Objectives

- Validate or refine AASHTO mix design criteria.
- Provide guidelines for applications.
- Provide guidelines for production and construction.

AASHTO Specifications for 4.75 mm Mixes

Background
- Survey of Usage
- Current Criteria
- Supporting Research
- Issues to Evaluate

Survey of states
21 State DOT responded

Typical HMA composition for Low-Volume Roads

- Marshall mix design
- Fine-graded blend
- Higher asphalt content
- Natural Sand contents 10 to 30%
- RAP contents 15 to 30%
- Unmodified grade of asphalt

Non DOT mixtures

- City and County Overlays, New Commercial & Residential Developments.
- We have a good level of comfort with these mixtures.
Superpave Criteria for Mixtures Used on Roads with < 300,000 ESALs/20 years

- \%Gmm @ N₆ = 91.5
- \%Gmm @ N₅₀ = 96.0
- \%Gmm @ N₇₅ = 98.0
- VFA: 70-80%, DP 0.6 to 1.2
- Min. 55% one crushed face, 40% SE
- No requirement on FAA or F&E
- Are these criteria appropriate?

Evaluation of the Superpave Gyratory Compactor for Low Volume Roads
Cross & Lee, Report No. KS-00-2, June 2000

- Kansas study of field produced mix and roadway cores
- Lowest Superpave Traffic Category SGC compactive effort is greater than 50 blow Marshall
- The major problem meeting the Superpave mix requirements is meeting the minimum VMA

Example Marshall Mixes Used on Low Volume Roads

<table>
<thead>
<tr>
<th>Number of Equivalent Gyrations</th>
<th>Missouri 1/2&quot; surface</th>
<th>Georgia Type G</th>
<th>Florida S-III</th>
<th>Kansas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>43</td>
<td>38</td>
<td>27</td>
<td>37 to 49</td>
</tr>
</tbody>
</table>

Superpave Gyration Compactive Effort

<table>
<thead>
<tr>
<th>Design ESALs (millions)</th>
<th>Nᵢᵢ</th>
<th>Nᵢᵢᵢ</th>
<th>N_max</th>
<th>Typical Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;0.3</td>
<td>6</td>
<td>50</td>
<td>75</td>
<td>Local roads with very light traffic volumes</td>
</tr>
<tr>
<td>0.3 to &lt;3</td>
<td>7</td>
<td>75</td>
<td>115</td>
<td>Collector roads, medium trafficked city streets &amp; county roads</td>
</tr>
<tr>
<td>3 to 30</td>
<td>8</td>
<td>100</td>
<td>160</td>
<td>Many two-lane, multilane, &amp; partially or completely controlled access roadways. Medium to heavy traffic city streets, state routes, US highways, and some rural Interstates</td>
</tr>
<tr>
<td>&gt;30</td>
<td>9</td>
<td>125</td>
<td>205</td>
<td>Majority of Interstate system...</td>
</tr>
</tbody>
</table>

AASHTO Specification (M 323) Gradation

<table>
<thead>
<tr>
<th>Sieve</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.5</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>9.5</td>
<td>95</td>
<td>100</td>
</tr>
<tr>
<td>4.75</td>
<td>90</td>
<td>100</td>
</tr>
<tr>
<td>2.36</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.19</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td>0.75</td>
<td>6</td>
<td>12</td>
</tr>
</tbody>
</table>

AASHTO Specification (M 323) Fine Aggregate Angularity and Sand Equivalent

<table>
<thead>
<tr>
<th>Design ESALs (millions)</th>
<th>Ndes</th>
<th>Depth from Surface</th>
<th>Sand Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;0.3</td>
<td>50</td>
<td>≤ 100 mm</td>
<td>40</td>
</tr>
<tr>
<td>0.3 to &lt;3</td>
<td>75</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>3 to &lt;10</td>
<td>75</td>
<td>45</td>
<td>40</td>
</tr>
<tr>
<td>10 to 30</td>
<td>100</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>&gt;30</td>
<td>100</td>
<td>45</td>
<td>50</td>
</tr>
</tbody>
</table>
AASHTO Specifications (M323)

4.75 mm Volumetric Requirements

• Air Voids: 4.0%
• VMA: 16.0% min.
• VFA:
  <0.3 M ESALs: 70-80%
  0.3 to 3.0 M ESALs: 68-78%
  >3.0 M ESALs: 75-78%
• Dust Proportion: 0.9 – 2.0
• %Gmm @ N_in: same as other NMAS

4.75 mm Mix Specifications

Supporting Research at NCAT

• 2 aggregate types: granite & limestone
  – Fine Agg. Angularity
    • granite: 49
    • limestone: 46
• 3 blends: coarse, med., fine
• 3 dust contents: 6, 9, 12%
• 1 binder: PG 67-22
• 2 design air void contents: 4 & 6%
• 1 compactive effort: 75 gyrations

4.75 mm Mix Specifications

Supporting Research - Findings

• All study mixes had % Gmm @ N_in ≤ 88.9%
  (passed strictest criteria)
• Only 1 of 18 mixes designed at 6% air voids had
  VFA > 68% (i.e. only one met VFA)
• Designing to 6% air voids typically reduced
  asphalt contents by about 0.7%

4.75 mm Superpave Mix

Refinement Study

Current Research Plan

Possible Criteria for Evaluation

• Gradation Control Points
• Design Air Void Content
• Minimum VMA
• VFA Range
• Dust Proportion

Volumetric Criteria

Rationale for Limits

• Target Air Voids of 4.0% is the same as specified for all
  other Superpave mixtures.
• Minimum VMA of 16.0% for 4.75 mm mixes follows the
  progression of 1.0% higher VMA for every NMAS
  decrease.
• Minimum VMA is considered a criteria to ensure good
  durability. For a fixed air void content, minimum VMA is
  the same as requiring a minimum effective asphalt
  volume percentage.
• The minimum VMA of 16.0% is somewhat supported by
  correlation with dust/asphalt ratio (DP). A maximum DP
  of 2.2 corresponded to a minimum VMA of 16.0%.
Volumetric Criteria

Rationale for Limits

- For 4.0% air voids and 16% minimum VMA…
  - the minimum VFA calculates to be 75%. So any VFA limit below 75% is pointless.
  - Maximum VFA of 78% is the same as a maximum VMA of 18.1%;
  - maximum VFA of 80% is the same as a maximum VMA of 20%.

Generalized Optimum Asphalt Content

for a Given Aggregate & Gradation

Phase 1

- Start
- Design Mixes
- 13 Aggregate Blends
- 4.75% Air Voids
- 50 & 75 Gyrations
- Fractional Experimental Design
- Obtain Field Produced Baseline Mixes
- Performance Testing
- Aging Test using PS
- Permeability Test using ASTM PS 129
- Rutting Test using MVT
- Stripping Test using AASHTO T283
- Ageing Test using FE Ratio
- Analysis
- Refine Criteria for 4.75 mm Mixtures
- Draft Phase 1 Report

Maryland 4.75 mm Superpave

75 gyrations, 3.5% voids, PG64-22

<table>
<thead>
<tr>
<th>Material</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>10's</td>
<td>45</td>
</tr>
<tr>
<td>89's</td>
<td>40</td>
</tr>
<tr>
<td>Sand</td>
<td>15</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sieve</th>
<th>Min</th>
<th>Max</th>
<th>JMF</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.75</td>
<td>90</td>
<td>100</td>
<td>96</td>
</tr>
<tr>
<td>2.36</td>
<td>-</td>
<td>-</td>
<td>61</td>
</tr>
<tr>
<td>1.18</td>
<td>30</td>
<td>60</td>
<td>43</td>
</tr>
<tr>
<td>0.60</td>
<td>-</td>
<td>-</td>
<td>31</td>
</tr>
<tr>
<td>0.30</td>
<td>-</td>
<td>-</td>
<td>19</td>
</tr>
<tr>
<td>0.075</td>
<td>6</td>
<td>12</td>
<td>8.1</td>
</tr>
<tr>
<td>PS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VMA</td>
<td>16.0</td>
<td></td>
<td>16.3</td>
</tr>
<tr>
<td>Vbe</td>
<td></td>
<td></td>
<td>13.2</td>
</tr>
<tr>
<td>DP</td>
<td>0.9</td>
<td>2.0</td>
<td>1.6</td>
</tr>
</tbody>
</table>
Georgia 4.75 mm Superpave 50 gyrations, 6.6% voids, PG67-22

<table>
<thead>
<tr>
<th>Material</th>
<th>Percent</th>
<th>Sieve</th>
<th>Min</th>
<th>Max</th>
<th>QC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Granite 810’s</td>
<td>66</td>
<td>4.75</td>
<td>90</td>
<td>100</td>
<td>70</td>
</tr>
<tr>
<td>RAP</td>
<td>25</td>
<td>2.36</td>
<td>58</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Granite W10’s</td>
<td>8</td>
<td>1.18</td>
<td>60</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>Hydrated Lime</td>
<td>0.9</td>
<td>0.60</td>
<td>45</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Mississippi 4.75 mm Superpave 50 gyrations, 4.0% voids, PG76-22

<table>
<thead>
<tr>
<th>Material</th>
<th>Percent</th>
<th>Sieve</th>
<th>Min</th>
<th>Max</th>
<th>QC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lime</td>
<td>69</td>
<td>4.75</td>
<td>90</td>
<td>100</td>
<td>98</td>
</tr>
<tr>
<td>Crushed Gravel</td>
<td>19</td>
<td>2.36</td>
<td>70</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural Sand</td>
<td>11</td>
<td>1.18</td>
<td>50</td>
<td>60</td>
<td>50</td>
</tr>
<tr>
<td>Hydrated Lime</td>
<td>1</td>
<td>0.60</td>
<td>30</td>
<td>45</td>
<td>35</td>
</tr>
</tbody>
</table>

Performance Testing

Mix Verification Tester
- Smaller version of the Asphalt Pavement Analyzer
- Ndes samples
- 100 lbs.
- 100 psi
- 64°C
- 8000 cycles

Permeability Testing
- ASTM PS 129
- Lab specimens compacted in SGC to 1 inch height, 9±0.5% air voids.

Moisture Susceptibility Testing
- AASHTO T 283
  - 9±0.5% air voids.
- No antistrip additive used

Fracture Energy Ratio
- Indirect Tensile Strength
  - 20 C
  - Measure horizontal and vertical strain
  - Calculate fracture energy as area beneath the stress-strain plot