Asphalt Mix Design
Greg Harder, P.E.
Asphalt Institute Regional Engineer
Tully, NY

HMA Mix Design
Strength/Stability
Rut Resistance
Raveling
Durability
Crack Resistance
Shoving
Flushing

HMA Mix Characteristics
Let’s start with the basics – A layer of HMA pavement has 3 components:

<table>
<thead>
<tr>
<th>Component</th>
<th>Typical % By Mass</th>
<th>Typical % By Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate</td>
<td>94 - 96</td>
<td>83 - 84</td>
</tr>
<tr>
<td>Asphalt Binder</td>
<td>4 - 6</td>
<td>11 - 12</td>
</tr>
<tr>
<td>Air</td>
<td>0</td>
<td>4 - 7</td>
</tr>
</tbody>
</table>

Volumetrics
We evaluate the quality of the HMA by setting parameters on these three components, which have historically provided a good indication of a mixture’s probable performance.

Basic Design Procedure
No matter whether it’s Superpave, Marshall, Hveem, Texas Gyratory, or something else, the mix design process has some common procedures and goals.

Mix Design Flowchart
Choose an aggregate blend
Proceed with all materials
Conduct in-depth volumetric mix design
Choose optimum % asphalt binder
Test for stripping or moisture damage or performance testing
Basic Design Procedure

- Choose binder type and test binder
  - Usually specified in contract

Binder Specific Gravity

Basic Design Procedure

- Choose aggregate types, sources, and test
  - Sometimes specify polish-resistant aggregates in surface
  - Locate aggregate sources that can be combined to meet specifications
  - Determine if RAP and/or RAS can be used

Basic Design Procedure

- Determine trial combination(s) and batch dry aggregates
  - Each aggregate or batch is sieved and carefully combined

Basic Design Procedure

- Heat aggregates and binder, then mix
  - Until all aggregate is fully coated

Mixing / Compaction Temperatures

- Oven-age the mixture to account for absorption, binder stiffening

Think about how this relates to field production and placement!
Basic Design Procedure

• Determine the theoretical maximum specific gravity, $G_{mm}$

Volumetrics

Various volumetric properties are then calculated, such as:

• Percent binder
• Percent air voids
• Percent effective binder
• Voids in the Mineral Aggregate (VMA)
• Voids Filled with Asphalt (VFA)
• Dust Proportion (Ratio of % Passing No. 200 sieve to % effective binder)

Mechanical Tests - Moisture Sensitivity

AASHTO T 283

• Prepare set of 6 specimens
  • 6.5 to 7.5% voids
    – Represents anticipated in-service voids
  • Use 3 specimens as controls
  • Remaining 3 specimens are vacuum-saturated 70 to 80%
  • Min. 16 hour freezing at 0°F
  • 24 Hours in 140°F water bath
  • Bring all specimens to test temperature (77°F) and determine indirect tensile strength

Mechanical Tests - Rut Testing

• Determine the indirect tensile strengths of both sets of 3 specimens
• Calculate the Tensile Strength Ratio (TSR)

\[
TSR = \frac{\text{Avg. conditioned tensile strength}}{\text{Avg. control tensile strength}}
\]

Minimum of 80% needed
Let’s take a closer look at:

- **Binder Content**
- **Lab-Molded Density / Air Voids**
- **Voids in the Mineral Aggregate (VMA)**

**Binder Content**

The goal of establishing the correct binder content is to:

- Provide a sufficient film coating around the aggregates to bind and waterproof
- Provide enough coating to make the HMA durable
- Not so much as to make the HMA susceptible to rutting

**Lab-Molded Density / Air Voids**

We use lab-molded properties to estimate the aggregate structure and binder content needed to withstand the anticipated traffic at the designed pavement thickness.

<table>
<thead>
<tr>
<th>Nominal Max. Aggregate Size</th>
<th>1&quot;</th>
<th>3/4&quot;</th>
<th>1/2&quot;</th>
<th>3/8&quot;</th>
<th>No. 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Binder Content</td>
<td>4.0</td>
<td>4.4</td>
<td>4.9</td>
<td>5.4</td>
<td>5.9</td>
</tr>
</tbody>
</table>

**Lab-Molded Density / Air Voids**

\[
\% \text{ Air Voids} = 100 - \% \text{ Density} \\
\% \text{ Density} = 100 - \% \text{ Air Voids}
\]

**Traffic Level (ESALs)**

<table>
<thead>
<tr>
<th>Traffic Level (ESALs)</th>
<th>No. of Gyrations</th>
<th>Required Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.3M</td>
<td>50</td>
<td>96.0%</td>
</tr>
<tr>
<td>0.3M - &lt; 3M</td>
<td>75</td>
<td>96.0%</td>
</tr>
<tr>
<td>3M - &lt; 30M</td>
<td>100</td>
<td>96.0%</td>
</tr>
<tr>
<td>≥ 30M</td>
<td>125</td>
<td>96.0%</td>
</tr>
</tbody>
</table>

- Number of gyrations change with expected ESALs
- Density requirement remains the same
- To maintain 96.0% density the amount of binder must be increased or decreased if aggregate structure stays the same (the aggregate structure will often have to be changed to maintain volumetrics at different compaction levels)
- More gyrations → Less Binder
Lab-Molded / Roadway Air Voids

Why are the target values for lab-molded air voids and roadway air voids different? Lab-molded air voids simulate the in-place density of HMA after it has endured several years of traffic in the roadway.

In-place Density

Lab-Molded Density

Future Traffic

Air Voids

≈20-25% Before Rolling

6 - 7% After Rolling

4% Suprapave

Lab-Molded Air Voids

Roadway Air Voids

Don’t confuse roadway density with lab-molded density:

• Lab-molded density tells us about the mix properties
• Roadway density tells us about the quality of compactive effort on the roadway

VMA

VMA is the volumetric void space created by the aggregate particles in an asphalt mixture. It is filled with the volume of air voids plus the volume of the binder not absorbed into the aggregate.

The mix needs a minimum VMA to have enough volume to hold the proper amount of air voids and the proper amount of binder.

VMA

If the VMA drops below the specified minimums, the asphalt film thickness gets thinner and the pavement becomes less durable.

VMA Requirements (AASHTO M 323)

<table>
<thead>
<tr>
<th>Nominal Max. Aggregate Size</th>
<th>1&quot;</th>
<th>3/4&quot;</th>
<th>1/2&quot;</th>
<th>3/8&quot;</th>
<th>No. 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum VMA</td>
<td>12.0</td>
<td>13.0</td>
<td>14.0</td>
<td>15.0</td>
<td>16.0</td>
</tr>
</tbody>
</table>

Question:

Why can’t you add the percent effective binder \( P_{be} \) to the percent air voids \( P_a \) to get the VMA?

Answer:

Because \( P_{be} \) is a percentage by mass and \( P_a \) is a percentage by volume.

Mix Composition

The mix design typically contains (at minimum) the following important information:

• Mix design type (Superpave, SMA, OGFC, etc.)
• Binder grade (PG 64-22, PG 76-22, etc)
• Binder source (ex. - Marathon: Tampa, FL)
• Nominal Maximum Aggregate Size of mix
• Aggregate Types (1/2" Chips, Screenings, Sand, etc.)
• Aggregate Sources (ex. - Vulcan: Dalton, GA Quarry)
• Percentage of each aggregate used
• Individual and combined aggregate gradations
• Design binder content
• Test data for binder, aggregates, and mix
Mix Composition

The rule of thumb would be to never allow a different material or different source to be used than what is on the mix design. You need to know if your local agency allows:

- Switching binder grade on same design (maybe)
- Switching binder source within same grade (maybe)
- Aggregate Types (never)
- Aggregate Sources (never)
- Changing % of each aggregate used (± small tolerance)
- Individual and combined aggregate gradations (maybe)
- Changing design binder content (maybe)

Calculating unit weights for input into density gauges

Nuclear or electromagnetic density gauges require a maximum (or voidless) unit weight to calculate density

Check local agency to determine whether to use $G_{mm}$ from:

- mix design
- latest field Rice's test
- calculation using $G_{se}$ from:
  - mix design
  - latest field Rice's test
- calculation using $P_b$ from:
  - job mix formula
  - field lot or subplot

Max. Unit Weight = $G_{mm} \times 62.4 \text{ lbs/ft}^3$

Note: Density gauges must be correlated with roadway cores to determine accurate densities.

QUESTIONS?

Good Reference Materials on the Topic:

- MS-2: Mix Design Methods
- SP-2: Superpave Mix Design
- MS-4: The Asphalt Handbook
- MS-22: HMA Construction

http://www.asphaltinstitute.org