2017 Local Roads Workshop
Mix Design Basics
March 2017
Mix Design Basics

ASPHALT PAVEMENT ASSOCIATION OF MICHIGAN

2937 Atrium Drive, Suite 202
Okemos, MI 48864
517-323-7800  www.apa-mi.org
Outline

- HMA Volumetric Properties/Terms
- Mix Design
The 3 A’s of Hot Mix Asphalt

Asphalt (binder), Aggregates, and Air

HMA = Asphalt + Aggregates + Air
Mix Design Goals
Balancing Act

Smooth Quite Ride

Strength & Stability

No
• Rutting
• Shoving
• Flushing

Workability

Durable

No
• Cracking
• Raveling

Skid Resistance
Important HMA Mix Properties

We want
- Stability
- Durability
  - Fatigue resistance
  - Low temperature crack resistance
- Impermeability
- Workability
- Skid Resistance

How?
Materials Selection
Volumetric design
Volumetric Analysis
Definition

The measurement or calculation of the relative masses and volumes occupied by the aggregate, asphalt binder, and air voids in a compacted asphalt mixture.
The difference between mass and weight is that mass is the amount of matter in a material and weight is a measure of how the force of gravity acts upon that mass.

**Mass** is the measure of the amount of matter in a body. Mass is denoted using $m$ or $M$.

**Weight** is the measure of the amount of force acting on a mass due to the acceleration due to gravity. Weight is usually denoted as $W$. Weight is mass multiplied by the acceleration of gravity.

\[ W = m \times g \]
Volumetric Analysis

- All matter has mass and occupies space
- Volumetric analysis is a way of evaluating the relationships between mass and volume
- Volumetric characteristics assure that there is adequate space within the aggregate structure to accommodate the optimum amount of air and asphalt

Detailed description
- MS-2, Chapter 4
- SP-2, Chapter 4
Specific Gravity

- Ratio of a material’s weight to the weight of an equal volume of water
  - Dimensionless number (no units attached)

Specific Gravity = 2.70 means that the rock weighs 2.70 times an equal volume of water
HMA Volumetric Terms

- Bulk specific gravity of compacted HMA - Gmb
- Maximum specific gravity - Gmm
- Air voids - Va
- Voids in mineral aggregate, VMA
- Effective specific gravity of aggregate - Gse
- Voids filled with asphalt, VFA
HMA Volumetric Terms

Gmb

- Specific Gravity
- Mixture
- Bulk
BSG of Compacted HMA

- Asphalt binder mixed with aggregate and compacted into a sample

\[ G_{mb} = \text{Mass agg. and AC} / \text{Vol. agg., AC, air voids} \]
Testing

- Mixing of asphalt and aggregate
- Compaction of sample
- Mass of dry sample
- Mass under water
- Mass saturated surface dry (SSD)
Obtain mass of dry compacted sample
Testing

Obtain mass under water
Testing

Obtain mass of specimen at SSD
Calculations

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

Where:

- \( A \) = mass of dry sample
- \( B \) = mass of SSD sample
- \( C \) = mass of sample under water
Example Calculations

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

- mass of dry sample \( A = 4819.7 \)
- mass of SSD sample \( B = 4822.3 \)
- mass of sample under water \( C = 2816.3 \)

\[ 4819.7 / (4822.3 - 2816.3) = 2.403 \]
HMA Volumetric Terms

- Bulk specific gravity of compacted HMA - $G_{mb}$
- Maximum specific gravity - $G_{mm}$
- Air voids
- Voids in mineral aggregate, VMA
- Effective specific gravity of aggregate - $G_{se}$
- Voids filled with asphalt, VFA
Maximum Specific Gravity - $G_{mm}$

Loose (uncompacted) mixture

$G_{mm} = \frac{\text{Mass agg. and AC}}{\text{Vol. agg. and AC}}$
Testing of Specimens

- Maximum Specific Gravity of Mixture
  - “Zero” air voids
  - Tested on Loose Mix
  - Dry Weight in Air
  - Vacuum and vibrating to get all air out
  - Submerged Weight in Water
Testing

- Sample of asphalt and aggregate
  - Cool to room temperature
- Mass in air
- Mass under water
Testing

Loose Mix at Room Temperature
Calculations

Maximum Specific Gravity

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

Where:

\( A \) = mass of dry sample

\( C \) = mass of sample under water
Example Calculations

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

mass of dry sample \( A = 2050.0 \)

mass of sample under water \( C = 1226.4 \)

\[ \frac{2050.0}{(2050.0 - 1226.4)} = 2.489 \]
TMD – Theoretical Maximum Density

What is it?

- Density at 100% compaction
- Rock + Oil….No Air
TMD – Theoretical Maximum Density

\[ TMD = G_{mm} \times \text{unit wt. of water (62.4 lbs/ft}^3) \]

If \( G_{mm} = 2.489 \),

\[ TMD = 2.489 \times 62.4 = 155 \text{ lbs/ft}^3 \]
HMA Volumetric Terms

- Bulk specific gravity (BSG) of compacted HMA - Gmb
- Maximum specific gravity - Gmm
- Air voids - Va
- Voids in mineral aggregate, VMA
- Effective specific gravity of aggregate - Gse
- Voids filled with asphalt, VFA
Air Voids

AGGREGATE

ASPHALT CEMENT

AIR VOIDS

FRACTURED OR CRUSHED FACES ARE BEST!
Hot Mix Asphalt Compaction

Field performance has shown design air voids:
- Below 3% are susceptible to rutting & shoving
- Over 5% are susceptible to raveling, oxidation
- 4% air voids typically allows for optimal design
  - Not too open
  - Little extra compaction under traffic
Percent Air Voids

Calculated using both specific gravities

\[
\text{Air voids} = \left( 1 - \frac{G_{mb}}{G_{mm}} \right) 100
\]

\[
\frac{\text{Mass agg + AC}}{\text{Vol. agg, AC, Air Voids}} = \frac{\text{Vol. agg, AC}}{\text{Vol. agg, AC, Air Voids}}
\]
Example Calculations

Air voids:
- $G_{mb} = 2.403$
- $G_{mm} = 2.489$

$\left(1 - \frac{2.403}{2.489}\right) \times 100 = 3.5\%$
Intent of Laboratory Compaction?

Simulate the in-place density of HMA after it has endured several years of traffic in the roadway.

**In-place Density**
- Air Voids: 15-25% Before Rolling
- Air Voids: 6 – 9% After Rolling

**Design Density**
- Future Traffic
- Air Voids: 3 – 5% Marshall
- Air Voids: 4% Superpave

**Lab**
Air Voids

• Important for Pavement Performance
  – Stiffness and Strength
    • Rutting
  – Durability
    • Cracking
    • Raveling
  – Fatigue Life
  – Moisture Damage
HMA Volumetric Terms

- Bulk specific gravity of compacted HMA - Gmb
- Maximum specific gravity - Gmm
- Air voids - Va
- Voids in mineral aggregate, VMA
- Effective specific gravity of aggregate - Gse
- Voids filled with asphalt, VFA
Voids in Mineral Aggregate

VMA is the void space available for effective asphalt and Air. It is also an indication of film thickness on the surface of the aggregate.

VMA is determined by gradation and particle texture.
Component Diagram

**VOLUME**

- VMA
- Vol air
- Vol eff asph
- Vol abs asph

**MASS**

- Mass air = 0
- Mass asph
- Mass eff asph
- Total Mass

**Component Diagram**

- air
- asphalt
- absorbed asphalt
- aggregate

SP-2, Fig. 4.2
Voids in Mineral Aggregate

\[ VMA = 100 - \frac{G_{mb} \cdot P_s}{G_{sb}} \]

Given that \( G_{mb} = 2.455, P_s = 95\%, \) and \( G_{sb} = 2.703 \)

\[ VMA = 100 - \frac{(2.455) \cdot (95)}{2.703} = 13.7 \]
# Minimum VMA Requirements

<table>
<thead>
<tr>
<th>Nominal Maximum Aggregate Size, mm (in)</th>
<th>Minimum VMA, percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.5 (3/8)</td>
<td>15.0</td>
</tr>
<tr>
<td>12.5 (1/2)</td>
<td>14.0</td>
</tr>
<tr>
<td>19.0 (3/4)</td>
<td>13.0</td>
</tr>
<tr>
<td>25.0 (1.0)</td>
<td>12.0</td>
</tr>
<tr>
<td>37.5 (1.5)</td>
<td>11.0</td>
</tr>
</tbody>
</table>

SP-2, Table 5.2
VMA and %AC

VMA Relationship

% VMA

% Asphalt Binder
HMA Volumetric Terms

- Bulk specific gravity of compacted HMA - Gmb
- Maximum specific gravity - Gmm
- Air voids - Va
- Voids in mineral aggregate, VMA
- Effective specific gravity of aggregate - Gse
- Voids filled with asphalt, VFA
Effective Specific Gravity

\[ G_{se} = \frac{\text{Mass, dry}}{\text{Effective Volume}} \]

Surface Voids

Solid Agg. Particle

Absorbed asphalt

Vol. of water-perm. voids not filled with asphalt

Effective volume = volume of solid aggregate particle + volume of surface voids not filled with asphalt
Effective Specific Gravity

\[ G_{se} = \frac{100 - P_b}{\frac{100}{G_{mm}} - \frac{P_b}{G_b}} \]

\( G_{se} \) is an aggregate property, and is used to calculate asphalt absorption.
Example Calculations

- Mixed with 5% asphalt cement
- $G_{mm} = 2.535$
- $G_b = 1.03$

$$G_{se} = \frac{100 - 5}{2.535 - 1.03} = 2.770$$
Percent Binder Absorbed

\[ P_{ba} = 100 \left( \frac{G_{se} - G_{sb}}{G_{sb} \cdot G_{se}} \right) G_b \]

\( P_{ba} \) is the percent of absorbed asphalt by mass of aggregate
Effective Asphalt Content

\[ P_{be} = P_b - \frac{P_{ba}}{Ps} \times 100 \]

The effective asphalt content is the total asphalt content minus the percent lost to absorption (based on mass of total mix).
HMA Volumetric Terms

- Bulk specific gravity of compacted HMA - $G_{mb}$
- Maximum specific gravity - $G_{mm}$
- Air voids - $V_a$
- Voids in mineral aggregate, VMA
- Effective specific gravity of aggregate - $G_{se}$
- Voids filled with asphalt, VFA
Voids Filled with Asphalt (VFA)

- **Definition**
  - percentage of VMA filled with asphalt
- **Similar to** degree of saturation in soils
Voids Filled with Asphalt

\[ VFA = 100 \times \frac{VMA - V_a}{VMA} \]

VFA is the percent of VMA that is filled with asphalt cement
Summary of Terms

- $G_{mb}$ = Specific gravity of compacted HMA
- $G_{mm}$ = Maximum specific gravity of loose HMA
- $V_a$ = Air voids
- VMA = Voids in mineral aggregates
- $G_{se}$ = Effective specific gravity of aggregate
- VFA = Voids filled with asphalt binder
- $G_b$ = Specific gravity, asphalt binder
- $G_{sb}$ = Bulk specific gravity of aggregate
- $P_{be}$ = % of effective asphalt binder by total mass of mixture
- $P_b$ = % of total asphalt binder by total mass of mixture
- $P_{ba}$ = % of absorbed asphalt binder by mass of aggregate
MIXTURE DESIGN
Requirements in Common

- Sufficient asphalt binder to ensure a durable pavement
- Sufficient stability under traffic loads
- Sufficient air voids
  - Upper limit to prevent excessive environmental damage
  - Lower limit to allow room for initial densification due to traffic
- Sufficient workability
4 Steps of Superpave Mix Design

1. Materials Selection

2. Design Aggregate Structure

3. Design Binder Content

4. Moisture Sensitivity

TSR
Step 1: Materials Selection

- Materials Selection consists of:
  - Choosing the correct asphalt binder
  - Choosing the aggregates that meet the quality requirements for the mix
Superpave Asphalt Binder Specification

The grading system is based on climate

**PG 58 - 28**

- Performance Grade
- Average 7-day max pavement temperature
- Min pavement temperature
Developed from Air Temperatures

- Superpave Weather Database
  - 6500 stations in U.S. and Canada

- Annual air temperatures
  - hottest seven-day temp (avg and std dev)
  - coldest temp (avg and std dev)

- Calculated pavement temps used in PG selection

LTPP Bind Software

> 20 years

SHRP A-648A
Binder Grade vs. Pavement Performance

Other Performance Factors:
- Rutting - shear strength of mix, aggregate properties
- Fatigue Cracking - pavement structure, traffic

Important Factor:
- Low temperature Cracking – correlates well to binder properties
Thermal Cracking

Low Temperature Cracking

Courtesy of FHWA
The following guidelines have been developed at the request of Local Agency Engineers for use on Local Agency projects. These guidelines have been reviewed and approved by the County Road Association of Michigan Engineering Committee. Previous experience and performance shall permit variations from these guidelines as per Section D. Alternative Mixes.

A. HMA Mixture Type and Binder Selection

Selection is based on present day two-way commercial ADT. The commercial ADT ranges for each of the mixture types have taken into account an assumed future traffic growth rate.

<table>
<thead>
<tr>
<th>Mixture Type</th>
<th>Com. ADT 0-300</th>
<th>Com. ADT 301-700</th>
<th>Com. ADT 701-1000</th>
<th>Com. ADT 1001-3400</th>
<th>Com. ADT 3401-9999</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top</td>
<td>LVSP or 13A, 36A</td>
<td>4C 5E1/4E1</td>
<td>5E3, or 4E3</td>
<td>5E10, or 4E10</td>
<td>5E30, or 5E10</td>
</tr>
<tr>
<td>Leveling</td>
<td>LVSP or 13A</td>
<td>3C 4E1</td>
<td>4E3</td>
<td>4E10</td>
<td>4E30</td>
</tr>
<tr>
<td>Base</td>
<td>13A / 3C</td>
<td>2C / 3C</td>
<td>3E3</td>
<td>3E10</td>
<td>3E30</td>
</tr>
</tbody>
</table>

Binder Grades by Region

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Superior</td>
<td>PG 58-34</td>
<td>PG 58-34</td>
<td>PG 58-34</td>
<td>PG 58-34</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metro</td>
<td>PG 58-22</td>
<td>PG 64-22</td>
<td>PG 64-22</td>
<td>PG 64-22</td>
<td>PG 70-22P</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All Other</td>
<td>PG 58-28</td>
<td>PG64-28</td>
<td>PG-64-28</td>
<td>PG64-28</td>
<td>PG70-28P</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note 1: If the designer wishes to reduce the target air voids on projects to 3.5%, a note needs to be added to the plans on the HMA Application Table stating that the air voids have been changed to 3.5% for that particular project for top and leveling courses. For mixtures meeting the definition of base course, field regress air void content to 3.0 percent with liquid asphalt cement unless specified otherwise on HMA application estimate.

Note 2: The mixture type in each traffic category listed in the above table is specifically designed to perform under their respective Commercial ADT. Selecting a mixture type that is specifically designed for a higher Commercial ADT than the project being designed may adversely affect performance.
Local Agency Programs
HMA Selection Guidelines

- Developed for use on Local Agency Projects
- Reviewed and Approved by CRA
- Variations Allowed
Local Agency Programs
HMA Selection Guidelines

- SuperPave and Marshall mix designs
- SuperPave for Commercial ADT > 700
- Variations Allowed
Local Agency Programs
HMA Selection Guidelines

<table>
<thead>
<tr>
<th>Commercial ADT</th>
<th>0 – 300</th>
<th>301 – 700</th>
<th>701 – 1000</th>
<th>1001 – 3400</th>
<th>3401 – 9999</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superior</td>
<td>PG 58-34</td>
<td>PG 58-34</td>
<td>PG 58-34</td>
<td>PG 58-34</td>
<td></td>
</tr>
<tr>
<td>Metro</td>
<td>PG 58-22</td>
<td>PG 64-22</td>
<td>PG 64-22</td>
<td>PG 64-22</td>
<td>PG 70-22P</td>
</tr>
<tr>
<td>All Other</td>
<td>PG 58-28</td>
<td>PG 64-28</td>
<td>PG 64-28</td>
<td>PG 64-28</td>
<td>PG 70-28P</td>
</tr>
</tbody>
</table>

Binder Grades by Region

For Surface and Leveling Courses
## Aggregate Consensus Properties

### Table 902-6: Superpave Final Aggregate Blend Physical Requirements

<table>
<thead>
<tr>
<th>Est. Traffic (million ESAL)</th>
<th>Mix Type</th>
<th>Percent Crushed Minimum Criteria</th>
<th>Fine Aggregate Angularity Minimum Criteria</th>
<th>% Sand Equivalent Minimum Criteria</th>
<th>Los Angeles Abrasion % Loss Maximum Criteria</th>
<th>% Soft Particles Maximum Criteria (a)</th>
<th>% Flat and Elongated Particles Maximum Criteria (b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.3</td>
<td>LVSP</td>
<td>55/—</td>
<td>—</td>
<td>40</td>
<td>45</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>&lt; 0.3</td>
<td>E03</td>
<td>55/—</td>
<td>—</td>
<td>40</td>
<td>45</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>≥0.3 - &lt;1.0</td>
<td>E1</td>
<td>65/—</td>
<td>—</td>
<td>40</td>
<td>45</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>≥1.0 - &lt;3</td>
<td>E3</td>
<td>75/—</td>
<td>50/—</td>
<td>43</td>
<td>40</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>≥3 - &lt;10</td>
<td>E10</td>
<td>85/80</td>
<td>60/—</td>
<td>45</td>
<td>45</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>≥10 - &lt;30</td>
<td>E30</td>
<td>95/90</td>
<td>80/75</td>
<td>45</td>
<td>45</td>
<td>3</td>
<td>4.5</td>
</tr>
<tr>
<td>≥30 - &lt;100</td>
<td>E50</td>
<td>100/100</td>
<td>95/90</td>
<td>45</td>
<td>50</td>
<td>3</td>
<td>4.5</td>
</tr>
</tbody>
</table>

(a) Soft particles maximum is the sum of the shale, siltstone, ochre, coal, clay-ironstone and particles that are structurally weak or are non-durable in service.

(b) Maximum by weight with a 1 to 5 aspect ratio.

Note: “85/80” denotes that 85 percent of the coarse aggregate has one fractured face and 80 percent has at least two fractured faces.
Steps of Superpave HMA Mix Design

1. Materials Selection

2. Design Aggregate Structure

3. Design Binder Content

4. Moisture Sensitivity
Step 2: Aggregate Gradation

- Establish trial aggregate blends
  - 3 suggested
  - evaluate combined aggregate properties
- Estimate optimum asphalt binder content
- Manufacture and compact trial blends
- Evaluate the trial blends
- Select the most promising blend
# Aggregate Gradation

![Table 902-5: Superpave Final Aggregate Blend Gradation Requirements](image)

<table>
<thead>
<tr>
<th>Standard Sieve</th>
<th>Mixture Number</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>LVSP (a)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>1½ inch</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>100</td>
<td>—</td>
</tr>
<tr>
<td>1 inch</td>
<td>—</td>
<td>—</td>
<td>100</td>
<td>100</td>
<td>90–100</td>
<td>—</td>
</tr>
<tr>
<td>3/4 inch</td>
<td>—</td>
<td>100</td>
<td>90–100</td>
<td>90–100</td>
<td>≤90</td>
<td>100</td>
</tr>
<tr>
<td>1/2 inch</td>
<td>100</td>
<td>90–100</td>
<td>≤90</td>
<td>≤90</td>
<td>—</td>
<td>75–95</td>
</tr>
<tr>
<td>3/8 inch</td>
<td>90–100</td>
<td>≤90</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>60–90</td>
</tr>
<tr>
<td>No. 4</td>
<td>≤90</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>45–80</td>
</tr>
<tr>
<td>No. 16</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>20–50</td>
</tr>
<tr>
<td>No. 30</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>15–40</td>
</tr>
<tr>
<td>No. 50</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>10–25</td>
</tr>
<tr>
<td>No. 100</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>5–15</td>
</tr>
<tr>
<td>No. 200</td>
<td>2.0–10.0</td>
<td>2.0–10.0</td>
<td>2.0–8.0</td>
<td>2.0–8.0</td>
<td>1.0–7.0</td>
<td>3–6</td>
</tr>
</tbody>
</table>

a. For LVSP, less than 50 percent of the material passing the No. 4 sieve may pass the No. 30 sieve.
Establish Trial Blends

- Develop three gradations based on
  - Stockpile gradation information
  - Gradation specification
- Optimize use of materials in the most economical blends
- Estimate properties of combined stockpiles
Establish trial asphalt binder content

- Superpave Method
- Engineering judgement method
Trial Asphalt Binder Content

- Use known or estimated values for
  - Effective aggregate specific gravity, $G_{se}$
  - Asphalt binder absorbed, $V_{ba}$
- Calculate the effective binder content, $V_{be}$
Calculate the initial asphalt binder content:

\[ P_{bi} = \frac{100 \ G_b \ (V_{be} + V_{ba})}{(G_b \ (V_{be} + V_{ba})) + W_s} \]

Where:

\[ W_s = \frac{P_s \ (1 - V_a)}{(P_b / G_b) + (P_s G_s)} \]
Next steps

- Sample preparation
  - Select mixing and compaction temperatures
  - Preheat aggregates and asphalt
  - Mix components
  - Compact specimens
- Extrude and determine volumetrics
Compact the trial mixtures in accordance with AASHTO T 312 which now requires specimens be compacted to the design number of gyrations ($N_d$).

When doing a mix design you compact a pair of samples to $N_{\text{maximum}}$ and check them to see if the $N_{\text{maximum}}$ value of 98% is exceeded.
# Superpave Compaction criteria

<table>
<thead>
<tr>
<th>Estimated Traffic (million ESAL)</th>
<th>Mix Type</th>
<th>%G&lt;sub&gt;mm&lt;/sub&gt; at (N&lt;sub&gt;i&lt;/sub&gt;)</th>
<th>Number of Gyrations (a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤0.3</td>
<td>LVSP</td>
<td>91.5%</td>
<td>N&lt;sub&gt;i&lt;/sub&gt; 6, N&lt;sub&gt;d&lt;/sub&gt; 45, N&lt;sub&gt;m&lt;/sub&gt; 70</td>
</tr>
<tr>
<td>≤0.3</td>
<td>E03</td>
<td>91.5%</td>
<td>N&lt;sub&gt;i&lt;/sub&gt; 7, N&lt;sub&gt;d&lt;/sub&gt; 50, N&lt;sub&gt;m&lt;/sub&gt; 75</td>
</tr>
<tr>
<td>&gt;0.3 – ≤1.0</td>
<td>E1</td>
<td>90.5%</td>
<td>N&lt;sub&gt;i&lt;/sub&gt; 7, N&lt;sub&gt;d&lt;/sub&gt; 76, N&lt;sub&gt;m&lt;/sub&gt; 117</td>
</tr>
<tr>
<td>&gt;1.0 – ≤3.0</td>
<td>E3</td>
<td>90.5%</td>
<td>N&lt;sub&gt;i&lt;/sub&gt; 7, N&lt;sub&gt;d&lt;/sub&gt; 86, N&lt;sub&gt;m&lt;/sub&gt; 134</td>
</tr>
<tr>
<td>&gt;3.0 – ≤10</td>
<td>E10</td>
<td>89.0%</td>
<td>N&lt;sub&gt;i&lt;/sub&gt; 8, N&lt;sub&gt;d&lt;/sub&gt; 96, N&lt;sub&gt;m&lt;/sub&gt; 152</td>
</tr>
<tr>
<td>&gt;10 – ≤30</td>
<td>E30</td>
<td>89.0%</td>
<td>N&lt;sub&gt;i&lt;/sub&gt; 8, N&lt;sub&gt;d&lt;/sub&gt; 109, N&lt;sub&gt;m&lt;/sub&gt; 174</td>
</tr>
<tr>
<td>&gt;30 – ≤100</td>
<td>E50</td>
<td>89.0%</td>
<td>N&lt;sub&gt;i&lt;/sub&gt; 9, N&lt;sub&gt;d&lt;/sub&gt; 126, N&lt;sub&gt;m&lt;/sub&gt; 204</td>
</tr>
</tbody>
</table>

a. Compact mix specimens fabricated in the SGC to N<sub>d</sub>. Use height data provided by the SGC to calculate volumetric properties at N<sub>i</sub>. Compact mix specimens at optimum P<sub>b</sub> to verify N<sub>m</sub> for mix design specimens only.
## Estimate Aggregate Blend Properties (Example)

<table>
<thead>
<tr>
<th>Property Criteria</th>
<th>Trial Blend</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>( N_{\text{initial}} ), %</td>
<td>&lt; 89.0</td>
</tr>
<tr>
<td>( N_{\text{design}} ), %</td>
<td>96.0</td>
</tr>
<tr>
<td>( N_{\text{max}} ), %</td>
<td>&lt; 98.0</td>
</tr>
<tr>
<td>Air Voids, %</td>
<td>4</td>
</tr>
<tr>
<td>VMA, %</td>
<td>13</td>
</tr>
</tbody>
</table>
4 Steps of Superpave Mix Design

1. Materials Selection

2. Design Aggregate Structure

3. Design Binder Content

4. Moisture Sensitivity

TSR
Design Binder Content

1) Choose the “Best” Trial Blend
2) Mix Aggregates and Binder at 4 different Asphalt Contents
   - 0.5% Increments
3) Compact Specimens
4) Extrude and Determine Volumetric Properties
Design Binder Content

Air Voids

V_a

% binder

VMA

VMA

% binder

VFA

VFA

% binder

Dust/Asphalt

DP

%G_{mm} \at \ N_{ini}

%G_{mm} \at \ N_{ini}

% binder

%G_{mm} \at \ N_{max}

%G_{mm} \at \ N_{max}

% binder

%G_{mm} \at \ N_{max}
Superpave Mixture Requirements

- **Mixture Volumetrics**
  - Air Voids ($V_a$)
  - Mixture Density Characteristics
  - Voids in the Mineral Aggregate (VMA)
  - Voids Filled with Asphalt (VFA)

- **Dust Proportion**

- **Moisture Sensitivity**
Mix Design Summary Sheet - SuperPave

### SUPERPAVE MIX DESIGN SUMMARY SHEET

<table>
<thead>
<tr>
<th>ITEM</th>
<th>TEST POINTS</th>
<th>4 POINT DESIGN</th>
<th>RECOMMENDED OPTIMUM Regression Value at Optimum Asphalt Content</th>
<th>VERIFICATION TEST RESULTS @ ( N_{\text{MAX}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASPHALT CONTENT (%)</td>
<td>5.0</td>
<td>5.5</td>
<td>6.0</td>
<td>6.5</td>
</tr>
<tr>
<td>BULK SPECIFIC GRAVITY @ ( N_{\text{DES}} )</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BULK SPECIFIC GRAVITY @ ( N_{\text{MAX}} )</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>THEORETICAL MAXIMUM (S.G.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AIR VOIDS (%) @ ( N_{\text{DES}} )</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VOIDS IN MINERAL AGGREGATE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% (VMA) @ ( N_{\text{DES}} )</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Voids Filled with Asphalt</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% ( G_{\text{max}} ) @ ( N_{\text{INT}} )</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% ( G_{\text{max}} ) @ ( N_{\text{DES}} )</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% ( G_{\text{max}} ) @ ( N_{\text{MAX}} )</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**FINES/EFF ASPHALT RATIO**

The submitted superpave mix design final blend shall have a minimum of 4 test points at 0.5 percent asphalt content increments. At least one full asphalt content (0.5%) above and below optimum asphalt content is required.

ASPHALT CONTENT OF SUBMITTED SUPERPAVE MIX DESIGN: **5.7**

ASPHALT SPECIFIC GRAVITY

SPECIFIC GRAVITY OF COMBINED AGGREGATE **G_{\text{sa}}**
Mix Design Summary Sheet – Marshall

### Marshall Mix Properties at Tested & Optimum Asphalt Content

<table>
<thead>
<tr>
<th>Item</th>
<th>Test Points</th>
<th>Actual Test Data</th>
<th>Recommended Optimum Regression Value at Optimum Asphalt Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt Content (%)</td>
<td>4.5</td>
<td>5.0</td>
<td>5.5</td>
</tr>
<tr>
<td>Bulk Specific Gravity (Compacted)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Theoretical Maximum (S.G.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air Voids (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Voids in Mineral Aggregate % (VMA)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Voids Filled with Asphalt % (VFA)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stability (LBS.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow (0.01 IN.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compactive Effort (Blows)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Notes

- Specific Gravity QF
- Combined Aggregate Gsb
- Asphalt Content of Submitted Mix Design 5.7
- Asphalt Specific Gravity

The submitted mix design shall have a minimum of 4 test points at 0.5 percent asphalt content increments. At least one full asphalt content (0.5%) above and below optimum asphalt content is required.
### Mix Design Example

<table>
<thead>
<tr>
<th>Mix Design Number</th>
<th>Project Location</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>54321A</td>
<td>BIG RAPIDS</td>
<td>03SP501(F)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>% Air Void</th>
<th>VMA</th>
<th>VFA</th>
<th>P200/P100</th>
<th>AWI</th>
<th>AI</th>
<th>Film Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0</td>
<td>15.9</td>
<td>74.8</td>
<td>1.1</td>
<td>288</td>
<td>40.9</td>
<td>7.21</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gravel Size</th>
<th>MMB</th>
<th>GMB</th>
<th>GB</th>
<th>GB</th>
<th>GB</th>
<th>GB</th>
<th>GMB</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.457</td>
<td>2.309</td>
<td>1.029</td>
<td>2.644</td>
<td>2.682</td>
<td>1.264</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2&quot;</td>
<td>-</td>
<td>-</td>
<td>100.0%</td>
<td>-</td>
<td>-</td>
<td>100.0%</td>
<td>-</td>
<td>-</td>
<td>100.0%</td>
<td>-</td>
</tr>
<tr>
<td>3/4&quot;</td>
<td>-</td>
<td>-</td>
<td>100.0%</td>
<td>-</td>
<td>-</td>
<td>100.0%</td>
<td>-</td>
<td>-</td>
<td>100.0%</td>
<td>-</td>
</tr>
<tr>
<td>1&quot;</td>
<td>-</td>
<td>-</td>
<td>100.0%</td>
<td>-</td>
<td>-</td>
<td>100.0%</td>
<td>-</td>
<td>-</td>
<td>100.0%</td>
<td>-</td>
</tr>
<tr>
<td>1 1/2&quot;</td>
<td>-</td>
<td>-</td>
<td>100.0%</td>
<td>-</td>
<td>-</td>
<td>100.0%</td>
<td>-</td>
<td>-</td>
<td>100.0%</td>
<td>-</td>
</tr>
<tr>
<td>2&quot;</td>
<td>-</td>
<td>-</td>
<td>100.0%</td>
<td>-</td>
<td>-</td>
<td>100.0%</td>
<td>-</td>
<td>-</td>
<td>100.0%</td>
<td>-</td>
</tr>
<tr>
<td>3&quot;</td>
<td>-</td>
<td>-</td>
<td>100.0%</td>
<td>-</td>
<td>-</td>
<td>100.0%</td>
<td>-</td>
<td>-</td>
<td>100.0%</td>
<td>-</td>
</tr>
<tr>
<td>4&quot;</td>
<td>-</td>
<td>-</td>
<td>100.0%</td>
<td>-</td>
<td>-</td>
<td>100.0%</td>
<td>-</td>
<td>-</td>
<td>100.0%</td>
<td>-</td>
</tr>
</tbody>
</table>

**L.A. Abrasion & Wear**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Gauge</th>
<th>Supplier I.D.</th>
<th>% New Ac. Added</th>
</tr>
</thead>
<tbody>
<tr>
<td>54-28</td>
<td>A.C.</td>
<td>ABS 1005</td>
<td>0.16</td>
</tr>
</tbody>
</table>

**Remarks:**

This design method and aggregate characteristics are based on the assumptions and procedures of the SUPERPAVÉ ITM HMA Design Mix Formula. Results are intended for guidance and should be verified through laboratory testing. The data presented is for informational purposes only and is not intended to be used as a substitute for laboratory testing. The Michigan Department of Transportation is not responsible for any errors or omissions. The Michigan Department of Transportation reserves the right to modify these procedures and specifications at any time.
Mix Design Example

### Table: SUPERPAVE™ HMA Design Mix Formula

<table>
<thead>
<tr>
<th>Distribution: Project Engineer (1) -- TMI (1) -- Mix Design (1) -- Contractor (1) -- Bit File (1)</th>
<th>ACCEPTED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Section</td>
<td>Job Number</td>
</tr>
<tr>
<td>B06 54038</td>
<td>54321A</td>
</tr>
<tr>
<td>Contractor</td>
<td>General Pavement</td>
</tr>
<tr>
<td>Mix Type</td>
<td>Mix Design Number</td>
</tr>
<tr>
<td>5E3</td>
<td>06MD540</td>
</tr>
<tr>
<td>% Air Voids</td>
<td>VMA</td>
</tr>
<tr>
<td>4.0</td>
<td>15.9</td>
</tr>
<tr>
<td>Gmm</td>
<td>Gmb</td>
</tr>
<tr>
<td>2.457</td>
<td>2.359</td>
</tr>
</tbody>
</table>

### Pit Number

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
</tr>
</thead>
<tbody>
<tr>
<td>54-101</td>
<td>54-101</td>
<td>95-76</td>
<td>95-76</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Aggregate Type

<table>
<thead>
<tr>
<th>Blend %</th>
<th>Sand F8</th>
<th>Slag Sand</th>
<th>5/16 F8</th>
<th>5%</th>
<th>DIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.0%</td>
<td>15.0%</td>
<td>26.0%</td>
<td>33.0%</td>
<td>1.0%</td>
<td></td>
</tr>
</tbody>
</table>

### Sieve Size

<table>
<thead>
<tr>
<th>Gradation</th>
<th>% Binder of RAP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 1/2&quot; - (37.5mm)</td>
<td>0.0%</td>
</tr>
<tr>
<td>1&quot; - (25.0mm)</td>
<td>0.0%</td>
</tr>
<tr>
<td>3/4&quot; - (19mm)</td>
<td>0.0%</td>
</tr>
<tr>
<td>1/2&quot; - (12.5mm)</td>
<td>100.0%</td>
</tr>
<tr>
<td>3/8&quot; - (9.5mm)</td>
<td>100.0%</td>
</tr>
<tr>
<td>#4 - (4.75mm)</td>
<td>91.3%</td>
</tr>
<tr>
<td>#8 - (2.36mm)</td>
<td>69.9%</td>
</tr>
</tbody>
</table>
### Mix Design Example

<table>
<thead>
<tr>
<th>Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>#4 - (9.53mm)</td>
</tr>
<tr>
<td>#8 - (2.36mm)</td>
</tr>
<tr>
<td>#16 - (1.18mm)</td>
</tr>
<tr>
<td>#30 - (0.80mm)</td>
</tr>
<tr>
<td>#50 - (0.30mm)</td>
</tr>
<tr>
<td>#100 - (0.1mm)</td>
</tr>
<tr>
<td>#200 - (0.075mm)</td>
</tr>
<tr>
<td>1 FACE CRUSH %</td>
</tr>
<tr>
<td>2 FACE CRUSH %</td>
</tr>
<tr>
<td>L.A. ABRASION &amp; YEAR</td>
</tr>
<tr>
<td>Angularity Index</td>
</tr>
<tr>
<td>AWI FACTOR</td>
</tr>
<tr>
<td>AWI VALUE #16</td>
</tr>
<tr>
<td>COMBINED Calc. Gsb</td>
</tr>
<tr>
<td>#4+ COARSE BULK S.G.</td>
</tr>
<tr>
<td>#8 COARSE BULK S.G.</td>
</tr>
<tr>
<td>FINE BULK S.G.</td>
</tr>
<tr>
<td>FLAT &amp; ELONGATED %</td>
</tr>
<tr>
<td>SOFT PARTICLES %</td>
</tr>
<tr>
<td>Asphalt Binder</td>
</tr>
<tr>
<td>A.C. Supplier I.D. #</td>
</tr>
<tr>
<td>% New AC Added</td>
</tr>
</tbody>
</table>

**Remarks:**

The bitumen content and aggregate characteristics are based on the submitted materials with the gradation and blend values indicated. Variations in gradation or field conditions may require adjustments to this mix design (see TMA for item 1411 for field application). The laboratory design is valid for two construction seasons from date reported and should not be applied or adjusted without written approval of the Bituminous Services Unit. A signed copy is on file with the Bituminous Services Unit. Telephone for information.

---

Bituminous Engineer
4 Steps of Superpave Mix Design

1. Materials Selection
2. Design Aggregate Structure
3. Design Binder Content
4. Moisture Sensitivity

HMA Superpave Mix Design 87
Moisture Sensitivity

AASTHO T-283, Tensile Strength Ratio (TSR) Test

- 6 specimens compacted to 6 – 8% air voids
  - 3 conditioned and 3 unconditioned
- Conditioned specimens
  - 55 to 80 percent saturation
  - Freeze-thaw cycle (min. 16 Hrs. freeze)
  - 24 hour soak in 140°F water bath
  - Cooled to 77°F and broken on IDT Tester
- Unconditioned specimens
  - Left undisturbed until broken on IDT Tester
- TSR ≥ 80%
Moisture Sensitivity

AASTHO T-283, Tensile Strength Ratio (TSR) Test

- Testing of specimens
  - Remove from 77°F (25°C) water bath and place between two bearing plates.
  - Apply load to specimens by means of constant rate movement, two inches (50 mm) per minute.
  - Record maximum compressive strength.
Moisture Sensitivity

AASTHO T-283, Tensile Strength Ratio (TSR) Test

- **Calculations**
  - Take the average tensile strength of the three conditioned specimens and divide by the average of the three unconditioned specimens.
  - The ratio has to be a minimum of 80%.

\[
TSR = \frac{T_{\text{Conditioned (Avg.)}}}{T_{\text{Unconditioned (Avg.)}}}
\]
Questions?

www.apa-mi.org
517.323.7800   800.292.5959