Design Considerations and Methods for WMA

- NCHRP 714 - Special Mixture Design Considerations and Methods for Warm Mix Asphalt
  - Summarizes work and finalizes draft procedure presented in NCHRP 691

WMA Mix Design References

- Ministry of Transportation Ontario
  - LS-318: Draft - PRACTICE FOR THE DESIGN OF SUPERPAVE WARM MIX ASPHALT (WMA)
    - Developed by MTO / OHMPA Task group for use on MTO project

  - LS-319: Draft - PRACTICE FOR THE DESIGN OF Marshall WARM MIX ASPHALT (WMA)
    - Developed by Ontario Good Roads Association Municipal Liason Committee
WMA vs. HMA Mix Design

- Options

- Existing HMA Mix is Converted with the use of a WMA Additive
  - Prepare test specimens according to Mix Design JMF and use additive as per suppliers recommendation.

- Complete WMA Mix Design
  - Use WMA Additive Modification for all Testing
    - Prepare specimens at a range of AC contents as typical for HMA Mix Design
    - Preferred method

WMA vs. HMA Mix Designs

Common Procedures:
- Compaction Level
- Nominal Aggregate Size
- Target Mix Volumetric Properties
- Aggregate Volumes
- Aggregate Proportioning
- Trial Mixture Proportions
- Mix Design Compilation
WMA Specific Considerations

- **Project Information**
  - Planned Production and Compaction Temperatures??
  - Available WMA Process and Additive

- **Select Asphalt Binder**
  - Same Grade as HMA for Virgin Binder Mixes
  - RAP Considerations:
    - RAP binders and new binders do mix at WMA process temperatures.

WMA Specific Considerations

**RAP in WMA Mix Design**

- Design WMA mixtures containing RAP in the same manner as HMA
- The RAP binder should have a high-temperature grade that is less than the compaction temperature for the WMA.
- Higher RAP % Can be used due to Lower Plant Mixing Temperatures
  - 10% Additional RAP Binder without impact to original grade of AC when using Blending Charts for high RAP %
WMA Specific Considerations

- **Binder Content**
  - Lower Aggregate Absorption = Lower AC %
  - 0.05% (NCHRP 691) - Possibly less

- **WMA Process Specific Specimen Preparation**
  - Four Generic Categories:
    - Additives blended into the binder,
    - Additives added to the mixture,
    - Wet aggregate mixtures, and
    - Foamed asphalt.

- **Evaluate Trial Mixture / Design**
  - Viscosity Based Mixing and Compaction Temps replaced
    - Coating - AASHTO T195
    - Compactability – Developed for WMA
  - Mix Performance Testing
    - Moisture Sensitivity - AASHTO T 283 / AASHTO T 312
    - Rutting Resistance - AASHTO TP 79 / AASHTO PP 60
WMA Laboratory Equipment

- **Typical HMA Lab Equipment plus:**
  - All WMA Processes
    - Mechanical planetary mixer
      - 20 qt. capacity or a 5 gal. bucket mixer.
  - Binder Additive WMA Processes:
    - Low shear mechanical stirrer to blend the additive in the binder.
  - Plant Foaming Processes:
    - Laboratory scale foamed asphalt plant

Preparation of WMA Mixtures - Superpave and Marshall

**Table 2. Specimen Requirements.**

<table>
<thead>
<tr>
<th>Type</th>
<th>Gyratory Specimen Size</th>
<th>Approximate Specimen Mass</th>
<th>Number Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Specific Gravity</td>
<td>NA</td>
<td>500 to 6000 g depending on maximum aggregate size</td>
<td>2 per trial blend plus K to determine design binder content plus 1 at design binder content for compactability evaluation</td>
</tr>
<tr>
<td>Volumetric Design</td>
<td>150 mm diameter by 115 mm high</td>
<td>4700 g</td>
<td>2 per trial blend plus K to determine design binder content</td>
</tr>
<tr>
<td>Coating</td>
<td>NA</td>
<td>500 to 6000 g depending on maximum aggregate size</td>
<td>1 at the design binder content</td>
</tr>
<tr>
<td>Compactability</td>
<td>150 mm diameter by 115 mm high</td>
<td>4700 g</td>
<td>4 at the design binder content</td>
</tr>
<tr>
<td>AASHTO T 283</td>
<td>150 mm diameter by 95 mm high</td>
<td>3900 g</td>
<td>6 at the design binder content</td>
</tr>
<tr>
<td>Flow Number</td>
<td>150 mm diameter by 175 mm high</td>
<td>7000 g</td>
<td>4 at the design binder content</td>
</tr>
</tbody>
</table>

- If Marshall Design
  - Adjust sample numbers and weights appropriately
  - Gyratory Compactor required for Compactability and Flow Number
Preparation of WMA Mixtures - General

- **Heating**
  - Dry Aggregate: Heat to approximately 15 °C higher than the Planned Production Temperature.
  - Heat the RAP with the aggregates
    - limit the heating time for the RAP to 2 hours
  - Heat the binder, mixing bowls and other tools to the planned production temperature.

- **After Binder Addition and Mixing**
  - Short term age samples for 2 hours at planned compaction temperature
    - Stir after 1st hour

Additive Specific Procedures -

- **WMA Mixtures With WMA Additives Added to the Binder**
  - Typically specified as a percent by weight of binder.
    - Refer to WMA Suppliers Instructions
    - With RAP, additive weight based on the total binder
    - Binder and additive can be premixed and stored

- **WMA Mixtures With WMA Additive Added to the Mixture**
  - Additive may be specified as a percent by weight of binder or as percent by weight of total mixture
    - Refer to WMA Suppliers Instructions
    - Additive added to binder in mixing bowl before mixing
Additive Specific Procedures -

**WMA Mixtures With A Wet Fraction of Aggregate**
- Follow WMA process supplier instructions
  - Additive dosage rates, mixing temperatures, percentage of wet aggregate and wet aggregate moisture content.
- Add required moisture content to the wet fraction of aggregate - Allow to stand for at least 2 hrs before mixing
- Combine Dry Aggregate, Binder and WMA Additive to in Mixing Bowl
- Mix for 30 seconds then add wet fraction of aggregate
- Mix additional 60 seconds
- After mixing - Temp. between 90 and 100 °C.

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Additive Specific Procedures -

**Preparation of Foamed Asphalt Mixture**
- Lab asphalt foaming equipment to use production moisture.
  - Plant foaming unit manufacturers specify different moisture %
- Batch Size - Within Calibrated Range of Equipment
  - Typical size of batch = 20Kg
  - Split larger batch into individual samples
    - two gyratory specimens and the two maximum specific gravity specimens at each asphalt %.
- Some Field Adjustment May be Necessary
WMA MIXTURE EVALUATIONS

- Trial Mixes and Design are Completed at Planned Compaction Temp / Manufacturers Recommendation
  - Coating
    - Evaluates if Additive Dosage Correct for Planned temperature
    - AASHTO T195
      - Separate Coarse Aggregate Particles From Mix
      - Evaluate Percentage of Completely Coated Particles
    - Minimum Percent Coated = 95%

WMA MIXTURE EVALUATIONS

- Compactability
  - Mix 4 Gyratory specimens and 1 MRD Sample
  - Compact 2 Gyratory Specimens at Planned Compaction Temp
  - Compact 2 Gyratory Specimens at 30 C Lower
  - Measure Height and Determine Bulk Density of All Specimens
  - Determine corrected specimen relative densities for each gyration

\[ \frac{G_{mN}}{G_{m0}} = \left( \frac{G_{mb} \times h}{G_{mb} \times h} \right) \]

\( G \) = relative density at \( N \) gyrations;
\( G_{mb} = \) bulk specific gravity of specimen compacted to \( N \) design gyrations;
\( h \) = height of the specimen after \( N \) design gyrations, from the Superpave gyratory compactor, mm; and
\( h_N = \) height of the specimen after \( N \) gyrations, from the Superpave gyratory compactor, mm.
WMA MIXTURE EVALUATIONS

**Compactability**
- Calculate average number of gyrations to reach 92 percent relative density at:
  - Planned field compaction temperature.
  - 30°C below the planned field compaction temperature.
- Determine the gyration ratio

\[
\text{Ratio} = \frac{(N_{92})_{T-30}}{(N_{92})_T}
\]

- Gyration Ratio should be Less Than or Equal to 1.25

**Moisture Sensitivity**
- Compact test specimens to 7.0 ± 0.5 percent air voids in accordance with AASHTO T 312.
- Group, condition and test the specimens in accordance with AASHTO T 283.
- The tensile strength ratio should be greater than 0.80
  - there should not be any visual evidence of stripping
WMA MIXTURE EVALUATIONS

- Rutting
  - Determine flow number with AMPT- AASHTO TP 79.
  - 4 flow number samples - 7.0 ± 1.0 percent air voids
    - Make 150 mm diam by at least 175 mm high gyratory samples
    - saw and core 100 mm diam by 150 mm high test sample from larger gyratory specimens
  - Condition to Design temperature of AC Grade
    - 50 % reliability determined using LTPP Bind Version 3.1.
    - Surface Courses - Temp @ 20 mm deep
    - Binder / Intermediate Courses - Temp @Top of Pavement

- Rutting Resistance
  - Use AMPT to determine flow number test for each specimen and Calculate Average
    - Unconfined repeated deviatoric stress of 600 kPa
    - Contact deviatoric stress of 30 kPa.

- Minimum Flow Number Requirements
  
<table>
<thead>
<tr>
<th>Traffic Level, Million ESALs</th>
<th>Minimum Flow Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;3</td>
<td>NA</td>
</tr>
<tr>
<td>3 to &lt; 10</td>
<td>30</td>
</tr>
<tr>
<td>10 to &lt; 30</td>
<td>105</td>
</tr>
<tr>
<td>≥ 30</td>
<td>415</td>
</tr>
</tbody>
</table>
Marshall WMA Mix Consideration

- Coating and Compactability Replace Temp Visc based Mix and Comp Temps
  - WMA Additive Dosage and WMA Compaction Temp Required from Manufacturer
    - Coating can be performed
    - Compactability can not be performed with Marshall
- Confirming Effectiveness of Dosage Used and Compaction Temp required in Ontario Test Method LS -319.
  - No specific method identified
  - Possible Method: Compacting lab or field samples at different temps and compare air voids obtained at manufacturers recommended temp to air voids obtained at full HMA temp

Closing Summary

- WMA mix design procedure same as HMA with some additional tests
- Follow WMA Additive suppliers instructions
- All WMA Lab work done at planned production and compaction temps
  - Coating and Compactability Replace Temp Visc based Mix and Comp Temps
- RAP in WMA is treated the same as in HMA
  - High Temp grade of RAP should be considered
  - More RAP can be used but not significant with low RAP mixes
- AC content in WMA can be slightly lower due to reduced aggregate absorption.
Thank You

Questions ??