HMA TESTING EQUIPMENT AND METHODS
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CEW – February 8, 2022
Acceptance Testing Requirements

OUTLINE
• PREPARING FOR TESTING
• SAMPLING
• DETERMINING COMPOSITION OF MIXTURE
• VOLUMETRIC TESTING
• TEST RESULTS AND RELATIONSHIPS
Acceptance Testing Requirements

Pre-Production Meeting is KEY
• Sampling Method
• Asphalt Content Procedure
• Method for Measuring In-Place Density
• Contractor Lab Use?
• Dispute Resolution Lab
• Special Provision for HMA Acceptance

*QC Lab and QA Lab Should be Present
Acceptance Testing Requirements

MIX DESIGN for Targets

- Aggregate Gradation
- Aggregate Source
- Asphalt Content
- Volumetrics
- In-place Density
HMA Sampling

STARTS OR ENDS WITH SAMPLING
• A number of sampling methods.
• Splitting sample to proper size.
• A sample must be representative of material being produced!
• Sample Certified

Acurate  Repeatable

• Too Coarse – Result in Lower AC content
• Too Fine – Result in Higher AC Content
• Also Affect TMD
The **Asphalt Content** is probably the most important component in the HMA.

- **Solvent Extraction Method.** A sample of asphalt mixture is placed in a solvent and the asphalt is removed from the aggregate. This allows the amount of asphalt to be determined. **Hazardous Solvents.**

- **Ignition Extraction Method.** This test determines the asphalt content by burning out the asphalt allowing the amount to be determined. **Need Correction Factors!**

* Back calculation not allowed for LAP projects.*
LEVEL 1: Composition of the Mixture

Solvent Extraction Method.

Vacuum Extraction
LEVEL 1: Composition of the Mixture

Ignition Extraction Method.

- Correction Factors!
- Ignition Temperatures!
- 1,000 Deg F
LEVEL 1: Composition of the Mixture

Determined from the aggregate blend once the binder has been removed from either the Solvent Wash or Ignition Oven

- Gradation
- Crushed content
LEVEL 1: Composition of the Mixture

**SPECIAL PROVISION: ACCEPTANCE OF HMA MIXTURES ON LOCAL AGENCY PROJECTS**

Table 1: Uniformity Tolerance Limits for HMA Mixtures

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
<th>Top and Leveling Course</th>
<th>Base Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>% Binder Content</td>
<td>-0.30 to +0.40</td>
<td>-0.30 to +0.40</td>
</tr>
<tr>
<td>2</td>
<td># 8 and Larger Sieves</td>
<td>±5.0</td>
<td>±7.0</td>
</tr>
<tr>
<td></td>
<td>% Passing</td>
<td></td>
<td>±9.0</td>
</tr>
<tr>
<td></td>
<td># 30 Sieve</td>
<td>±6.0</td>
<td>±9.0</td>
</tr>
<tr>
<td></td>
<td># 200 Sieve</td>
<td>±2.0</td>
<td>±3.0</td>
</tr>
<tr>
<td>3</td>
<td>Crushed Particle Content (b)</td>
<td>Below 10%</td>
<td>Below 10%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Below 15%</td>
<td>Below 15%</td>
</tr>
<tr>
<td></td>
<td>(b)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **a.** This range allows for normal mixture and testing variations. The mixture must be proportioned to test as closely as possible to the Job-Mix-Formula (JMF).
- **b.** Deviation from JMF.

Pay Adjustment Parameters: **Binder, Gradation, Crushed Content**

**Two consecutive tests** (same parameter) to trigger a pay adjustment

*Requires at least **Bit Level One Certification**
**LEVEL 1: Composition of the Mixture**

**SPECIAL PROVISION: ACCEPTANCE OF HMA MIXTURES ON LOCAL AGENCY PROJECTS**

**Table 4: Calculating Total Price Adjustment**

<table>
<thead>
<tr>
<th>Number of Parameters Out-of-Specification</th>
<th>Range(s) Outside of Tolerance Limits of Table 1 per Parameter</th>
<th>Total Price Adjustment</th>
</tr>
</thead>
<tbody>
<tr>
<td>One</td>
<td>Range 1</td>
<td>10%</td>
</tr>
<tr>
<td></td>
<td>Range 2</td>
<td>25%</td>
</tr>
<tr>
<td>Two</td>
<td>Range 1 &amp; Range 1</td>
<td>20%</td>
</tr>
<tr>
<td></td>
<td>Range 1 &amp; Range 2</td>
<td>35%</td>
</tr>
<tr>
<td></td>
<td>Range 2 &amp; Range 2</td>
<td>50%</td>
</tr>
<tr>
<td>Three</td>
<td>Range 1, Range 1 &amp; Range 1</td>
<td>20%</td>
</tr>
<tr>
<td></td>
<td>Range 1, Range 1 &amp; Range 2</td>
<td>35%</td>
</tr>
<tr>
<td></td>
<td>Range 1, Range 2 &amp; Range 2</td>
<td>50%</td>
</tr>
<tr>
<td></td>
<td>Range 2, Range 2 &amp; Range 2</td>
<td>50%</td>
</tr>
</tbody>
</table>

Pay Adjustment Parameters: **Binder and Gradation**

**Two consecutive tests** (same parameter) to trigger a pay adjustment
LEVEL 2: HMA Volumetrics

Volumetrics are the relationships between mass and volume.

Specific gravity is the ratio of the density of a material to the density of a reference substance.

Requires Bit Level Two Certified or Bit QA/QC Technician Certified to perform testing.
Most mix designs are now conducted in accordance with the Superpave procedures and criteria. However, Marshall mix are still common on the local agency and commercial projects. The primary component of these tests is to compact the HMA using some specified compaction effort and determining the volumetric properties.
LEVEL 2: HMA Volumetrics

Common Marshall Mixes

- 2C  Base
- 3C  Leveling
- 4C  Wearing
- 13A  Base, Leveling, Wearing
- 36A  Wearing

- **Impact method** of compaction
- **Load perpendicular** to compaction axis
- **Does not consider** shear strength
- **Standard compaction** between mixtures
LEVEL 2: HMA Volumetrics

Superpave Mixes – 2003
LVSP, #E03, #E1, #E3, #E10, #E30, #E50

Superpave Mixes – 2020 (Mix Reduction)
EL, #EML, #EMH, #EH

- Compaction Method simulates field
- Estimates density at critical service points (ini, des, max)
- # Gyrations (compaction) adjusted based on traffic

Gyratory Compactor
LEVEL 2: HMA Volumetrics

<table>
<thead>
<tr>
<th>ESAL</th>
<th>2003 Mix</th>
<th>2020 Mix</th>
<th>2003 Ni, Nd, Nm</th>
<th>2020 Ni, Nd, Nm</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0-0.3</td>
<td>0.0-0.3</td>
<td>LVSP</td>
<td>EL</td>
<td>6, 45, 70</td>
</tr>
<tr>
<td>0.0-0.3</td>
<td></td>
<td>E03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.3-1.0</td>
<td>0.3-3.0</td>
<td>E1</td>
<td>EML</td>
<td>7, 76, 117</td>
</tr>
<tr>
<td>1.0-3.0</td>
<td></td>
<td>E3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.0-10</td>
<td>3.0-30</td>
<td>E10</td>
<td>EMH</td>
<td>8, 96, 152</td>
</tr>
<tr>
<td>10-30</td>
<td></td>
<td>E30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30-100</td>
<td>30-100</td>
<td>E50</td>
<td>EH</td>
<td>9, 126, 204</td>
</tr>
</tbody>
</table>

4E1  4EMH
Compacted to N - Design
KEY TERMS

• Bulk Specific Gravity ($G_{mb}$) of compacted HMA
• Maximum Specific Gravity ($G_{mm}$)
• Air Voids ($V_a$)
• Voids in mineral aggregate ($VMA$)
• Voids filled with asphalt ($VFA$)

*Covert Specific Gravity to Density: SG x 62.4

(Specific weight of water lb/ft³)
HMA Volumetrics – Air Voids

- Measure of air, Percentage of total volume
- Typically, 3 to 4 percent laboratory compacted
- There are two properties that are used to determine the air voids in the mixture.

Calculated Using:
- **Bulk SG of the Compacted Sample**
- **Theoretical Maximum SG**

\[
\text{Air Voids} = 100 \times \left[ \frac{Gmm - Gmb}{Gmm} \right]
\]
The first property that is needed to determine air voids in a mixture is the bulk SG of the compacted mixture, which is determined by weighing the sample in air and then weighing while submerged in water and calculating the bulk density.

**Testing (G_{mb})**

- Compact Sample (Gyratory or Marshall)
- Mass of dry sample
- Mass under water
- Mass saturated surface dry
HMA Volumetrics – Bulk SG of Mixture

- Compact Sample (Gyratory or Marshall)
- **Mass of dry sample**
  - Mass under water
  - Mass saturated surface dry

4,857.6 g
HMA Volumetrics – Bulk SG of Mixture

- Compact Sample (Gyratory or Marshall)
- Mass of dry sample
- **Mass under water**
  - Mass saturated surface dry

2,854.8 g
HMA Volumetrics – Bulk SG of Mixture

- Compact Sample (Gyratory or Marshall)
- Mass of dry sample
- Mass under water

**Mass saturated surface dry**

4,858.3 g
HMA Volumetrics – Bulk SG of Mixture

\[ G_{mb} = \frac{A}{(B-C)} \]

\[ 2.425 = \frac{4,857.6}{(4,858.3-2,854.8)} \]

Where:
A = mass of dry sample
B = mass of SSD sample
C = mass of sample under water

\[ 2.425 \times 62.4 = 151.32 \text{ lb/ft}^3 \]
The second property that is needed to determine the air voids in a mixture is the theoretical maximum SG, which is the SG at which there would be no air voids.

**Testing (G<sub>mm</sub>)**

- Mass in air
- Mass under water
HMA Volumetrics – Maximum SG of Mixture

- Mass of dry sample
  - Mass under water

2,178.2 g

Loose Dry Mixture at Room Temperature
HMA Volumetrics – Maximum SG of Mixture

- Mass in air
- **Mass under water**

- Metal Bowl
- Shaker Table
- Vacuum Pump

1,305.7 g
Theoretical Maximum Density

\[ G_{mm} = \frac{A}{(A-C)} \]

\[ 2.497 = \frac{2,178.2}{(2,178.2-1,305.7)} \]

Where:

A = mass of dry sample
C = mass of sample under water

\[ 2.497 \times 62.4 = 155.8 \text{ lb/ft}^3 \]
Now that we have calculated:
- **Bulk SG of the Compacted Sample** ($G_{mb}$)
- **Theoretical Maximum SG** ($G_{mm}$)

\[
\text{Air Voids} = 100 \times \left[ \frac{G_{mm} - G_{mb}}{G_{mm}} \right]
\]

\[
2.88 = 100 \times \left[ \frac{2.497 - 2.425}{2.497} \right]
\]

Deviation 0.12, Target 3%
HMA Volumetrics - VMA

- VMA is a measure of the **voids in between the mineral aggregate particles in a compacted mixture**.

- Determined by? $G_{mb}$, %AC, $G_{sb}$

- When the VMA is too low, enough asphalt can not be added to produce a durable mixture. So setting a minimum VMA is an approach that is used to **ensure that adequate asphalt is added** to the mixture.

\[
VMA = 100 - \frac{G_{mb} \times \% \text{ Aggregate}}{G_{sb}}
\]

\[
14.69 = 100 - \frac{2.425 \times (100 - 5.75)}{2.679}
\]

VMA is an indication of film thickness on the surface of the aggregate.
Another mixture property that is important is the **amount of the VMA that is filled with asphalt.**

The voids filled should be high enough so that the mixture is not permeable to air and water and not so high that bleeding and rutting occur under traffic.

\[
VFA = 100 \times \frac{VMA - \% \text{ Air Voids}}{VMA}
\]

\[
80.39 = 100 \times \frac{14.69 - 2.88}{14.69}
\]

VFA is the percent of VMA that is filled with asphalt binder
• SINGLE TEST ACCEPTANCE (STA)
• STA SAMPLES LESS THAN 1,000 TONS
• VI UP TO 500 TONS PER MIXTURE TYPE PER PROJECT
• Pay Adjustment Parameters: Density, Air Voids, Binder, & VMA
SPECIAL PROVISION: VOLUMETRIC SINGLE TEST ACCEPTANCE OF HMA MIXTURES ON LOCAL AGENCY PROJECTS

Table 1: HMA Quality Index Parameters Specification Limits

<table>
<thead>
<tr>
<th>Quality Index Parameter</th>
<th>Specification Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Voids, %</td>
<td>Target Air Voids ± 0.50</td>
</tr>
<tr>
<td>Vma</td>
<td>Target Vma ± 0.60</td>
</tr>
<tr>
<td></td>
<td>Vma Targets</td>
</tr>
<tr>
<td>13A and LVSP</td>
<td>15.00</td>
</tr>
<tr>
<td>2C and 2E</td>
<td>2C - 12.00, 2E - 13.00</td>
</tr>
<tr>
<td>3C and 3E</td>
<td>14.00</td>
</tr>
<tr>
<td>4C and 4E</td>
<td>15.00</td>
</tr>
<tr>
<td>36A and 5E</td>
<td>16.00</td>
</tr>
<tr>
<td>Binder Content</td>
<td>Target ± 0.30</td>
</tr>
</tbody>
</table>

\[ OSPF = (30 \times PF_D) + (40 \times PF_{AV}) + (20 \times PF_{BINDER}) + (10 \times PF_{VMA}) \]

STA sample Payment Adjustment = \((100-OSPF)/100 \times (\text{Contract Unit Price})\times (\text{STA sample Quantity})\).

**Single Test** to trigger a pay adjustment
HMA Volumetrics - LAP PILOT

SPECIAL PROVISION: VOLUMETRIC SINGLE TEST ACCEPTANCE OF HMA MIXTURES ON LOCAL AGENCY PROJECTS

<table>
<thead>
<tr>
<th>Deviation from JMF (± percent)</th>
<th>PF&lt;sub&gt;AV&lt;/sub&gt;</th>
<th>Deviation from JMF (± percent)</th>
<th>PF&lt;sub&gt;VMA&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 0.50</td>
<td>1.00</td>
<td>≤ 0.60</td>
<td>1.00</td>
</tr>
<tr>
<td>0.51 – 0.60</td>
<td>0.98</td>
<td>0.61 – 1.00</td>
<td>0.90</td>
</tr>
<tr>
<td>0.61 – 0.70</td>
<td>0.96</td>
<td>1.01 – 1.50</td>
<td>0.70</td>
</tr>
<tr>
<td>0.71 – 0.80</td>
<td>0.94</td>
<td>1.51 – 2.00</td>
<td>0.30</td>
</tr>
<tr>
<td>0.81 – 0.90</td>
<td>0.92</td>
<td>&gt; 2.00</td>
<td>RQL</td>
</tr>
<tr>
<td>0.91 – 1.00</td>
<td>0.90</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.01 – 1.20</td>
<td>0.84</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.21 – 1.40</td>
<td>0.78</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.41 – 1.60</td>
<td>0.72</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.61 – 1.80</td>
<td>0.66</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.81 – 2.00</td>
<td>0.60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 2.00</td>
<td>RQL</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Rejectable Quality Limit

Overall STA Sample Pay Factor

\[
\text{OSPF} = (30 \times \text{PF}_D) + (40 \times \text{PF}_AV) + (20 \times \text{PF}_{\text{BINDER}}) + (10 \times \text{PF}_{\text{VMA}})
\]

STA sample Payment Adjustment = \((100 - \text{OSPF})/100 \times (\text{Contract Unit Price}) \times (\text{STA sample Quantity})\).
In-Place Density

Density Testing

• Destructive Testing: Cut cores from the in-place mixture and measure the bulk density by weighing in air and water. This is the most accurate test.

• Non-Destructive Testing: Density Gauge
RICE AND BULK SG OF AGGREGATES

- **Theoretical Maximum Specific Gravity** (rice value) is the key measurement during both laboratory mix design and quality control procedures.

- **Change in Rice value** may indicate a change in the Bulk Specific Gravity of the Aggregate. **Material Substitution!**

- $G_{sb}$ can have a big affect on volumetric property calculations which are typically taken from the mix design. Determining of $G_{sb}$ is somewhat cumbersome.

- However, **Effective SG of combined aggregate** can be calculated from QC routine test results including mixture $G_{mm}$ and asphalt content. Monitored during productions.
LOW ASPHALT CONTENT

• **Higher Air Voids**
• **Higher TMD**
• **Permeability Increases** - causing susceptible to moisture damage and stripping
• **Reduces film thickness** on the aggregate – accelerated oxidation - early aging and loss of roadway life.
Relationships

HIGH ASPHALT CONTENT

• **Lower Air Voids.**

• **Lower TMD.**

• **VMA** will generally *decrease slightly* to a minimum value *then increase* with increasing asphalt contents becoming unstable.

• **Increases VFA** and takes the space for air voids.
Relationships – Gradation and Voids

- **Dense** graded **BUT not too dense**! Need VMA
- Higher fines = lower % air voids compacted
- Aggregate texture & shape affect void content.
- Higher VMA for smaller aggregate mixtures (more void space)
- Smaller crushed aggregate can increase VMA
Relationships

- Percent compaction when *compared to TMD* is = to compacted air voids
- This is different to specification that *compare to* Marshall.
- For local agency project looking for field compaction from *92% to 98% TMD* compaction (2% to 8% air voids)
Relationships – TMD and Density

OBTAINING DENSITY MAY BE MOST IMPORTANT TO LONG TERM PERFORMANCE!

Accurate TMD value is Critical for mix that is being placed!

- EX. 143.0 (gauge reading)
  
  \[
  \frac{143.0}{155.4} \text{ (JMF)} = 92.0 \\
  \frac{143.0}{155.8} \text{ (New Rice)} = 91.8
  \]

Low AC, Higher TMD
QUESTIONS